

## Supplementary Material

# MR POTATOHEAD: Real Estate Market Edition — Development of a common description template for agent- based residential real estate market models

This section contains summary comparison tables between our six models for each template item.

**Table 1. MR POTATOHEAD Real Estate Market Framework – Comparison table for the Landscape Class Template**

|                                                                                                                                                                                                                                                                                                          |                                                    |           |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------|-----------|
| 1. What is the form of the base landscape?                                                                                                                                                                                                                                                               |                                                    |           |
| a. Is the landscape abstract or empirical?                                                                                                                                                                                                                                                               |                                                    |           |
| Abstract                                                                                                                                                                                                                                                                                                 |                                                    | Magliocca |
|                                                                                                                                                                                                                                                                                                          |                                                    | Prunetti  |
|                                                                                                                                                                                                                                                                                                          |                                                    | Ge        |
|                                                                                                                                                                                                                                                                                                          |                                                    | Carro     |
| Empirical                                                                                                                                                                                                                                                                                                |                                                    | Filatova  |
|                                                                                                                                                                                                                                                                                                          |                                                    | Parker    |
| b. Is the landscape cell (tessellation) based or vector?                                                                                                                                                                                                                                                 |                                                    |           |
| Vector                                                                                                                                                                                                                                                                                                   |                                                    | Filatova  |
|                                                                                                                                                                                                                                                                                                          |                                                    | Parker    |
| Cell-based                                                                                                                                                                                                                                                                                               |                                                    | Magliocca |
|                                                                                                                                                                                                                                                                                                          |                                                    | Prunetti  |
|                                                                                                                                                                                                                                                                                                          |                                                    | Ge        |
| A-spatial                                                                                                                                                                                                                                                                                                |                                                    | Carro     |
| c. How is the landscape initialized                                                                                                                                                                                                                                                                      |                                                    |           |
| Generic grid, uniform tessellation                                                                                                                                                                                                                                                                       |                                                    | Magliocca |
|                                                                                                                                                                                                                                                                                                          |                                                    | Prunetti  |
|                                                                                                                                                                                                                                                                                                          |                                                    | Ge        |
| CSV file                                                                                                                                                                                                                                                                                                 |                                                    |           |
| GIS file                                                                                                                                                                                                                                                                                                 |                                                    | Filatova  |
|                                                                                                                                                                                                                                                                                                          |                                                    | Parker    |
| d. Define coarse-scale land uses                                                                                                                                                                                                                                                                         |                                                    |           |
| Developable                                                                                                                                                                                                                                                                                              |                                                    | Magliocca |
|                                                                                                                                                                                                                                                                                                          |                                                    | Ge        |
|                                                                                                                                                                                                                                                                                                          |                                                    | Prunetti  |
| Agricultural                                                                                                                                                                                                                                                                                             |                                                    | Magliocca |
| Residential                                                                                                                                                                                                                                                                                              |                                                    | Parker    |
|                                                                                                                                                                                                                                                                                                          |                                                    | Prunetti  |
|                                                                                                                                                                                                                                                                                                          |                                                    | Magliccca |
|                                                                                                                                                                                                                                                                                                          |                                                    | Carro     |
|                                                                                                                                                                                                                                                                                                          |                                                    | Ge        |
| Other Undevelopable                                                                                                                                                                                                                                                                                      | Flood zones                                        | Filatova  |
|                                                                                                                                                                                                                                                                                                          |                                                    | Magliccca |
|                                                                                                                                                                                                                                                                                                          | Water                                              | Filatova  |
|                                                                                                                                                                                                                                                                                                          | Open Space                                         | Parker    |
|                                                                                                                                                                                                                                                                                                          |                                                    | Filatova  |
| 2. What unique products are being bought and sold? This is designed to represent containers with no explicit internal spatial structure. The user should be able to feed this a list or units, each with a table of attributes, or define multiple options themselves. This defines the patch structure. |                                                    |           |
| a. Number of container types                                                                                                                                                                                                                                                                             |                                                    |           |
| 1                                                                                                                                                                                                                                                                                                        |                                                    | Filatova  |
|                                                                                                                                                                                                                                                                                                          |                                                    | Parker    |
|                                                                                                                                                                                                                                                                                                          |                                                    | Prunetti  |
|                                                                                                                                                                                                                                                                                                          |                                                    | Carro     |
| 4 (1, 2, 5, and 10 acre lots)                                                                                                                                                                                                                                                                            |                                                    | Magliocca |
| 3 (City center cell, near suburb cell, far suburb cell)                                                                                                                                                                                                                                                  |                                                    | Ge        |
| i. Characteristics of the spatial entity                                                                                                                                                                                                                                                                 |                                                    |           |
| A. Spatial location(s), if not                                                                                                                                                                                                                                                                           | Cells are characterized by distance from amenities | Magliocca |
|                                                                                                                                                                                                                                                                                                          |                                                    | Prunetti  |

|                                                         |                                                                                                                                                                                                                                                            |                                                                                                                                                                                                                                                                                                         |           |
|---------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------|
| read from GIS or CSV                                    | A fixed number of neighborhoods with heterogeneous neighborhood and location qualities in a stylized landscape. Represented by a numeric location index, which is median for city center cells, high for near suburb cells, and low for near suburb cells. |                                                                                                                                                                                                                                                                                                         | Ge        |
|                                                         | All properties are vector-based polygons                                                                                                                                                                                                                   |                                                                                                                                                                                                                                                                                                         | Parker    |
|                                                         |                                                                                                                                                                                                                                                            |                                                                                                                                                                                                                                                                                                         | Filatova  |
| B. Entire lot area (parcel polygon)                     | Parcel polygon                                                                                                                                                                                                                                             |                                                                                                                                                                                                                                                                                                         | Filatova  |
|                                                         |                                                                                                                                                                                                                                                            |                                                                                                                                                                                                                                                                                                         | Parker    |
|                                                         | For the land market model: 100 1-acre cells. The spatial location and total size of the land parcels owned by a landowner agent. Each landowner is assigned 100 acres each (10-by-10 cells).<br>For the residence market model: 1-10 acres.                |                                                                                                                                                                                                                                                                                                         | Magliocca |
| C. Building footprint area (building footprint polygon) |                                                                                                                                                                                                                                                            |                                                                                                                                                                                                                                                                                                         | Parker    |
| D. Number of Stories                                    |                                                                                                                                                                                                                                                            |                                                                                                                                                                                                                                                                                                         |           |
| E. Transportation accessibility                         | Annual cost of transportation to and from house location and CBD at a rate of \$25.85 per cell (\$1.30/mile, 0.0395 miles per cell, and 500 miles traveled per year)                                                                                       |                                                                                                                                                                                                                                                                                                         | Magliocca |
|                                                         | Access to nearest transit and bus stop; cumulative employment access; and being in Central Transit Corridor (Section 3.2, Babin, 2016)                                                                                                                     |                                                                                                                                                                                                                                                                                                         | Parker    |
|                                                         | Numeric distance to city center, set as short for city center cells (short is preferred), medium long for near suburb cells, and long for near suburb cells.                                                                                               |                                                                                                                                                                                                                                                                                                         | Ge        |
|                                                         | Daily cost of transportation to and from house location and CBD at a rate of €0.5404 by km.                                                                                                                                                                |                                                                                                                                                                                                                                                                                                         | Prunetti  |
| F. Neighborhood amenities                               | Distance to the central business district (CBD)                                                                                                                                                                                                            |                                                                                                                                                                                                                                                                                                         | Filatova  |
|                                                         |                                                                                                                                                                                                                                                            |                                                                                                                                                                                                                                                                                                         | Magliocca |
|                                                         |                                                                                                                                                                                                                                                            |                                                                                                                                                                                                                                                                                                         | Prunetti  |
|                                                         | Proximity to the coastline                                                                                                                                                                                                                                 | Measured in terms of distance from coastal water and sound, and a Boolean measure of waterfront                                                                                                                                                                                                         | Filatova  |
|                                                         |                                                                                                                                                                                                                                                            | A proximity-based coastal amenity level that decays with distance from the coast (Eq. 2, Section 1.2.2, Appendix 1, Magliocca & Walls, 2018). For baseline settings, the amenity level at the coast ( $A_0$ ) is 500,000, and the rate of amenity decline with distance from the coast ( $r$ ) is 0.08. | Magliocca |
|                                                         |                                                                                                                                                                                                                                                            | Distance to the beach                                                                                                                                                                                                                                                                                   | Prunetti  |

|                                                          |                                                                                                                                                                                                                                                                                                                                                                                                |                  |
|----------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------|
|                                                          | Distances to national parks                                                                                                                                                                                                                                                                                                                                                                    | Filatova         |
|                                                          | Open space access and adjacency                                                                                                                                                                                                                                                                                                                                                                | Parker           |
|                                                          | Walkability                                                                                                                                                                                                                                                                                                                                                                                    | Parker           |
|                                                          | Sea-view-index: (estimated) access to sea-view (0-100) SVI <sub>i</sub>                                                                                                                                                                                                                                                                                                                        | Prunetti         |
|                                                          | No direct representation of neighborhood amenities. An exogenous numeric index for location quality (each grid has a ‘quality index’ that is the quality of the neighborhood), initialized parametrically, 0.65. Also, an endogenous numeric quality represented by the mean income of residents in the cell (higher is preferred) (Eq 1, Section 3.1.1, Ge, 2016).                            | Ge               |
| G. Neighborhood disamenities                             | Categorization of locations based on potential damages from storms. Classifications are waterfront (immediately adjacent to coast), waterview (within 0.2 miles from coast), and inland.                                                                                                                                                                                                       | Magliocca        |
|                                                          | Dummy for being in a flood zone                                                                                                                                                                                                                                                                                                                                                                | Filatova         |
|                                                          | Regional road adjacency                                                                                                                                                                                                                                                                                                                                                                        | Parker           |
| H. Rate of appreciation                                  | $RoA_{it} = \frac{LAV_{it} - LAV_{it-1}}{LAV_{it-1}} \times 100$ <p>Where <math>RoA_{it}</math> is the rate of change in lagged average values between period <math>t-1</math> to period <math>t</math> in neighborhood <math>i</math>, and <math>LAV_{it}</math> is the lagged average value in neighborhood <math>i</math> at time period <math>t</math> (Section 3.2.3.1, Babin, 2016).</p> | Parker           |
| I. Education rate                                        | $EduRate = \frac{Population\ with\ postsecondary}{Population} \times 100$ <p>(Section 3.2.3.4, Babin, 2016)</p>                                                                                                                                                                                                                                                                                | Parker           |
| J. Population density                                    | $PopDen = \frac{Population}{Area}$ <p>(Section 3.2.3.5, Babin, 2016)</p>                                                                                                                                                                                                                                                                                                                       | Parker           |
| ii. Number of different unit categories in the container |                                                                                                                                                                                                                                                                                                                                                                                                |                  |
| 1 (single residence)                                     |                                                                                                                                                                                                                                                                                                                                                                                                | Filatova         |
|                                                          |                                                                                                                                                                                                                                                                                                                                                                                                | Prunetti         |
|                                                          |                                                                                                                                                                                                                                                                                                                                                                                                | Ge               |
|                                                          |                                                                                                                                                                                                                                                                                                                                                                                                | Parker           |
|                                                          |                                                                                                                                                                                                                                                                                                                                                                                                | Carro            |
| 3 (small, medium, large residences)                      |                                                                                                                                                                                                                                                                                                                                                                                                | Magliocca        |
| iii. Unit category descriptions                          |                                                                                                                                                                                                                                                                                                                                                                                                |                  |
| A. Number of units of this type                          | 4- ¼ acre lots; 2-1/2 acre lots; 1-1,2,5, or 10 acre lots                                                                                                                                                                                                                                                                                                                                      | Magliocca        |
| B. Unit area                                             | Square foot                                                                                                                                                                                                                                                                                                                                                                                    | Filatova, Parker |
|                                                          | 1500, 2000, 2500 sq. ft.                                                                                                                                                                                                                                                                                                                                                                       | Magliocca        |
|                                                          | Square meters                                                                                                                                                                                                                                                                                                                                                                                  | Prunetti         |
| C. Number of room/bedrooms                               |                                                                                                                                                                                                                                                                                                                                                                                                | Filatova         |
| D. Number of baths                                       |                                                                                                                                                                                                                                                                                                                                                                                                |                  |
| E. Yard/lot size                                         | Acres                                                                                                                                                                                                                                                                                                                                                                                          | Filatova, Parker |
|                                                          | ¼-10 acres                                                                                                                                                                                                                                                                                                                                                                                     | Magliocca        |
| F. Garage                                                |                                                                                                                                                                                                                                                                                                                                                                                                |                  |
| G. Age                                                   |                                                                                                                                                                                                                                                                                                                                                                                                | Filatova, Parker |
| H. Quality                                               | No spatial factors apply. Each house is characterized by a single integer variable that is called “quality”                                                                                                                                                                                                                                                                                    | Carro            |

|           |                                                                                                                                                                                                        |  |
|-----------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--|
|           | and sets the house's desirability; House quality is assigned uniformly at random when the house is created from a discrete set of possible integer values, with higher values implying higher quality. |  |
| I. Others |                                                                                                                                                                                                        |  |

**Table 2. MR POTATOHEAD Real Estate Market Framework – Comparison table for the Property Exchange Class Template – Land Market**

|                                                                                                                                       |                                                                                                                                                                                                         |           |
|---------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------|
| 1. Which market is being modeled?                                                                                                     |                                                                                                                                                                                                         |           |
| Residences                                                                                                                            |                                                                                                                                                                                                         |           |
| Land                                                                                                                                  |                                                                                                                                                                                                         | Magliocca |
|                                                                                                                                       |                                                                                                                                                                                                         | Prunetti  |
| 2. Who are the market participants?                                                                                                   |                                                                                                                                                                                                         |           |
| a. Buyers                                                                                                                             |                                                                                                                                                                                                         | Magliocca |
|                                                                                                                                       |                                                                                                                                                                                                         | Prunetti  |
| i. Developers                                                                                                                         |                                                                                                                                                                                                         | Magliocca |
|                                                                                                                                       |                                                                                                                                                                                                         | Prunetti  |
| ii. Investors                                                                                                                         |                                                                                                                                                                                                         |           |
| iii. Households                                                                                                                       |                                                                                                                                                                                                         |           |
| b. Sellers                                                                                                                            |                                                                                                                                                                                                         |           |
| i. Developers                                                                                                                         |                                                                                                                                                                                                         |           |
| ii. Investors                                                                                                                         |                                                                                                                                                                                                         |           |
| iii. Households                                                                                                                       |                                                                                                                                                                                                         |           |
| iv. Landowners                                                                                                                        | Farmer                                                                                                                                                                                                  | Magliocca |
|                                                                                                                                       | Households landowners                                                                                                                                                                                   | Prunetti  |
| c. Renters                                                                                                                            |                                                                                                                                                                                                         |           |
| i. People who rent units (demand)                                                                                                     |                                                                                                                                                                                                         |           |
| ii. People who rent out units (supply)                                                                                                |                                                                                                                                                                                                         |           |
| 3. Initialize buyer and seller locations (call to agent's location field)                                                             |                                                                                                                                                                                                         |           |
| a. One agent per spatial container                                                                                                    |                                                                                                                                                                                                         | Magliocca |
|                                                                                                                                       |                                                                                                                                                                                                         | Prunetti  |
| b. Multiple agents per spatial container                                                                                              |                                                                                                                                                                                                         |           |
| 4. What are your ask and bid price rules for market-based land allocation?                                                            |                                                                                                                                                                                                         |           |
| a. How ask prices posted?                                                                                                             |                                                                                                                                                                                                         |           |
| i. Public information                                                                                                                 |                                                                                                                                                                                                         | Prunetti  |
|                                                                                                                                       |                                                                                                                                                                                                         | Magliocca |
| ii. Information held by realtor agents                                                                                                |                                                                                                                                                                                                         |           |
| b. Bid submission: How many properties can a buyer bid on?                                                                            | Developers have a building capacity constraint. One developer $m$ only bid on $n_m = n - \sigma_m$ parcels of land, where $\sigma_m$ is the number of construction site in progress for this developer. | Prunetti  |
|                                                                                                                                       | All properties                                                                                                                                                                                          | Magliocca |
| c. Bid acceptance: How many bids are accepted per property?                                                                           | One, if conditions are met—there is only one developer bidder in the model.                                                                                                                             | Magliocca |
|                                                                                                                                       | All bids                                                                                                                                                                                                | Prunetti  |
| 5. Matching algorithm: How are buyers matched to purchased properties?                                                                |                                                                                                                                                                                                         |           |
| a. Custom rule                                                                                                                        |                                                                                                                                                                                                         |           |
| b. How units are matched to the seller - subdivision model (many to one) or single property model (one to one). Call to seller ADM(s) | Single property model (one to one)                                                                                                                                                                      | Magliocca |
|                                                                                                                                       |                                                                                                                                                                                                         | Prunetti  |
| c. How are buyer bids matched to units? Call to buyer ADM(s)                                                                          | Developers with remaining building capacity ( $\sigma_m > 0$ ) bid on each parcel where $WTP > 0$ .                                                                                                     | Prunetti  |
|                                                                                                                                       | The representative developer bids on every parcel where $WTP > WTA$ .                                                                                                                                   | Magliocca |
| d. How are winning bids selected? Call to seller ADM(s)                                                                               | The buyer who has the highest bid is matched to the seller if $WTP \geq WTA$ . (if 2                                                                                                                    | Prunetti  |
|                                                                                                                                       |                                                                                                                                                                                                         | Magliocca |

|                                                                         |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |           |
|-------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------|
|                                                                         | or more buyers have the same WTP, the winning buyer is randomly selected).                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |           |
| e. How is the transaction price defined?                                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |           |
| i. Bid price if multiple bids                                           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |           |
| ii. Mean of bid and ask if one bid                                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |           |
| iii. Negotiation process (describe, calling ADM negotiation strategies) | <p>“If the developer’s WTP for a given farm is greater than the farmer’s WTA for his land, then the two enter into bilateral negotiation to determine the final transaction price of each parcel.”</p> <p>Bargaining power is defined as <math>\varepsilon = \frac{d_{Land} - A_{F*}}{d_{Land} + A_{F*}}</math>, where <math>d_{Land}</math> is the acreage demanded by the developer and <math>A_{F*}</math> is the acreage supplied by participating farmers.</p> <p>“If the developer demands more land than the farmers supply, <math>\varepsilon</math> is positive and farmers bid above their WTA. If farmers supply more land than is demanded by the developer, <math>\varepsilon</math> is negative and the developer will bid below his initial WTP.” (Page 187, Section 3.3.1, Magliocca et al., 2011).</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | Magliocca |
|                                                                         | <p>- If there are some bid prices where <math>Bidprice_m \geq Askprice_{i,t}</math>, a direct transaction happens with the transaction price set to the Ask price of the landowner: <math>\bar{P}_i(z_i) = Askprice_{i,t}</math></p> <p>- Otherwise, the negotiation power for the parcel of land <math>i</math> held by landowner <math>q</math> depends on the number of potential demands <math>ND_i</math> for <math>i</math>, for which <math>WTP_{m'}(z_i) \geq WTA_{i,t}^q(z_i)</math>; <math>ND_i \leq \chi</math>.</p> <p>Where <math>\chi</math> is the number of developers with remaining building capacity of <math>n_m \geq 0</math>, with <math>m' = (1, \dots, \chi)</math>.</p> <p>Two cases are possible:</p> <ul style="list-style-type: none"> <li>• If the landowner’s WTA for a given parcel <math>i</math> is higher than all developers’ WTP or if <math>\chi = 0</math>, no transaction happens.</li> <li>• Otherwise, if the developer <math>\mu</math> with the highest WTP has a WTP higher than the landowner’s WTA, the owner of the land <math>i</math> and the developer with the highest WTP match. The transaction price is given by the following expression: <math>\bar{P}_i(z_i) = WTA_{i,t}^q(z_i) + \frac{ND_i}{\chi} [WTP_{\mu}(z_i) - WTA_{i,t}^q(z_i)]</math></li> </ul> | Prunetti  |
| iv. Custom                                                              |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |           |
| 6. What market housekeeping occurs in your model?                       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |           |
| a. Change ownership                                                     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | Magliocca |
|                                                                         |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | Prunetti  |

|                                                                                                         |                                                                                                                                                                                 |           |
|---------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------|
| b. Age homes                                                                                            | There is a construction timeline only for houses under construction, which increments each time step.                                                                           | Prunetti  |
| c. Record sales prices for next round                                                                   |                                                                                                                                                                                 | Magliocca |
| d. Seller adjustments for un-sold units (call to ADM functions)                                         |                                                                                                                                                                                 |           |
| e. Rules for buyers who did not find a home (call to ADM functions)                                     | Developers who did not find properties stay in the market and continue to bid in the next time step, as long as they still have remaining building capacity ( $\sigma_m > 0$ ). | Prunetti  |
|                                                                                                         | The developer stays on the market and continue to bid in the next step.                                                                                                         | Magliocca |
| f. Identify active buyers and sellers for next round                                                    |                                                                                                                                                                                 | Magliocca |
|                                                                                                         |                                                                                                                                                                                 | Prunetti  |
| 7. What are your stopping rules for market activity?                                                    |                                                                                                                                                                                 |           |
| a. No market activity in X time periods (numerical entry for number of time periods) (equilibrium rule) |                                                                                                                                                                                 |           |
| b. End time periods (numerical entry for number of time periods) (non-equilibrium rule) (“new round”)   | 30 time steps                                                                                                                                                                   | Magliocca |
|                                                                                                         | 40 time steps                                                                                                                                                                   | Prunetti  |
| c. Others                                                                                               | All lands are sold.                                                                                                                                                             | Prunetti  |

**Table 3. MR POTATOHEAD Real Estate Market Framework – Comparison table for the Property Exchange Class Template – Residence Market**

|                                                                            |     |           |
|----------------------------------------------------------------------------|-----|-----------|
| 1. Which market is being modeled?                                          |     |           |
| Residences                                                                 |     | Parker    |
|                                                                            |     | Filatova  |
|                                                                            |     | Magliocca |
|                                                                            |     | Prunetti  |
|                                                                            |     | Ge        |
|                                                                            |     | Carro     |
| Land                                                                       |     |           |
| 2. Who are the market participants?                                        |     |           |
| a. Buyers                                                                  |     |           |
| i. Developers                                                              |     |           |
| ii. Investors                                                              |     | Prunetti  |
|                                                                            |     | Ge        |
|                                                                            |     | Carro     |
| iii. Households                                                            |     | Parker    |
|                                                                            |     | Filatova  |
|                                                                            |     | Magliocca |
|                                                                            |     | Prunetti  |
|                                                                            |     | Ge        |
|                                                                            |     | Carro     |
| b. Sellers                                                                 |     |           |
| i. Developers                                                              |     |           |
|                                                                            |     | Magliocca |
|                                                                            |     | Prunetti  |
|                                                                            |     | Ge        |
|                                                                            |     | Carro     |
| ii. Investors                                                              |     | Ge        |
|                                                                            |     | Carro     |
|                                                                            |     |           |
| iii. Households                                                            |     | Parker    |
|                                                                            |     | Filatova  |
|                                                                            |     | Ge        |
|                                                                            |     | Carro     |
| iv. Landowners                                                             |     |           |
| c. Renters                                                                 |     |           |
| i. People who rent units (demand)                                          |     |           |
| ii. People who rent out units (supply)                                     |     |           |
| 3. Initialize buyer and seller locations (call to agent's location field)  |     |           |
| a. One agent per spatial container                                         |     | Parker    |
|                                                                            |     | Filatova  |
|                                                                            |     | Prunetti  |
|                                                                            |     | Magliocca |
| b. Multiple agents per spatial container                                   |     | Ge        |
|                                                                            |     | Carro     |
| 4. What are your ask and bid price rules for market-based land allocation? |     |           |
| a. How ask prices posted?                                                  |     |           |
| i. Public information                                                      |     | Prunetti  |
|                                                                            |     | Carro     |
|                                                                            |     | Parker    |
| ii. Information held by realtor agents                                     |     | Filatova  |
|                                                                            |     | Magliocca |
|                                                                            |     | Ge        |
|                                                                            | One | Parker    |

|                                                                        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |           |
|------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------|
| b. Bid submission: How many properties can a buyer bid on?             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | Filatova  |
|                                                                        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | Ge        |
|                                                                        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | Carro     |
|                                                                        | Households bid on one property and the investor can bid on all properties.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | Prunetti  |
|                                                                        | All houses for which their WTP is greater than or equal to the developer's asking price, and the house generates a positive utility given the asking price.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | Magliocca |
| c. Bid acceptance: How many bids are accepted per property?            | One                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | Filatova  |
|                                                                        | All bids are accepted                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | Magliocca |
|                                                                        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | Ge        |
|                                                                        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | Prunetti  |
|                                                                        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | Parker    |
|                                                                        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | Carro     |
| 5. Matching algorithm: How are buyers matched to purchased properties? |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |           |
| a. Custom rule                                                         | <p>After the bidding process is completed, the highest bidder for each house is identified. For each consumer in the set of winning bidders, the set of houses for which the consumer owns the highest bid is identified.</p> <p>“The consumer's utility is recalculated for each of these houses using the winning bid instead of the initial asking price. Given these new levels of utility, the consumer is matched with the house that produces the highest utility. Once a consumer is matched with a house, both the consumer and house are removed from the market. The matching process is reiterated with the remaining bids, which are kept constant, until all consumers are matched, all houses are occupied, or all positive bids are exhausted. This process ensures consumers are matched to houses that generate their maximum possible utility levels given competitive bids from other consumers and discrete housing options provided by the developer.”</p> <p>(Magliocca et al., 2011; Page 188, Section 3.4.4) If there is a tie between buyer's bids, the buyer with the higher utility is awarded the house. If there is still a tie, then the winner is chosen randomly.</p> | Magliocca |

|                                                                                                                                          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |           |
|------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------|
|                                                                                                                                          | Home buyers are matched to the highest quality house they can afford, and to the cheapest possible house within a given quality band (this is due to the fact that qualities are integer numbers, say, from 0 to 30, for example, so there will be multiple houses with the same quality and different prices, in which case all buyers would prefer the cheapest one. Qualities are randomly assigned when the house is created, i.e., at the beginning of the simulation). House investors, on the contrary, are matched to the highest yield house they can afford, and to the cheapest possible house within a given yield (note that having exactly the same yield is very unlikely, as it is a float). Investors can be both buyers and sellers, that is, they can increase or decrease their portfolio of investment properties. | Carro     |
| b. How units are matched to the seller - subdivision model (many to one) or single property model (one to one).<br>Call to seller ADM(s) | One to one                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | Parker    |
|                                                                                                                                          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | Filatova  |
|                                                                                                                                          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | Magliocca |
|                                                                                                                                          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | Ge        |
|                                                                                                                                          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | Prunetti  |
|                                                                                                                                          | Many to one                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | Carro     |
| c. How are buyer bids matched to units? Call to buyer ADM(s)                                                                             | Buyers bid on the property that provides the highest utility or willingness-to-pay                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | Parker    |
|                                                                                                                                          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | Prunetti  |
|                                                                                                                                          | Call from buyer search strategy. Buyers 'sort' all vacant affordable houses according to their price. Secondly, out of the most expensive ones they randomly choose N and proceed with this set further to estimate utility and bid price. We commonly use N=5 in RHEA (based on the sensitivity analysis).                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | Filatova  |
|                                                                                                                                          | Call from buyer search strategy. Buyers search a random subset of all neighborhoods (due to imperfect information) and bid on one house in a cell with the highest utility.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | Ge        |
|                                                                                                                                          | See custom rule above                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Carro     |
|                                                                                                                                          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | Magliocca |
| d. How are winning bids selected? Call to seller ADM(s)                                                                                  | The highest bid is accepted if the price is higher than the ask price (if 2 or more buyers have the same WTP, the winning buyer is randomly selected).                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | Parker    |
|                                                                                                                                          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | Prunetti  |
|                                                                                                                                          | Max bid, with a negotiation mechanism (see negotiation below).                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Filatova  |
|                                                                                                                                          | The real estate agent settles market prices by collecting all the bids and asks (see transaction price below). After settling the transaction price, all bids above the market prices are successful. All winning bids can transact because there are                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Ge        |



|            |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |           |
|------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------|
|            | <p>WTP for the house of type <math>m</math> built on parcel of land <math>i</math>. If this WTP is higher than WTA's developer, the developer <math>m</math> and the individual <math>v</math> match. The transaction price is given by the following expression:</p> $\bar{P}_{H,i,m,v}(z_i, h_m) = WTA_{i,\mu,t}(z_i, h_\mu) + \frac{ND_\mu}{C+1} [WTP_{v,i,\mu,t}(z_i, h_\mu) - WTA_{i,\mu,t}(z_i, h_\mu)]$                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |           |
|            | <p>The housing-market competition factor, <math>HMC</math>, describes the competition for housing each consumer faces in the housing market: <math>HMC_c = \frac{N_c - N_H}{N_c + N_H}</math>, where <math>N_H</math> is the number of houses the consumer bids on and <math>N_c</math> is the number of other consumers bidding on those same houses. Consumer <math>c</math> then modifies their bid price, <math>R^*</math>, for each house in response to market conditions using <math>HMC</math>. Competition is high for a given consumer if there are more bidders for the houses he/she is bidding on than there are houses, and the bid will be increased. Competition is relatively low if there are more houses he/she is bidding on than total bidders for those houses, and the bid is adjusted downward. The adjustment of consumers' bid prices in response to market conditions allows consumers to attempt to maximize their gains from trade and the likelihood that they will be the highest bidder.</p> | Magliocca |
|            | <p>Bargaining power depending on the number of buyers vs sellers. When the real estate agent settles the prices, in a seller's market, since there are more bids than asks and buyers compete for sellers, price is settled at the <math>n</math>'s highest bid, where <math>n</math> is the number of sellers. In a buyer's market, because there are more asks than bids and sellers would have to compete for buyers, price is settled at the <math>n</math>'s lowest asks, where <math>n</math> is the number of buyers (Section 3.1.5, Ge, 2017).</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Ge        |
| iv. Custom | <p>Offers matched to a single bidder are directly transacted, while offers matched to multiple bidders have a certain probability to increase their price, with both the probability and the price increase size roughly calibrated from data (Table A8, Appendix 2, Carro et al., 2023). If there is no household able to afford the</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | Carro     |

|                                                   |                                                                                                                                                                                                                                                                                                                                                                                                                                            |           |
|---------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------|
|                                                   | new price, then the highest bidder is chosen, even if below the new price. If there are multiple households able to afford the new price, then a random one is chosen and the house is transacted at the new price. In the case of multiple bids, a bidder is finally chosen at random among those who can still pay for the property.                                                                                                     |           |
|                                                   | The real estate agent settles prices by collecting all the bids and asks, ordering the bids from high to low, and the asks from low to high. The market price is found at where the descending bids meet the ascending asks (Section 3.1.5, Ge, 2016).                                                                                                                                                                                     | Ge        |
| 6. What market housekeeping occurs in your model? |                                                                                                                                                                                                                                                                                                                                                                                                                                            |           |
| a. Change ownership                               |                                                                                                                                                                                                                                                                                                                                                                                                                                            | Parker    |
|                                                   |                                                                                                                                                                                                                                                                                                                                                                                                                                            | Filatova  |
|                                                   |                                                                                                                                                                                                                                                                                                                                                                                                                                            | Magliocca |
|                                                   |                                                                                                                                                                                                                                                                                                                                                                                                                                            | Prunetti  |
|                                                   |                                                                                                                                                                                                                                                                                                                                                                                                                                            | Ge        |
| b. Age homes                                      |                                                                                                                                                                                                                                                                                                                                                                                                                                            | Carro     |
|                                                   |                                                                                                                                                                                                                                                                                                                                                                                                                                            |           |
| c. Record sales prices for next round             |                                                                                                                                                                                                                                                                                                                                                                                                                                            | Filatova  |
|                                                   |                                                                                                                                                                                                                                                                                                                                                                                                                                            | Magliocca |
|                                                   |                                                                                                                                                                                                                                                                                                                                                                                                                                            | Prunetti  |
|                                                   |                                                                                                                                                                                                                                                                                                                                                                                                                                            | Carro     |
| d. Seller adjustments for un-sold units           | Sellers adjust ask price on 3 occasions. The estimated ask price is adjusted if (i) a property was not sold for two consecutive trade periods (by 4%), (ii) or have been flooded (by 15.7% and 13.8% for 1:100 and 1:500 flood zone correspondingly), (iii) or if demand for properties in the neighborhood goes up or down (even if no sales have been there yet; by 10% adjusted by the relative changes in demand in the neighborhood). | Filatova  |
|                                                   | For each year on the market, the unsold housing price is decreased by the discount rate.                                                                                                                                                                                                                                                                                                                                                   | Magliocca |
|                                                   | “ $\delta$ is the percentage decrease in price each period a seller's bid is not accepted, which is set to 2%.” (Page 189, Section 3.1.8, Ge, 2017)                                                                                                                                                                                                                                                                                        | Ge        |
|                                                   | The seller has a certain probability of reducing its price, each month the property is unsold. The new price will be $p_s^t = p_s^{t-1}(1 - \exp(\epsilon))$ , where $t$ indicates the time step and $\epsilon$ is a normal noise. Both the probability of a price reduction and the specific mechanism or functional form of the updated price are estimated using empirical data (Appendix 2 Table A5, Carro et al., 2023)               | Carro     |

|                                                                                                         |                                                                                                                                                                                                                       |           |
|---------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------|
| e. Rules for buyers who did not find a home (call to ADM functions)                                     | Buyers who cannot successfully buy a home will be removed from the market, and every step has random 140 buyers.                                                                                                      | Parker    |
|                                                                                                         | Buyer adjusts bid prices during negotiations. After an unsuccessful attempt, they just keep bidding in the next time steps for another property. After buyers leave after being unsuccessful on the market > 2 years. | Filatova  |
|                                                                                                         | Leave the market (after 3 time steps of unsuccessful bids)                                                                                                                                                            | Magliocca |
|                                                                                                         | Buyers who did not find properties stay in the market and continue to bid on next time step.                                                                                                                          | Prunetti  |
|                                                                                                         | Buyers quit searching after searching period exceeds maximum time-on-market.                                                                                                                                          | Ge        |
|                                                                                                         | They go back to “social housing” status, so next month they will decide again whether to buy or rent.                                                                                                                 | Carro     |
| f. Identify active buyers and sellers for next round                                                    |                                                                                                                                                                                                                       | Parker    |
|                                                                                                         |                                                                                                                                                                                                                       | Filatova  |
|                                                                                                         |                                                                                                                                                                                                                       | Magliocca |
|                                                                                                         |                                                                                                                                                                                                                       | Prunetti  |
|                                                                                                         |                                                                                                                                                                                                                       | Ge        |
| g. Check for new home supply                                                                            |                                                                                                                                                                                                                       | Prunetti  |
| 7. What are your stopping rules for market activity?                                                    |                                                                                                                                                                                                                       |           |
| a. No market activity in X time periods (numerical entry for number of time periods) (equilibrium rule) |                                                                                                                                                                                                                       |           |
| b. End time periods (numerical entry for number of time periods) (non-equilibrium rule) (“new round”)   | 25 time steps                                                                                                                                                                                                         | Filatova  |
|                                                                                                         | 30 time steps                                                                                                                                                                                                         | Magliocca |
|                                                                                                         | 40 time steps                                                                                                                                                                                                         | Prunetti  |
|                                                                                                         | 24 time steps                                                                                                                                                                                                         | Ge        |
|                                                                                                         | 30 time steps                                                                                                                                                                                                         | Parker    |
| c. Others                                                                                               | All lands are sold.                                                                                                                                                                                                   | Prunetti  |
|                                                                                                         | Matching and clearing rounds take place until no houses are left for sale, until no buyers are left, or until no buyer can afford any of the remaining houses.                                                        | Carro     |

**Table 4. MR POTATOHEAD Real Estate Market Framework – Comparison table for the Property Exchange Class Template – Rental Market**

|                                                                                                                                       |                                                                                                                                                                                                                                                                                                                                              |       |
|---------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|
| 1. Which market is being modeled?                                                                                                     |                                                                                                                                                                                                                                                                                                                                              |       |
| Residences                                                                                                                            |                                                                                                                                                                                                                                                                                                                                              | Carro |
| Land                                                                                                                                  |                                                                                                                                                                                                                                                                                                                                              |       |
| 2. Who are the market participants?                                                                                                   |                                                                                                                                                                                                                                                                                                                                              |       |
| a. Buyers                                                                                                                             |                                                                                                                                                                                                                                                                                                                                              |       |
| i. Developers                                                                                                                         |                                                                                                                                                                                                                                                                                                                                              |       |
| ii. Investors                                                                                                                         |                                                                                                                                                                                                                                                                                                                                              |       |
| iii. Households                                                                                                                       |                                                                                                                                                                                                                                                                                                                                              |       |
| b. Sellers                                                                                                                            |                                                                                                                                                                                                                                                                                                                                              |       |
| i. Developers                                                                                                                         |                                                                                                                                                                                                                                                                                                                                              |       |
| ii. Investors                                                                                                                         |                                                                                                                                                                                                                                                                                                                                              |       |
| iii. Households                                                                                                                       |                                                                                                                                                                                                                                                                                                                                              |       |
| iv. Landowners                                                                                                                        |                                                                                                                                                                                                                                                                                                                                              |       |
| c. Renters                                                                                                                            |                                                                                                                                                                                                                                                                                                                                              |       |
| i. People who rent units (demand)                                                                                                     | Households                                                                                                                                                                                                                                                                                                                                   | Carro |
| ii. People who rent out units (supply)                                                                                                | Investors                                                                                                                                                                                                                                                                                                                                    | Carro |
| 3. Initialize buyer and seller locations (call to agent's location field)                                                             |                                                                                                                                                                                                                                                                                                                                              |       |
| a. One agent per spatial container                                                                                                    |                                                                                                                                                                                                                                                                                                                                              | Carro |
| b. Multiple agents per spatial container                                                                                              |                                                                                                                                                                                                                                                                                                                                              |       |
| 4. What are your ask and bid price rules for market-based land allocation?                                                            |                                                                                                                                                                                                                                                                                                                                              |       |
| a. How ask prices posted?                                                                                                             |                                                                                                                                                                                                                                                                                                                                              |       |
| i. Public information                                                                                                                 |                                                                                                                                                                                                                                                                                                                                              | Carro |
| ii. Information held by realtor agents                                                                                                |                                                                                                                                                                                                                                                                                                                                              |       |
| b. Bid submission: How many properties can a buyer bid on?                                                                            | Households submit their bids on houses they can afford.                                                                                                                                                                                                                                                                                      | Carro |
| c. Bid acceptance: How many bids are accepted per property?                                                                           | Before matching takes place, bids are not bids for a specific property, but just abstract bids for a given price to the market. It is via the matching algorithm that bids get matched to specific properties. At that stage, properties can be matched to whatever number of bidders. It is only later, that a specific bidder is selected. | Carro |
| 5. Matching algorithm: How are buyers matched to purchased properties?                                                                |                                                                                                                                                                                                                                                                                                                                              |       |
| a. Custom rule                                                                                                                        | All households will be matched to the best quality house renters can afford, and to the cheapest possible house within a given quality band.                                                                                                                                                                                                 | Carro |
| b. How units are matched to the seller - subdivision model (many to one) or single property model (one to one). Call to seller ADM(s) | Many to one                                                                                                                                                                                                                                                                                                                                  | Carro |
| c. How are buyer bids matched to units? Call to buyer ADM(s)                                                                          | All households will be matched to the best quality house they can afford, and to the cheapest possible house within a given quality band.                                                                                                                                                                                                    | Carro |
| d. How are winning bids selected? Call to seller ADM(s)                                                                               | Highest bid                                                                                                                                                                                                                                                                                                                                  | Carro |
| e. How is the transaction price defined?                                                                                              |                                                                                                                                                                                                                                                                                                                                              |       |
| i. Bid price if multiple bids                                                                                                         |                                                                                                                                                                                                                                                                                                                                              |       |

|                                                                                                         |                                                                                                                                                                                                                                          |       |
|---------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|
| ii. Mean of bid and ask if one bid                                                                      |                                                                                                                                                                                                                                          |       |
| iii. Negotiation process                                                                                |                                                                                                                                                                                                                                          |       |
| iv. Custom (long text field)                                                                            | Price is given by the market equal to lessor's ask price for houses                                                                                                                                                                      | Carro |
| 6. What market housekeeping occurs in your model?                                                       |                                                                                                                                                                                                                                          |       |
| a. Change ownership                                                                                     |                                                                                                                                                                                                                                          |       |
| b. Age homes                                                                                            |                                                                                                                                                                                                                                          |       |
| c. Record sales prices for next round                                                                   |                                                                                                                                                                                                                                          | Carro |
| d. Seller adjustments for un-sold units (call to ADM functions)                                         | Each month a house remains vacant on the rental market, with a certain probability its price is reduced as $r_s^t = r_s^{t-1}(1 - \exp(\varepsilon))$ , where $\varepsilon$ is a normal noise (Appendix 2 Table A6, Carro et al., 2023). | Carro |
| e. Rules for buyers who did not find a home (call to ADM functions)                                     | They go back to "social housing" status, so next month they will decide again whether to buy or rent.                                                                                                                                    | Carro |
| f. Identify active buyers and sellers for next round                                                    |                                                                                                                                                                                                                                          |       |
| 7. What are your stopping rules for market activity?                                                    |                                                                                                                                                                                                                                          |       |
| a. No market activity in X time periods (numerical entry for number of time periods) (equilibrium rule) |                                                                                                                                                                                                                                          |       |
| b. End time periods (numerical entry for number of time periods) (non-equilibrium rule) ("new round")   |                                                                                                                                                                                                                                          |       |
| c. Others                                                                                               | Market stops when no more activity is possible, that is, when there are no more houses on offer, or no more bidders looking for a house or the houses on offer are too expensive for the bidders that remain on the market.              | Carro |

**Table S5. MR POTATOHEAD Real Estate Market Framework – Comparison table for the Agent Decision Template – Landowner land seller**

|                                                                                                                                                                                                                                                                 |                                                                                                                                                                                                                                                                                                                                                     |           |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------|
| 1. Buyers                                                                                                                                                                                                                                                       |                                                                                                                                                                                                                                                                                                                                                     |           |
| a. Developers - Land buyers                                                                                                                                                                                                                                     |                                                                                                                                                                                                                                                                                                                                                     |           |
| b. Investors                                                                                                                                                                                                                                                    |                                                                                                                                                                                                                                                                                                                                                     |           |
| i. Land                                                                                                                                                                                                                                                         |                                                                                                                                                                                                                                                                                                                                                     |           |
| ii. Residences                                                                                                                                                                                                                                                  |                                                                                                                                                                                                                                                                                                                                                     |           |
| c. Households                                                                                                                                                                                                                                                   |                                                                                                                                                                                                                                                                                                                                                     |           |
| 2. Sellers                                                                                                                                                                                                                                                      |                                                                                                                                                                                                                                                                                                                                                     | Magliocca |
|                                                                                                                                                                                                                                                                 |                                                                                                                                                                                                                                                                                                                                                     | Prunetti  |
| a. Developers                                                                                                                                                                                                                                                   |                                                                                                                                                                                                                                                                                                                                                     |           |
| b. Investors                                                                                                                                                                                                                                                    |                                                                                                                                                                                                                                                                                                                                                     |           |
| i. Land                                                                                                                                                                                                                                                         |                                                                                                                                                                                                                                                                                                                                                     |           |
| ii. Residences                                                                                                                                                                                                                                                  |                                                                                                                                                                                                                                                                                                                                                     |           |
| c. Households                                                                                                                                                                                                                                                   |                                                                                                                                                                                                                                                                                                                                                     |           |
| d. Land owners                                                                                                                                                                                                                                                  | Farmer                                                                                                                                                                                                                                                                                                                                              | Magliocca |
|                                                                                                                                                                                                                                                                 | Households Landowners                                                                                                                                                                                                                                                                                                                               | Prunetti  |
| 3. Renters                                                                                                                                                                                                                                                      |                                                                                                                                                                                                                                                                                                                                                     |           |
| a. People who rent residence units (demand)                                                                                                                                                                                                                     |                                                                                                                                                                                                                                                                                                                                                     |           |
| b. People who rent out residence units (supply)                                                                                                                                                                                                                 |                                                                                                                                                                                                                                                                                                                                                     |           |
| 4. Central bank                                                                                                                                                                                                                                                 |                                                                                                                                                                                                                                                                                                                                                     |           |
| 5. Government                                                                                                                                                                                                                                                   |                                                                                                                                                                                                                                                                                                                                                     |           |
| Decision making class                                                                                                                                                                                                                                           |                                                                                                                                                                                                                                                                                                                                                     |           |
| Four types: class (breed) C; attributes, (-own variable) A; links/relationships (directed-link breeds (parent), undirected-link breeds (friend, neighbor, can have own-variables for links in Netlogo, non-binary) L; processes (go, set-up) P; Documentation D |                                                                                                                                                                                                                                                                                                                                                     |           |
| 1. A / P - Attributes (methods/function and parameters) that affect real estate decisions                                                                                                                                                                       |                                                                                                                                                                                                                                                                                                                                                     |           |
| a. Budget (this might call a mortgage calculation function)                                                                                                                                                                                                     |                                                                                                                                                                                                                                                                                                                                                     |           |
| b. Preferences                                                                                                                                                                                                                                                  |                                                                                                                                                                                                                                                                                                                                                     |           |
| c. Time horizon/discount rate                                                                                                                                                                                                                                   | Discount rate of 5% is used to annualize all land or housing prices, costs, and price expectations. All prices/costs are annualized assuming a 30-years mortgage and similar loan rate for development/construction costs.                                                                                                                          | Magliocca |
|                                                                                                                                                                                                                                                                 | Time horizon is 20 years. It is the same for all agents and corresponds to the mean duration of a loan. Interest rate $r$ is an stochastic input parameterized as $r \sim \text{uniform}[0.02, 0.04]$ .                                                                                                                                             | Prunetti  |
| d. Risk perceptions                                                                                                                                                                                                                                             |                                                                                                                                                                                                                                                                                                                                                     |           |
| e. Price expectations                                                                                                                                                                                                                                           | “Farmer expectations of land prices are formed using a randomly allocated set of twenty prediction models. Each prediction model uses one of six different methods for forming predictions based on up to 10 years of past land prices from which to extrapolate next period’s price expectation” (Page 186, Section 3.2.3, Magliocca et al. 2011). | Magliocca |
|                                                                                                                                                                                                                                                                 | Price expectation mechanism relies on a linear regression with spatial fixed effects using the PERVAL dataset (produced by                                                                                                                                                                                                                          | Prunetti  |

|                                                                 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |           |
|-----------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------|
|                                                                 | <p>the Chamber of Notaries on property transactions) on land market transactions.</p> $\ln(P_{t-1}) = \alpha_L + \beta_{1L} \ln(LA_L) + \beta_{2L} [\ln(LA_L)]^2 + \beta_{3L}/dB_L + \beta_{4L}/dCBD_L + \beta_{5L}SVI_L + \beta_{6L}t + \beta_{7L}CD_L + \epsilon_{1L}$ <p>The regression model estimates price of a parcel of land based on previous prices for parcel of land with the same characteristics <math>z_i</math>; <math>LA_L</math> is land area ; <math>dB_L</math> is distance to the nearest beach; <math>dCBD_L</math> is distance to the nearest city center; <math>SVI_L</math> is Sea View Index; <math>CD_L</math> is county dummy; and <math>\epsilon_{1L}</math> is error term.</p> |           |
| f. Commuting/Transportation costs                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |           |
| g. Utility function                                             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |           |
| h. Expected return from renting                                 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |           |
| i. Model to determine what will be built (developer land buyer) |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |           |
| j. Willingness to Pay                                           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |           |
| k. Ask price                                                    | <p>Ask price is greater than or equal to WTA subject to land market competition. If the developer demands more land than farmers supply, each farmer will mark up his asking price to potentially maximize gains from trade. (Eq 13, Section 3.3.2, Magliocca et al., 2011)</p>                                                                                                                                                                                                                                                                                                                                                                                                                              | Magliocca |
|                                                                 | <p><math>Askprice_{i,t} = (1 + \psi)WTA</math>; where <math>\psi</math> is maximum expected leeway or negotiation margin, which shows the percentage mark-up a seller adds above their ask price to create a buffer for negotiation.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | Prunetti  |
| l. Willingness to Accept                                        | <p>WTA is set based on a comparison of returns to agriculture vs. expected sales prices using multiple expectations mechanisms. The projected land price for a cell on a farm F, consists of spatially discounted and predicted price components, is compared to the farmer's baseline WTA (the value of the farm's agricultural return per acre in perpetuity), and the farmer's WTA is dynamically set to the greater of the two values (Eq 11, Section 3.2.3, Magliocca et al., 2011).</p>                                                                                                                                                                                                                | Magliocca |
|                                                                 | $WTA_{HA}(z_i) = P_{t-1}(z_i)$                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Prunetti  |
| m. Bid price                                                    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |           |
| n. Information sources (i.e. Realtor, listings, neighbors)      | <p>They have information about the past prices of parcel sold as a common knowledge.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | Prunetti  |
|                                                                 | <p>Farmers are assumed to have access to data on farming returns plus up to ten years of land prices.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | Magliocca |
| o. Search strategies                                            |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |           |

|                                             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |           |
|---------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------|
| p. Negotiation strategies/negotiation power | <p>“Bargaining power in the land market is adapted from Parker and Filatova (2008) and captures differences in the developer's demand for, and the landowners' supply of, land at the initial WTP of the developer. If the developer's WTP for a given farm is greater than the farmer's WTA for his land, then the two enter into bilateral negotiation to determine the final transaction price of each parcel.”</p> <p>Bargaining power is defined as <math>\varepsilon = \frac{d_{Land} - A_{F*}}{d_{Land} + A_{F*}}</math>, where <math>d_{Land}</math> is the acreage demanded by the developer and <math>A_{F*}</math> is the acreage supplied by participating farmers.</p> <p>“If the developer demands more land than the farmers supply, <math>\varepsilon</math> is positive and farmers bid above their WTA. If farmers supply more land than is demanded by the developer, <math>\varepsilon</math> is negative and the developer will bid below his initial WTP.” (Page 187, Section 3.3.1, Magliocca et al., 2011).</p>                                                                                                                                                                                                                                                                                                                                                                                            | Magliocca |
|                                             | <p>- If there are some bid prices where <math>Bidprice_m \geq Askprice_{i,t}</math> a direct transaction occurs with price equal to the Ask price of the landowner: <math>\bar{P}_i(z_i) = Askprice_{i,t}</math></p> <p>- If there are no bid prices such as <math>Bidprice_m \geq Askprice_{i,t}</math>, the negotiation power for the parcel of land <math>i</math> held by landowner of type <math>q</math> (<math>q = \{1,2\}</math>) depends on the number of potential demands <math>ND_i</math> for <math>i</math>, i.e. for which: <math>WTP_{m'}(z_i) \geq WTA_{i,t}^q(z_i)</math>; <math>ND_i \leq \chi</math>. Where <math>\chi</math> is the number of developers, for which <math>n_m \geq 0</math>, with <math>m' = (1, \dots, \chi)</math>.</p> <p>Two cases are possible:</p> <ul style="list-style-type: none"> <li>• If the WTA of landowners for a given parcel <math>i</math> is higher than developers'WTP or if <math>\chi = 0</math>, no transaction is observed.</li> <li>• Otherwise, assuming <math>\mu \in \{1, \dots, \chi\}</math> is the developer with the highest bid for <math>i</math>. If this WTP is higher than WTA's landowner, the owner of the land <math>i</math> and the developer <math>\mu</math> match. The transaction price is given by the following expression: <math>\bar{P}_i(z_i) = WTA_{i,t}^q(z_i) + \frac{ND_i}{\chi} [WTP_{\mu}(z_i) - WTA_{i,t}^q(z_i)]</math></li> </ul> | Prunetti  |
| q. Household composition                    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |           |
| r. Partnership status                       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |           |
|                                             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | Magliocca |

|                                                                                                            |                                                                                                                                                                                                                  |                       |
|------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------|
| s. Location (note this will be read by the landscape initialization algorithms)                            | See characteristics of spatial entity in the landscape template.                                                                                                                                                 | Prunetti              |
| t. Production functions (Developers)                                                                       |                                                                                                                                                                                                                  |                       |
| u. Cost functions (Developers)                                                                             |                                                                                                                                                                                                                  |                       |
| v. Constraints (i.e. buy/sell, proximity to work - these are likely conditions)                            |                                                                                                                                                                                                                  |                       |
| 2. P - Decision to participate in the market (become active as a buyer, seller, investor, or renter)       |                                                                                                                                                                                                                  |                       |
| a. Decision to participate in the market as a seller                                                       | Farmers compare the returns from farming to expected profit from selling their land to a single representative developer and make the decision each period whether to continue farming or enter the land market. | Magliocca             |
|                                                                                                            | Parcels of household landowners are always on the market                                                                                                                                                         | Prunetti              |
| i. Decision to relocate?                                                                                   |                                                                                                                                                                                                                  |                       |
| b. Decision to participate in the market as a buyer                                                        |                                                                                                                                                                                                                  |                       |
| c. Decision to participate in the market as a renter                                                       |                                                                                                                                                                                                                  |                       |
| 3. P - Participate in the market as a buyer                                                                |                                                                                                                                                                                                                  |                       |
| a. Property budget (includes mortgage decision) - Call from above                                          |                                                                                                                                                                                                                  |                       |
| b. Which properties are evaluated (searching strategy)                                                     |                                                                                                                                                                                                                  |                       |
| c. WTP - call from above                                                                                   |                                                                                                                                                                                                                  |                       |
| d. Bid price - call from above                                                                             |                                                                                                                                                                                                                  |                       |
| e. Which property(s) to bid on?                                                                            |                                                                                                                                                                                                                  |                       |
| i. One per buyer                                                                                           |                                                                                                                                                                                                                  |                       |
| ii. Multiple per buyer                                                                                     |                                                                                                                                                                                                                  |                       |
| f. Negotiation strategy / Negotiation power - call from above                                              |                                                                                                                                                                                                                  |                       |
| g. Rules if you don't succeed to purchase                                                                  |                                                                                                                                                                                                                  |                       |
| i. Adjust budget/WTP/bid price (details)                                                                   |                                                                                                                                                                                                                  |                       |
| ii. Leave market (details)                                                                                 |                                                                                                                                                                                                                  |                       |
| 4. P - Participate in the market as a renter (renting a residence unit)                                    |                                                                                                                                                                                                                  |                       |
| a. Determination of budget                                                                                 |                                                                                                                                                                                                                  |                       |
| b. Which properties are evaluated (searching strategy, assume price taker at fixed offer price)            |                                                                                                                                                                                                                  |                       |
| c. WTP (from above)                                                                                        |                                                                                                                                                                                                                  |                       |
| d. Which property(s) to apply for?                                                                         |                                                                                                                                                                                                                  |                       |
| e. Rules if you don't succeed to purchase                                                                  |                                                                                                                                                                                                                  |                       |
| i. Adjust budget/WTP (details)                                                                             |                                                                                                                                                                                                                  |                       |
| ii. Leave market (details)                                                                                 |                                                                                                                                                                                                                  |                       |
| 5. P - Participate in the market as a leasor (renting unit to someone else) (rules need to be constructed) |                                                                                                                                                                                                                  |                       |
| 6. P - Participate in the market as a seller                                                               |                                                                                                                                                                                                                  |                       |
| a. WTA                                                                                                     | Call from above                                                                                                                                                                                                  | Magliocca<br>Prunetti |
| b. Ask/List price (What proposed sales price do you post to the market?)                                   | Call from above                                                                                                                                                                                                  | Magliocca<br>Prunetti |
| c. At what scale are the bids collected?                                                                   |                                                                                                                                                                                                                  |                       |
| i. Unique unit scale                                                                                       |                                                                                                                                                                                                                  | Magliocca<br>Prunetti |

|                                                                                  |                                                                                                                          |                       |
|----------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------|-----------------------|
| ii. Aggregate market scale                                                       |                                                                                                                          |                       |
| d. Rules for collecting bids: How many bids to you accept?                       |                                                                                                                          |                       |
| i. One per property up for sale                                                  | The model has only one representative developer; the land market is a series of bilateral negotiations and transactions. | Magliocca             |
| ii. Multiple per property                                                        | All bids are accepted                                                                                                    | Prunetti              |
| e. Who to sell to (how to pick the accepted bid)                                 |                                                                                                                          |                       |
| i. Single bid rule                                                               |                                                                                                                          |                       |
| A. Accept                                                                        |                                                                                                                          |                       |
| B. Accept if $\geq$ ask price, else reject                                       |                                                                                                                          | Magliocca             |
| C. Accept if $\geq$ WTA, else reject                                             |                                                                                                                          |                       |
| D. Other                                                                         |                                                                                                                          |                       |
| ii. Multiple bid rule                                                            |                                                                                                                          | Prunetti              |
| A. Highest price if $\geq$ ask price                                             |                                                                                                                          |                       |
| B. Highest price if $\geq$ WTA                                                   |                                                                                                                          |                       |
| C. Random selection if multiple highest bids                                     |                                                                                                                          | Magliocca<br>Prunetti |
| D. Other (short text field)                                                      |                                                                                                                          |                       |
| iii. Custom (long text field)                                                    |                                                                                                                          |                       |
| f. Negotiation strategy                                                          | Call from above                                                                                                          | Magliocca<br>Prunetti |
| g. List price/time on market adjustment rules (price decrease/repackage/upgrade) |                                                                                                                          |                       |
| i. Adjust price                                                                  |                                                                                                                          |                       |
| ii. Take unit off the market (text field for details)                            |                                                                                                                          |                       |
| iii. Default on loan (text field for details)                                    |                                                                                                                          |                       |

**Table S6 MR POTATOHEAD Real Estate Market Framework – Comparison table for the Agent Decision Template – Developer land buyer**

|                                                                                                                                                                                                                                                                                          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |           |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------|
| 1. Buyers                                                                                                                                                                                                                                                                                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Magliocca |
|                                                                                                                                                                                                                                                                                          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Prunetti  |
|                                                                                                                                                                                                                                                                                          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Ge        |
| a. Developers - Land buyers                                                                                                                                                                                                                                                              |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Magliocca |
|                                                                                                                                                                                                                                                                                          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Prunetti  |
|                                                                                                                                                                                                                                                                                          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Ge        |
| b. Investors                                                                                                                                                                                                                                                                             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |           |
| i. Land                                                                                                                                                                                                                                                                                  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |           |
| ii. Residences                                                                                                                                                                                                                                                                           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |           |
| c. Households                                                                                                                                                                                                                                                                            |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |           |
| 2. Sellers                                                                                                                                                                                                                                                                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |           |
| a. Developers                                                                                                                                                                                                                                                                            |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |           |
| b. Investors                                                                                                                                                                                                                                                                             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |           |
| i. Land                                                                                                                                                                                                                                                                                  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |           |
| ii. Residences                                                                                                                                                                                                                                                                           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |           |
| c. Households                                                                                                                                                                                                                                                                            |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |           |
| d. Land owners                                                                                                                                                                                                                                                                           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |           |
| 3. Renters                                                                                                                                                                                                                                                                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |           |
| a. People who rent residence units (demand)                                                                                                                                                                                                                                              |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |           |
| b. People who rent out residence units (supply)                                                                                                                                                                                                                                          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |           |
| 4. Central bank                                                                                                                                                                                                                                                                          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |           |
| 5. Government                                                                                                                                                                                                                                                                            |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |           |
| Decision making class<br>Four types: class (breed) C; attributes, (-own variable) A; links/relationships (directed-link breeds (parent), undirected-link breeds (friend, neighbor, can have own-variables for links in Netlogo, non-binary) L; processes (go, set-up) P; Documentation D |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |           |
| 1. A / P - Attributes (methods/function and parameters) that affect real estate decisions                                                                                                                                                                                                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |           |
| a. Budget (this might call a mortgage calculation function)                                                                                                                                                                                                                              | “Available developer budget in a given period is constrained by the amount of vacant land or houses the developer owns, which influences how much land the developer can acquire each period. There is carrying costs to the developer associated with holding vacant property; for example, interest accrued on loans financing the development project or foregone interest on an alternative safe investment” (Page 9, Section 2.2.1.3, Appendix 1, Magliocca et al., 2018). | Magliocca |
| b. Preferences                                                                                                                                                                                                                                                                           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |           |
| c. Time horizon/discount rate                                                                                                                                                                                                                                                            | Discount rate of 5% is used to annualize all land or housing prices, costs, and price expectations. All prices/costs are annualized assuming a 30-yr mortgage and similar loan rate for development / construction costs.                                                                                                                                                                                                                                                       | Magliocca |
|                                                                                                                                                                                                                                                                                          | Time horizon, $T$ , is 20 years. It is the same for all agents and corresponds to the mean duration of a loan. Interest rate $r$ is an stochastic input                                                                                                                                                                                                                                                                                                                         | Prunetti  |

|                       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                  |
|-----------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------|
|                       | parameterized as $r \sim \text{uniform}[0.02, 0.04]$ .                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                  |
| d. Risk perceptions   | When assessing potential lands for purchasing, loss-aversion is taken into account using the prediction error, $\sigma$ , associated with the most successful rent prediction model for each housing type. High and low estimates of expected returns are then considered in a risk-aversion framework modified from Ligmann-Zielinska (2009) to conform to prospect theory. Potential gains (potgain) and losses (potloss) are calculated relative to a reference point of zero, which represents meeting the profit target of a normal rate of return applied in the equations (Eq 16, Section 2.2.1.3, Appendix 1, Magliocca et al., 2018).                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | Magliocca                        |
| e. Price expectations | <p>“Developers make pricing decisions informed by expectations of future housing prices. Adapted from price expectation models used in agent-based financial literature (e.g. Arthur, 1994, 2006; Axtell, 2005), agents try to predict next period's price based on current and past price information. An agent is given a set of twenty prediction models. Each prediction model may use one of six different prediction methods, and there may be more than one model applying the same prediction method in the agent's set of twenty models. Some of these prediction methods map past and present prices (P) into the next period using various extrapolation methods” (Page 1, Section A.1.1, Appendix A, Magliocca et al. 2011).</p> <p>The price expectation mechanism relies on the following hedonic regression of past housing prices:</p> $\ln(P_{H,t-1}) = \alpha_H + \beta_{1H} \text{Liv}A_L + \beta_{2H} \text{Liv}A_L^2 + \beta_{3H} \text{Liv}A_L^3 + \beta_{4H} \text{Liv}A_L^4 + \beta_{5H} LA_L + \beta_{6H} dB_L + \beta_{7H} /dCDB_L + \beta_{8H} SVI_L + \beta_{9H} t + \epsilon_H$ <p>where <math>P_{H,t-1}</math> is past price of a house of type <math>m</math> built on the parcel of land with the characteristics, <math>\text{Liv}A_L</math> is total</p> | <p>Magliocca</p> <p>Prunetti</p> |

|                                                                 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |           |
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|                                                                 | surface in square meters of the house built by the developer $m$ ; $LA_L$ is Land Area; $CDB_{RT}$ is the distance to the nearest city center; $SVI_{RT}$ is the Sea View Index; and $\epsilon_H$ is Error Term. It will be given by the results of a spatial regression using the PERVAL dataset (produced by the Chamber of Notaries on property transactions) on the detached house market transactions.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |           |
| f. Commuting/Transportation costs                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |           |
| g. Utility function                                             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |           |
| h. Expected return from renting                                 | Rent projections are calculated as the weighted combination of local and regional (suburb-wide) expected rents for existing houses (Section 3.2.2, Magliocca et al., 2011). The method of rent projection depends on the level of uncertainty in rent expectations. If a given housing type has been built, a spatially weighted extrapolation is made based on distance and price trends. If the given housing type has not yet been built within the region, the developer relies on a hedonic regression model based on existing housing characteristics. The hedonic regression uses median consumer income ( $x_1$ ) from similar housing types, lot size of the given housing type, $h(x_2)$ , and travel costs ( $x_3$ ) to and amenity level ( $x_4$ ) in the given location, $i$ , to project an expected rent: $R_{proj}(i, h) = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + x_4 \beta_4$ . | Magliocca |
| i. Model to determine what will be built (developer land buyer) | Decision to build is based on expected profits given observed housing prices among contiguous developed land parcels for each housing type to inform future price expectations.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Magliocca |
|                                                                 | “The representative developer will supply the amount of new houses so that the marginal cost of building the new house equals the price the house is expected to be sold. As a result, the number of houses being built in each period differs in each region. More houses will be built in regions with relatively high housing prices and low construction costs” (Page 185, and Eq 11-17, Section 3.1.4, Ge, 2017). Marginal cost is set to the residence                                                                                                                                                                                                                                                                                                                                                                                                                                                  | Ge        |

|                                                            |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |           |
|------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------|
|                                                            | price 6 months ago (assuming a 6 month construction period).                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |           |
|                                                            | There are $M$ developers, each of them buys a parcel and build a unique house of type $m$ , with $m = \{1; \dots; M\}$ . They build only one house by parcel.                                                                                                                                                                                                                                                                                                                                                                                                                                            | Prunetti  |
| j. Willingness to Pay                                      | Maximum price per acre the developer is willing to pay for a landowners holdings based on expected profit from rents of residences. See rent projection above (Eq 10, Section 3.2.2, and Eq 14, Section 3.3.3, Magliocca et al. 2011).                                                                                                                                                                                                                                                                                                                                                                   | Magliocca |
|                                                            | WTP is determined by requiring that the selling price allow them to generate a margin $\pi_m$ on the total cost of the house built on the parcel of land $i$ (sum of the price paid for buying the parcel of land $i$ and the construction cost to build a house). WTP for a developer $m$ for a given parcel with the vector characteristics $z_i$ , is given by the following expression:<br>$WTP_m(z_i) = \frac{P_{H,i,t-1}(z_i, LivA_m)}{1 + \pi_m} - C_{LivA}(z_i)LivA_m$ Where $C_{LivA}$ is the construction cost per unit area and $LivA_m$ represents the surface area of a house of type $m$ . | Prunetti  |
| k. Ask price                                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |           |
| l. Willingness to Accept                                   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |           |
| m. Bid price                                               | Equal to WTP                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | Magliocca |
|                                                            | $Bidprice_m = (1 - \psi)WTP_m$ ;<br>$\psi$ : maximum expected leeway or negotiation margin on the selling price, which shows the percentage mark-up a buyer considers below their WTP to create a buffer for negotiation.                                                                                                                                                                                                                                                                                                                                                                                | Prunetti  |
| n. Information sources (i.e. Realtor, listings, neighbors) | The developer uses housing information, which would be available from a listing service or similar source, to form expectations of annual rental payments for different housing types in the next period.                                                                                                                                                                                                                                                                                                                                                                                                | Magliocca |
|                                                            | They have information about the past prices of parcel and houses built on a parcel sold as a common knowledge.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | Prunetti  |
| o. Search strategies                                       | The representative developer considers all undeveloped cells and makes spatially explicit rent                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | Magliocca |

|                                             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |           |
|---------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------|
|                                             | projections for all housing types, and bids on the parcels.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |           |
|                                             | Developers consider all land parcels and bid on them if $WTP > 0$ and they have remaining building capacity ( $\sigma_m > 0$ ).                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | Prunetti  |
| p. Negotiation strategies/negotiation power | Following Parker and Filatova (2008), if the developer's WTP for a given farm is greater than the farmer's WTA for his land, then the two enter into bilateral negotiation to determine the final transaction price of each parcel. Bargaining power is defined as $\varepsilon = \frac{d_{Land} - A_{F*}}{d_{Land} + A_{F*}}$ , where $d_{Land}$ is the acreage demanded by the developer and $A_{F*}$ is the acreage supplied by participating farmers. "If the developer demands more land than the farmers supply, $\varepsilon$ is positive and farmers bid above their WTA. If farmers supply more land than is demanded by the developer, $\varepsilon$ is negative and the developer will bid below his initial WTP" (Page 187, Section 3.3.1, Magliocca et al., 2011).                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | Magliocca |
|                                             | <p>- If there are some bid prices such as <math>Bidprice_m \geq Askprice_{i,t}</math> an efficient-rationing rule is applied: the developers with the highest bid price buy the land parcel. The transaction price is then equal to the Ask price of the landowner: <math>\bar{P}_i(z_i) = Askprice_{i,t}</math></p> <p>- If there are no bid prices such as <math>Bidprice_m \geq Askprice_{i,t}</math>, no direct sales occur. Instead, the negotiation starts where the negotiation power for the parcel of land <math>i</math> held by landowner of type <math>q</math> (<math>q = \{1,2\}</math>) depends on the number of potential demands <math>ND_i</math> for <math>i</math>, i.e. for which: <math>WTP_{m'}(z_i) \geq WTA_{i,t}^q(z_i)</math>; <math>ND_i \leq \chi</math>. Where <math>\chi</math> is the number of developers, for which <math>n_m \geq 0</math>, with <math>m' = (1, \dots, \chi)</math>. Two cases are possible:</p> <ul style="list-style-type: none"> <li>• If the WTA of landowners for a given parcel <math>i</math> is higher than developers' WTP or if <math>\chi = 0</math>, no transaction is observed.</li> <li>• Otherwise, let be <math>\mu \in \{1, \dots, \chi\}</math> the developer with the highest bid for <math>i</math>. If this WTP is higher than WTA's</li> </ul> | Prunetti  |



|                                                                                                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |           |
|------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------|
|                                                                                                      | <p>accrued on loans financing the development project or foregone interest on an alternative safe investment. Carrying costs for vacant land equal 5% interest on the price paid for land. Carrying costs for vacant houses equal 5% interest on the combined price paid for land and annualized construction costs of the particular housing type.” (Page 9, Appendix 1, Section 2.2.1.3, Magliocca et al., 2018)</p> <p>Costs of construction and infrastructure by housing types are given in Table 1, Page 186, Magliocca et al., 2011.</p> |           |
|                                                                                                      | <p>Total cost is quadratic function of number of houses built in a given period and the total number of houses built in the neighborhood.</p> $TC_t^g(q_t^g) = c_1 h + \frac{c_2}{2} (q_t^g)^2 + \frac{c_3}{2} (Q_{t-1}^g)^2$ <p>(Eq 11, Section 3.1., Ge, 2017)</p>                                                                                                                                                                                                                                                                            | Ge        |
|                                                                                                      | <p><math>C_{LivA}(z_i)LivA_m</math> is the construction cost to build a house of type <math>m</math>;<br/> <math>C_{LivA}(z_i)LivA_m</math> is a constant showing construction cost by square meters;<br/> <math>LivA_m</math> is living area of a house of type <math>m</math>.</p>                                                                                                                                                                                                                                                            | Prunetti  |
| v. Constraints (i.e. buy/sell, proximity to work - these are likely conditions)                      | Constraint of construction time, between 8 and 11 timesteps.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | Prunetti  |
| w. Margin rate of the developer                                                                      | $\pi_m$ shows the expected developer’s profit margin above the total cost of constructing a house.                                                                                                                                                                                                                                                                                                                                                                                                                                              | Prunetti  |
| 2. P - Decision to participate in the market (become active as a buyer, seller, investor, or renter) |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |           |
| a. Decision to participate in the market as a seller                                                 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |           |
| i. Decision to relocate?                                                                             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |           |
| b. Decision to participate in the market as a buyer                                                  | Always active.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | Magliocca |
|                                                                                                      | They are always active, unless they have reached their building capacity constraint, in which case they will bid when current construction is finished, and they have available building capacity.                                                                                                                                                                                                                                                                                                                                              | Prunetti  |
| c. Decision to participate in the market as a renter                                                 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |           |
| 3. P - Participate in the market as a buyer                                                          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |           |
| a. Property budget (includes mortgage decision) - Call from above                                    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |           |
| b. Which properties are evaluated (searching strategy)                                               | All land parcels are evaluated.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Magliocca |
|                                                                                                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Prunetti  |
| c. WTP                                                                                               | Call from above                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Magliocca |

|                                                                                                                                                                          |                                                                                                                                                                                                                            |           |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------|
|                                                                                                                                                                          |                                                                                                                                                                                                                            | Prunetti  |
| d. Bid price                                                                                                                                                             | Call from above                                                                                                                                                                                                            | Magliocca |
|                                                                                                                                                                          |                                                                                                                                                                                                                            | Prunetti  |
| e. Which property(s) to bid on?                                                                                                                                          |                                                                                                                                                                                                                            |           |
| i. One per buyer                                                                                                                                                         |                                                                                                                                                                                                                            |           |
| ii. Multiple per buyer                                                                                                                                                   |                                                                                                                                                                                                                            | Magliocca |
|                                                                                                                                                                          | With respect of their building capacity constraints.                                                                                                                                                                       | Prunetti  |
| f. Negotiation strategy / Negotiation power - call from above                                                                                                            | Call from above                                                                                                                                                                                                            | Magliocca |
|                                                                                                                                                                          |                                                                                                                                                                                                                            | Prunetti  |
| g. Rules if you don't succeed to purchase                                                                                                                                |                                                                                                                                                                                                                            |           |
| i. Adjust budget/WTP/bid price (details)                                                                                                                                 |                                                                                                                                                                                                                            |           |
| ii. Leave market (details)                                                                                                                                               | If, over two consecutive periods, A developer fails to make any positive sales, the developer is deemed bankrupt and is replaced by another developer agent. Otherwise, developers remain in the land and housing markets. | Prunetti  |
| iii. Stay in the market                                                                                                                                                  |                                                                                                                                                                                                                            |           |
| 4. P - Participate in the market as a renter (renting a residence unit)                                                                                                  |                                                                                                                                                                                                                            |           |
| a. Determination of budget                                                                                                                                               |                                                                                                                                                                                                                            |           |
| b. Which properties are evaluated (searching strategy, assume price taker at fixed offer price)                                                                          |                                                                                                                                                                                                                            |           |
| c. WTP (from above)                                                                                                                                                      |                                                                                                                                                                                                                            |           |
| d. Which property(s) to apply for?                                                                                                                                       |                                                                                                                                                                                                                            |           |
| e. Rules if you don't succeed to purchase                                                                                                                                |                                                                                                                                                                                                                            |           |
| i. Adjust budget/WTP (details)                                                                                                                                           |                                                                                                                                                                                                                            |           |
| ii. Leave market (details)                                                                                                                                               |                                                                                                                                                                                                                            |           |
| 5. P - Participate in the market as a leasor (renting unit to someone else) (rules need to be constructed)                                                               |                                                                                                                                                                                                                            |           |
| 6. P - Participate in the market as a seller                                                                                                                             |                                                                                                                                                                                                                            |           |
| a. WTA (from above)                                                                                                                                                      |                                                                                                                                                                                                                            |           |
| b. Ask/List price (What proposed sales price do you post to the market?)                                                                                                 |                                                                                                                                                                                                                            |           |
| c. At what scale are the bids collected? (pick list) (This is related to the container issues. You might have a container of units, but still list each one separately.) |                                                                                                                                                                                                                            |           |
| i. Unique unit scale:                                                                                                                                                    |                                                                                                                                                                                                                            |           |
| ii. Aggregate market scale                                                                                                                                               |                                                                                                                                                                                                                            |           |
| d. Rules for collecting bids: How many bids to you accept?                                                                                                               |                                                                                                                                                                                                                            |           |
| i. One per property up for sale                                                                                                                                          |                                                                                                                                                                                                                            |           |
| ii. Multiple per property                                                                                                                                                |                                                                                                                                                                                                                            |           |
| e. Who to sell to (how to pick the accepted bid)                                                                                                                         |                                                                                                                                                                                                                            |           |
| i. Single bid rule                                                                                                                                                       |                                                                                                                                                                                                                            |           |
| A. Accept                                                                                                                                                                |                                                                                                                                                                                                                            |           |
| B. Accept if $\geq$ ask price, else reject                                                                                                                               |                                                                                                                                                                                                                            |           |
| C. Accept if $\geq$ WTA, else reject                                                                                                                                     |                                                                                                                                                                                                                            |           |

|                                                                                  |  |  |
|----------------------------------------------------------------------------------|--|--|
| D. Other (short text field)                                                      |  |  |
| ii. Multiple bid rule                                                            |  |  |
| A. Highest price if $\geq$ ask price                                             |  |  |
| B. Highest price if $\geq$ WTA                                                   |  |  |
| C. Random selection if multiple highest bids                                     |  |  |
| D. Other (short text field)                                                      |  |  |
| iii. Custom (long text field)                                                    |  |  |
| f. Negotiation strategy                                                          |  |  |
| g. List price/time on market adjustment rules (price decrease/repackage/upgrade) |  |  |
| i. Adjust price (text field for details)                                         |  |  |
| ii. Take unit off the market (text field for details)                            |  |  |
| iii. Default on loan (text field for details)                                    |  |  |

**Table S7. MR POTATOHEAD Real Estate Market Framework – Comparison table for the Agent Decision Template – Developer residence seller**

|                                                                                                                                                                                                                                                                                          |                                                                                                                                                                                                                                                                                                                        |           |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------|
| 1. Buyers                                                                                                                                                                                                                                                                                |                                                                                                                                                                                                                                                                                                                        |           |
| a. Developers - Land buyers                                                                                                                                                                                                                                                              |                                                                                                                                                                                                                                                                                                                        |           |
| b. Investors                                                                                                                                                                                                                                                                             |                                                                                                                                                                                                                                                                                                                        |           |
| i. Land                                                                                                                                                                                                                                                                                  |                                                                                                                                                                                                                                                                                                                        |           |
| ii. Residences                                                                                                                                                                                                                                                                           |                                                                                                                                                                                                                                                                                                                        |           |
| c. Households                                                                                                                                                                                                                                                                            |                                                                                                                                                                                                                                                                                                                        |           |
| 2. Sellers                                                                                                                                                                                                                                                                               |                                                                                                                                                                                                                                                                                                                        | Magliocca |
|                                                                                                                                                                                                                                                                                          |                                                                                                                                                                                                                                                                                                                        | Prunetti  |
|                                                                                                                                                                                                                                                                                          |                                                                                                                                                                                                                                                                                                                        | Ge        |
|                                                                                                                                                                                                                                                                                          |                                                                                                                                                                                                                                                                                                                        | Carro     |
| a. Developers                                                                                                                                                                                                                                                                            |                                                                                                                                                                                                                                                                                                                        | Magliocca |
|                                                                                                                                                                                                                                                                                          |                                                                                                                                                                                                                                                                                                                        | Prunetti  |
|                                                                                                                                                                                                                                                                                          |                                                                                                                                                                                                                                                                                                                        | Ge        |
|                                                                                                                                                                                                                                                                                          |                                                                                                                                                                                                                                                                                                                        | Carro     |
| b. Investors                                                                                                                                                                                                                                                                             |                                                                                                                                                                                                                                                                                                                        |           |
| i. Land                                                                                                                                                                                                                                                                                  |                                                                                                                                                                                                                                                                                                                        |           |
| ii. Residences                                                                                                                                                                                                                                                                           |                                                                                                                                                                                                                                                                                                                        |           |
| c. Households                                                                                                                                                                                                                                                                            |                                                                                                                                                                                                                                                                                                                        |           |
| d. Land owners                                                                                                                                                                                                                                                                           |                                                                                                                                                                                                                                                                                                                        |           |
| 3. Renters                                                                                                                                                                                                                                                                               |                                                                                                                                                                                                                                                                                                                        |           |
| a. People who rent residence units (demand)                                                                                                                                                                                                                                              |                                                                                                                                                                                                                                                                                                                        |           |
| b. People who rent out residence units (supply)                                                                                                                                                                                                                                          |                                                                                                                                                                                                                                                                                                                        |           |
| 4. Central bank                                                                                                                                                                                                                                                                          |                                                                                                                                                                                                                                                                                                                        |           |
| 5. Government                                                                                                                                                                                                                                                                            |                                                                                                                                                                                                                                                                                                                        |           |
| Decision making class<br>Four types: class (breed) C; attributes, (-own variable) A; links/relationships (directed-link breeds (parent), undirected-link breeds (friend, neighbor, can have own-variables for links in Netlogo, non-binary) L; processes (go, set-up) P; Documentation D |                                                                                                                                                                                                                                                                                                                        |           |
| 1. A / P - Attributes (methods/function and parameters) that affect real estate decisions                                                                                                                                                                                                |                                                                                                                                                                                                                                                                                                                        |           |
| a. Budget (this might call a mortgage calculation function)                                                                                                                                                                                                                              |                                                                                                                                                                                                                                                                                                                        |           |
| b. Preferences                                                                                                                                                                                                                                                                           |                                                                                                                                                                                                                                                                                                                        |           |
| c. Time horizon/discount rate                                                                                                                                                                                                                                                            | Discount rate of 5% is used to annualize all land or housing prices, costs, and price expectations. All prices/costs are annualized assuming a 30-yr mortgage and similar loan rate for development / construction costs                                                                                               | Magliocca |
|                                                                                                                                                                                                                                                                                          | Time horizon, T, is 20 years. It is the same for all agents and corresponds to the mean duration of a loan. Interest rate r is an stochastic input parameterized as $r \sim \text{uniform}[0.02, 0.04]$ .                                                                                                              | Prunetti  |
| d. Risk perceptions                                                                                                                                                                                                                                                                      |                                                                                                                                                                                                                                                                                                                        |           |
| e. Price expectations                                                                                                                                                                                                                                                                    | “Developers make pricing decisions informed by expectations of future housing prices. Adapted from price expectation models used in agent-based financial literature (e.g. Arthur, 1994, 2006; Axtell, 2005), agents try to predict next period's price based on current and past price information. An agent is given | Magliocca |

|                                                                 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |           |
|-----------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------|
|                                                                 | a set of twenty prediction models. Each prediction model may use one of six different prediction methods, and there may be more than one model applying the same prediction method in the agent's set of twenty models. Some of these prediction methods map past and present prices (P) into the next period using various extrapolation methods.” (Page 1, Section A.1.1, Appendix A, Magliocca et al. 2011)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |           |
|                                                                 | Developers form expectations regarding the price at which they will be able to sell a house constructed on a parcel. They rely on past average price paid for an equivalent house with characteristics $z_i$ , denoted as $P_{H,i,t-1}(z_i, Liv_{Am})$ ; where $Liv_{Am}$ is the living area of a house of a $m$ type. As soon as the number of house sales exceeds the number of elements in $z_i$ plus one, the price expectation $P_{H,i,t-1}(z_i, Liv_{Am})$ is corrected by the agents based on a regression of house sales prices.                                                                                                                                                                                                                                                                                                                                                       | Prunetti  |
|                                                                 | Ask price for a house with a given quality is updated based on the exponential moving average sale price of houses of the same quality (Table A5 Appendix 2, Carro et al., 2023).                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | Carro     |
| f. Commuting/Transportation costs                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |           |
| g. Utility function                                             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |           |
| h. Expected return from renting                                 | Rent projections are calculated as the weighted combination of local and regional (suburb-wide) expected rents for existing houses (Magliocca et al., 2011). The method of rent projection depends on the level of uncertainty in rent expectations. If a given housing type has been built, a spatially weighted extrapolation is made based on distance and price trends. If the given housing type has not yet been built within the region, the developer relies on a hedonic regression model based on existing housing characteristics. The hedonic regression uses median consumer income ( $x_1$ ) from similar housing types, lot size of the given housing type, $h(x_2)$ , and travel costs ( $x_3$ ) to and amenity level ( $x_4$ ) in the given location, $i$ , to project an expected rent: $R_{proj}(i, h) = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + x_4 \beta_4$ . | Magliocca |
| i. Model to determine what will be built (developer land buyer) | See developer land buyer template.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | Magliocca |
|                                                                 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | Ge        |
|                                                                 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | Prunetti  |

|                                                            |                                                                                                                                                                                                                                                                                                                      |           |
|------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------|
| j. Willingness to Pay                                      |                                                                                                                                                                                                                                                                                                                      |           |
| k. Ask price                                               | <p>For existing housing, the asking price equals the developer's expected rent, which is formed using the price expectation models (See price expectation above).</p> <p>For newly constructed houses, the asking price equals the developer's expected rent (See expected return from renting above).</p>           | Magliocca |
|                                                            | $Askprice_{i,m,t} = (1 + \psi) WTA_{i,m,t};$<br>$\psi$ : maximum expected leeway or negotiation margin, which shows the percentage mark-up a seller adds above their ask price to create a buffer for negotiation.                                                                                                   | Prunetti  |
|                                                            | Equal to WTA                                                                                                                                                                                                                                                                                                         | Ge        |
|                                                            |                                                                                                                                                                                                                                                                                                                      | Carro     |
| l. Willingness to Accept                                   | Based on a profit target equal to normal rate of return on investment, assumed to be 5%, above cost to acquire and develop property.                                                                                                                                                                                 | Magliocca |
|                                                            | $WTA_{i,m}(z_i, LivA_m) = (1 + \pi_m)(\bar{P}_l(z_i) + C_{LivA} \times LivA_m)$ , where $\bar{P}_l(z_i)$ is the price paid for the land, $LivA_m$ is living area, $C_{LivA}$ is construction cost per unit area, and $\pi_m$ is the expected developer's profit margin above the total cost of constructing a house. | Prunetti  |
|                                                            | Equal to marginal construction costs, which increases with the number of houses built in a given period (Eq 18, Section 3.1.4, Ge, 2017).                                                                                                                                                                            | Ge        |
|                                                            | Ask price is directly taken from the real distribution of housing prices, for the percentile corresponding to the house quality of the specific house to be sold (Table A5, Appendix 2, Carro et al., 2023). Note that this quality is chosen at random.                                                             | Carro     |
| m. Bid price                                               |                                                                                                                                                                                                                                                                                                                      |           |
| n. Information sources (i.e. Realtor, listings, neighbors) | The developer uses housing information to form expectations of annual rental payments for different housing types in the next period.                                                                                                                                                                                | Magliocca |
|                                                            | The developer has access to housing characteristics to estimate WTA prices.                                                                                                                                                                                                                                          | Prunetti  |
|                                                            | The developer has access to the current population, the current number of houses and the distribution of real housing prices.                                                                                                                                                                                        | Carro     |
| o. Search strategies                                       |                                                                                                                                                                                                                                                                                                                      |           |

|                                                                                                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                             |
|------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------|
| p. Negotiation strategies/negotiation power                                                          | <p>- If there are some bid prices where <math>Bidprice_v \geq Askprice_{i,m,t}</math>, the agent (household or investor) with the highest bid price buy the house of type <math>m</math> built on parcel of land <math>i</math>. The transaction price is then equal to the Ask price of the developer: <math>\bar{P}_{H,i,m,v}(z_i, h_m) = Askprice_{i,m,t}</math></p> <p>- If there are no bid prices such as <math>Bidprice \geq Askprice</math>, the negotiation power for the house of type <math>m</math> built on parcel of land <math>i</math> depends on the number of demands <math>ND_{i,m}</math> from households for whom this house corresponds to the maximal utility and from the investor if her WTP is higher than the WTA of the developer, <math>ND_{\mu} \leq C + 1</math>. Where <math>C</math> is the total number of households in search of a house. Two cases are possible:</p> <ul style="list-style-type: none"> <li>• If the WTA of the developer is always higher than the WTP of the buyers, there is no transaction and the housing will be put back and replace on the market in the next step.</li> <li>• Otherwise, let <math>v</math> be the individual who has the highest WTP for the house of type <math>m</math> built on parcel of land <math>i</math>. If this WTP is higher than WTA's developer, the developer <math>m</math> and the individual <math>v</math> match. The transaction price is given by the following expression:<br/> <math display="block">\bar{P}_{H,i,m,v}(z_i, h_m) = WTA_{i,\mu,t}(z_i, h_{\mu}) + \frac{ND_{\mu}}{C+1} [WTP_{v,i,\mu,t}(z_i, h_{\mu}) - WTA_{i,\mu,t}(z_i, h_{\mu})]</math></li> </ul> | Prunetti                    |
| q. Household composition                                                                             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                             |
| r. Partnership status                                                                                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                             |
| s. Location (note this will be read by the landscape initialization algorithms)                      | See characteristics of spatial entity in the landscape template.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | Prunetti<br>Magliocca<br>Ge |
| t. Production functions (Developers)                                                                 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                             |
| u. Cost functions (Developers)                                                                       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                             |
| v. Constraints (i.e. buy/sell, proximity to work - these are likely conditions)                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                             |
| 2. P - Decision to participate in the market (become active as a buyer, seller, investor, or renter) |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                             |
| a. Decision to participate in the market as a seller                                                 | All houses ready for sale go on the market.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | Magliocca<br>Prunetti<br>Ge |
|                                                                                                      | The developer simply puts as many new houses in the market as needed in order                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | Carro                       |

|                                                                                                            |                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                      |
|------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------|
|                                                                                                            | to instantaneously reach a given target ratio of houses per household (taken from data on the actual ratio of houses per household in the UK in 2011), which is a parameter of the model. Thus, at each time step, the developer checks the current number of households compares it with the current number of houses and decides how many new houses are needed. For each of these houses, the developer assigns a random quality. |                                      |
| i. Decision to relocate?                                                                                   |                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                      |
| b. Decision to participate in the market as a buyer                                                        |                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                      |
| c. Decision to participate in the market as a renter                                                       |                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                      |
| 3. P - Participate in the market as a buyer                                                                |                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                      |
| a. Property budget (includes mortgage decision) - Call from above                                          |                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                      |
| b. Which properties are evaluated (searching strategy)                                                     |                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                      |
| c. WTP - call from above                                                                                   |                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                      |
| d. Bid price - call from above                                                                             |                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                      |
| e. Which property(s) to bid on?                                                                            |                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                      |
| i. One per buyer                                                                                           |                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                      |
| ii. Multiple per buyer                                                                                     |                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                      |
| f. Negotiation strategy / Negotiation power - call from above                                              |                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                      |
| g. Rules if you don't succeed to purchase                                                                  |                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                      |
| i. Adjust budget/WTP/bid price (details)                                                                   |                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                      |
| ii. Leave market (details)                                                                                 |                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                      |
| 4. P - Participate in the market as a renter (renting a residence unit)                                    |                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                      |
| a. Determination of budget                                                                                 |                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                      |
| b. Which properties are evaluated (searching strategy, assume price taker at fixed offer price)            |                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                      |
| c. WTP (from above)                                                                                        |                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                      |
| d. Which property(s) to apply for?                                                                         |                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                      |
| e. Rules if you don't succeed to purchase                                                                  |                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                      |
| i. Adjust budget/WTP (details)                                                                             |                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                      |
| ii. Leave market (details)                                                                                 |                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                      |
| 5. P - Participate in the market as a leasor (renting unit to someone else) (rules need to be constructed) |                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                      |
| 6. P - Participate in the market as a seller                                                               |                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                      |
| a. WTA                                                                                                     | Call from above                                                                                                                                                                                                                                                                                                                                                                                                                      | Magliocca<br>Prunetti<br>Ge          |
| b. Ask/List price (What proposed sales price do you post to the market?)                                   | Call from above                                                                                                                                                                                                                                                                                                                                                                                                                      | Magliocca<br>Prunetti<br>Ge<br>Carro |
| c. At what scale are the bids collected?                                                                   |                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                      |
| i. Unique unit scale                                                                                       | Each residential unit                                                                                                                                                                                                                                                                                                                                                                                                                | Magliocca                            |

|                                                                                  |                                                                                                                                                                                                                                                                                                                                                                                                                    |           |
|----------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------|
|                                                                                  |                                                                                                                                                                                                                                                                                                                                                                                                                    | Prunetti  |
| ii. Aggregate market scale                                                       | Single price for each neighborhood, which is settled by listing all bids and asks, and find the ‘equilibrium’ price to maximize transaction volume. If there is no bids or asks in a period (so no transaction), price is also adjusted to reflect the market condition.                                                                                                                                           | Ge        |
|                                                                                  | All bids are aggregated and matched based on the house quality.                                                                                                                                                                                                                                                                                                                                                    | Carro     |
| d. Rules for collecting bids: How many bids do you accept?                       |                                                                                                                                                                                                                                                                                                                                                                                                                    |           |
| i. One per property up for sale                                                  |                                                                                                                                                                                                                                                                                                                                                                                                                    |           |
| ii. Multiple per property                                                        |                                                                                                                                                                                                                                                                                                                                                                                                                    | Magliocca |
|                                                                                  |                                                                                                                                                                                                                                                                                                                                                                                                                    | Prunetti  |
|                                                                                  |                                                                                                                                                                                                                                                                                                                                                                                                                    | Ge        |
|                                                                                  |                                                                                                                                                                                                                                                                                                                                                                                                                    | Carro     |
| e. Who to sell to (how to pick the accepted bid)                                 |                                                                                                                                                                                                                                                                                                                                                                                                                    |           |
| i. Single bid rule                                                               |                                                                                                                                                                                                                                                                                                                                                                                                                    |           |
| A. Accept                                                                        |                                                                                                                                                                                                                                                                                                                                                                                                                    |           |
| B. Accept if $\geq$ ask price, else reject                                       |                                                                                                                                                                                                                                                                                                                                                                                                                    |           |
| C. Accept if $\geq$ WTA, else reject                                             |                                                                                                                                                                                                                                                                                                                                                                                                                    |           |
| D. Other (short text field)                                                      |                                                                                                                                                                                                                                                                                                                                                                                                                    |           |
| ii. Multiple bid rule                                                            |                                                                                                                                                                                                                                                                                                                                                                                                                    |           |
| A. Highest price if $\geq$ ask price                                             |                                                                                                                                                                                                                                                                                                                                                                                                                    |           |
| B. Highest price if $\geq$ WTA                                                   |                                                                                                                                                                                                                                                                                                                                                                                                                    | Magliocca |
| C. Random selection if multiple highest bids                                     |                                                                                                                                                                                                                                                                                                                                                                                                                    | Prunetti  |
| D. Other (short text field)                                                      | See negotiation strategy above                                                                                                                                                                                                                                                                                                                                                                                     | Prunetti  |
|                                                                                  | The market is cleared by matching bids to the offer with the highest quality that buyers can afford and, within a given quality, to the cheapest house available. When a given house offered in any of the sales or rental markets is matched with more than one bidder, the ask price is increased by rule, then select randomly among buyers who can afford still. (Section 1.5, Appendix 1, Carro et al., 2023) | Carro     |
| iii. Custom (long text field)                                                    | Single price for each neighborhood. Price is settled by listing all bids and asks, and find the ‘equilibrium’ price to maximize transaction volume. If there are no bids or asks in period (so no transaction), price is also adjusted to reflect the market condition. Sellers with asks/WTA $\leq$ price will sell; and buyers with bids/WTP $\geq$ price will buy.                                              | Ge        |
| f. Negotiation strategy                                                          | Call from above                                                                                                                                                                                                                                                                                                                                                                                                    | Prunetti  |
| g. List price/time on market adjustment rules (price decrease/repackage/upgrade) |                                                                                                                                                                                                                                                                                                                                                                                                                    |           |

|                                                       |                                                                                                                                                                                                                                           |           |
|-------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------|
| i. Adjust price (text field for details)              | For each year on the market, the housing price is decreased by the discount rate.                                                                                                                                                         | Magliocca |
|                                                       | Every period a seller fails to sell, they will lower the price margin by a fixed percentage (2%) relative to expected market price (Section 3.1.8, Ge, 2017).                                                                             | Ge        |
|                                                       | List price is decreased by a certain percentage every time step that the property remains unsold, with no lower bound for the developer (there is a lower bound for households and investors) (Table A6, Appendix 2. Carro et al., 2023). | Carro     |
| ii. Take unit off the market (text field for details) | If the seller fails to sell for a period that exceeds the maximum set by the model (24 periods or months), the house is taken off the market.                                                                                             | Ge        |
| iii. Default on loan (text field for details)         | If the market price is lower than the outstanding mortgage of the seller, and the associated costs of default, the seller defaults.                                                                                                       | Ge        |
| iv. Keep trying to sell the house to new buyers.      |                                                                                                                                                                                                                                           | Prunetti  |

**Table S8. MR POTATOHEAD Real Estate Market Framework – Comparison table for the Agent Decision Template – Investor residence seller**

|                                                                                                                                                                                                                                                                                          |                                                                                                                                                                                                                                                                                   |       |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|
| 1. Buyers                                                                                                                                                                                                                                                                                |                                                                                                                                                                                                                                                                                   |       |
| a. Developers - Land buyers                                                                                                                                                                                                                                                              |                                                                                                                                                                                                                                                                                   |       |
| b. Investors                                                                                                                                                                                                                                                                             |                                                                                                                                                                                                                                                                                   |       |
| i. Land                                                                                                                                                                                                                                                                                  |                                                                                                                                                                                                                                                                                   |       |
| ii. Residences                                                                                                                                                                                                                                                                           |                                                                                                                                                                                                                                                                                   |       |
| c. Households                                                                                                                                                                                                                                                                            |                                                                                                                                                                                                                                                                                   |       |
| 2. Sellers                                                                                                                                                                                                                                                                               | Ge                                                                                                                                                                                                                                                                                |       |
|                                                                                                                                                                                                                                                                                          | Carro                                                                                                                                                                                                                                                                             |       |
| a. Developers                                                                                                                                                                                                                                                                            |                                                                                                                                                                                                                                                                                   |       |
| b. Investors                                                                                                                                                                                                                                                                             | Ge                                                                                                                                                                                                                                                                                |       |
|                                                                                                                                                                                                                                                                                          | Carro                                                                                                                                                                                                                                                                             |       |
| i. Land                                                                                                                                                                                                                                                                                  |                                                                                                                                                                                                                                                                                   |       |
| ii. Residences                                                                                                                                                                                                                                                                           | Ge                                                                                                                                                                                                                                                                                |       |
|                                                                                                                                                                                                                                                                                          | Carro                                                                                                                                                                                                                                                                             |       |
| c. Households                                                                                                                                                                                                                                                                            |                                                                                                                                                                                                                                                                                   |       |
| d. Land owners                                                                                                                                                                                                                                                                           |                                                                                                                                                                                                                                                                                   |       |
| 3. Renters                                                                                                                                                                                                                                                                               |                                                                                                                                                                                                                                                                                   |       |
| a. People who rent residence units (demand)                                                                                                                                                                                                                                              |                                                                                                                                                                                                                                                                                   |       |
| b. People who rent out residence units (supply)                                                                                                                                                                                                                                          |                                                                                                                                                                                                                                                                                   |       |
| 4. Central bank                                                                                                                                                                                                                                                                          |                                                                                                                                                                                                                                                                                   |       |
| 5. Government                                                                                                                                                                                                                                                                            |                                                                                                                                                                                                                                                                                   |       |
| Decision making class<br>Four types: class (breed) C; attributes, (-own variable) A; links/relationships (directed-link breeds (parent), undirected-link breeds (friend, neighbor, can have own-variables for links in Netlogo, non-binary) L; processes (go, set-up) P; Documentation D |                                                                                                                                                                                                                                                                                   |       |
| 1. A / P - Attributes (methods/function and parameters) that affect real estate decisions                                                                                                                                                                                                |                                                                                                                                                                                                                                                                                   |       |
| a. Budget (this might call a mortgage calculation function)                                                                                                                                                                                                                              |                                                                                                                                                                                                                                                                                   |       |
| b. Preferences                                                                                                                                                                                                                                                                           | See investor residence buyer template.                                                                                                                                                                                                                                            | Carro |
| c. Time horizon/discount rate                                                                                                                                                                                                                                                            | See household residence buyer template.                                                                                                                                                                                                                                           | Ge    |
|                                                                                                                                                                                                                                                                                          |                                                                                                                                                                                                                                                                                   | Carro |
| d. Risk perceptions                                                                                                                                                                                                                                                                      | Risk averse in that investors apply a discount rate to past price appreciation, which serves as a ‘cautionary principle’.                                                                                                                                                         | Ge    |
| e. Price expectations                                                                                                                                                                                                                                                                    | Price expectation depends on past price appreciation in the neighborhood, which is heterogeneous across neighborhoods. A discount rate is applied to past price appreciation to dampen the circle, or to account for the ‘cautionary principle’ (Eq 22, Section 3.1.7, Ge, 2017). | Ge    |
|                                                                                                                                                                                                                                                                                          | These are set by recent trend extrapolation, $HPA_{expectation} = HPA_{recent} * a + b$ , where $a$ and $b$ are parameters calibrated from data (Table A4, Appendix 2, Carro et al., 2023).                                                                                       | Carro |
| f. Commuting/Transportation costs                                                                                                                                                                                                                                                        |                                                                                                                                                                                                                                                                                   |       |
| g. Utility function                                                                                                                                                                                                                                                                      |                                                                                                                                                                                                                                                                                   |       |
| h. Expected return from renting                                                                                                                                                                                                                                                          | “Expected annual return rate of speculative buyer $b$ for a property in region $g$ equals<br>$ER_t^b(g) = (1 - \omega^b) \left( \frac{p_t^g}{p_{t-12}^g} - 1 \right) - m_t - r^H.$ where $\omega^b$ is the discount rate that speculative                                         | Ge    |

|                                                                                 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |       |
|---------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|
|                                                                                 | <p>buyer <math>b</math> assigns to price appreciation, which is heterogeneous across buyers and <math>\omega^b \in (0,1)</math>.</p> <p>The term <math>\frac{p_t^g}{p_{t-12}^g}</math> is the appreciation in housing price in region <math>g</math> during the last 12 months.” (Page 188, Section 3.1.7, Ge, 2017)</p>                                                                                                                                                                                  |       |
|                                                                                 | Effective rental yield $s$ is computed by multiplying its current rental price by the expected average occupancy of houses of the same quality. The expected sales/rental price is estimated by checking current market prices of houses of the same quality, both in the rental and the sales market.                                                                                                                                                                                                    | Carro |
| i. Model to determine what will be built (developer land buyer)                 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |       |
| j. Willingness to Pay                                                           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |       |
| k. Ask price                                                                    | <p><math>AskPrice = (1 + ER_t^{h,g*}/12)p_{t-1}^{g*}</math>, where <math>ER_t^b(g)</math> is expected annual return rate of speculative buyer <math>b</math> for a property in region <math>g</math> equals (Eq 22, Section 3.17, Ge, 2017) and <math>p_t</math> is the aggregate pricing index (Eq 19, Section 3.1.5, Ge, 2017).</p>                                                                                                                                                                     | Ge    |
|                                                                                 | It is equal to WTA.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Carro |
| l. Willingness to Accept                                                        | Equal to ask price.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Ge    |
|                                                                                 | Ask price is determined as a mark-up over the exponential average price of houses of the same quality, with the mark-up drawn from a distribution of real mark-ups, that is, $AskPrice = markup * expAvSalePriceForQuality(q)$ , for a house of quality $q$ .                                                                                                                                                                                                                                             | Carro |
| m. Bid price                                                                    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |       |
| n. Information sources (i.e. Realtor, listings, neighbors)                      | Investors have full information of past housing price.                                                                                                                                                                                                                                                                                                                                                                                                                                                    | Ge    |
|                                                                                 | Investors need information on average market sales and rent prices for each quality and the trend in house prices.                                                                                                                                                                                                                                                                                                                                                                                        | Carro |
| o. Search strategies                                                            |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |       |
| p. Negotiation strategies/negotiation power                                     | Bargaining power depending on the number of buyers vs sellers. When the real estate agent settles the prices, in a seller’s market, since there are more bids than asks and buyers compete for sellers, price is settled at the $n$ ’s highest bid, where $n$ is the number of sellers. In a buyer’s market, because there are more asks than bids and sellers would have to compete for buyers, price is settled at the $n$ ’s lowest asks, where $n$ is the number of buyers (Section 3.1.5, Ge, 2017). | Ge    |
| q. Household composition                                                        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |       |
| r. Partnership status                                                           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |       |
| s. Location (note this will be read by the landscape initialization algorithms) |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |       |
| t. Production functions (Developers)                                            |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |       |
| u. Cost functions (Developers)                                                  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |       |

|                                                                                                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |       |
|------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|
| v. Constraints (i.e. buy/sell, proximity to work - these are likely conditions)                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Ge    |
| x. Age                                                                                               | Investors are households and have the same characteristics. See household residence buyer template.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | Carro |
| y. Income                                                                                            | See household residence buyer template.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | Carro |
| z. Wealth                                                                                            | See household residence buyer template.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | Carro |
| 2. P - Decision to participate in the market (become active as a buyer, seller, investor, or renter) |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |       |
| a. Decision to participate in the market as a seller                                                 | <p>Investor households try to always keep at least one investment property. A sale is never attempted when the house is occupied by a tenant. To decide whether to sell a given property, investor households compute its expected yield, which is a combination of its expected rental yield and the expected capital gains, with given weights for these terms characterizing the investor. In particular, the expected yield is <math>expectedYield = \frac{marketPriceForThisQuality}{(marketPriceForThisQuality - (mortgagePrincipal) * ((1 - capitalGainsCoefficient) * rentalYield + capitalGainsCoefficient * HPA_{expectation}) - annualMortgagePayments / (marketPriceForThisQuality - mortgagePrincipal)}</math></p> <p>Finally, investor households use a sigma function to make the decision (Eq 8, Section 3.3.3, Carro et al., 2023).</p> | Carro |
|                                                                                                      | The seller will decide to sell if the expected return from holding the property, taking into account price appreciation, rental income and property tax, is less than the best return they can get elsewhere (exogenous).                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | Ge    |
| i. Decision to relocate?                                                                             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |       |
| b. Decision to participate in the market as a buyer                                                  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |       |
| c. Decision to participate in the market as a renter                                                 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |       |
| 3. P - Participate in the market as a buyer                                                          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |       |
| a. Property budget (includes mortgage decision) - Call from above                                    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |       |
| b. Which properties are evaluated (searching strategy)                                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |       |
| c. WTP - call from above                                                                             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |       |
| d. Bid price - call from above                                                                       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |       |
| e. Which property(s) to bid on?                                                                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |       |
| i. One per buyer                                                                                     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |       |
| ii. Multiple per buyer                                                                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |       |
| f. Negotiation strategy / Negotiation power - call from above                                        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |       |
| g. Rules if you don't succeed to purchase                                                            |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |       |
| i. Adjust budget/WTP/bid price (details)                                                             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |       |

|                                                                                                            |                                                                                                                                                                                                                                                                                                                                                                                                                    |             |
|------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------|
| ii. Leave market (details)                                                                                 |                                                                                                                                                                                                                                                                                                                                                                                                                    |             |
| 4. P - Participate in the market as a renter (renting a residence unit)                                    |                                                                                                                                                                                                                                                                                                                                                                                                                    |             |
| a. Determination of budget                                                                                 |                                                                                                                                                                                                                                                                                                                                                                                                                    |             |
| b. Which properties are evaluated (searching strategy, assume price taker at fixed offer price)            |                                                                                                                                                                                                                                                                                                                                                                                                                    |             |
| c. WTP (from above)                                                                                        |                                                                                                                                                                                                                                                                                                                                                                                                                    |             |
| d. Which property(s) to apply for?                                                                         |                                                                                                                                                                                                                                                                                                                                                                                                                    |             |
| e. Rules if you don't succeed to purchase                                                                  |                                                                                                                                                                                                                                                                                                                                                                                                                    |             |
| i. Adjust budget/WTP (details)                                                                             |                                                                                                                                                                                                                                                                                                                                                                                                                    |             |
| ii. Leave market (details)                                                                                 |                                                                                                                                                                                                                                                                                                                                                                                                                    |             |
| 5. P - Participate in the market as a leasor (renting unit to someone else) (rules need to be constructed) |                                                                                                                                                                                                                                                                                                                                                                                                                    |             |
| 6. P - Participate in the market as a seller                                                               |                                                                                                                                                                                                                                                                                                                                                                                                                    |             |
| a. WTA                                                                                                     | Call from above                                                                                                                                                                                                                                                                                                                                                                                                    | Ge<br>Carro |
| b. Ask/List price (What proposed sales price do you post to the market?)                                   | Call from above                                                                                                                                                                                                                                                                                                                                                                                                    | Ge<br>Carro |
| c. At what scale are the bids collected?                                                                   |                                                                                                                                                                                                                                                                                                                                                                                                                    |             |
| i. Unique unit scale                                                                                       |                                                                                                                                                                                                                                                                                                                                                                                                                    |             |
| ii. Aggregate market scale                                                                                 | Single price for each neighborhood, which is settled by listing all bids and asks, and find the 'equilibrium' price to maximize transaction volume. If there is no bids or asks in period (so no transaction), price is also adjusted to reflect the market condition.                                                                                                                                             | Ge          |
|                                                                                                            | Market-clearing mechanism aggregated by house quality                                                                                                                                                                                                                                                                                                                                                              | Carro       |
| d. Rules for collecting bids: How many bids do you accept?                                                 |                                                                                                                                                                                                                                                                                                                                                                                                                    |             |
| i. One per property up for sale                                                                            |                                                                                                                                                                                                                                                                                                                                                                                                                    |             |
| ii. Multiple per property                                                                                  | No limit, all bids are accepted.                                                                                                                                                                                                                                                                                                                                                                                   | Ge<br>Carro |
| e. Who to sell to (how to pick the accepted bid)                                                           |                                                                                                                                                                                                                                                                                                                                                                                                                    |             |
| i. Single bid rule                                                                                         |                                                                                                                                                                                                                                                                                                                                                                                                                    |             |
| A. Accept                                                                                                  |                                                                                                                                                                                                                                                                                                                                                                                                                    |             |
| B. Accept if $\geq$ ask price, else reject                                                                 |                                                                                                                                                                                                                                                                                                                                                                                                                    |             |
| C. Accept if $\geq$ WTA, else reject                                                                       |                                                                                                                                                                                                                                                                                                                                                                                                                    |             |
| D. Other (short text field)                                                                                |                                                                                                                                                                                                                                                                                                                                                                                                                    |             |
| ii. Multiple bid rule                                                                                      |                                                                                                                                                                                                                                                                                                                                                                                                                    | Carro       |
| A. Highest price if $\geq$ ask price                                                                       |                                                                                                                                                                                                                                                                                                                                                                                                                    |             |
| B. Highest price if $\geq$ WTA                                                                             |                                                                                                                                                                                                                                                                                                                                                                                                                    |             |
| C. Random selection if multiple highest bids                                                               |                                                                                                                                                                                                                                                                                                                                                                                                                    |             |
| D. Other                                                                                                   | The market is cleared by matching bids to the offer with the highest quality that buyers can afford and, within a given quality, to the cheapest house available. When a given house offered in any of the sales or rental markets is matched with more than one bidder, the ask price is increased by rule, then select randomly among buyers who can afford still. (Section 1.5, Appendix 1, Carro et al., 2023) | Carro       |

|                                                                                  |                                                                                                                                                                                                                                                                                                                                                                      |       |
|----------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|
| iii. Custom                                                                      | Single price for each neighborhood. Price is settled by listing all bids and asks, and find the ‘equilibrium’ price to maximize transaction volume. If there is no bids or asks in period (so no transaction), price is also adjusted to reflect the market condition. Sellers with asks/WTB $\leq$ price will sell; and buyers with bids/WTP $\geq$ price will buy. | Ge    |
| f. Negotiation strategy                                                          | Call from above                                                                                                                                                                                                                                                                                                                                                      | Ge    |
| g. List price/time on market adjustment rules (price decrease/repackage/upgrade) |                                                                                                                                                                                                                                                                                                                                                                      |       |
| i. Adjust price                                                                  | Every period a seller fails to sell, they will lower the price margin by a fixed percentage relative to expected market price.                                                                                                                                                                                                                                       | Ge    |
|                                                                                  | List price is decreased by a certain percentage every time step that the property remains unsold, with a lower bound for households and investors (Table A5, Appendix 2, Carro et al., 2023).                                                                                                                                                                        | Carro |
| ii. Take unit off the market                                                     | If the seller fails to sell for a period that exceeds the maximum set by the model (24 periods or months).                                                                                                                                                                                                                                                           | Ge    |
|                                                                                  | If decreasing the ask price would bring the house below its net value (offered price minus any mortgage principal left) below zero, then the house is taken off the market.                                                                                                                                                                                          | Carro |
| iii. Default on loan                                                             | If the market price is lower than the outstanding mortgage of the seller, and the associated costs of default, an investor seller will default on the property.                                                                                                                                                                                                      | Ge    |

**Table S9. MR POTATOHEAD Real Estate Market Framework – Comparison table for the Agent Decision Template – Household residence seller**

|                                                                                                                                                                                                                                                                                          |                                                                                                                                                                                                                                                                                                                |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1. Buyers                                                                                                                                                                                                                                                                                |                                                                                                                                                                                                                                                                                                                |
| a. Developers - Land buyers                                                                                                                                                                                                                                                              |                                                                                                                                                                                                                                                                                                                |
| b. Investors                                                                                                                                                                                                                                                                             |                                                                                                                                                                                                                                                                                                                |
| i. Land                                                                                                                                                                                                                                                                                  |                                                                                                                                                                                                                                                                                                                |
| ii. Residences                                                                                                                                                                                                                                                                           |                                                                                                                                                                                                                                                                                                                |
| c. Households                                                                                                                                                                                                                                                                            |                                                                                                                                                                                                                                                                                                                |
| 2. Sellers                                                                                                                                                                                                                                                                               | Parker                                                                                                                                                                                                                                                                                                         |
|                                                                                                                                                                                                                                                                                          | Filatova                                                                                                                                                                                                                                                                                                       |
|                                                                                                                                                                                                                                                                                          | Ge                                                                                                                                                                                                                                                                                                             |
|                                                                                                                                                                                                                                                                                          | Carro                                                                                                                                                                                                                                                                                                          |
| a. Developers                                                                                                                                                                                                                                                                            |                                                                                                                                                                                                                                                                                                                |
| b. Investors                                                                                                                                                                                                                                                                             |                                                                                                                                                                                                                                                                                                                |
| i. Land                                                                                                                                                                                                                                                                                  |                                                                                                                                                                                                                                                                                                                |
| ii. Residences                                                                                                                                                                                                                                                                           |                                                                                                                                                                                                                                                                                                                |
| c. Households                                                                                                                                                                                                                                                                            | Parker                                                                                                                                                                                                                                                                                                         |
|                                                                                                                                                                                                                                                                                          | Filatova                                                                                                                                                                                                                                                                                                       |
|                                                                                                                                                                                                                                                                                          | Ge                                                                                                                                                                                                                                                                                                             |
|                                                                                                                                                                                                                                                                                          | Carro                                                                                                                                                                                                                                                                                                          |
| d. Land owners                                                                                                                                                                                                                                                                           |                                                                                                                                                                                                                                                                                                                |
| 3. Renters                                                                                                                                                                                                                                                                               |                                                                                                                                                                                                                                                                                                                |
| a. People who rent residence units (demand)                                                                                                                                                                                                                                              |                                                                                                                                                                                                                                                                                                                |
| b. People who rent out residence units (supply)                                                                                                                                                                                                                                          |                                                                                                                                                                                                                                                                                                                |
| 4. Central bank                                                                                                                                                                                                                                                                          |                                                                                                                                                                                                                                                                                                                |
| 5. Government                                                                                                                                                                                                                                                                            |                                                                                                                                                                                                                                                                                                                |
| Decision making class<br>Four types: class (breed) C; attributes, (-own variable) A; links/relationships (directed-link breeds (parent), undirected-link breeds (friend, neighbor, can have own-variables for links in Netlogo, non-binary) L; processes (go, set-up) P; Documentation D |                                                                                                                                                                                                                                                                                                                |
| 1. A / P - Attributes (methods/function and parameters) that affect real estate decisions                                                                                                                                                                                                |                                                                                                                                                                                                                                                                                                                |
| a. Budget (this might call a mortgage calculation function)                                                                                                                                                                                                                              | See budget in household residence buyer template.                                                                                                                                                                                                                                                              |
|                                                                                                                                                                                                                                                                                          | Filatova                                                                                                                                                                                                                                                                                                       |
|                                                                                                                                                                                                                                                                                          | Parker                                                                                                                                                                                                                                                                                                         |
|                                                                                                                                                                                                                                                                                          | Ge                                                                                                                                                                                                                                                                                                             |
|                                                                                                                                                                                                                                                                                          | Carro                                                                                                                                                                                                                                                                                                          |
| b. Preferences                                                                                                                                                                                                                                                                           | Sellers have heterogeneous preferences for houses (see the household residence buyer template for description). These are not actively used when trading in the role of a Seller, i.e. only when Sellers decide to relocate and become Buyers.                                                                 |
|                                                                                                                                                                                                                                                                                          | Filatova                                                                                                                                                                                                                                                                                                       |
|                                                                                                                                                                                                                                                                                          | Parker                                                                                                                                                                                                                                                                                                         |
|                                                                                                                                                                                                                                                                                          | Ge                                                                                                                                                                                                                                                                                                             |
| c. Time horizon/discount rate                                                                                                                                                                                                                                                            | See time horizon/discount rate in the household residence buyer template.                                                                                                                                                                                                                                      |
|                                                                                                                                                                                                                                                                                          | Filatova                                                                                                                                                                                                                                                                                                       |
|                                                                                                                                                                                                                                                                                          | Parker                                                                                                                                                                                                                                                                                                         |
|                                                                                                                                                                                                                                                                                          | Ge                                                                                                                                                                                                                                                                                                             |
|                                                                                                                                                                                                                                                                                          | Carro                                                                                                                                                                                                                                                                                                          |
| d. Risk perceptions                                                                                                                                                                                                                                                                      | Homeowners may decide to move out of flood zone according to their risk of flood perception, influenced by fear (a dynamic 4-point scale score), flood experience, costs of moving and costs of flood insurance, and perceived likelihood of damage that depends on the information Sellers collect from their |
|                                                                                                                                                                                                                                                                                          | Filatova                                                                                                                                                                                                                                                                                                       |

|                                                                 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |          |
|-----------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|
|                                                                 | neighbors (within 2000 feet radius) (Section 2.2.3, Filatova, 2015).<br>Sellers of flood-prone properties reduce ask prices after a flood event (by 13.8% in 1:500 zone and by 15.7% in 1:100 flood zone, according to the survey data).                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |          |
| e. Price expectations                                           | Real-estate agent pursues adaptive learning at the level of the market. He forms prices expectations using the predictions on the hedonic analysis of the past N trade periods. At initialization Realtor relies on the actual transactions data from the US (Bin, Landry, 2013) and runs hedonic-kriging analysis on them. Further on, Realtor relies on simulated transactions, which he records together with all the relevant attributes of a house. $\ln(H_{tran}) = \beta_0 + \sum_{i=1}^n \beta_i x_i + \varepsilon$<br>Here $\ln(H_{tran})$ is the log of transaction price, $x_i$ is a variable for the ith housing attribute (structural), $\beta$ are regression coefficients, and $\varepsilon$ is the error term that captures the value of spatial attributes used for kriging. The model considers house age, its size (in sq. footage), size of the land lot (in acres), number of bedrooms, dummy on whether a house is flood-prone, and neighborhood quality (captured by kriging of the regression residuals to capture proximity to various amenities and other salient neighborhood characteristics) (Section 2.2.3, Filatova, 2015). | Filatova |
|                                                                 | Price expectation equals price in the last period.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | Ge       |
|                                                                 | These are set by recent trend extrapolation, $HPA_{expectation} = HPA_{recent} * a + b$ , where $a$ and $b$ are parameters calibrated from data (Table A4, Appendix 2, Carro et al., 2023).                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | Carro    |
| f. Commuting/Transportation costs                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |          |
| g. Utility function                                             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |          |
| h. Expected return from renting                                 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |          |
| i. Model to determine what will be built (developer land buyer) |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |          |
| j. Willingness to Pay                                           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |          |
| k. Ask price                                                    | Equal to willingness to accept                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | Filatova |
|                                                                 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | Ge       |
|                                                                 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | Carro    |
|                                                                 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | Parker   |
| l. Willingness to Accept                                        | WTA is determined based on a hedonic function, where the dependent variable is the property assessment value, and the independent variables are those attributes (living area, yard size, building age,                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | Parker   |

|                                                            |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                |
|------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------|
|                                                            | education rate, population density, open space access, transit access, walkability etc.) (Babin, 2016).                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                |
|                                                            | Sellers use the current market information from the Realtor agent to form ask prices. Realtor bases his predictions on the hedonic analysis of the past simulated transaction. Sellers apply the latest regression coefficients (see price expectation above for the hedonic model details). At initialization Realtor relies on the actual transactions data from the US (Bin, Landry, 2013) and runs hedonic-kriging analysis on them. For sellers with remaining mortgage balance, WTA is the maximum of remaining mortgage balance and price determined using the hedonic model. Estimated ask price could be adjusted if a property have been flooded (see risk perceptions), or if demand for properties in the neighborhood goes up or down (even if no sales have been there yet; by 10% adjusted by the relative changes in demand in the neighborhood). | Filatova       |
|                                                            | Equal to last period price plus adjustment for time-on-market (TOM) (the longer the TOM, the lower the WTA, which is lowered by a fixed rate) (Section 3.1.8, Ge, 2017).                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Ge             |
|                                                            | WTA is determined as a mark-up over the exponential average price of houses of the same quality, with the mark-up drawn from a distribution of real mark-ups, that is, $AskPrice = markup * expAvSalePriceForQuality(q)$ , for a house of quality $q$ .                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | Carro          |
| m. Bid price                                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                |
| n. Information sources (i.e. Realtor, listings, neighbors) | Realtor agent that analyses previous simulated transactions (see the separate template). Sellers also get some information from their neighbors (e.g. on flood damage, demand for neighboring properties) within 2000 feet radius.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | Filatova       |
|                                                            | Full information of past price. Sellers have no information regarding buyers' bids.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Ge             |
|                                                            | Households need information on the average market price for each quality and the trend in house prices (in order to form expectations).                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | Carro          |
| o. Search strategies                                       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                |
| p. Negotiation strategies/negotiation power                | See household the residence buyer template.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Filatova<br>Ge |
| q. Household composition                                   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                |

|                                                                                                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |          |
|------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|
| r. Partnership status                                                                                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |          |
| s. Location (note this will be read by the landscape initialization algorithms)                      | See spatial locations in landscape template.                                                                                                                                                                                                                                                                                                                                                                                                                                  | Parker   |
|                                                                                                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Filatova |
|                                                                                                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Ge       |
| t. Production functions (Developers)                                                                 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |          |
| u. Cost functions (Developers)                                                                       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |          |
| v. Constraints (i.e. buy/sell, proximity to work - these are likely conditions)                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |          |
| x. Age                                                                                               | See household residence buyer template.                                                                                                                                                                                                                                                                                                                                                                                                                                       | Carro    |
| y. Income                                                                                            | See household residence buyer template.                                                                                                                                                                                                                                                                                                                                                                                                                                       | Carro    |
|                                                                                                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Parker   |
|                                                                                                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Filatova |
|                                                                                                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Ge       |
| z. Wealth                                                                                            | See household residence buyer template.                                                                                                                                                                                                                                                                                                                                                                                                                                       | Carro    |
| 2. P - Decision to participate in the market (become active as a buyer, seller, investor, or renter) |                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |          |
| a. Decision to participate in the market as a seller                                                 | For the initial step, a total number of 6,278 households were allocated to the same number of land parcels with single-family dwellings. The population of sellers are randomly selected from the local residents. The number of sellers is estimated based on the data on the number of emigrants who moved out of the region to other areas in Canada (Statistics Canada, 2023). Also, local movers who have purchased a new house will list their old house on the market. | Parker   |
|                                                                                                      | Homeowners decide to put their house on sale predominantly randomly (with exogenously defined mean and standard deviation; about 10%). Those in the flood zone may decide to become Sellers endogenously (see relocate).                                                                                                                                                                                                                                                      | Filatova |
|                                                                                                      | See relocate                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | Ge       |
|                                                                                                      | Non-investor households have a certain probability of selling their home per time step, calibrated with data (Table A5, Appendix 1, Carro et al., 2023).                                                                                                                                                                                                                                                                                                                      | Carro    |
| i. Decision to relocate?                                                                             | Emigrants exit the model once they sell their property. Local sellers move to new location when they purchase a new property.                                                                                                                                                                                                                                                                                                                                                 | Parker   |
|                                                                                                      | At initialization, agents are assigned a status of Buyer or Seller. Some Sellers in the flood zone decide to relocate (fixed %, defined randomly) because their house is at risk of natural hazards; so they search for another home to evade the hazard (Table 3, Section 2.1.2 and Section 2.2.2, Filatova, 2015)                                                                                                                                                           | Filatova |
|                                                                                                      | There is a probability that each homeowner decides to sell for exogenous reasons (e.g. job move). Non-investor homeowners default if the outstanding debts exceeds the market                                                                                                                                                                                                                                                                                                 | Ge       |

|                                                                                                            |                                                                                                                                                                                                                                                                        |          |
|------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|
|                                                                                                            | value of the house plus costs associated with default, in which case the house goes to the bank and will not be listed on the market (Section 3.1.8, Ge, 2017).                                                                                                        |          |
| b. Decision to participate in the market as a buyer                                                        |                                                                                                                                                                                                                                                                        |          |
| c. Decision to participate in the market as a renter                                                       |                                                                                                                                                                                                                                                                        |          |
| 3. P - Participate in the market as a buyer                                                                |                                                                                                                                                                                                                                                                        |          |
| a. Property budget (includes mortgage decision) - Call from above                                          |                                                                                                                                                                                                                                                                        |          |
| b. Which properties are evaluated (searching strategy)                                                     |                                                                                                                                                                                                                                                                        |          |
| c. WTP - call from above                                                                                   |                                                                                                                                                                                                                                                                        |          |
| d. Bid price - call from above                                                                             |                                                                                                                                                                                                                                                                        |          |
| e. Which property(s) to bid on?                                                                            |                                                                                                                                                                                                                                                                        |          |
| i. One per buyer                                                                                           |                                                                                                                                                                                                                                                                        |          |
| ii. Multiple per buyer                                                                                     |                                                                                                                                                                                                                                                                        |          |
| f. Negotiation strategy / Negotiation power - call from above                                              |                                                                                                                                                                                                                                                                        |          |
| g. Rules if you don't succeed to purchase                                                                  |                                                                                                                                                                                                                                                                        |          |
| i. Adjust budget/WTP/bid price (details)                                                                   |                                                                                                                                                                                                                                                                        |          |
| ii. Leave market (details)                                                                                 |                                                                                                                                                                                                                                                                        |          |
| 4. P - Participate in the market as a renter (renting a residence unit)                                    |                                                                                                                                                                                                                                                                        |          |
| a. Determination of budget                                                                                 |                                                                                                                                                                                                                                                                        |          |
| b. Which properties are evaluated (searching strategy, assume price taker at fixed offer price)            |                                                                                                                                                                                                                                                                        |          |
| c. WTP (from above)                                                                                        |                                                                                                                                                                                                                                                                        |          |
| d. Which property(s) to apply for?                                                                         |                                                                                                                                                                                                                                                                        |          |
| e. Rules if you don't succeed to purchase                                                                  |                                                                                                                                                                                                                                                                        |          |
| i. Adjust budget/WTP (details)                                                                             |                                                                                                                                                                                                                                                                        |          |
| ii. Leave market (details)                                                                                 |                                                                                                                                                                                                                                                                        |          |
| 5. P - Participate in the market as a leasor (renting unit to someone else) (rules need to be constructed) |                                                                                                                                                                                                                                                                        |          |
| 6. P - Participate in the market as a seller                                                               |                                                                                                                                                                                                                                                                        |          |
| a. WTA                                                                                                     | Call from above                                                                                                                                                                                                                                                        | Parker   |
|                                                                                                            |                                                                                                                                                                                                                                                                        | Filatova |
|                                                                                                            |                                                                                                                                                                                                                                                                        | Ge       |
|                                                                                                            |                                                                                                                                                                                                                                                                        | Carro    |
| b. Ask/List price (What proposed sales price do you post to the market?)                                   | Call from above                                                                                                                                                                                                                                                        | Parker   |
|                                                                                                            |                                                                                                                                                                                                                                                                        | Filatova |
|                                                                                                            |                                                                                                                                                                                                                                                                        | Ge       |
|                                                                                                            |                                                                                                                                                                                                                                                                        | Carro    |
| c. At what scale are the bids collected?                                                                   |                                                                                                                                                                                                                                                                        |          |
| i. Unique unit scale                                                                                       |                                                                                                                                                                                                                                                                        | Parker   |
|                                                                                                            |                                                                                                                                                                                                                                                                        | Filatova |
| ii. Aggregate market scale                                                                                 | Single price for each neighborhood, which is settled by listing all bids and asks, and find the 'equilibrium' price to maximize transaction volume. If there is no bids or asks in period (so no transaction), price is also adjusted to reflect the market condition. | Ge       |

|                                                                                  |                                                                                                                                                                                                                                                                                                                                                                                                                    |          |
|----------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|
|                                                                                  | Market-clearing mechanism where bids are matched to the offer with the highest quality that buyers can afford and, within a given quality, to the cheapest house available.                                                                                                                                                                                                                                        | Carro    |
| d. Rules for collecting bids: How many bids to you accept?                       |                                                                                                                                                                                                                                                                                                                                                                                                                    |          |
| i. One per property up for sale                                                  |                                                                                                                                                                                                                                                                                                                                                                                                                    |          |
| ii. Multiple per property                                                        | No limit, all bids are accepted.                                                                                                                                                                                                                                                                                                                                                                                   | Parker   |
|                                                                                  |                                                                                                                                                                                                                                                                                                                                                                                                                    | Filatova |
|                                                                                  |                                                                                                                                                                                                                                                                                                                                                                                                                    | Ge       |
|                                                                                  |                                                                                                                                                                                                                                                                                                                                                                                                                    | Carro    |
| e. Who to sell to (how to pick the accepted bid)                                 |                                                                                                                                                                                                                                                                                                                                                                                                                    |          |
| i. Single bid rule                                                               |                                                                                                                                                                                                                                                                                                                                                                                                                    |          |
| A. Accept                                                                        |                                                                                                                                                                                                                                                                                                                                                                                                                    |          |
| B. Accept if $\geq$ ask price, else reject                                       |                                                                                                                                                                                                                                                                                                                                                                                                                    |          |
| C. Accept if $\geq$ WTA, else reject                                             |                                                                                                                                                                                                                                                                                                                                                                                                                    |          |
| D. Other (short text field)                                                      |                                                                                                                                                                                                                                                                                                                                                                                                                    |          |
| ii. Multiple bid rule                                                            |                                                                                                                                                                                                                                                                                                                                                                                                                    | Parker   |
|                                                                                  |                                                                                                                                                                                                                                                                                                                                                                                                                    | Filatova |
|                                                                                  |                                                                                                                                                                                                                                                                                                                                                                                                                    | Carro    |
| A. Highest price if $\geq$ ask price                                             | Note that ask price = WTA, and each seller chooses the highest bid which is equal to or higher than the ask price (or WTA).                                                                                                                                                                                                                                                                                        | Parker   |
| B. Highest price if $\geq$ WTA                                                   |                                                                                                                                                                                                                                                                                                                                                                                                                    |          |
| C. Random selection if multiple highest bids                                     |                                                                                                                                                                                                                                                                                                                                                                                                                    |          |
| D. Other                                                                         | See Negotiations above                                                                                                                                                                                                                                                                                                                                                                                             | Filatova |
|                                                                                  | The market is cleared by matching bids to the offer with the highest quality that buyers can afford and, within a given quality, to the cheapest house available. When a given house offered in any of the sales or rental markets is matched with more than one bidder, the ask price is increased by rule, then select randomly among buyers who can afford still. (Section 1.5, Appendix 1, Carro et al., 2023) | Carro    |
| iii. Custom                                                                      | Single price for each neighborhood. Price is settled by listing all bids and asks, and find the 'equilibrium' price to maximize transaction volume. If there is no bids or asks in period (so no transaction), price is also adjusted to reflect the market condition. Sellers with $\text{asks}/\text{WTA} \leq \text{price}$ will sell; and buyers with $\text{bids}/\text{WTP} \geq \text{price}$ will buy.     | Ge       |
| f. Negotiation strategy                                                          | Call from above                                                                                                                                                                                                                                                                                                                                                                                                    | Filatova |
|                                                                                  |                                                                                                                                                                                                                                                                                                                                                                                                                    | Ge       |
| g. List price/time on market adjustment rules (price decrease/repackage/upgrade) |                                                                                                                                                                                                                                                                                                                                                                                                                    |          |

|                              |                                                                                                                                                                                                                                                                                                                                                                                                                                           |          |
|------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|
| i. Adjust price              | Sellers adjust ask price on 3 occasions. The estimated ask price is adjusted if (i) a property was not sold for two consecutive trade periods (by 4%), (ii) or have been flooded (by 15.7% and 13.8% for 1:100 and 1:500 flood zone correspondingly), (iii) or if demand for properties in the neighborhood goes up or down (even if no sales have been there yet; by 10% adjusted by the relative changes in demand in the neighborhood) | Filatova |
|                              | Every period a seller fails to sell, they will lowers the price margin by a fixed percentage (2%) relative to expected market price (Section 3.1.8, Ge, 2017).                                                                                                                                                                                                                                                                            | Ge       |
|                              | Price decreases by a certain amount, with a certain probability, if seller unsuccessful to sell. Price decreases drawn from a calibrated normal distribution (Table A5, Appendix 2, Carro et al., 2023).                                                                                                                                                                                                                                  | Carro    |
| ii. Take unit off the market | Sellers with successful transactions will take their units off the market; otherwise, they will stay on the market until they are sold.                                                                                                                                                                                                                                                                                                   | Parker   |
|                              | If the anticipated market price is below own mortgage dept.                                                                                                                                                                                                                                                                                                                                                                               | Filatova |
|                              | If the seller fails to sell for a period that exceeds the maximum set by the model (24 periods or months).                                                                                                                                                                                                                                                                                                                                | Ge       |
|                              | If decreasing the ask price would bring the house below its net value (offered price minus any mortgage principal left) below zero, then the house is taken off the market.                                                                                                                                                                                                                                                               | Carro    |
| iii. Default on loan         | Default if the market price is lower than the outstanding mortgage of the seller and the associated costs of default, which is heterogeneous across sellers (Sections 3.1.3 and 3.1.8, Ge, 2017).                                                                                                                                                                                                                                         | Ge       |

**Table S10. MR POTATOHEAD Real Estate Market Framework – Comparison table for the Agent Decision Template – Household residence buyer**

|                                                                                                                                                                                                                                                                 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |           |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------|
| 1. Buyers                                                                                                                                                                                                                                                       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Parker    |
|                                                                                                                                                                                                                                                                 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Filatova  |
|                                                                                                                                                                                                                                                                 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Magliocca |
|                                                                                                                                                                                                                                                                 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Prunetti  |
|                                                                                                                                                                                                                                                                 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Ge        |
|                                                                                                                                                                                                                                                                 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Carro     |
| a. Developers - Land buyers                                                                                                                                                                                                                                     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |           |
| b. Investors                                                                                                                                                                                                                                                    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |           |
| i. Land                                                                                                                                                                                                                                                         |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |           |
| ii. Residences                                                                                                                                                                                                                                                  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |           |
| c. Households                                                                                                                                                                                                                                                   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Parker    |
|                                                                                                                                                                                                                                                                 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Filatova  |
|                                                                                                                                                                                                                                                                 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Magliocca |
|                                                                                                                                                                                                                                                                 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Prunetti  |
|                                                                                                                                                                                                                                                                 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Ge        |
|                                                                                                                                                                                                                                                                 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Carro     |
| 2. Sellers                                                                                                                                                                                                                                                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |           |
| a. Developers                                                                                                                                                                                                                                                   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |           |
| b. Investors                                                                                                                                                                                                                                                    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |           |
| i. Land                                                                                                                                                                                                                                                         |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |           |
| ii. Residences                                                                                                                                                                                                                                                  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |           |
| c. Households                                                                                                                                                                                                                                                   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |           |
| d. Land owners                                                                                                                                                                                                                                                  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |           |
| 3. Renters                                                                                                                                                                                                                                                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |           |
| a. People who rent residence units (demand)                                                                                                                                                                                                                     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |           |
| b. People who rent out residence units (supply)                                                                                                                                                                                                                 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |           |
| 4. Central bank                                                                                                                                                                                                                                                 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |           |
| 5. Government                                                                                                                                                                                                                                                   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |           |
| Decision making class                                                                                                                                                                                                                                           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |           |
| Four types: class (breed) C; attributes, (-own variable) A; links/relationships (directed-link breeds (parent), undirected-link breeds (friend, neighbor, can have own-variables for links in Netlogo, non-binary) L; processes (go, set-up) P; Documentation D |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |           |
| 1. A / P - Attributes (methods/function and parameters) that affect real estate decisions                                                                                                                                                                       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |           |
| a. Budget (this might call a mortgage calculation function)                                                                                                                                                                                                     | All the local and external buyers are sampled from the synthetic population dataset (Prédhumeau & Manley, 2023), and they already have household characteristics associated with them, such as income levels, education and family type.<br>Budget for housing is calculated based on a budget-income ratio, assumed to be equal tot 0.3.<br>Maximum affordable mortgage is calculated as $MaxMortgage = (MonthlyIncome \times BudgetRatio) \times \frac{1-(1+r)^{-n}}{r}$<br>where r is monthly interest rate set to be 0.03/12 = 0.0025; and n is mortgage months set as 12 * (25 years) = 300. | Parker    |
|                                                                                                                                                                                                                                                                 | The ‘budget’ of households is parameterized based on the empirical data on the annual income distribution in the US (Statista, 2017).                                                                                                                                                                                                                                                                                                                                                                                                                                                             | Filatova  |

|  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |           |
|--|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------|
|  | <p>Each Buyers has an individual ‘housing budget’ (<math>Y_H</math>), which is heterogeneous among agents, with low income households spending a larger share of their incomes on housing compared to affluent ones (de Koning, Filatova, 2020). This share in the model is estimated using the equation below as based on our survey data, and is validated on the U.S. national statistics data (Statista, 2017): <math>Y_H = \exp(4.96 + 0.63 + \ln(Y))</math>. The housing budget covers mortgage and eventual flood insurance, in case the latter is mandatory. When applicable, flood insurance costs are defined based on the U.S. FEMA insurance premiums quantification. Most homeowners have a mortgage paid linearly over 30 years; a few are cash buyers (share based on U.S. national statistics (Statista, 2017)).</p>                                                                                       |           |
|  | <p>Proportion of income spent on housing in Cobb-Douglas utility function varies based on income level: \$40 – \$80k is 0.35 – 0.42; \$80 – \$120k is 0.27 – 0.34; and &gt; \$120k is 0.18 – 0.26. “A consumer's budget constraint is given by: <math>I_c = x + P_{ask i} [1 + \rho(C(d_i) - IP_{d_i}^{cov})] + \psi_i + IP_{d_i}^{cost}</math>; where <math>I_c</math> is income, <math>\psi_i</math> is the travel cost from the location <math>i</math> to the CBD, <math>\rho</math> is subjective risk perception of the occurrence of a storm, <math>C</math> is the expected damage from a storm in location <math>i</math>, and <math>IP_{d_i}^{cov}</math> and <math>IP_{d_i}^{cost}</math> are the amount of coverage and cost of an insurance premium, respectively, in location <math>i</math> with distance from the coast <math>d</math>.” (Page 7, Section 2.2.1.1, Appendix 1, Magliocca et al., 2018)</p> | Magliocca |
|  | <p>Household <math>c</math> has a sum of money allocated to the purchase of a property:<br/> <math>YD_c = \omega Y_c + \frac{W}{T} - TC(D)</math>, where <math>Y_c</math> is the income of the household <math>c</math>; <math>\omega</math> is the share of household monthly income spent on housing good, <math>W</math> represents the household's wealth, excluding the agent's wage income, if it has sold one or more parcels of land on the land market, <math>T</math> is the time horizon and <math>TC(D)</math> is the commuting cost for a distance <math>D</math> to the CBD.</p>                                                                                                                                                                                                                                                                                                                             | Prunetti  |
|  | <p>There are two restraints in budget: down payment and monthly payment. Savings are initialized to be positively correlated with monthly income with a random factor. Monthly income follows a log normal distribution. Household's savings should be more than the down payment required by the regulator. Their monthly payment as a</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | Ge        |

|                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |           |
|----------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------|
|                | percentage of income should be below the upper limit set by the regulator, too (Section 3.1.2, Ge, 2017).                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |           |
|                | <p>The budget for buying is considered as a desired purchase price, <math>p_d</math>, estimated as an exponentially noisy and nonlinear function of the household's gross annual income, capped by the price corresponding to the maximum mortgage available to the household <math>p_{max}</math>:</p> $p_d = \min(\alpha y^\beta e^\varepsilon, p_{max})$ <p>(Table A4, Appendix 2, Carro et al., 2023)<br/> Bank considers four types of constraints on mortgages: 1) Loan-to-value limit, 2) Loan-to-income limit, 3) Debt-service-to-income limit, 4) Interest-coverage-ratio limit (Eqs. 12-15, Section 3.4, Carro et al., 2023)</p> | Carro     |
| b. Preferences | To account for the preference heterogeneity of buyers, we proposed a new approach using a two-stage hedonic model created by Huang et al. (2023) to estimate the WTP of households with different socio-demographic characteristics. The second-stage hedonic model captures the effect of household socio-demographics (i.e., family type, income, education, age, and immigration status) on their WTP for various housing attributes.                                                                                                                                                                                                   | Parker    |
|                | Buyers have heterogeneous preferences for houses. The preference parameter vector $\beta_b$ are the weights regular buyers put on neighborhood quality, location quality, and affordability (Section 3.1.6, Ge, 2017).                                                                                                                                                                                                                                                                                                                                                                                                                     | Ge        |
|                | Buyers have heterogeneous preferences for houses. They differ in the preferences for the (1) house age, (2) its size (in sq. footage), (3) size of the land lot (in acres), (4) number of bedrooms and (5) neighborhood quality (capturing proximity to various amenities and other salient neighborhood characteristics). These preferences are defined from the empirical housing transactions dataset (Section 2.2.8, Filatova, 2015).                                                                                                                                                                                                  | Filatova  |
|                | The model considers a “psychological cost of renting” factor that determines how much lower the cost of a property, if rented, would need to be in order for households to be indifferent between renting or buying it. Households inherently prefer buying a property over renting it, if they had either option (Eq 4, Section 3.3.1, Carro et al., 2023).                                                                                                                                                                                                                                                                               | Carro     |
|                | Households have heterogenous preferences for consumer good, house size, lot size, environmental amenity (e.g., coastal, open space), all of which affecting household utility (Section 3.2.1.1, Magliocca et al., 2011).                                                                                                                                                                                                                                                                                                                                                                                                                   | Magliocca |

|                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |          |
|-------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|
|                               | $\alpha_k(s_c)$ reflects the preference of a household belonging to class $c$ for the characteristic $\eta_k$ , including distance to the CBD $dCBD_i$ , distance to the beach $db_i$ , sea-view-index or (estimated) access to sea-view (0-100) $SVI_i$ . It will be noted that $\sum_{k=1}^K \alpha_k(s_c) = 1$ .                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | Prunetti |
| c. Time horizon/discount rate | Buyers make decisions considering their annual housing costs and incomes remain stable, with mortgage spread evenly over 30 years. There is no discounting in the current version.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Filatova |
|                               | Discount rate for the agent $c$ is $\delta_c$ . It is drawn randomly according to a normal distribution will be applied $d_c \in [0.01, 0.1]$ . Interest rate for investment in financial market, $r$ , is determined uniformly at random between $[0.02, 0.04]$ . The time horizon is 20 years. It is the same for all agents and corresponds to the mean duration of a loan.                                                                                                                                                                                                                                                                                                                                                                                                       | Prunetti |
|                               | Mortgage rate is endogenous determined by a representative bank agent, affected by perceived default risks, which equals discount rate. Time horizon is 20 years, the length of the mortgage duration (Section 3.1.3, Ge, 2017).                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | Ge       |
|                               | Households consider a one year time horizon for making buying/renting decisions. The interest rate paid by households on their mortgages is the sum of a fixed policy rate exogenously set by the Central Bank and a variable interest rate spread set by the bank. Interest rate spread movements are modeled as a linear function of movements of the amount of credit per household (Eq A.2, Section 1.4, Appendix 1, Carro et al., 2023).                                                                                                                                                                                                                                                                                                                                        | Carro    |
|                               | Mortgage affordability is based on a 25-year horizon and a 3% annual discount rate.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | Parker   |
| d. Risk perceptions           | When searching for a house Buyers may choose to avoid flood zone (a 4 point scale score, separately for 1:100 and 1:500 flood zone). At initialization a fixed % (from the survey) of Buyers is assigned to 'avoid flood zone'. As the model runs, the Buyers tendency to avoid flood zone is updated using Bayesian conditional probability that depends on their initial intention to avoid/not and the evolving fear score.<br>Lastly, these attitudes towards flood risks influence individual Buyers demand, and eventually market demand for flood-prone properties. Therefore, subjective dynamics risk perceptions capitalize in property values as the market evolves, driving the dynamics of flood-prone properties up or down over time (Section 2.2.3, Filatova, 2015). | Filatova |

|                       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |           |
|-----------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------|
|                       | <p>Dynamically updated based on direct experience (or lack thereof) of storm events, which affects locations choices of existing consumers that have not located and new incoming consumers (Section 3.4.5, Appendix A, Magliocca et al., 2018)).</p> <p>“The expected annual probability of a storm <math>E(p)</math>, or subjective risk perception, at time <math>t</math> is formalized as: <math>E(p S'_t, t') = \frac{(S'_t + \alpha)}{t' + \alpha + \beta}</math>, where <math>\alpha</math> and <math>\beta</math> are parameters of a beta distribution, <math>S'_t = \sum_{s=1}^t y_s \delta^{t-s}</math> are weighted storm observations, and <math>t' = \sum_{s=1}^t \delta^{t-s}</math> is the number of yearly observation ‘equivalents’ with time-weighting parameter <math>\delta = 0.91</math> following the findings of Gallagher (2014)” (Page 18, Appendix A, Section 3.4.4, Magliocca et al. 2018).</p> | Magliocca |
| e. Price expectations | <p>Since buyer bid price is anchored to sellers’ ask prices, the household buyer relies on the same price expectation mechanism as the seller, which is re-running the hedonic model of WTA using transaction data (See household residence seller template).</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | Filatova  |
|                       | <p>Price expectation equals price in the last period plus expected appreciation/depreciation (Eq 21, Section 3.1.6, Ge, 2017).</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | Ge        |
|                       | <p>These are set by recent trend extrapolation, <math>HPA_{expectation} = HPA_{recent} * a + b</math>, where <math>a</math> and <math>b</math> are parameters calibrated from data (Table A4, Appendix 2, Carro et al., 2023).</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | Carro     |
|                       | <p>The price expectation mechanism relies on the following hedonic regression of past housing prices to estimate current price:</p> $\ln(P_{H,t-1}) = \alpha_H + \beta_{1H} LivA_L + \beta_{2H} LivA_L^2 + \beta_{3H} LivA_L^3 + \beta_{4H} LivA_L^4 + \beta_{5H} LA_L + \beta_{6H} dBL + \beta_{7H} /dCDB_L + \beta_{8H} SVI_L + \beta_{9H} t + \epsilon_H$ <p>where <math>P_{H,t-1}</math> is past price of a house of type <math>m</math> built on the parcel of land with the characteristics, <math>LivA_L</math> is total surface in square meters of the house built by the developer <math>m</math>; <math>LA_L</math> is Land Area; <math>CDB_{RT}</math> is the distance to the nearest city center; <math>SVI_{RT}</math> is the Sea View Index; and <math>\epsilon_H</math> is Error Term.</p>                                                                                                                   | Prunetti  |
|                       | <p>At the end of each simulation time step (each month), the first-stage hedonic regression model of WTP is re-run using the transaction data for the past 4 time steps and the regression coefficients are updated to reflect the buyers’ expectations of prices. At each time step, the buyers use the updated hedonic</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Parker    |

|                                                                 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |           |
|-----------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------|
|                                                                 | model coefficients to estimate the WTP for different properties.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |           |
| f. Commuting/Transportation costs                               | Annual cost of transportation to and from house location and CBD at a rate of \$25.85 per cell (\$1.30/mile, 0.0395 miles per cell, and 500 miles traveled per year; Magliocca et al., 2011).                                                                                                                                                                                                                                                                                                                                                                            | Magliocca |
|                                                                 | Households bid on house according to their budget constraint which includes the commuting cost for the distance to the CBD: $TC(D) = 0.5404 * D$ (Tax data).                                                                                                                                                                                                                                                                                                                                                                                                             | Prunetti  |
|                                                                 | Embedded in location index. See preferences above.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Ge        |
| g. Utility function                                             | Utility = Willingness to Pay (WTP)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Parker    |
|                                                                 | Utility is a multi-attribute function, which depends on a bundle of property attributes, neighborhood quality and a potential exposure to flood hazards. The base multi-attribute utility function ( $U_{0L}$ , Eq.4.1, Section 2.2.1 in the ODD+D) for a house in a safe area is parameterized using weights ( $A_{ij}$ ) that reflect relative importance of each characteristic ( $X_{i,norm}$ ) for each individual agent j: $U_{0L} = A_{ij} * X_{i,norm}$ . Weights are estimated using the empirical housing transactions dataset (Section 2.2.8, Filatova, 2015) | Filatova  |
|                                                                 | Consumer c's utility function has a Cobb-Douglas form: $U(c, i) = x^{\alpha_c}(d_i)^{\beta_c}$ (Eq 1, Section 3.2.1.1, Magliocca et al., 2011).                                                                                                                                                                                                                                                                                                                                                                                                                          | Magliocca |
|                                                                 | The utility function of the households for the house $\mu$ is a quasi-linear utility function. It is given by the following expression:<br>$U_c(\eta, x) = \sum_{j=1}^n \alpha_j \eta_j + x$ $\eta$ is the vector of characteristics of the parcel $i$ and of the house and $x$ is the amount of money spent for a composite good.                                                                                                                                                                                                                                       | Prunetti  |
|                                                                 | Cobb-Douglas utility function of neighborhood quality, location and price/affordability, with heterogeneous weights on each element for different buyers (Section 3.1.6, Ge, 2017).                                                                                                                                                                                                                                                                                                                                                                                      | Ge        |
| h. Expected return from renting                                 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |           |
| i. Model to determine what will be built (developer land buyer) |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |           |
| j. Willingness to Pay                                           | WTP is determined using a two-stage hedonic model. The first-stage relies on a spatial hedonic model proposed by Babin (2016) using data on sales transactions of 26,873 residential properties in Kitchener-Waterloo from 2005 to 2015. In the first-stage model, WTP is a function of structural attributes (living area, yard size, building age),                                                                                                                                                                                                                    | Parker    |

|                          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |           |
|--------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------|
|                          | <p>neighborhood attributes (education rate, population density) and environmental attributes (open space access, transit access, walkability).</p> <p>WTP estimated using the one-stage hedonic model proposed by Babin (2016) is adjusted using a deviation term to account for household's taste for various housing attributes, according to their socio-demographic characteristics (i.e., family type, income, education, age, and immigration status). This deviation term is estimated based on two-stage hedonic regressions created by Huang et al. (2023) who used transaction and housing survey data to examine the relationship between implicit attribute prices and household socio-demographics during the construction of a new Light Rail Transit (LRT) system in Waterloo Region.</p> <p>When the calculated WTP is larger than the budget of the buyer, then WTP is adjusted to the budget.</p> |           |
|                          | WTP equals housing budget                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | Filatova  |
|                          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | Carro     |
|                          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | Magliocca |
|                          | <p>Household <math>c</math> considers all the house available on the market at time <math>t</math> and computes his maximal utility and bid only on this house. Then he determines his bid function (periodical WTP) for this house. This function is given by the following equation:</p> $\theta_c(\eta) = \frac{YD_c * (V_c^{Max})^2}{b^2 + (V_c^{Max})^2}$ <p>Where <math>b</math> controls the steepness of the WTP function. Hence, the total WTP in <math>t</math> for house <math>\eta</math> is given by:</p> $WTP_c(\eta) = \frac{(1 + \delta_c)[(1 + \delta_c)^T - 1]}{\delta_c} \theta_c(\eta)$                                                                                                                                                                                                                                                                                                         | Prunetti  |
|                          | Equal to past price adjusted for expected price appreciation/depreciation, and adjusted for time-on-market (Eq 21, Section 3.1.6, Ge, 2017).                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | Ge        |
| k. Ask price             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |           |
| l. Willingness to Accept |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |           |
| m. Bid price             | <p>Bid price of a buyer is anchored to the seller's ask price, as revealed from semi-structured interviews with realtors. Buyers bid price is affected by how long a property has been on a market and the buyer's relative market power. Buyers typically bid between 3% and 5% below ask price (randomly drawn), and up to 7–10% below ask price if a property is on the market for a long time. In a sellers' market, buyers bid above the ask price (Eqs. 6-7, Section 2.2.2, Filatova, 2015).</p>                                                                                                                                                                                                                                                                                                                                                                                                              | Filatova  |

|                                                            |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |           |
|------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------|
|                                                            | <p>A bid, <math>R^*(c, n)</math>, for each housing option available for each consumer reflects the relative utility difference between that option and the one that produces the maximum utility, <math>U^*</math>: <math>R^*(c, n) = P_{ask n} \frac{U(c, n)}{U^*}</math>. The consumer's bid for any particular house is then the minimum of their WTP or the bid price calculated here.</p> <p>The bid prices are adjusted using a housing-market competition factor, <math>HMC</math>, to account for the competition for housing each consumer faces in the housing market: <math>HMC_c = \frac{N_c - N_H}{N_c + N_H}</math>, where <math>N_H</math> is the number of houses the consumer bids on and <math>N_c</math> is the number of other consumers bidding on those same houses. Consumer <math>c</math> then modifies their bid price, <math>R^*</math>, for each house in response to market conditions using <math>HMC</math>.</p> | Magliocca |
|                                                            | <p><math>Bidprice_m = (1 - \psi_c)WTP_c(\eta)</math><br/> <math>\psi_c</math>: maximum expected leeway, or negotiation margin on the selling price, which shows the percentage mark-up a buyer considers below their WTP to create a buffer for negotiation.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | Prunetti  |
|                                                            | Equal to WTP                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | Parker    |
|                                                            |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Ge        |
| n. Information sources (i.e. Realtor, listings, neighbors) | Realtor agent, who have access to all bid and ask prices, analyzes previous simulated transactions.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | Filatova  |
|                                                            | Housing consumers are assumed to know how many other housing consumers are bidding on the same set of houses. It is assumed that this information is communicated by a real estate agent.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Magliocca |
|                                                            | Imperfect information, i.e., full knowledge of a random subset of cells, including house characteristics and prices.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | Ge        |
|                                                            | Households are assumed to have access to the average market price for each quality and the trend in house prices (in order to form expectations).                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Carro     |
|                                                            | Household buyers have information on listing properties, including their attributes and listing price.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Parker    |
|                                                            |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Prunetti  |
| o. Search strategies                                       | If the ask price (or WTA) of a property is between 50% and 110% of a buyer's budget, then it comes into the search list of this buyer.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Parker    |
|                                                            | Firstly, buyers 'sort' all vacant affordable houses according to their price. Secondly, out of the top most expensive ones they randomly choose N and proceed with this set further to estimate utility and bid price. We commonly                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | Filatova  |

|                                             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |           |
|---------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------|
|                                             | use $N=5$ in RHEA (based on the sensitivity analysis).                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |           |
|                                             | Search a random subset of all neighborhoods (due to imperfect information) (Section 3.1.6, Ge, 2017).                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | Ge        |
|                                             | Household $c$ considers all the house available on the market at time $t$ and computes his maximal utility.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | Prunetti  |
|                                             | Buyers only consider bidding on houses for which his willingness-to-bid is greater than or equal to the developer's asking prices, multiplied by the bid level, for a given housing type. The bid level is the running average percentage that sale prices have been above/below the original asking prices for houses of a given type in the past (Section 3.4.2, Magliocca et al., 2011).                                                                                                                                                                                                                                                                                                                  | Magliocca |
| p. Negotiation strategies/negotiation power | If a buyer's highest bid meets or exceeds the asking price, the trade executes immediately. If the bid falls short, market power dictates the negotiation. When a seller receives multiple bids, the highest bidder must reconsider; they will accept the asking price if the difference is less than their 6-month opportunity cost of waiting (measured as average city rent). Conversely, if the seller receives only one bid, the seller must reconsider; they will accept the lower bid if the difference is less than their 6-month holding cost (measured as mortgage payments). If the seller and the buyer do not agree on a price the negotiation fails (Figure 3, Section 2.2.6, Filatova, 2015). | Filatova  |
|                                             | Bid prices are adjusted using a competition factor to account for market competition (See bid price above). Competition is high for a given consumer if there are more bidders for the houses he/she is bidding on than there are houses, and the bid will be increased. Competition is relatively low if there are more houses he/she is bidding on than total bidders for those houses, and the bid is adjusted downward. The adjustment of consumers' bid prices in response to market conditions allows consumers to attempt to maximize their gains from trade and the likelihood that they will be the highest bidder (Section 3.3.1, Magliocca et al., 2011).                                         | Magliocca |
|                                             | Bargaining power depending on the number of buyers vs sellers. When the real estate agent settles the prices, in a seller's market, since there are more bids than asks and buyers compete for sellers, price is settled at the $n$ 's highest bid, where $n$ is the number of sellers. In a buyer's market, because there are more asks than bids and sellers would have to                                                                                                                                                                                                                                                                                                                                 | Ge        |

|                                                                                 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                   |
|---------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------|
|                                                                                 | <p>compete for buyers, price is settled at the n's lowest asks, where n is the number of buyers (Section 3.1.5, Ge, 2017).</p> <p>- If there are some bid prices such as <math>Bidprice_v \geq Askprice_{i,m,t}</math> an efficient-rationing rule applied the agent (household or investor) with the highest bid price buy the house of type <math>m</math> built on parcel of land <math>i</math>. The transaction price is then equal to the Ask price of the developer: <math>\bar{P}_{H,i,m,v}(z_i, h_m) = Askprice_{i,m,t}</math></p> <p>- If there are no bid prices such as <math>Bidprice \geq Askprice</math>, the negotiation power for the house of type <math>m</math> built on parcel of land <math>i</math> depends on the number of demands <math>ND_{i,m}</math> from households for whom this house corresponds to the maximal utility and from the investor if her WTP is higher than the WTA of the developer, <math>ND_\mu \leq C + 1</math>. Where <math>C</math> is the total number of households in search of a house. Two cases are possible:</p> <ul style="list-style-type: none"> <li>• If the WTA of the developer is always higher than the WTP of the buyers, there is no transaction and the housing will be put back and replace on the market in the next step.</li> <li>• Otherwise, let be <math>v</math> the individual who has the highest WTP for the house of type <math>m</math> built on parcel of land <math>i</math>. If this WTP is higher than WTA's developer, the developer <math>m</math> and the individual <math>v</math> match. The transaction price is given by the following expression:<br/> <math display="block">\bar{P}_{H,i,m,v}(z_i, h_m) = WTA_{i,\mu,t}(z_i, h_\mu) + \frac{ND_\mu}{C+1} [WTP_{v,i,\mu,t}(z_i, h_\mu) - WTA_{i,\mu,t}(z_i, h_\mu)]</math></li> </ul> | Prunetti                                          |
| q. Household composition                                                        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                   |
| r. Partnership status                                                           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                   |
| s. Location (note this will be read by the landscape initialization algorithms) | See characteristics of the spatial entity in landscape template.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | Parker<br>Filatova<br>Prunetti<br>Magliocca<br>Ge |
| t. Production functions (Developers)                                            |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                   |
| u. Cost functions (Developers)                                                  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                   |
| v. Constraints (i.e. buy/sell, proximity to work - these are likely conditions) |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                   |
| y. Age                                                                          | Age of the Household Reference Person, which will evolve in time (increases every time step) and drive the evolution of other household attributes.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | Carro                                             |

|            |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |           |
|------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------|
|            | Age of the head of family, initialized using synthetic population data. Age does not evolve during the model but it affects household preferences of various housing attributes.                                                                                                                                                                                                                                                                                                                    | Parker    |
| z. Income  | Households are assigned an income percentile, generated uniformly at random at model initialization, which is fixed for the whole life of the household. Household income changes every time step. At each time step an income is assigned from an inverse cumulative distribution of income dependent on age, using the age and the income percentile of the household. For investor households, their current gross rental income has to be added in order to arrive at their gross total income. | Carro     |
|            | Household income is taken from the synthetic population of households for the Waterloo Region (Prédhumeau, M., & Manley, E., 2023). Household income distributions are generated to match census data at census dissemination area level.                                                                                                                                                                                                                                                           | Parker    |
|            | Monthly income is generated using a normal random function as $\exp(N(0,1))$ . (Table 1, Section 3.3, Ge, 2017).                                                                                                                                                                                                                                                                                                                                                                                    | Ge        |
|            | Household annual income (empirical distribution/average empirical). Source: USA statisticsa. The statistical data on income distribution for the Carteret county (NC) was available for 2011; to match the price levels of hedonic analysis the incomes were adjusted to 2004 prices using Consumer Price Index. (Table 2, Section 2.1., Filatova, 2015)                                                                                                                                            | Filatova  |
|            | Household c has a sum of money allocated to the purchase of a property:<br>$YD_c = \omega Y_c + \frac{w}{T} - TC(D)$ , where $Y_c$ is the income of the household c. Buyers are categorized into three groups based on their average income, inferred by occupation (Household agents in Appendix A1, Prunetti et al., 2025)                                                                                                                                                                        | Prunetti  |
|            | Incomes are heterogeneous among agents and drawn randomly from a log-normal distribution with $\mu=\$86,450$ and $\sigma=\$39,095$ and a range of [40,000, 200,000].                                                                                                                                                                                                                                                                                                                                | Magliocca |
| aa. Wealth | Wealth is dynamic, varying according to income and consumption. Consumption is a combination of essential consumption (a fixed minimum amount calibrated from data) and a desired consumption, which is set so that the wealth of the household relaxes towards a target level calibrated from a distribution of wealth given income. That is, households will only have non-essential consumption once                                                                                             | Carro     |

|                                                                                                      |                                                                                                                                                                                                                                                                                                                                                                                           |           |
|------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------|
|                                                                                                      | they are about to reach their target level and will consistently increase their consumption once they pass this threshold (they'll basically consume half the difference between their current bank balance and their target bank balance), with a cap setting a maximum consumption per month. All parameter values are calibrated from data (Table A3, Appendix 2, Carro et al., 2023). |           |
|                                                                                                      | Wealth is dynamic, coming from the sale of land on the land market. Wealth is used for the purchase of houses. If a household is unable to buy a house in a given period, it invests this amount in the financial market, and its wealth excluding wage income increases by $W(1 + r)$ in the following period.                                                                           | Prunetti  |
| 2. P - Decision to participate in the market (become active as a buyer, seller, investor, or renter) |                                                                                                                                                                                                                                                                                                                                                                                           |           |
| a. Decision to participate in the market as a seller                                                 |                                                                                                                                                                                                                                                                                                                                                                                           |           |
| i. Decision to relocate?                                                                             | Endogenous relocation can be triggered by updated utility for a given residence and location following a storm event. If higher utility properties exist and decrease in utility exceeds moving costs, then housing consumer will vacate residence and re-enter the housing consumer pool.                                                                                                | Magliocca |
|                                                                                                      | The number of potential local and external movers in the market is estimated based on census data on local movers and inter- and intra-provincial migration by the census metropolitan area of origin and destination (Statistics Canada, 2023). Local movers are randomly sampled from the resident population, and incoming immigrants are generated as new agents.                     | Parker    |
|                                                                                                      | At initialization, agents are assigned a status of Buyer or Seller. Some Sellers may decide to relocate (either a randomly defined fixed percentage or least satisfied households, determined as input by model user).                                                                                                                                                                    | Filatova  |
| b. Decision to participate in the market as a buyer                                                  | All local and external movers become potential buyers in the housing market.                                                                                                                                                                                                                                                                                                              | Parker    |
|                                                                                                      | Sellers who decided to relocate look for a house in the same town, hence become Buyers.                                                                                                                                                                                                                                                                                                   | Filatova  |
|                                                                                                      | Consumers have a stochastic residence time, and when their residence time is up, they look for a new home. New consumers are also introduced to the market each year (Section 2.6.1, Appendix A, Magliocca et al., 2018).                                                                                                                                                                 | Magliocca |
|                                                                                                      | As long as he does not have a house, the households is always an active buyer.                                                                                                                                                                                                                                                                                                            | Prunetti  |
|                                                                                                      | A given percentage of non-investor buyer (initially set as 5%) activate as buyers. In                                                                                                                                                                                                                                                                                                     | Ge        |

|                                                        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                            |
|--------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------|
|                                                        | each period, the number of buyers can range between zero and a few thousands.                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                            |
|                                                        | Agents without a home (whether rented or owned) decide whether participate in the rental or the ownership market based on a comparison of expected annual costs (based, in its turn, on current average prices and current trends). In order to make a decision, the household will use a sigma function with $x = costOfRent * (1 - psychological_{cost}) - costOfPurchase$ , where $psychological_{cost}$ is a parameter representing the psychological cost of renting as opposed to buying, given same annual costs otherwise. | Carro                                                      |
| c. Decision to participate in the market as a renter   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                            |
| 3. P - Participate in the market as a buyer            |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                            |
| a. Property budget (includes mortgage decision)        | Call from above                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | Parker<br>Filatova<br>Magliocca<br>Prunetti<br>Ge          |
| b. Which properties are evaluated (searching strategy) | Call from Searching strategies above                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Parker<br>Filatova<br>Magliocca<br>Ge                      |
|                                                        | All houses are evaluated                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | Prunetti                                                   |
|                                                        | No searching strategy. The buyer submits the bid and the market mechanism returns the best quality they could buy and, within that quality, the cheapest house.                                                                                                                                                                                                                                                                                                                                                                    | Carro                                                      |
| c. WTP                                                 | Call from above                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | Parker<br>Filatova<br>Magliocca<br>Prunetti<br>Ge<br>Carro |
| d. Bid price                                           | Call from above                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | Parker<br>Filatova<br>Magliocca<br>Prunetti<br>Ge<br>Carro |
| e. Which property(s) to bid on?                        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                            |
| i. One per buyer                                       | Household only bids on the house that provides the highest utility within budget constraint.                                                                                                                                                                                                                                                                                                                                                                                                                                       | Parker<br>Filatova<br>Prunetti<br>Ge                       |
|                                                        | Buyer submits one bid to the market.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Carro                                                      |
| ii. Multiple per buyer                                 | Consumer c will bid on houses for which his willingness-to-buy is greater than or equal to the developer's asking prices (Eq 15, Section 3.4.2, Magliocca et al., 2011).                                                                                                                                                                                                                                                                                                                                                           | Magliocca                                                  |

|                                                                                                            |                                                                                                                                                                                                                                                                                                                 |           |
|------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------|
| f. Negotiation strategy / Negotiation power                                                                | Call from above                                                                                                                                                                                                                                                                                                 | Filatova  |
|                                                                                                            |                                                                                                                                                                                                                                                                                                                 | Magliocca |
|                                                                                                            |                                                                                                                                                                                                                                                                                                                 | Prunetti  |
|                                                                                                            |                                                                                                                                                                                                                                                                                                                 | Ge        |
| g. Rules if you don't succeed to purchase                                                                  |                                                                                                                                                                                                                                                                                                                 |           |
| i. Adjust budget/WTP/bid price (details)                                                                   | Buyers adjust bid prices during negotiations. After an unsuccessful attempt, they just keep bidding in the next time steps for another property.                                                                                                                                                                | Filatova  |
|                                                                                                            |                                                                                                                                                                                                                                                                                                                 | Prunetti  |
|                                                                                                            | Non-investor buyers adjust their bidding price up every period their bid price is not accepted. The longer their time-on-market is, the higher their bid and the higher the chance their bid will be accepted (Eq 21, Section 3.1.6, Ge, 2017).                                                                 | Ge        |
|                                                                                                            | Bid prices are adjusted using a competition factor to account for market competition (See bid price above).                                                                                                                                                                                                     | Magliocca |
|                                                                                                            | When a given house offered in any of the two housing markets—sales or rental—is matched with more than one bidder, the seller or property owner bids up the price $k$ times by multiplying it $k$ times by a bid-up factor larger than 1 and estimated from data (Section 1.5, Appendix 1, Carro et al., 2023). | Carro     |
| ii. Leave market (details)                                                                                 | Potential buyers who have no accepted bid offer or no bids after four months will be removed from the market.                                                                                                                                                                                                   | Parker    |
|                                                                                                            | Buyers leave after being unsuccessful on the market $> 2$ years.                                                                                                                                                                                                                                                | Filatova  |
|                                                                                                            | Buyers leave the market after 3 time steps of unsuccessful bids.                                                                                                                                                                                                                                                | Magliocca |
|                                                                                                            | If they reach a maximum search period (set to be two year or 24 months in the model) without buying a house, they exit the market.                                                                                                                                                                              | Ge        |
|                                                                                                            | If bid is not successful, household returns to “social housing”, an intermediary step from which households always try again bidding for a home, whether renting or buying.                                                                                                                                     | Carro     |
| iii. Stay in the market                                                                                    |                                                                                                                                                                                                                                                                                                                 | Prunetti  |
| 4. P - Participate in the market as a renter (renting a residence unit)                                    |                                                                                                                                                                                                                                                                                                                 |           |
| a. Determination of budget                                                                                 |                                                                                                                                                                                                                                                                                                                 |           |
| b. Which properties are evaluated (searching strategy, assume price taker at fixed offer price)            |                                                                                                                                                                                                                                                                                                                 |           |
| c. WTP (from above)                                                                                        |                                                                                                                                                                                                                                                                                                                 |           |
| d. Which property(s) to apply for?                                                                         |                                                                                                                                                                                                                                                                                                                 |           |
| e. Rules if you don't succeed to purchase                                                                  |                                                                                                                                                                                                                                                                                                                 |           |
| i. Adjust budget/WTP (details)                                                                             |                                                                                                                                                                                                                                                                                                                 |           |
| ii. Leave market (details)                                                                                 |                                                                                                                                                                                                                                                                                                                 |           |
| 5. P - Participate in the market as a leasor (renting unit to someone else) (rules need to be constructed) |                                                                                                                                                                                                                                                                                                                 |           |
| 6. P - Participate in the market as a seller                                                               |                                                                                                                                                                                                                                                                                                                 |           |
| a. WTA (from above)                                                                                        |                                                                                                                                                                                                                                                                                                                 |           |

|                                                                                  |  |  |
|----------------------------------------------------------------------------------|--|--|
| b. Ask/List price (What proposed sales price do you post to the market?)         |  |  |
| c. At what scale are the bids collected?                                         |  |  |
| i. Unique unit scale:                                                            |  |  |
| ii. Aggregate market scale                                                       |  |  |
| d. Rules for collecting bids: How many bids to you accept?                       |  |  |
| i. One per property up for sale                                                  |  |  |
| ii. Multiple per property                                                        |  |  |
| e. Who to sell to (how to pick the accepted bid)                                 |  |  |
| i. Single bid rule                                                               |  |  |
| A. Accept                                                                        |  |  |
| B. Accept if $\geq$ ask price, else reject                                       |  |  |
| C. Accept if $\geq$ WTA, else reject                                             |  |  |
| D. Other (short text field)                                                      |  |  |
| ii. Multiple bid rule                                                            |  |  |
| A. Highest price if $\geq$ ask price                                             |  |  |
| B. Highest price if $\geq$ WTA                                                   |  |  |
| C. Random selection if multiple highest bids                                     |  |  |
| D. Other (short text field)                                                      |  |  |
| iii. Custom (long text field)                                                    |  |  |
| f. Negotiation strategy                                                          |  |  |
| g. List price/time on market adjustment rules (price decrease/repackage/upgrade) |  |  |
| i. Adjust price (text field for details)                                         |  |  |
| ii. Take unit off the market (text field for details)                            |  |  |
| iii. Default on loan (text field for details)                                    |  |  |

**Table S11. MR POTATOHEAD Real Estate Market Framework – Comparison table for the Agent Decision Template – Investor residence buyer**

|                                                                                                                                                                                                                                                                 |                                                                                                                                                                                                                                                                                                                                                                                                                            |          |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|
| 1. Buyers                                                                                                                                                                                                                                                       |                                                                                                                                                                                                                                                                                                                                                                                                                            | Prunetti |
|                                                                                                                                                                                                                                                                 |                                                                                                                                                                                                                                                                                                                                                                                                                            | Ge       |
|                                                                                                                                                                                                                                                                 |                                                                                                                                                                                                                                                                                                                                                                                                                            | Carro    |
| a. Developers - Land buyers                                                                                                                                                                                                                                     |                                                                                                                                                                                                                                                                                                                                                                                                                            |          |
| b. Investors                                                                                                                                                                                                                                                    |                                                                                                                                                                                                                                                                                                                                                                                                                            | Prunetti |
|                                                                                                                                                                                                                                                                 |                                                                                                                                                                                                                                                                                                                                                                                                                            | Ge       |
|                                                                                                                                                                                                                                                                 |                                                                                                                                                                                                                                                                                                                                                                                                                            | Carro    |
| i. Land                                                                                                                                                                                                                                                         |                                                                                                                                                                                                                                                                                                                                                                                                                            |          |
| ii. Residences                                                                                                                                                                                                                                                  |                                                                                                                                                                                                                                                                                                                                                                                                                            | Prunetti |
|                                                                                                                                                                                                                                                                 |                                                                                                                                                                                                                                                                                                                                                                                                                            | Ge       |
|                                                                                                                                                                                                                                                                 |                                                                                                                                                                                                                                                                                                                                                                                                                            | Carro    |
| c. Households                                                                                                                                                                                                                                                   |                                                                                                                                                                                                                                                                                                                                                                                                                            |          |
| 2. Sellers                                                                                                                                                                                                                                                      |                                                                                                                                                                                                                                                                                                                                                                                                                            |          |
| a. Developers                                                                                                                                                                                                                                                   |                                                                                                                                                                                                                                                                                                                                                                                                                            |          |
| b. Investors                                                                                                                                                                                                                                                    |                                                                                                                                                                                                                                                                                                                                                                                                                            |          |
| i. Land                                                                                                                                                                                                                                                         |                                                                                                                                                                                                                                                                                                                                                                                                                            |          |
| ii. Residences                                                                                                                                                                                                                                                  |                                                                                                                                                                                                                                                                                                                                                                                                                            |          |
| c. Households                                                                                                                                                                                                                                                   |                                                                                                                                                                                                                                                                                                                                                                                                                            |          |
| d. Land owners                                                                                                                                                                                                                                                  |                                                                                                                                                                                                                                                                                                                                                                                                                            |          |
| 3. Renters                                                                                                                                                                                                                                                      |                                                                                                                                                                                                                                                                                                                                                                                                                            |          |
| a. People who rent residence units (demand)                                                                                                                                                                                                                     |                                                                                                                                                                                                                                                                                                                                                                                                                            |          |
| b. People who rent out residence units (supply)                                                                                                                                                                                                                 |                                                                                                                                                                                                                                                                                                                                                                                                                            |          |
| 4. Central bank                                                                                                                                                                                                                                                 |                                                                                                                                                                                                                                                                                                                                                                                                                            |          |
| 5. Government                                                                                                                                                                                                                                                   |                                                                                                                                                                                                                                                                                                                                                                                                                            |          |
| Decision making class                                                                                                                                                                                                                                           |                                                                                                                                                                                                                                                                                                                                                                                                                            |          |
| Four types: class (breed) C; attributes, (-own variable) A; links/relationships (directed-link breeds (parent), undirected-link breeds (friend, neighbor, can have own-variables for links in Netlogo, non-binary) L; processes (go, set-up) P; Documentation D |                                                                                                                                                                                                                                                                                                                                                                                                                            |          |
| 1. A / P - Attributes (methods/function and parameters) that affect real estate decisions                                                                                                                                                                       |                                                                                                                                                                                                                                                                                                                                                                                                                            |          |
| a. Budget (this might call a mortgage calculation function)                                                                                                                                                                                                     | The investor has an unlimited budget, estimated as the total investment in the housing market over the simulation period.                                                                                                                                                                                                                                                                                                  | Prunetti |
|                                                                                                                                                                                                                                                                 | Same as households. See household residence buyer template.                                                                                                                                                                                                                                                                                                                                                                | Ge       |
|                                                                                                                                                                                                                                                                 |                                                                                                                                                                                                                                                                                                                                                                                                                            | Carro    |
| b. Preferences                                                                                                                                                                                                                                                  | “Three types of investors are considered with different weights on capital gains as opposed to rental yield: (i) capital-gain-driven investors, with a large weight on capital gains; (ii) rental-income-driven investors, with a small weight on capital gains; and (iii) mixed investors, with equal weights on capital gains and rental yield” (Page 395, Section 3.3.3, and Table A6, Appendix 2, Carro et al., 2023). | Carro    |
| c. Time horizon/discount rate                                                                                                                                                                                                                                   | Same as households. See household residence buyer template.                                                                                                                                                                                                                                                                                                                                                                | Prunetti |
|                                                                                                                                                                                                                                                                 |                                                                                                                                                                                                                                                                                                                                                                                                                            | Carro    |
|                                                                                                                                                                                                                                                                 |                                                                                                                                                                                                                                                                                                                                                                                                                            | Ge       |
| d. Risk perceptions                                                                                                                                                                                                                                             |                                                                                                                                                                                                                                                                                                                                                                                                                            |          |
| e. Price expectations                                                                                                                                                                                                                                           | Average daily revenue of tourist residence is estimated using the following spatial regression:                                                                                                                                                                                                                                                                                                                            | Prunetti |

|                                   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |          |
|-----------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|
|                                   | $\varphi_{t-1} = \alpha_{RT} + \beta_{1RT}Bed_{RT} + \beta_{2RT}LT_{RT} + \frac{\beta_{3RT}}{dB_{RT}} + \frac{\beta_{4RT}}{dCBD_{RT}} + \frac{\beta_{5RT}}{dCDB_L^2} + \beta_{6RT}SVI_L + \beta_{7RT}MCD_{RT} + \epsilon_{RT}$ <p>where <math>Bed_{RT}</math> is the number of bedrooms; <math>LT_{RT}</math> corresponds to the listing type (with “Room” as the baseline); <math>dB_{RT}</math> is the distance to the nearest beach; <math>dCBD_{RT}</math> is the distance to the nearest city center; <math>SVI_{RT}</math> is the Sea View Index; <math>MCD_{RT}</math> is a Main City Dummy; and <math>\epsilon_{RT}</math> is the error term.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |          |
|                                   | Price expectation depends on past price appreciation in the neighborhood, which is heterogeneous across neighborhoods. A discount rate is applied to past price appreciation to dampen the circle, or to account for the ‘cautionary principle’. (Section 3.1.7, Ge, 2017)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Ge       |
|                                   | These are set by recent trend extrapolation, $HPA_{expectation} = HPA_{recent} * a + b$ , where a and b are parameters calibrated from data (Table A4, Appendix 2, Carro et al., 2023).                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | Carro    |
| f. Commuting/Transportation costs |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |          |
| g. Utility function               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |          |
| h. Expected return from renting   | <p>This investor decisions are based only on objective criteria: their expected returns if she buys the house <math>\mu</math> built on a given land <math>i</math> at <math>P_i(\eta)</math>, that is</p> $R_{tour}(\eta) = \sum_{t=1}^T (1+r)^{-t} \gamma \zeta \varphi(\eta) - P_i(\eta) + \rho(1+r)^{-T} P_i(\eta),$ <p>Where <math>\gamma</math> is the coefficient of net return on rental (net of maintenance costs) and <math>\zeta</math> is the duration of the tourist season in days, <math>\varphi(\eta)</math> is the average daily revenue for a tourist residence with corresponding characteristics, and T denotes the average loan duration.</p> <p>Average daily revenue of tourist residence is estimated using the following spatial regression:</p> $\varphi_{t-1} = \alpha_{RT} + \beta_{1RT}Bed_{RT} + \beta_{2RT}LT_{RT} + \frac{\beta_{3RT}}{dB_{RT}} + \frac{\beta_{4RT}}{dCBD_{RT}} + \frac{\beta_{5RT}}{dCDB_L^2} + \beta_{6RT}SVI_L + \beta_{7RT}MCD_{RT} + \epsilon_{RT}$ <p>where <math>Bed_{RT}</math> is the number of bedrooms; <math>LT_{RT}</math> corresponds to the listing type (with “Room” as the baseline); <math>dB_{RT}</math> is the distance to the nearest beach; <math>dCBD_{RT}</math> is the distance to the nearest city center; <math>SVI_{RT}</math> is the Sea View Index; <math>MCD_{RT}</math> is a Main City Dummy; and <math>\epsilon_{RT}</math> is the error term.</p> | Prunetti |
|                                   | <p>“Expected annual return rate of speculative buyer b for a property in region g equals:</p> $ER_t^b(g) = (1 - \omega^b) \left( \frac{p_t^g}{p_{t-12}^g} - 1 \right) - m_t - r^H$ <p>where <math>\omega_b</math> is the discount rate that speculative buyer b assigns to price appreciation, which is heterogeneous</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | Ge       |

|                                                                 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |          |
|-----------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|
|                                                                 | across buyers and $\omega_b \in (0,1)$ . The term $\frac{p_t^g}{p_{t-12}^g}$ is the appreciation in housing price in region $g$ during the last 12 months” (Page 7, Section 3.1.7, Ge, 2016).                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |          |
|                                                                 | Expected rental yield of an investment property with a given quality $q$ is estimated as the current exponential moving average rental yield over all houses with quality $q$ , multiplied by the expected average occupancy of the investment property (Eq 7, Section 3.3.3, Carro et al., 2023).                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | Carro    |
| i. Model to determine what will be built (developer land buyer) |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |          |
| j. Willingness to Pay                                           | <p>Willingness to Pay of the investor is derived by comparing an investment in the real estate and an investment in the financial market, with decision leaning toward investment in the real estate if the expected revenue from a tourist residence is greater than financial market return (see expected revenue from renting above). WTP for a housing <math>m</math> on a parcel of land <math>i</math> is:</p> $WTP_i(\eta) = \frac{1 - (1 + r)^{-T}}{r(1 - \rho)(1 + r)^{-T} + rT - 1 + (1 + r)^{-T}} \gamma \zeta \varphi(\eta)$ <p>Where <math>\gamma</math> is the coefficient of net return on rental (net of maintenance costs) and <math>\zeta</math> is the duration of the tourist season in days, <math>\varphi(\eta)</math> is the average daily revenue for a tourist residence with corresponding characteristics, and <math>T</math> denotes the average loan duration.</p> | Prunetti |
|                                                                 | Equal to expected price for the next period.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | Ge       |
|                                                                 | Equal to their budget                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | Carro    |
| k. Ask price                                                    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |          |
| l. Willingness to Accept                                        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |          |
| m. Bid price                                                    | <p><math>Bidprice_m = (1 - \psi_l)</math>; <math>\psi</math>: maximum expected leeway, or negotiation margin on the selling price, which shows the percentage mark-up a buyer considers below their WTP to create a buffer for negotiation.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Prunetti |
|                                                                 | Equal to willingness to pay                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | Ge       |
|                                                                 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Carro    |
| n. Information sources (i.e. Realtor, listings, neighbors)      | <p>They have information about the previous tourist rental price of a housing as a common knowledge and the previous tourist rental price of a housing <math>m</math> on the parcel of land <math>i</math>.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Prunetti |
|                                                                 | Imperfect information about neighborhoods.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | Ge       |
|                                                                 | Households need information on the average market price for each quality and the trend in house prices (in order to form expectations). Apart from the sources of information required by normal households, investors also need information about the rental market, such as average rental prices for houses of a given quality.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | Carro    |
| o. Search strategies                                            | Search a random subset of all neighborhoods (due to imperfect information).                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | Ge       |
|                                                                 | Buyers search all properties listed on the market.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | Prunetti |

|                                                                                 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                |
|---------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------|
|                                                                                 | There is no searching strategy. Buyers submit their bids and they are matched with properties using the market clearing mechanism.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | Carro          |
| p. Negotiation strategies/negotiation power                                     | Bargaining power depending on the number of buyers vs sellers. When the real estate agent settles the prices, in a seller's market, since there are more bids than asks and buyers compete for sellers, price is settled at the n's highest bid, where n is the number of sellers. In a buyer's market, because there are more asks than bids and sellers would have to compete for buyers, price is settled at the n's lowest asks, where n is the number of buyers (Section 3.1.5, Ge, 2017).                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | Ge             |
|                                                                                 | <p>- If there are some bid prices such as <math>Bidprice_v \geq Askprice_{i,m,t}</math> an efficient-rationing rule applied the agent (household or investor) with the highest bid price buy the house of type <math>m</math> built on parcel of land <math>i</math>. The transaction price is then equal to the Ask price of the developer: <math>\bar{P}_{H,i,m,v}(z_i, h_m) = Askprice_{i,m,t}</math></p> <p>- If there are no bid prices such as <math>Bidprice \geq Askprice</math>, the negotiation power for the house of type <math>m</math> built on parcel of land <math>i</math> depends on the number of demands <math>ND_{i,m}</math> from households for whom this house corresponds to the maximal utility and from the investor if her WTP is higher than the WTA of the developer, <math>ND_{\mu} \leq C + 1</math>. Where <math>C</math> is the total number of households in search of a house. Two cases are possible:</p> <ul style="list-style-type: none"> <li>• If the WTA of the developer is always higher than the WTP of the buyers, there is no transaction and the housing will be put back and replace on the market in the next step.</li> <li>• Otherwise, let be <math>v</math> the individual who has the highest WTP for the house of type <math>m</math> built on parcel of land <math>i</math>. If this WTP is higher than WTA's developer, the developer <math>m</math> and the individual <math>v</math> match. The transaction price is given by the following expression: <math>\bar{P}_{H,i,m,v}(z_i, h_m) = WTA_{i,\mu,t}(z_i, h_{\mu}) + \frac{ND_{\mu}}{C+1} [WTP_{v,i,\mu,t}(\cdot) - WTA_{i,\mu,t}(z_i, h_{\mu})]</math></li> </ul> | Prunetti       |
| q. Household composition                                                        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                |
| r. Partnership status                                                           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                |
| s. Location (note this will be read by the landscape initialization algorithms) | See characteristics of the spatial entity in the landscape template.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | Prunetti<br>Ge |
| t. Production functions (Developers)                                            |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                |
| u. Cost functions (Developers)                                                  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                |
| v. Constraints (i.e. buy/sell, proximity to work - these are likely conditions) |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                |

|                                                                                                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                         |
|------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------|
| ac. Age                                                                                              | Investors are the same as households. See household residence buyer template.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | Carro                   |
| ad. Income                                                                                           | See household residence buyer template.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | Carro<br>Prunetti<br>Ge |
| ae. Wealth                                                                                           | See household residence buyer template.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | Carro<br>Prunetti       |
| 2. P - Decision to participate in the market (become active as a buyer, seller, investor, or renter) |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                         |
| a. Decision to participate in the market as a seller                                                 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                         |
| i. Decision to relocate?                                                                             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                         |
| b. Decision to participate in the market as a buyer                                                  | <p>The investor will invest in a tourist rental house if:</p> $R_{tour}(\eta) \geq R_{fin}(\eta) \Leftrightarrow \frac{\gamma \zeta \varphi(\eta) [1 - (1+r)^{-T}]}{r(1-\rho)(1+r)^{-T} + rT - 1 + (1+r)^{-T}} \geq P_t(\eta),$ <p>and the investor participate to the market.</p> <p>Invest if the highest expected return from the housing market exceeds that from the outside (assumed to be fixed).</p> <p>Investor households try to always keep at least one investment property, so if they have none, then they try to get one. In order to decide whether to buy a new investment property, investor households compute a theoretical expected yield, which is a combination of the current expected rental yield and the expected capital gains, with given weights for these terms characterizing the investor. In particular, the expected yield is estimated as:</p> $expectedYield = \left( \frac{marketPriceForThisQuality}{marketPriceForThisQuality - mortgagePrincipal} \right) * ((1 - capitalGainsCoefficient) * rentalYield + capitalGainsCoefficient * HPAexpectation) - annualMortgagePayments / (marketPriceForThisQuality - mortgagePrincipal)$ <p>Finally, investor households use a sigma function to make the decision (Eq 8, Section 3.3.3, Carro et al., 2023).</p> | Prunetti<br>Ge<br>Carro |
| c. Decision to participate in the market as a renter                                                 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                         |
| 3. P - Participate in the market as a buyer                                                          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                         |
| a. Property budget (includes mortgage decision)                                                      | Call from above                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | Ge                      |
| b. Which properties are evaluated (searching strategy)                                               | Call from search strategies above                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | Prunetti<br>Ge<br>Carro |
| c. WTP                                                                                               | Call from above                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | Prunetti<br>Ge<br>Carro |
| d. Bid price                                                                                         | Call from above                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | Prunetti<br>Ge<br>Carro |
| e. Which property(s) to bid on?                                                                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                         |
| i. One per buyer                                                                                     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | Ge                      |

|                                                                                                            |                                                                                                                                                                                                                                                     |                |
|------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------|
|                                                                                                            | Households trying to buy an investment (buy-to-let) house will bid for the highest expected yield house that they can afford (with an ask price below or equal to their WTP), choosing the cheapest house if there are several with the same yield. | Carro          |
| ii. Multiple per buyer                                                                                     | The investor bids on all houses if WTP is positive and can buy multiple houses                                                                                                                                                                      | Prunetti       |
| f. Negotiation strategy /<br>Negotiation power                                                             | Call from above                                                                                                                                                                                                                                     | Prunetti<br>Ge |
| g. Rules if you don't succeed to purchase                                                                  |                                                                                                                                                                                                                                                     |                |
| i. Adjust budget/WTP/bid price (details)                                                                   |                                                                                                                                                                                                                                                     |                |
| ii. Leave market (details)                                                                                 | If buyer's bid is rejected, they simply leave the market, and will decide on whether or not to invest in the next step.                                                                                                                             | Carro          |
| iii. Continue to bid on the next time step                                                                 | Investor buyers are always there to look for profitable opportunities. If there is none in this period or their bids are not accepted, they will wait for the next period.                                                                          | Prunetti<br>Ge |
| 4. P - Participate in the market as a renter (renting a residence unit)                                    |                                                                                                                                                                                                                                                     |                |
| a. Determination of budget                                                                                 |                                                                                                                                                                                                                                                     |                |
| b. Which properties are evaluated (searching strategy, assume price taker at fixed offer price)            |                                                                                                                                                                                                                                                     |                |
| c. WTP (from above)                                                                                        |                                                                                                                                                                                                                                                     |                |
| d. Which property(s) to apply for?                                                                         |                                                                                                                                                                                                                                                     |                |
| e. Rules if you don't succeed to purchase                                                                  |                                                                                                                                                                                                                                                     |                |
| i. Adjust budget/WTP (details)                                                                             |                                                                                                                                                                                                                                                     |                |
| ii. Leave market (details)                                                                                 |                                                                                                                                                                                                                                                     |                |
| 5. P - Participate in the market as a leasor (renting unit to someone else) (rules need to be constructed) |                                                                                                                                                                                                                                                     |                |
| 6. P - Participate in the market as a seller                                                               |                                                                                                                                                                                                                                                     |                |
| a. WTA (from above)                                                                                        |                                                                                                                                                                                                                                                     |                |
| b. Ask/List price (What proposed sales price do you post to the market?)                                   |                                                                                                                                                                                                                                                     |                |
| c. At what scale are the bids collected?                                                                   |                                                                                                                                                                                                                                                     |                |
| i. Unique unit scale:                                                                                      |                                                                                                                                                                                                                                                     |                |
| ii. Aggregate market scale                                                                                 |                                                                                                                                                                                                                                                     |                |
| d. Rules for collecting bids:<br>How many bids to you accept?                                              |                                                                                                                                                                                                                                                     |                |
| i. One per property up for sale                                                                            |                                                                                                                                                                                                                                                     |                |
| ii. Multiple per property                                                                                  |                                                                                                                                                                                                                                                     |                |
| e. Who to sell to (how to pick the accepted bid)                                                           |                                                                                                                                                                                                                                                     |                |
| i. Single bid rule                                                                                         |                                                                                                                                                                                                                                                     |                |
| A. Accept                                                                                                  |                                                                                                                                                                                                                                                     |                |

|                                                                                  |  |  |
|----------------------------------------------------------------------------------|--|--|
| B. Accept if $\geq$ ask price, else reject                                       |  |  |
| C. Accept if $\geq$ WTA, else reject                                             |  |  |
| D. Other (short text field)                                                      |  |  |
| ii. Multiple bid rule                                                            |  |  |
| A. Highest price if $\geq$ ask price                                             |  |  |
| B. Highest price if $\geq$ WTA                                                   |  |  |
| C. Random selection if multiple highest bids                                     |  |  |
| D. Other (short text field)                                                      |  |  |
| iii. Custom (long text field)                                                    |  |  |
| f. Negotiation strategy                                                          |  |  |
| g. List price/time on market adjustment rules (price decrease/repackage/upgrade) |  |  |
| i. Adjust price (text field for details)                                         |  |  |
| ii. Take unit off the market (text field for details)                            |  |  |
| iii. Default on loan (text field for details)                                    |  |  |

**Table S12. MR POTATOHEAD Real Estate Market Framework – Comparison table for the Agent Decision Template – Investor residence lessor**

|                                                                                                                                                                                                                                                                 |                                                                                                                                                                                                                                                                                                |       |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|
| 1. Buyers                                                                                                                                                                                                                                                       |                                                                                                                                                                                                                                                                                                |       |
| a. Developers - Land buyers                                                                                                                                                                                                                                     |                                                                                                                                                                                                                                                                                                |       |
| b. Investors                                                                                                                                                                                                                                                    |                                                                                                                                                                                                                                                                                                |       |
| i. Land                                                                                                                                                                                                                                                         |                                                                                                                                                                                                                                                                                                |       |
| ii. Residences                                                                                                                                                                                                                                                  |                                                                                                                                                                                                                                                                                                |       |
| c. Households                                                                                                                                                                                                                                                   |                                                                                                                                                                                                                                                                                                |       |
| 2. Sellers                                                                                                                                                                                                                                                      |                                                                                                                                                                                                                                                                                                |       |
| a. Developers                                                                                                                                                                                                                                                   |                                                                                                                                                                                                                                                                                                |       |
| b. Investors                                                                                                                                                                                                                                                    |                                                                                                                                                                                                                                                                                                |       |
| i. Land                                                                                                                                                                                                                                                         |                                                                                                                                                                                                                                                                                                |       |
| ii. Residences                                                                                                                                                                                                                                                  |                                                                                                                                                                                                                                                                                                |       |
| c. Households                                                                                                                                                                                                                                                   |                                                                                                                                                                                                                                                                                                |       |
| d. Land owners                                                                                                                                                                                                                                                  |                                                                                                                                                                                                                                                                                                |       |
| 3. Renters                                                                                                                                                                                                                                                      |                                                                                                                                                                                                                                                                                                | Carro |
| a. People who rent residence units (demand)                                                                                                                                                                                                                     |                                                                                                                                                                                                                                                                                                |       |
| b. People who rent out residence units (supply)                                                                                                                                                                                                                 | Investors                                                                                                                                                                                                                                                                                      | Carro |
| 4. Central bank                                                                                                                                                                                                                                                 |                                                                                                                                                                                                                                                                                                |       |
| 5. Government                                                                                                                                                                                                                                                   |                                                                                                                                                                                                                                                                                                |       |
| Decision making class                                                                                                                                                                                                                                           |                                                                                                                                                                                                                                                                                                |       |
| Four types: class (breed) C; attributes, (-own variable) A; links/relationships (directed-link breeds (parent), undirected-link breeds (friend, neighbor, can have own-variables for links in Netlogo, non-binary) L; processes (go, set-up) P; Documentation D |                                                                                                                                                                                                                                                                                                |       |
| 1. A / P - Attributes (methods/function and parameters) that affect real estate decisions                                                                                                                                                                       |                                                                                                                                                                                                                                                                                                |       |
| a. Budget (this might call a mortgage calculation function)                                                                                                                                                                                                     |                                                                                                                                                                                                                                                                                                |       |
| b. Preferences                                                                                                                                                                                                                                                  | Investor households have a certain preference for capital gains over rental income. This will affect their investment decisions.                                                                                                                                                               | Carro |
| c. Time horizon/discount rate                                                                                                                                                                                                                                   |                                                                                                                                                                                                                                                                                                |       |
| d. Risk perceptions                                                                                                                                                                                                                                             |                                                                                                                                                                                                                                                                                                |       |
| e. Price expectations                                                                                                                                                                                                                                           | These are set by recent trend extrapolation, $HPA_{expectation} = HPA_{recent} * a + b$ , where $a$ and $b$ are parameters calibrated from data (Table A4, Appendix 2, Carro et al., 2023)                                                                                                     | Carro |
| f. Commuting/Transportation costs                                                                                                                                                                                                                               |                                                                                                                                                                                                                                                                                                |       |
| g. Utility function                                                                                                                                                                                                                                             |                                                                                                                                                                                                                                                                                                |       |
| h. Expected return from renting                                                                                                                                                                                                                                 | See investor residence buyer template.                                                                                                                                                                                                                                                         | Carro |
| i. Model to determine what will be built (developer land buyer)                                                                                                                                                                                                 |                                                                                                                                                                                                                                                                                                |       |
| j. Willingness to Pay                                                                                                                                                                                                                                           |                                                                                                                                                                                                                                                                                                |       |
| k. Ask price                                                                                                                                                                                                                                                    | Equal to WTA.                                                                                                                                                                                                                                                                                  | Carro |
| l. Willingness to Accept                                                                                                                                                                                                                                        | Ask price is determined as a mark-up over the exponential average rental price of houses of the same quality, with a mark-up drawn from a distribution of real rental mark-ups, that is, $AskPrice = markup * expAvRentPriceForQuality(q)$ , for a house of quality $q$ . Then, each month the | Carro |

|                                                                                                      |                                                                                                                                                                                              |       |
|------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|
|                                                                                                      | property remains empty, there is a certain probability of reducing its price, applying a normally distributed price decrease calibrated from data (Table A5, Appendix 2, Carro et al., 2023) |       |
| m. Bid price                                                                                         |                                                                                                                                                                                              |       |
| n. Information sources (i.e. Realtor, listings, neighbors)                                           | Investors are assumed to have access to information about the rental market, such as average rental prices for houses of a given quality.                                                    | Carro |
| o. Search strategies                                                                                 |                                                                                                                                                                                              |       |
| p. Negotiation strategies/negotiation power                                                          |                                                                                                                                                                                              |       |
| q. Household composition                                                                             |                                                                                                                                                                                              |       |
| r. Partnership status                                                                                |                                                                                                                                                                                              |       |
| s. Location (note this will be read by the landscape initialization algorithms)                      |                                                                                                                                                                                              |       |
| t. Production functions (Developers)                                                                 |                                                                                                                                                                                              |       |
| u. Cost functions (Developers)                                                                       |                                                                                                                                                                                              |       |
| v. Constraints (i.e. buy/sell, proximity to work - these are likely conditions)                      |                                                                                                                                                                                              |       |
| x. Age                                                                                               | Same as households, See household residence buyer template.                                                                                                                                  | Carro |
| y. Income                                                                                            | See household residence buyer template.                                                                                                                                                      | Carro |
| z. Wealth                                                                                            | See household residence buyer template.                                                                                                                                                      | Carro |
| 2. P - Decision to participate in the market (become active as a buyer, seller, investor, or renter) |                                                                                                                                                                                              |       |
| a. Decision to participate in the market as a seller                                                 |                                                                                                                                                                                              |       |
| i. Decision to relocate?                                                                             |                                                                                                                                                                                              |       |
| b. Decision to participate in the market as a buyer                                                  |                                                                                                                                                                                              |       |
| c. Decision to participate in the market as a renter                                                 |                                                                                                                                                                                              |       |
| 3. P - Participate in the market as a buyer                                                          |                                                                                                                                                                                              |       |
| a. Property budget (includes mortgage decision) - Call from above                                    |                                                                                                                                                                                              |       |
| b. Which properties are evaluated (searching strategy)                                               |                                                                                                                                                                                              |       |
| c. WTP - call from above                                                                             |                                                                                                                                                                                              |       |
| d. Bid price - call from above                                                                       |                                                                                                                                                                                              |       |
| e. Which property(s) to bid on?                                                                      |                                                                                                                                                                                              |       |
| i. One per buyer                                                                                     |                                                                                                                                                                                              |       |
| ii. Multiple per buyer                                                                               |                                                                                                                                                                                              |       |
| f. Negotiation strategy / Negotiation power - call from above                                        |                                                                                                                                                                                              |       |
| g. Rules if you don't succeed to purchase                                                            |                                                                                                                                                                                              |       |
| i. Adjust budget/WTP/bid price (details)                                                             |                                                                                                                                                                                              |       |
| ii. Leave market (details)                                                                           |                                                                                                                                                                                              |       |
| 4. P - Participate in the market as a renter (renting a residence unit)                              |                                                                                                                                                                                              |       |
| a. Determination of budget                                                                           |                                                                                                                                                                                              |       |
| b. Which properties are evaluated (searching strategy, assume price taker at fixed offer price)      |                                                                                                                                                                                              |       |
| c. WTP (from above)                                                                                  |                                                                                                                                                                                              |       |
| d. Which property(s) to apply for?                                                                   |                                                                                                                                                                                              |       |

|                                                                                                                                                                          |       |  |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|--|
| e. Rules if you don't succeed to purchase                                                                                                                                |       |  |
| i. Adjust budget/WTP (details)                                                                                                                                           |       |  |
| ii. Leave market (details)                                                                                                                                               |       |  |
| 5. P - Participate in the market as a leasor (renting unit to someone else) (rules need to be constructed)                                                               |       |  |
| Rules are the same as for households selling a house. Only difference is here we are talking about rental prices.                                                        | Carro |  |
| 6. P - Participate in the market as a seller                                                                                                                             |       |  |
| a. WTA (from above)                                                                                                                                                      |       |  |
| b. Ask/List price (What proposed sales price do you post to the market?)                                                                                                 |       |  |
| c. At what scale are the bids collected? (pick list) (This is related to the container issues. You might have a container of units, but still list each one separately.) |       |  |
| i. Unique unit scale:                                                                                                                                                    |       |  |
| ii. Aggregate market scale                                                                                                                                               |       |  |
| d. Rules for collecting bids: How many bids to you accept?                                                                                                               |       |  |
| i. One per property up for sale                                                                                                                                          |       |  |
| ii. Multiple per property                                                                                                                                                |       |  |
| e. Who to sell to (how to pick the accepted bid)                                                                                                                         |       |  |
| i. Single bid rule                                                                                                                                                       |       |  |
| A. Accept                                                                                                                                                                |       |  |
| B. Accept if $\geq$ ask price, else reject                                                                                                                               |       |  |
| C. Accept if $\geq$ WTA, else reject                                                                                                                                     |       |  |
| D. Other (short text field)                                                                                                                                              |       |  |
| ii. Multiple bid rule                                                                                                                                                    |       |  |
| A. Highest price if $\geq$ ask price                                                                                                                                     |       |  |
| B. Highest price if $\geq$ WTA                                                                                                                                           |       |  |
| C. Random selection if multiple highest bids                                                                                                                             |       |  |
| D. Other (short text field)                                                                                                                                              |       |  |
| iii. Custom (long text field)                                                                                                                                            |       |  |
| f. Negotiation strategy                                                                                                                                                  |       |  |
| g. List price/time on market adjustment rules (price decrease/repackage/upgrade)                                                                                         |       |  |
| i. Adjust price (text field for details)                                                                                                                                 |       |  |
| ii. Take unit off the market (text field for details)                                                                                                                    |       |  |
| iii. Default on loan (text field for details)                                                                                                                            |       |  |

**Table S13. MR POTATOHEAD Real Estate Market Framework – Comparison table for the Agent Decision Template – Household residence renter**

|                                                                                                                                                                                                                                                                 |                                                                                                                                                                                                                                                                                                                           |       |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|
| 1. Buyers                                                                                                                                                                                                                                                       |                                                                                                                                                                                                                                                                                                                           |       |
| a. Developers - Land buyers                                                                                                                                                                                                                                     |                                                                                                                                                                                                                                                                                                                           |       |
| b. Investors                                                                                                                                                                                                                                                    |                                                                                                                                                                                                                                                                                                                           |       |
| i. Land                                                                                                                                                                                                                                                         |                                                                                                                                                                                                                                                                                                                           |       |
| ii. Residences                                                                                                                                                                                                                                                  |                                                                                                                                                                                                                                                                                                                           |       |
| c. Households                                                                                                                                                                                                                                                   |                                                                                                                                                                                                                                                                                                                           |       |
| 2. Sellers                                                                                                                                                                                                                                                      |                                                                                                                                                                                                                                                                                                                           |       |
| a. Developers                                                                                                                                                                                                                                                   |                                                                                                                                                                                                                                                                                                                           |       |
| b. Investors                                                                                                                                                                                                                                                    |                                                                                                                                                                                                                                                                                                                           |       |
| i. Land                                                                                                                                                                                                                                                         |                                                                                                                                                                                                                                                                                                                           |       |
| ii. Residences                                                                                                                                                                                                                                                  |                                                                                                                                                                                                                                                                                                                           |       |
| c. Households                                                                                                                                                                                                                                                   |                                                                                                                                                                                                                                                                                                                           |       |
| d. Land owners                                                                                                                                                                                                                                                  |                                                                                                                                                                                                                                                                                                                           |       |
| 3. Renters                                                                                                                                                                                                                                                      |                                                                                                                                                                                                                                                                                                                           | Carro |
| a. People who rent residence units (demand)                                                                                                                                                                                                                     | Households                                                                                                                                                                                                                                                                                                                | Carro |
| b. People who rent out residence units (supply)                                                                                                                                                                                                                 |                                                                                                                                                                                                                                                                                                                           |       |
| 4. Central bank                                                                                                                                                                                                                                                 |                                                                                                                                                                                                                                                                                                                           |       |
| 5. Government                                                                                                                                                                                                                                                   |                                                                                                                                                                                                                                                                                                                           |       |
| Decision making class                                                                                                                                                                                                                                           |                                                                                                                                                                                                                                                                                                                           |       |
| Four types: class (breed) C; attributes, (-own variable) A; links/relationships (directed-link breeds (parent), undirected-link breeds (friend, neighbor, can have own-variables for links in Netlogo, non-binary) L; processes (go, set-up) P; Documentation D |                                                                                                                                                                                                                                                                                                                           |       |
| 1. A / P - Attributes (methods/function and parameters) that affect real estate decisions                                                                                                                                                                       |                                                                                                                                                                                                                                                                                                                           |       |
| a. Budget (this might call a mortgage calculation function)                                                                                                                                                                                                     | See household residence buyer.                                                                                                                                                                                                                                                                                            | Carro |
| b. Preferences                                                                                                                                                                                                                                                  | See household residence buyer.                                                                                                                                                                                                                                                                                            | Carro |
| c. Time horizon/discount rate                                                                                                                                                                                                                                   | See household residence buyer.                                                                                                                                                                                                                                                                                            | Carro |
| d. Risk perceptions                                                                                                                                                                                                                                             |                                                                                                                                                                                                                                                                                                                           |       |
| e. Price expectations                                                                                                                                                                                                                                           | See household residence buyer.                                                                                                                                                                                                                                                                                            | Carro |
| f. Commuting/Transportation costs                                                                                                                                                                                                                               |                                                                                                                                                                                                                                                                                                                           |       |
| g. Utility function                                                                                                                                                                                                                                             |                                                                                                                                                                                                                                                                                                                           |       |
| h. Expected return from renting                                                                                                                                                                                                                                 |                                                                                                                                                                                                                                                                                                                           |       |
| i. Model to determine what will be built (developer land buyer)                                                                                                                                                                                                 |                                                                                                                                                                                                                                                                                                                           |       |
| j. Willingness to Pay                                                                                                                                                                                                                                           | A desired rental price or willingness to pay is computed as a nonlinear function of the household's income. In particular: $WTP = a * income^b * e^{(GaussianNoise)}$ . Note that this price is then capped to the household's net monthly income minus essential consumption (Table A4, Appendix 2, Carro et al., 2023). | Carro |
| k. Ask price                                                                                                                                                                                                                                                    |                                                                                                                                                                                                                                                                                                                           |       |
| l. Willingness to Accept                                                                                                                                                                                                                                        |                                                                                                                                                                                                                                                                                                                           |       |
| m. Bid price                                                                                                                                                                                                                                                    | Equal to WTP                                                                                                                                                                                                                                                                                                              | Carro |
| n. Information sources (i.e. Realtor, listings, neighbors)                                                                                                                                                                                                      | Investors are assumed to have access to information about the rental market, such as average rental prices for houses of a given quality                                                                                                                                                                                  | Carro |
| o. Search strategies                                                                                                                                                                                                                                            | No searching strategy. The renter submits the bid with bid price and the market mechanism                                                                                                                                                                                                                                 |       |

|                                                                                                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |       |
|------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|
|                                                                                                      | returns the best quality they could buy and, within that quality, the cheapest house.                                                                                                                                                                                                                                                                                                                                                                                                                                               |       |
| p. Negotiation strategies/negotiation power                                                          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |       |
| q. Household composition                                                                             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |       |
| r. Partnership status                                                                                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |       |
| s. Location (note this will be read by the landscape initialization algorithms)                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |       |
| t. Production functions (Developers)                                                                 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |       |
| u. Cost functions (Developers)                                                                       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |       |
| v. Constraints (i.e. buy/sell, proximity to work - these are likely conditions)                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |       |
| x. Age                                                                                               | See household residence buyer template.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | Carro |
| y. Income                                                                                            | See household residence buyer template.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | Carro |
| z. Wealth                                                                                            | See household residence buyer template.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | Carro |
| 2. P - Decision to participate in the market (become active as a buyer, seller, investor, or renter) |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |       |
| a. Decision to participate in the market as a seller                                                 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |       |
| i. Decision to relocate?                                                                             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |       |
| b. Decision to participate in the market as a buyer                                                  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |       |
| c. Decision to participate in the market as a renter                                                 | Agents without a home (whether rented or owned) decide whether participate in the rental or the ownership market, based on a comparison of expected annual costs (based, in its turn, on current average prices and current trends). In order to make a decision, the household will use a sigma function with $x = costOfRent * (1 * psychological_{cost}) - costOfPurchase$ , where $psychological_{cost}$ is a parameter representing the psychological cost of renting as opposed to buying, given same annual costs otherwise. | Carro |
| 3. P - Participate in the market as a buyer                                                          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |       |
| a. Property budget (includes mortgage decision) - Call from above                                    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |       |
| b. Which properties are evaluated (searching strategy)                                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |       |
| c. WTP - call from above                                                                             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |       |
| d. Bid price - call from above                                                                       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |       |
| e. Which property(s) to bid on?                                                                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |       |
| i. One per buyer                                                                                     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |       |
| ii. Multiple per buyer                                                                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |       |
| f. Negotiation strategy / Negotiation power - call from above                                        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |       |
| g. Rules if you don't succeed to purchase                                                            |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |       |
| i. Adjust budget/WTP/bid price (details)                                                             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |       |
| ii. Leave market (details)                                                                           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |       |
| 4. P - Participate in the market as a renter (renting a residence unit)                              |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | Carro |
| a. Determination of budget                                                                           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |       |
| b. Which properties are evaluated (searching strategy, assume price taker at fixed offer price)      | All properties                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | Carro |

|                                                                                                                                                                          |                                                                                                                                                                                                                                   |       |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|
| c. WTP                                                                                                                                                                   | Call from above                                                                                                                                                                                                                   | Carro |
| d. Which property(s) to apply for?                                                                                                                                       | All houses that the renter can afford are considered. The market clearing mechanism matches all bids to the offer with the highest house quality that they can afford and, cheaper houses are preferred in case of equal quality. | Carro |
| e. Rules if you don't succeed to purchase                                                                                                                                |                                                                                                                                                                                                                                   |       |
| i. Adjust budget/WTP (details)                                                                                                                                           |                                                                                                                                                                                                                                   |       |
| ii. Leave market (details)                                                                                                                                               | As for purchase market, if unsuccessful, go back to “social housing” status and try again in the next time step.                                                                                                                  | Carro |
| 5. P - Participate in the market as a leasor (renting unit to someone else) (rules need to be constructed)                                                               |                                                                                                                                                                                                                                   |       |
| 6. P - Participate in the market as a seller                                                                                                                             |                                                                                                                                                                                                                                   |       |
| a. WTA (from above)                                                                                                                                                      |                                                                                                                                                                                                                                   |       |
| b. Ask/List price (What proposed sales price do you post to the market?)                                                                                                 |                                                                                                                                                                                                                                   |       |
| c. At what scale are the bids collected? (pick list) (This is related to the container issues. You might have a container of units, but still list each one separately.) |                                                                                                                                                                                                                                   |       |
| i. Unique unit scale:                                                                                                                                                    |                                                                                                                                                                                                                                   |       |
| ii. Aggregate market scale                                                                                                                                               |                                                                                                                                                                                                                                   |       |
| d. Rules for collecting bids: How many bids to you accept?                                                                                                               |                                                                                                                                                                                                                                   |       |
| i. One per property up for sale ( <i>becomes a bilateral transaction model</i> )                                                                                         |                                                                                                                                                                                                                                   |       |
| ii. Multiple per property                                                                                                                                                |                                                                                                                                                                                                                                   |       |
| e. Who to sell to (how to pick the accepted bid)                                                                                                                         |                                                                                                                                                                                                                                   |       |
| i. Single bid rule                                                                                                                                                       |                                                                                                                                                                                                                                   |       |
| A. Accept                                                                                                                                                                |                                                                                                                                                                                                                                   |       |
| B. Accept if $\geq$ ask price, else reject                                                                                                                               |                                                                                                                                                                                                                                   |       |
| C. Accept if $\geq$ WTA, else reject                                                                                                                                     |                                                                                                                                                                                                                                   |       |
| D. Other (short text field)                                                                                                                                              |                                                                                                                                                                                                                                   |       |
| ii. Multiple bid rule                                                                                                                                                    |                                                                                                                                                                                                                                   |       |
| A. Highest price if $\geq$ ask price                                                                                                                                     |                                                                                                                                                                                                                                   |       |
| B. Highest price if $\geq$ WTA                                                                                                                                           |                                                                                                                                                                                                                                   |       |
| C. Random selection if multiple highest bids                                                                                                                             |                                                                                                                                                                                                                                   |       |
| D. Other (short text field)                                                                                                                                              |                                                                                                                                                                                                                                   |       |
| iii. Custom (long text field)                                                                                                                                            |                                                                                                                                                                                                                                   |       |
| f. Negotiation strategy                                                                                                                                                  |                                                                                                                                                                                                                                   |       |
| g. List price/time on market adjustment rules (price decrease/repackage/upgrade)                                                                                         |                                                                                                                                                                                                                                   |       |
| i. Adjust price (text field for details)                                                                                                                                 |                                                                                                                                                                                                                                   |       |
| ii. Take unit off the market (text field for details)                                                                                                                    |                                                                                                                                                                                                                                   |       |
| iii. Default on loan (text field for details)                                                                                                                            |                                                                                                                                                                                                                                   |       |

## Supplementary Material B

This section provides the MR POTATOHEAD templates for six models in the following order:

- Carro et al. (2023)
- Ge (2017)
- Valaei Sharif et al. (Unpublished)
- Filatova (2015)
- Prunetti et al. (2025)
- Magliocca et al. (2011)

**Mr. Potatohead Real Estate Market Edition – Landscape Class Template – Carro et al. (2023)**

1. What is the form of the base landscape?

**The model has no explicit representation of space, that is, there is no spatial variables, characteristics nor differentiations. All houses are, in principle, accessible to all households, all offers and bids are collected on a single national market (actually, one for rent and another one for sales). Even though we have a variable characterizing the “quality” of each house, which could be thought of as including location desirability, the fact that all houses are traded on a single national market makes it such that there is no landscape or spatial structure.**

- a. **Abstract** / Empirical
  - b. Vector or cell-based (uniform tessellation) **Neither, a-spatial**
  - c. Source of landscape initialization
    - i. Generic grid, uniform tessellation (*Netlogo default*)
    - ii. CSV file? (Y/N) Enter GIS base layer file name here, or provide link
    - iii. GIS file? (Y/N) Enter GIS base layer file name here, or provide link
  - d. Define coarse-scale land uses
2. What unique products are being bought and sold? **Only houses are bought and sold (or offered and taken for rental, in the rental market).**
    - a. Number of container types. For each container provide the following information:

**1 container type: house. Each house is characterized by a single integer variable that we call “quality” and sets its desirability, thus none of the below applies.**

      - i. Characteristics of the spatial entity
        1. Spatial location(s), if not read from GIS or CSV
        2. Entire lot area (*parcel polygon*)
        3. Building footprint area (*building footprint polygon*)
        4. Number of Stories
        5. Transportation accessibility
        6. Neighbourhood amenities
        7. Neighbourhood disamenities
      - ii. Number of different unit categories in the container. **Distribution of random quality**
      - iii. Unit category descriptions:
        1. Number of units of this type. **Endogenous; determined by the developer in order to construct enough initial house units to house the initial population**  
**If this refers to the number of houses, then it is decided by the developer, though via a very simple rule of providing houses to keep a target ratio of houses per household in the model. These houses are provided with**

**a random quality and offered on the market at a sale price taken from data using the quality of the house to compute a percentile price. Given that houses are never removed from the system and that the population oscillates around a target number, the construction sector is mostly active only on the initial time steps.**

2. Unit area
3. Number of room/bedrooms
4. Number of baths
5. Yard/lot size
6. Garage
7. Etc.

**Mr. Potatohead Real Estate Market Edition – Property Exchange Class Template – Sales Market – Carro et al. (2023)**

1. Which market is being modelled?
  - a. **Residences: Sales market**
  - b. Land
2. Who are the market participants?
  - a. **Buyers**
    - i. Developers
    - ii. **Investors**
    - iii. **Households**
  - b. **Sellers**
    - i. **Developers**
    - ii. **Investors**
    - iii. **Households**
    - iv. Land owners
  - c. **Renters**
    - i. People who rent units (demand)
    - ii. People who rent out units (supply)
3. Initialize buyer and seller locations (*call to agent's Location field*)
  - a. One agent per spatial container
  - b. Multiple agents per spatial container
4. What are your ask and bid price rules for market-based land allocation?
  - a. How ask prices posted?
    - i. **Public information**
    - ii. Information held by realtor agents
  - b. Bid submission: How many properties can a buyer bid on? **Only one.**
  - c. Bid acceptance: How many bids are accepted per property? **Multiple bids can be matched to a single offer, but only one bid will be finally accepted.**
5. Matching algorithm: How are buyers matched to purchased properties?
  - a. Custom rule
  - b. How units are matched to the seller—**subdivision model** (many to one) or single property model (one to one). *Call to seller ADM(s).*
  - c. How are buyer bids matched to units? **home buyers are matched to the highest quality house they can afford, and to the cheapest possible house within a given quality band (this is due to the fact that qualities are integer numbers, say, from 0 to 30, for example, so there will be multiple houses with the same quality and different prices, in which case all buyers would prefer the cheapest one). House investors, on the contrary, are matched to the highest yield house they can afford, and to the cheapest possible house within a given yield (note that having exactly the same yield is very unlikely, as it is a float). Call to buyer ADM(s)**
  - d. How are winning bids selected? **offers matched to a single bidder are directly transacted, while offers matched to multiple bidders have a**

certain probability to increase their price, with both the probability and the price increase size roughly calibrated from data. In the case of multiple bids, a bidder is finally chosen at random among those who can still pay for the property (*Call to seller ADM*)

- e. How is the transaction price defined?
  - i. Bid price if multiple bids
  - ii. Mean of bid and ask if one bid
  - iii. Negotiation process (*describe, calling ADM negotiation strategies*)
  - iv. Custom
- 6. What market housekeeping occurs in your model?
  - a. **Change ownership**
  - b. Age homes
  - c. **Record sales prices for next round**
  - d. **Seller adjustments for un-sold units (*call to ADM functions*)**
  - e. **Rules for buyers who did not find a home (*call to ADM functions*): they just go back to “social housing” status, so next month they’ll decide again whether to buy or rent.**
  - f. Identify active buyers and sellers for next round
- 7. What are your stopping rules for market activity?

**The market clearing proceeds in multiple steps, until all houses have been sold, all buyers have bought or no buyer can afford any of the available houses. Matching and clearing rounds take place until no houses are left for sale, until no buyers are left, or until no buyer can afford any of the remaining houses.**

**Note that the sales market clears before the rental market, and newly purchased BTL homes are then entered into the rental market.**

- a. No market activity in X time periods (numerical entry for number of time periods) (*equilibrium rule*)
- b. **End time periods (numerical entry for number of time periods) (*non-equilibrium rule*) (“new round”)**

**Mr. Potatohead Real Estate Market Edition – Property Exchange Class Template – Rental Market – Carro et al. (2023)**

1. Which market is being modelled?
  - a. **Residences: Rental market. Since most mechanisms are exactly equivalent to the sale market ones, I will focus here only on the differences.**
  - b. Land
2. Who are the market participants?
  - a. Buyers
    - i. Developers
    - ii. Investors
    - iii. Households: This is confusing, households are buyers of rental contracts
  - b. Sellers
    - i. Developers
    - ii. Investors: This is confusing, investors are sellers of rental contracts
    - iii. Households
    - iv. Land owners
  - c. Renters
    - i. **Households who rent units (demand)**
    - ii. **Investors who rent out units (supply)**
3. Initialize buyer and seller locations (*call to agent's Location field*)
  - a. One agent per spatial container
  - b. Multiple agents per spatial container
4. What are your ask and bid price rules for market-based land allocation?
  - a. How ask prices posted?
    - i. Public information
    - ii. Information held by realtor agents
  - b. Bid submission: How many properties can a buyer bid on?
  - c. Bid acceptance: How many bids are accepted per property?
5. Matching algorithm: How are buyers matched to purchased properties? **All households will be matched to the best quality house they can afford, and to the cheapest possible house within a given quality band.**
  - a. Custom rule
  - b. How units are matched to the seller—subdivision model (many to one) or single property model (one to one). *Call to seller ADM(s).*
  - c. How are buyer bids matched to units? *Call to buyer ADM(s)*
  - d. How are winning bids selected? (*Call to seller ADM*)
  - e. How is the transaction price defined?
    - i. Bid price if multiple bids
    - ii. Mean of bid and ask if one bid
    - iii. Negotiation process (*describe, calling ADM negotiation strategies*)
    - iv. Custom
6. What market housekeeping occurs in your model?
  - a. Change ownership

- b. Age homes
  - c. **Record sales prices for next round**
  - d. **Seller adjustments for un-sold units (*call to ADM functions*)**
  - e. **Rules for buyers who did not find a home (*call to ADM functions*)**
  - f. Identify active buyers and sellers for next round
7. What are your stopping rules for market activity?
- a. No market activity in X time periods (numerical entry for number of time periods) (*equilibrium rule*)
  - b. **End time periods (numerical entry for number of time periods) (*non-equilibrium rule*) (“new round”). The rental market operates and clears after the sales market.**

**Mr. Potatohead Real Estate Market Edition – Agent Decision Template – Developer Seller  
– Carro et al. (2023)**

**Demographic classes (These are agent types. Each agent type could buy, sell, or rent, or rent out. Select your agent type here)**

1. Buyers
  1. Developers – Land buyers
  2. Investors
    - Land
    - Residences
  3. Households
2. Sellers
  1. **Developers**: note that developers are only sellers in our model.
  2. Investors
    - Land
    - Residences
  3. Households
  4. Land owners
3. Renters
  1. People who rent residence units (demand)
  2. People who rent out residence units (supply)
4. Central bank (*For future—not in any current models*)
5. Government (*For future—not in any current models*)

**Decision making class (In MR POTATOHEAD, this is “agent decision model”) (filled out for each land-market agent type, 1-5 from above in current models)**

1. A / P – Attributes (methods/function and parameters) that affect decision real estate decision
  - Budget
  - Preferences
  - Time horizon/discount rate
  - Risk perceptions
  - Price expectations
  - Commuting/Transportation costs
  - Utility function
  - Expected return from renting
  - Model to determine what will be built (developer land buyer)
  - Willingness to Pay
  - **Ask price: Ask price is directly taken from the real distribution of housing prices, for the percentile corresponding to the house quality of the specific house to be sold. Note that this quality is chosen at random. Every time step that the house remains in the market unsold, the developer decreases the ask price by a certain percentage.**
  - Willingness to Accept
  - Bid price

- **Information sources (i.e. Realtor, listings, neighbours):** The developer has access to the current population, the current number of houses and the distribution of real housing prices (from data).
  - Search strategies
  - Negotiation strategies/negotiation power
  - Household composition
  - Partnership status
  - Location (note this will be read by the landscape initialization algorithms)
  - Production functions (Developers)
  - Cost functions (Developers)
  - Constraints (i.e. buy/sell, proximity to work—these are likely conditions)
2. P -- Decision to participate in the market (become active as a buyer, seller, investor, or renter)

**The developer is extremely simplified in our model: it simply puts as many new houses in the market as needed in order to instantaneously reach a given target ratio of houses per household, which is a parameter of the model. Thus, at each time step, the developer checks the current number of households, compares it with the current number of houses and decides how many new houses are needed. For each of these houses, the developer assigns a random quality.**

1. Decision to participate in the market as a seller
    1. Decision to relocate?
  2. Decision to participate in the market as a buyer
  3. Decision to participate in the market as a renter
3. P – Participate in the market as a seller
1. WTA (from above)
  2. Ask/List price (What proposed sales price do you post to the market?)  
**Described above.**
  3. At what scale are the bids collected?
    - a. Unique unit scale
    - b. Aggregate market scale: Offers are aggregated for the whole system in a single market.**
  4. Rules for collecting bids: How many bids to you accept?
    - i. One per property up for sale
    - ii. Multiple per property.**
  5. Who to sell to (how to pick the accepted bid)
    - a. Single bid rule (Only relevant if you have chosen 4 i.)
      - i. Accept
      - ii. Accept if  $\geq$  ask price, else reject
      - iii. Accept if  $\geq$  WTA, else reject
      - iv. Other (short text field)
    - b. Multiple bid rule
      - i. Highest price if  $\geq$  ask price
      - ii. Highest price if  $\geq$  WTA
      - iii. Random selection if multiple highest bids
      - iv. Other: increase ask price by rule if multiple bids, then select randomly among buyers who can afford still. If bids are**

**multiple, then a random bid-up is drawn. Finally, a bidder is randomly selected among those who can still pay for the property at the increased price.**

c. Custom

6. Negotiation strategy
7. List price/time on market adjustment rules (price decrease/repackage/upgrade)
  - i. **Adjust price: List price is decreased by a certain percentage every time step that the property remains unsold, with no lower bound for the developer (there is a lower bound for households).**
  - ii. Take unit off the market
  - iii. Default on loan

**Mr. Potatohead Real Estate Market Edition – Agent Decision Template – Household Seller  
– Carro et al. (2023)**

**Demographic classes (These are agent types. Each agent type could buy, sell, or rent, or rent out. Select your agent type here)**

1. Buyers
  1. Developers – Land buyers
  2. Investors
    - Land
    - Residences
  3. Households
2. Sellers
  1. Developers
  2. Investors
    - Land
    - Residences
  3. Households
  4. Land owners
3. Renters
  1. People who rent residence units (demand)
  2. People who rent out residence units (supply)
4. Central bank (*For future—not in any current models*)
5. Government (*For future—not in any current models*)

**Decision making class (In MR POTATOHEAD, this is “agent decision model”) (filled out for each land-market agent type, 1-5 from above in current models)**

1. A / P – Attributes (methods/function and parameters) that affect decision real estate decision
  - **Income percentile:** This percentile is fixed for the whole life of the household.
  - **Age:** It increases every time step.
  - **Income:** It changes every time step. At each time step an income is assigned from an inverse cumulative distribution of income dependent on age, using the age and the income percentile of the household.
  - **Wealth:** Dynamic, varying according to income and consumption. Consumption is a combination of essential consumption (a fixed minimum amount calibrated from data) and a desired consumption, which is set so that the wealth of the household relaxes towards a target level calibrated from a distribution of wealth given income. That is, households will only have non-essential consumption once they are about to reach their target level and will consistently increase their consumption once they pass this threshold (they'll basically consume half the difference between their current bank balance and their target bank balance), with a cap setting a maximum consumption per month. All parameter values are calibrated from data.
  - Budget
  - Propensity to save

- Preferences
  - Time horizon/discount rate
  - Risk perceptions
  - **Price expectations: These are set by recent trend extrapolation,  $HPA\_expectation = HPA\_recent * a + b$ , where a and b are parameters calibrated from data.**
  - Commuting/Transportation costs
  - Utility function
  - Expected return from renting
  - Model to determine what will be built (developer land buyer)
  - Willingness to Pay
  - **Ask price: Ask price is determined as a mark-up over the exponential average price of houses of the same quality (Eq. 6) , with the mark-up drawn from a distribution of real mark-ups, that is,  $AskPrice = markup * expAvSalePriceForQuality(q)$ , for a house of quality q. Then, each month the property remains unsold, there is a certain probability of reducing its price, applying a normally distributed price decrease calibrated from data.**
  - **Willingness to Accept: Equal to ask price**
  - Bid price
  - **Information sources (i.e. Realtor, listings, neighbours): Households can access information on the average market price for each quality and the trend in house prices (in order to form expectations).**
  - Search strategies
  - Negotiation strategies/negotiation power
  - Household composition
  - Partnership status
  - Location (note this will be read by the landscape initialization algorithms)
  - Production functions (Developers)
  - Cost functions (Developers)
  - Constraints (i.e. buy/sell, proximity to work—these are likely conditions)
2. P -- Decision to participate in the market (become active as a buyer, seller, investor, or renter)
    1. Decision to participate in the market as a seller: **The household simply has a per month probability of deciding to sell its home.**
      1. Decision to relocate?
    2. Decision to participate in the market as a buyer
    3. Decision to participate in the market as a renter: **See previous point.**
  3. P – Participate in the market as a seller
    1. WTA (from above)
    2. Ask/List price (What proposed sales price do you post to the market?)
    3. At what scale are the bids collected?
      - a. Unique unit scale
      - b. Aggregate market scale: Aggregate in single national market.**
    4. Rules for collecting bids: How many bids to you accept?
      - i. One per property up for sale

- ii. Multiple per property
- 5. Who to sell to (how to pick the accepted bid)
  - a. Single bid rule (Only relevant if you have chosen 4 i.)
    - i. Accept
    - ii. Accept if  $\geq$  ask price, else reject
    - iii. Accept if  $\geq$  WTA, else reject
    - iv. Other (short text field)
  - b. Multiple bid rule
    - i. Highest price if  $\geq$  ask price
    - ii. Highest price if  $\geq$  WTA
    - iii. Random selection if multiple highest bids
    - iv. Other: **Increase ask price by rule (A.3) if multiple bids, then select randomly among buyers who can afford still. Multiple bids are accepted per property. If bids are multiple, then a random bid-up is drawn. Finally, a bidder is randomly selected among those who can still pay for the property at the increased price.**
  - c. Custom
- 6. Negotiation strategy
- 7. List price/time on market adjustment rules (price decrease/repackage/upgrade)
  - i. **Adjust price: Price decreases by a certain amount, with a certain probability, if seller unsuccessful to sell. Price decreases drawn from a calibrated normal distribution.**
  - ii. **Take unit off the market: If decreasing the ask price would bring the house below its net value (offered price minus any mortgage principal left) below zero, then the house is taken off the market.**
  - iii. Default on loan
- 8. **Note sellers of own home return to social housing.**

**Mr. Potatohead Real Estate Market Edition – Agent Decision Template – Investor Seller – Carro et al. (2023)**

**Demographic classes (These are agent types. Each agent type could buy, sell, or rent, or rent out. Select your agent type here)**

1. Buyers
  1. Developers – Land buyers
  2. Investors
    - Land
    - Residences: Investors are normal households with a “buy-to-let gene” or marker that provides them with extra rules of behavior to decide on their investments. They buy houses, sell them and rent them out.
  3. Households
2. Sellers
  1. Developers
  2. **Investors**
    - Land
    - **Residences**
  3. Households
  4. Land owners
3. Renters
  1. People who rent residence units (demand)
  2. People who rent out residence units (supply)
4. Central bank (*For future—not in any current models*)
5. Government (*For future—not in any current models*)

**Decision making class (In MR POTATOHEAD, this is “agent decision model”) (filled out for each land-market agent type, 1-5 from above in current models)**

1. A / P – Attributes (methods/function and parameters) that affect decision real estate decision. **Most attributes are the same and work in exactly the same way as normal households, we thus deal here only with the differences.**
  - Budget
  - **Preferences: Investor households have a certain preference for capital gains over rental income. This will affect their investment decisions.**
  - Time horizon/discount rate
  - Risk perceptions
  - Price expectations
  - Commuting/Transportation costs
  - Utility function
  - **Expected return from renting: They don’t have any target rental yield, but they do form expectations regarding the rental yield on a property they’re exploring to buy or sell and they do so by checking current market prices of houses of the same quality, both in the rental and the sales market.**
  - Model to determine what will be built (developer land buyer)

- **Willingness to Pay:** For their investment purposes, they do not have a desired purchase price, as normal households, but rather always try to maximise leverage by, in principle, being willing to explore houses up to their maximum allowed mortgage.
  - **Ask price** Ask price is decided in the same way as normal households selling their homes.
  - **Willingness to Accept:**
  - **Bid price**
  - **Information sources (i.e. Realtor, listings, neighbours):** Apart from the sources of information required by normal households, investors also need information about the rental market, such as average rental prices for houses of a given quality.
  - **Search strategies**
  - **Negotiation strategies/negotiation power**
  - **Household composition**
  - **Partnership status**
  - **Location**
  - **Production functions (Developers)**
  - **Cost functions (Developers)**
  - **Constraints (i.e. buy/sell, proximity to work—these are likely conditions)**
2. P -- Decision to participate in the market (become active as a buyer, seller, investor, or renter)
    1. Decision to participate in the market as a seller  
**First of all, investor households try to always keep at least one investment property. A sale is never attempted when the house is occupied by a tenant. In order to decide whether to sell a given property, investor households compute its expected yield, which is a combination of its expected rental yield and the expected capital gains, with given weights for these terms characterising the investor. In particular, the expected yield is**

$$\text{expectedYield} = (\text{marketPriceForThisQuality} / (\text{marketPriceForThisQuality} - \text{mortgagePrincipal})) * ((1 - \text{capitalGainsCoefficient}) * \text{rentalYield} + \text{capitalGainsCoefficient} * \text{HPA\_expectation}) - \text{annualMortgagePayments} / (\text{marketPriceForThisQuality} - \text{mortgagePrincipal}),$$
**where the rental yield is simply the current average annual rental price for houses of the same quality times the average expected occupancy (current market average of occupancy, computed by looking at average time on the market) and divided by the current market sale price of houses of this quality. Finally, investor households use a sigma function to make the decision.**
      1. Decision to relocate?
    2. Decision to participate in the market as a buyer
    3. Decision to participate in the market as a renter
  3. P – Participate in the market as a buyer
    1. Property budget (includes mortgage decision) – Call from above
    2. Which properties are evaluated (searching strategy)
    3. WTP – call from above
    4. Bid price – call from above

5. Which property(s) to bid on?
  - i. One per buyer
  - ii. Multiple per buyer
6. Negotiation strategy / Negotiation power – call from above
7. Rules if you don't succeed to purchase
  - i. Adjust budget/WTP/bid price
  - ii. Leave market
4. P – Participate in the market as a renter (renting a residence unit)
  1. Determination of budget
  2. Which properties are evaluated (searching strategy, assume price taker at fixed offer price)
  3. WTP (from above)
  4. Which property(s) to apply for?
  5. Rules if you don't succeed to purchase
    - i. Adjust budget/WTP
    - ii. Leave market
2. P – Participate in the market as a leasor (renting unit to someone else)
 

**Investor households always offer their investment properties on the rental market if they are unoccupied. They will never willingly leave the unoccupied. The offer mechanism (initial ask price, further decreases if unsold, etc.) work as in the sale offers, though with different parameter values. Rental contracts have a random duration between a minimum and a maximum.**
5. P – Participate in the market as a seller
  1. WTA (from above)
  2. Ask/List price (What proposed sales price do you post to the market?)
  3. At what scale are the bids collected?
    - a. Unique unit scale
    - b. Aggregate market scale
  4. Rules for collecting bids: How many bids to you accept?
    - i. One per property up for sale
    - ii. Multiple per property
  5. Who to sell to (how to pick the accepted bid)
    - a. Single bid rule (Only relevant if you have chosen 4 i.)
      - i. Accept
      - ii. Accept if  $\geq$  ask price, else reject
      - iii. Accept if  $\geq$  WTA, else reject
      - iv. Other (short text field)
    - b. Multiple bid rule
      - i. Highest price if  $\geq$  ask price
      - ii. Highest price if  $\geq$  WTA
      - iii. Random selection if multiple highest bids
      - iv. Other
    - c. Custom
  6. Negotiation strategy
  7. List price/time on market adjustment rules (price decrease/repackage/upgrade)
    - i. Adjust price

- ii. Take unit off the market
- iii. Default on loan

**Mr. Potatohead Real Estate Market Edition – Agent Decision Template – Household Buyer  
– Carro et al. (2023)**

**Demographic classes (These are agent types. Each agent type could buy, sell, or rent, or rent out. Select your agent type here)**

**1. Buyers**

1. Developers – Land buyers
2. Investors
  - Land
  - Residences

**3. Households**

**2. Sellers**

1. Developers
2. Investors
  - Land
  - Residences

**3. Households**

**4. Land owners**

**3. Renters**

1. People who rent residence units (demand)
2. People who rent out residence units (supply)
4. Central bank (*For future—not in any current models*)
5. Government (*For future—not in any current models*)

**Decision making class (In MR POTATOHEAD, this is “agent decision model”) (filled out for each land-market agent type, 1-5 from above in current models)**

1. A / P – Attributes (methods/function and parameters) that affect decision real estate decision
  - **Income percentile:** This percentile is fixed for the whole life of the household.
  - **Age:** It increases every time step.
  - **Income:** It changes every time step. At each time step an income is assigned from an inverse cumulative distribution of income dependent on age, using the age and the income percentile of the household. Need equations
  - **Wealth:** Dynamic, varying according to income and consumption. Consumption is a combination of essential consumption (a fixed minimum amount calibrated from data) and a desired consumption, which is set so that the wealth of the household relaxes towards a target level calibrated from a distribution of wealth given income. That is, households will only have non-essential consumption once they are about to reach their target level and will consistently increase their consumption once they pass this threshold (they’ll basically consume half the difference between their current bank balance and their target bank balance), with a cap setting a maximum consumption per month. All parameter values are calibrated from data. Need equations.

- **Budget:** Note that the WTP (below) is then capped to the maximum mortgage the Bank is willing to extend to the household (this is a mortgage in principle letter, not an actual mortgages, since the household needs this information before bidding in the market).
  - **Preferences:** Psychological cost of renting
  - **Propensity to save**
  - **Desired consumption (eq. A.1):** “maximum monthly desired consumption  $C_{max}$ , which we define as a fraction of the household’s gross annual income, estimated by focusing on the consumption levels of households in the 99th income percentile.”
  - **Time horizon/discount rate:** Mortgage interest rate (eq. A.2)
  - Risk perceptions
  - **Price expectations:** These are set by recent trend extrapolation,  $HPA\_expectation = HPA\_recent * a + b$ , where  $a$  and  $b$  are parameters calibrated from data. (Equation 3) See housing and rental price indices in appendix 1.6. Households also form price expectations for particular quality segments, see A.6.
  - Commuting/Transportation costs
  - Utility function
  - Expected return from renting
  - Model to determine what will be built (developer land buyer)
  - **Willingness to Pay:** A desired purchase price or willingness to pay is computed as a nonlinear function of the household’s income. In particular:  $WTP = a * income^b * e^{(Gaussian\ noise)}$ . (Equation 1 in main paper)
  - Ask price
  - Willingness to Accept
  - **Bid price:** Equal to desired house price
  - **Information sources (i.e. Realtor, listings, neighbours):** Households have access to the average market price for each quality and the trend in house prices (in order to form expectations).
  - Search strategies
  - Negotiation strategies/negotiation power
  - Household composition
  - Partnership status
  - Location (note this will be read by the landscape initialization algorithms)
  - Production functions (Developers)
  - Cost functions (Developers)
  - Constraints (i.e. buy/sell, proximity to work—these are likely conditions)
2. P -- Decision to participate in the market (become active as a buyer, seller, investor, or renter)
    1. Decision to participate in the market as a seller:
      1. Decision to relocate?
    2. Decision to participate in the market as a buyer
 

**Agents without a home (whether rented or owned) decide whether participate in the rental or the ownership market. This decision is based on a**

comparison of expected annual costs (based, in its turn, on current average prices and current trends). In particular, the cost of buying is  $\text{costOfPurchase} = \text{mortgageMonthlyPayment} * 12 - \text{housePrice} * \text{HPA\_expectation}$ . Note that, at this point, the house price is still the desired house price. The cost of renting is simply  $\text{costOfRent} = 12 * \text{expAvRentPriceForQuality}(\text{max\_q})$ , where  $\text{max\_q}$  is the maximum quality this household could afford to buy given current house sale prices. In order to make a decision, the household will use a sigma function with  $x = \text{costOfRent} * (1 * \text{psychological\_cost}) - \text{costOfPurchase}$ , where  $\text{psychological\_cost}$  is a parameter representing the psychological cost of renting as opposed to buying, given same annual costs otherwise.

3. Decision to participate in the market as a renter:
3. P – Participate in the market as a buyer
  1. Property budget (includes mortgage decision) – Call from above
  2. Which properties are evaluated (searching strategy): **In principle, households could consider any property they can afford. The market mechanism returns the best quality they could buy and, within that quality, the cheapest house.**
  3. WTP – call from above. **Note households might pay cash for houses or get a mortgage.**
  4. Bid price – call from above
  5. Which property(s) to bid on?
 

**Households trying to buy home will bid for the highest quality house that they can afford (with an ask price below or equal to their WTP), choosing the cheapest house if there are several with the same quality.**

    - i. One per buyer
    - ii. Multiple per buyer
  6. Negotiation strategy / Negotiation power – call from above
  7. Rules if you don't succeed to purchase
    - i. Adjust budget/WTP/bid price
    - ii. **Leave market: If bid is not successful, household returns to “social housing”, an intermediary step from which households always try again bidding for a home in another round, whether renting or buying.**

**Mr. Potatohead Real Estate Market Edition – Agent Decision Template – Investor Buyer – Carro et al. (2023)**

**Demographic classes (These are agent types. Each agent type could buy, sell, or rent, or rent out. Select your agent type here)**

1. Buyers
  1. Developers – Land buyers
  2. **Investors**
    - Land
    - **Residences: Investors are normal households with a “buy-to-let gene” or marker that provides them with extra rules of behavior to decide on their investments. They buy houses, sell them and rent them out. Whether or not they are BLT depends on income.**
  3. Households
2. Sellers
  1. Developers
  2. Investors
    - Land
    - Residences
  3. Households
  4. Land owners
3. Renters
  1. People who rent residence units (demand)
  2. People who rent out residence units (supply)
4. Central bank (*For future—not in any current models*)
5. Government (*For future—not in any current models*)

**Decision making class (In MR POTATOHEAD, this is “agent decision model”) (filled out for each land-market agent type, 1-5 from above in current models)**

1. A / P – Attributes (methods/function and parameters) that affect decision real estate decision **Most attributes are the same and work in exactly the same way as normal households, we thus deal here only with the differences.**
  - Budget
  - **Preferences: Investor households have a certain preference for capital gains over rental income. This will affect their investment decisions. “Households receiving the BTL flag are also assigned an investor type: capital ains-driven, rental-income-driven, or mixed” (Carro 2022)**
  - Time horizon/discount rate
  - Risk perceptions
  - Price expectations
  - Commuting/Transportation costs
  - Utility function
  - **Expected return from renting: They don’t have any target rental yield, but they do form expectations regarding the rental yield on a property they’re exploring**

- to buy or sell and they do so by checking current market prices of houses of the same quality, both in the rental and the sales market. (Equation 7)
- Model to determine what will be built (developer land buyer)
  - **Willingness to Pay: For their investment purposes, they do not have a desired purchase price, as normal households, but rather always try to maximise leverage by bidding up to their maximum allowed mortgage.**
  - **Ask price Ask price is decided in the same way as normal households selling their homes.**
  - Willingness to Accept:
  - Bid price
  - **Information sources (i.e. Realtor, listings, neighbours): Apart from the sources of information required by normal households, investors also have access to information about the rental market, such as average rental prices for houses of a given quality.**
  - Search strategies
  - Negotiation strategies/negotiation power
  - Household composition
  - Partnership status
  - Location (note this will be read by the landscape initialization algorithms)
  - Production functions (Developers)
  - Cost functions (Developers)
  - Constraints (i.e. buy/sell, proximity to work—these are likely conditions)
2. P -- Decision to participate in the market (become active as a buyer, seller, investor, or renter)
    1. Decision to participate in the market as a seller
      1. Decision to relocate?
    2. Decision to participate in the market as a buyer
 

**Investors can only invest after they have secured a home. The investor household has a monthly probability of participating in the investment home purchase market (Equation 7)**
    3. Decision to participate in the market as a renter
  3. P – Participate in the market as a buyer
    1. Property budget (includes mortgage decision) – Call from above
    2. Which properties are evaluated (searching strategy)
    3. **WTP – call from above**
    4. Bid price – call from above
    5. Which property(s) to bid on?
 

**Households trying to buy an investment (buy-to-let) house will bid for the highest expected yield house that they can afford (with an ask price below or equal to their WTP), choosing the cheapest house if there are several with the same yield.**

      - i. One per buyer
      - ii. Multiple per buyer
    6. Negotiation strategy / Negotiation power – call from above
    7. Rules if you don't succeed to purchase
      - i. Adjust budget/WTP/bid price

**ii. Leave market: If unsuccessful, investors simply leave the market.**

4. P – Participate in the market as a renter (renting a residence unit): **Investors never rent, they always decide to buy a home, and they can only invest after they have secured a home.**
  1. Determination of budget
  2. Which properties are evaluated (searching strategy, assume price taker at fixed offer price)
  3. WTP (from above)
  4. Which property(s) to apply for?
  5. Rules if you don't succeed to purchase
    - i. Adjust budget/WTP (details)
    - ii. Leave market (details)
2. P – Participate in the market as a leasor (renting unit to someone else)
5. P – Participate in the market as a seller
  1. WTA (from above)
  2. Ask/List price (What proposed sales price do you post to the market?)
  3. At what scale are the bids collected?
    - a. Unique unit scale
    - b. Aggregate market scale
  4. Rules for collecting bids: How many bids to you accept?
    - i. One per property up for sale
    - ii. Multiple per property
  5. Who to sell to (how to pick the accepted bid)
    - a. Single bid rule (Only relevant if you have chosen 4 i.)
      - i. Accept
      - ii. Accept if  $\geq$  ask price, else reject
      - iii. Accept if  $\geq$  WTA, else reject
      - iv. Other (short text field)
    - b. Multiple bid rule
      - i. Highest price if  $\geq$  ask price
      - ii. Highest price if  $\geq$  WTA
      - iii. Random selection if multiple highest bids
      - iv. Other
    - c. Custom
  6. Negotiation strategy
  7. List price/time on market adjustment rules (price decrease/repackage/upgrade)
    - i. Adjust price
    - ii. Take unit off the market
    - iii. Default on loan

**Mr. Potatohead Real Estate Market Edition – Agent Decision Template – Household Renter – Carri et al. (2023)**

**Demographic classes (These are agent types. Each agent type could buy, sell, or rent, or rent out. Select your agent type here)**

1. Buyers
  1. Developers – Land buyers
  2. Investors
    - Land
    - Residences
  3. Households:
2. Sellers
  1. Developers
  2. Investors
    - Land
    - Residences
  3. Households.
  4. Land owners
3. Renters
  1. **People who rent residence units (demand)**
  2. People who rent out residence units (supply)
4. Central bank (*For future—not in any current models*)
5. Government (*For future—not in any current models*)

**Decision making class (In MR POTATOHEAD, this is “agent decision model”) (filled out for each land-market agent type, 1-4 from above in current models)**

1. A / P – Attributes (methods/function and parameters) that affect decision real estate decision
  - **Income percentile: This percentile is fixed for the whole life of the household.**
  - **Age: It increases every time step.**
  - **Income: It changes every time step. At each time step an income is assigned from an inverse cumulative distribution of income dependent on age, using the age and the income percentile of the household.**
  - **Wealth: Dynamic, varying according to income and consumption. Consumption is a combination of essential consumption (a fixed minimum amount calibrated from data) and a desired consumption, which is set so that the wealth of the household relaxes towards a target level calibrated from a distribution of wealth given income. That is, households will only have non-essential consumption once they are about to reach their target level and will consistently increase their consumption once they pass this threshold (they’ll basically consume half the difference between their current bank balance and their target bank balance), with a cap setting a maximum consumption per month. All parameter values are calibrated from data.**
  - Budget

- Preferences
  - Time horizon/discount rate
  - Risk perceptions
  - **Psychological cost of renting**
  - **Propensity to save**
  - **Price expectations: These are set by recent trend extrapolation,  $HPA\_expectation = HPA\_recent * a + b$ , where a and b are parameters calibrated from data.**
  - Commuting/Transportation costs
  - Utility function
  - Expected return from renting
  - Model to determine what will be built (developer land buyer)
  - Willingness to Pay
  - Ask price
  - Willingness to Accept
  - Bid price
  - **Information sources (i.e. Realtor, listings, neighbours): Households can access information on the average market price for each quality and the trend in house prices (in order to form expectations).**
  - Search strategies
  - Negotiation strategies/negotiation power
  - Household composition
  - Partnership status
  - Location (note this will be read by the landscape initialization algorithms)
  - Production functions (Developers)
  - Cost functions (Developers)
  - Constraints (i.e. buy/sell, proximity to work—these are likely conditions)
2. P – Participate in the market as a renter (renting a residence unit)
1. **Decision to participate in the rental market (try to rent a house) Agents without a home (whether rented or owned) decide whether participate in the rental or the ownership market. Note this may be because their rental term is up. This decision is based on a comparison of expected annual costs (based, in its turn, on current average prices and current trends). In particular, the cost of buying is  $costOfPurchase = mortgageMonthlyPayment * 12 - housePrice * HPA\_expectation$ . Note that, at this point, the house price is still the desired house price. The cost of renting is simply  $costOfRent = 12 * expAvRentPriceForQuality(max\_q)$ , where max\_q is the maximum quality this household could afford to buy given current house sale prices. In order to make a decision, the household will use a sigma function with  $x = costOfRent * (1 * psychological\_cost) - costOfPurchase$ , where psychological\_cost is a parameter representing the psychological cost of renting as opposed to buying, given same annual costs otherwise.**
  2. **Determination of budget: Rental budget is the household's monthly net income minus its essential consumption.**

3. Which properties are evaluated (searching strategy, assume price taker at fixed offer price)
4. **WTP: A desired rental price or willingness to pay on rent is computed as a nonlinear function of the household's income. In particular:  $WTP = a * income^b * e^{(\text{Gaussian noise})}$ .**
5. Which property(s) to apply for?
6. Rules if you don't succeed to purchase
  - i. Adjust budget/WTP
  - ii. **Leave market: As for purchase market, if unsuccessful, go back to "social housing" status and try again in the next time step.**
2. **Rules if you rent: Note that renters remain for the term of their rental contract.**

**Mr. Potatohead Real Estate Market Edition – Landscape Class Template – Ge (2017)**

1. What is the form of the base landscape?
  - a. **Abstract** / Empirical Abstract
  - b. Vector or **cell-based** (uniform tessellation) (See Figure 2, The landscape)
  - c. Source of landscape initialization
    - i. **Generic grid, uniform tessellation (*Netlogo default*)**  
**Generic grid, each grid has a ‘quality index’ that is the quality of the neighbourhood.**
    - ii. CSV file? (Y/N) Enter GIS base layer file name here, or provide link (text entry)
    - iii. GIS file? (Y/N) Enter GIS base layer file name here, or provide link (*text entry*)
  - d. Define coarse-scale land uses (*undevelopable land: water, open space; zoning, etc.*)
    - i. *Downtown residential*
    - ii. *Suburban residential*
    - iii. *Far suburban/Rural residential***There is no undeveloped land in the abstract landscape.**
2. What unique products are being bought and sold?
  - a. Number of container types. (3) For each container provide the following information:  
**City center cell:**
    - i. Characteristics of the spatial entity
      1. **Spatial location(s), if not read from GIS or CSV. City centre, represented by a numeric ‘location’ index, which is median for city center cells**
      2. Entire lot area (*parcel polygon*)
      3. Building footprint area (*building footprint polygon*)
      4. Number of Stories
      5. **Transportation accessibility. Numeric, measured by distance to city centre, which is short for city centre cells (short is preferred). Do not consider transport accessibility such as road network or public transport**
      6. **Neighbourhood amenities**
        - a. **Exogenous numeric location quality, initialized parametrically, 0.65.**
        - b. **Numeric endogenous to the model, neighbourhood quality represented by the mean income of residents in the cell (higher is preferred). No direct representation of neighbourhood amenities, see Equation 1.**
      7. **Neighbourhood disamenities (*example, flood risk*)**
    - ii. Number of different unit categories in the container. **1. The units are all the same**

iii. Unit category descriptions: (replicate as needed)

1. Number of units of this type
2. Unit area
3. Number of room/bedrooms
4. Number of baths
5. Yard/lot size
6. Garage
7. Etc.

**Near suburb cell:**

i. Characteristics of the spatial entity

- 1. Spatial location(s), if not read from GIS or CSV. Near suburb cell, represented by a numeric 'location' index, which is high for near suburb cells**
2. Entire lot area (*parcel polygon*)
3. Building footprint area (*building footprint polygon*)
4. Number of Stories
- 5. Transportation accessibility. Numeric, measured by distance to city centre, which is medium long for near suburb cells (short is preferred). Do not consider transport accessibility such as road network or public transport**
- 6. Neighbourhood amenities (*example, sea view index*)**
  - a. Numeric location quality, initialized parametrically, 0.85-1.**
  - b. Numeric endogenous to the model, neighbourhood quality represented by the mean income of residents in the cell (higher is preferred) , see Equation 1. No direct representation of neighbourhood amenities.**
7. Neighbourhood disamenities (*example, flood risk*)

ii. Number of different unit categories in the container. **1. The units are all the same**

iii. Unit category descriptions: (replicate as needed)

8. Number of units of this type
9. Unit area
10. Number of room/bedrooms
11. Number of baths
12. Yard/lot size
13. Garage
14. Etc.

**Far suburb cell (rural):**

i. Characteristics of the spatial entity

- 1. Spatial location(s), if not read from GIS or CSV. Far suburb cell, represented by a numeric 'location' index, which is low for near suburb cells**
2. Entire lot area (*parcel polygon*)

3. Building footprint area (*building footprint polygon*)
4. Number of Stories
5. **Transportation accessibility. Numeric, measured by distance to city centre, which is long for near suburb cells (short is preferred). Do not consider transport accessibility such as road network or public transport**
6. **Neighbourhood amenities (*example, sea view index*)**
  - a. **numeric location quality, initialized parametrically, 0.350-0.56.**
  - b. **Numeric endogenous to the model, neighbourhood quality represented by the mean income of residents in the cell (higher is preferred), see Equation 1. No direct representation of neighbourhood amenities.**
7. Neighbourhood disamenities (*example, flood risk*)
- ii. Number of different unit categories in the container. **1. The units are all the same**
- iii. Unit category descriptions: (replicate as needed)
  8. Number of units of this type
  9. Unit area
  10. Number of room/bedrooms
  11. Number of baths
  12. Yard/lot size
  13. Garage
  14. Etc.

**Mr. Potatohead Real Estate Market Edition – Property Exchange Class Template – Ge (2017)**

1. Which market is being modelled?
  - a. **Residences**
  - b. Land
2. Who are the market participants?
  - a. Buyers
    - i. Developers
    - ii. **Investors**
    - iii. **Households**
  - b. Sellers
    - i. **Developers**
    - ii. **Investors**
    - iii. **Households**
    - iv. Land owners
  - c. Renters
    - i. People who rent units (demand)
    - ii. People who rent out units (supply)
3. Initialize buyer and seller locations (*call to agent's Location field*)
  - a. One agent per spatial container
  - b. **Multiple agents per spatial container**
4. What are your ask and bid price rules for market-based land allocation
  - a. How ask prices posted?
    - i. Public information
    - ii. **Information held by realtor agents**
  - b. Bid submission: How many properties can a buyer bid on? **(1 at any time)**
  - c. Bid acceptance: How many bids are accepted per property? **(1 per property, multiple bids can be accepted in each cell)**
5. Matching algorithm: How are buyers matched to purchased properties?.
  - a. Custom rule
  - b. How units are matched to the seller—subdivision model (many to one) or single property model (one to one). *Call to seller ADM(s)*. **Units are the same in each cell**
  - c. How are buyer bids matched to units? *Call to buyer ADM(s)*. **Units are the same in each cell**
  - d. How are winning bids selected? (*Call to seller ADM*). **All winning bids can transact because there are multiple (uniform) units in each cell, and the price settling mechanism (see d) ensure that the number of successful buyers are matches by the number of successful sellers.**
  - e. How is the transaction price defined?
    - i. Bid price if multiple bids
    - ii. Mean of bid and ask if one bid
    - iii. Negotiation process (*describe, calling ADM negotiation strategies*)
    - iv. Custom (long text field)

**Price is settled by matching supply and demand from bids and asks from sellers and buyers. ‘Equilibrium’ price is found where downward sloped demand curve meets upward sloped supply curve.**

6. What market housekeeping occurs in your model?
  - a. **Change ownership**
  - b. Age homes
  - c. Record sales prices for next round
  - d. **Seller adjustments for un-sold units** (*call to ADM functions*)
  - e. **Rules for buyers who did not find a home** (*call to ADM functions*)  
*buyers quit searching after searching period exceeds maximum time-on-market*
  - f. **Identify active buyers and sellers for next round**
7. What are your stopping rules for market activity?
  - a. No market activity in X time periods (numerical entry for number of time periods) (*equilibrium rule*)
  - b. **End time periods (24 time periods (1 time period = 1 month))** (*non-equilibrium rule*) (*“new round”*)

**Mr. Potatohead Real Estate Market Edition – Agent Decision Template – Developer Seller – Ge (2017)**

(Note the representative developer is assumed to own and be able to develop all land; there is no land market.)

**Demographic classes (These are agent types. Each agent type could buy, sell, or rent, or rent out. Select your agent type here)**

1. Buyers
  1. Developers – Land buyers
  2. Investors
    - Land
    - Residences
  3. Households
2. Sellers
  1. **Developers**
  2. Investors
    - Land
    - Residences
  3. Households
  4. Land owners
3. Renters
  1. People who rent residence units (demand)
  2. People who rent out residence units (supply)
4. Central bank (*For future—not in any current models*)
5. Government (*For future—not in any current models*)

**Decision making class (In MR POTATOHEAD, this is “agent decision model”) (filled out for each land-market agent type, 1-5 from above in current models)**

1. A / P – Attributes (methods/function and parameters) that affect decision real estate decision
  - Budget
  - Preferences
  - Time horizon/discount rate
  - Risk perceptions
  - Price expectations
  - Commuting/Transportation costs
  - Utility function
  - Expected return from renting
  - **Model to determine what will be built (developer): “the representative developer will supply the amount of new houses so that the marginal cost of building the new house equals the price the house is expected to be sold. As a result, the number of houses being built in each period differs in each region. More houses will be built in regions with relatively high housing prices and low construction costs.... we introduce an increasing marginal construction cost to constrain the**

number of houses being built in a region.” (section 3.1.4). See equations 11-17. Marginal cost is set to the residence price 6 months ago (assume a 6 month construction period). See production function below.

- Willingness to Pay
- **Ask price: Equal to WTA**
- **Willingness to Accept: Equal to marginal construction costs, which increases with the number of houses built in a given period. See equation 18.**
- Bid price
- Information sources (i.e. Realtor, listings, neighbours)
- Search strategies
- Negotiation strategies/negotiation power
- Household composition
- Partnership status
- Location
- **Production functions (Developers): Production function satisfies classic economic theory: Marginal cost = Price**
- **Cost functions (Developers): Total cost is quadratic function of number of houses built in a given period and the total number of houses built in the neighbourhood.**

$$TC_t^g(q_t^g) = c_1 h + \frac{c_2}{2} (q_t^g)^2 + \frac{c_3}{2} (Q_{t-1}^g)^2$$

- **Constraints (i.e. buy/sell, proximity to work—these are likely conditions): There is no cap on the number of houses the develop can build in a neighbourhood, however the marginal cost of construction increases as more houses have been built in a neighbourhood**
2. P -- Decision to participate in the market (become active as a buyer, seller, investor, or renter)
    1. Decision to participate in the market as a seller
      1. Decision to relocate?
    2. Decision to participate in the market as a buyer
    3. Decision to participate in the market as a renter
  3. P – Participate in the market as a buyer
    1. Property budget (includes mortgage decision) – Call from above
    2. Which properties are evaluated (searching strategy)
    3. WTP – call from above
    4. Bid price – call from above
    5. Which property(s) to bid on?
      - i. One per buyer
      - ii. Multiple per buyer
    6. Negotiation strategy / Negotiation power – call from above
    7. Rules if you don’t succeed to purchase
      - i. Adjust budget/WTP/bid price (details)
      - ii. Leave market (details)
  4. P – Participate in the market as a renter (renting a residence unit)
    1. Determination of budget

2. Which properties are evaluated (searching strategy, assume price taker at fixed offer price)
3. WTP (from above)
4. Which property(s) to apply for?
5. Rules if you don't succeed to purchase
  - i. Adjust budget/WTP (details)
  - ii. Leave market (details)
2. P – Participate in the market as a leasor (renting unit to someone else)
5. P – Participate in the market as a seller
  1. **WTA (from above)**
  2. **Ask/List price (What proposed sales price do you post to the market?): ask price equal to WTA**
  3. At what scale are the bids collected?
    - a. Unique unit scale
    - b. **Aggregate market scale: single price for each neighbourhood, which is settled by listing all bids and asks, and find the 'equilibrium' price to maximise transaction volume. If there is no bids or asks in period (so no transaction), price is also adjusted to reflect the market condition.**
  4. Rules for collecting bids: How many bids to you accept?
    - i. One per property up for sale
    - ii. Multiple per property
    - iii. **Multiple bids are submitted to a single cell that can contain multiple identical properties for sale.**
  5. Who to sell to (how to pick the accepted bid)
    - a. Single bid rule (Only relevant if you have chosen 4 i.)
      - i. Accept
      - ii. Accept if  $\geq$  ask price, else reject
      - iii. Accept if  $\geq$  WTA, else reject
      - iv. Other (short text field)
    - b. Multiple bid rule
      - i. Highest price if  $\geq$  ask price
      - ii. Highest price if  $\geq$  WTA
      - iii. Random selection if multiple highest bids
      - iv. Other.
    - c. **Custom: Single price for each neighbourhood. Price is settled by listing all bids and asks, and find the 'equilibrium' price to maximize transaction volume WTA and WTP may differ by buyers/sellers, even though all properties are assumed to be identical. If there are no bids or asks in period (so no transaction), price is also adjusted to reflect the market condition. Sellers with asks/WTA  $\leq$  price will sell; and buyers with bids/WTP  $\geq$  price will buy. See section 3.1.5 and Figure 3.**
  6. **Negotiation strategy: No direct negotiation between sellers or buyers, but see Figure 3 and explanation for cases when the last WTP is higher than the last WTA and numbers are equal, then the price is the average of WTP and WTA.**

7. List price/time on market adjustment rules (price decrease/repackage/upgrade)
  - i. **Adjust price (text field for details): Every period a seller fails to sell, they will lowers the price margin by a fixed percentage relative to expected market price**
  - ii. **Take unit off the market (text field for details): if the seller fails to sell for a period that exceeds the maximum set by the model (24 periods or months)**
  - iii. **Default on loan (text field for details): If the market price is lower than the outstanding mortgage of the seller, and the associated costs of default.**

**Mr. Potatohead Real Estate Market Framework – Agent Decision Template – Investor Seller – Ge (2017)**

**Demographic classes (These are agent types. Each agent type could buy, sell, or rent, or rent out. Select your agent type here)**

1. Buyers
  1. Developers – Land buyers
  2. Investors
    - Land
    - Residences
  3. Households
2. Sellers
  1. Developers
  2. Investors
    - Land
    - **Residences**
  3. Households
  4. Land owners
3. Renters
  1. People who rent residence units (demand)
  2. People who rent out residence units (supply)
4. Central bank (*For future—not in any current models*)
5. Government (*For future—not in any current models*)

**Decision making class (In MR POTATOHEAD, this is “agent decision model”) (filled out for each land-market agent type, 1-5 from above in current models)**

1. A / P – Attributes (methods/function and parameters) that affect decision real estate decision
  - Budget
  - **Preferences: Speculator home owners maximize their expected return from defaulting, holding, or lists, using equation 22 as they would if a buyer. Investor sellers differ in their expectation formation for future price appreciation. They apply a different discount (or trend dampening) rate to the past price appreciation/depreciation.**
  - **Time horizon/discount rate: See investor buyer and equation 22.**
  - **Risk perceptions: See investor buyer and equation 22.**
  - **Price expectations: See investor buyer and equation 22.**
  - Commuting/Transportation costs
  - Utility function
  - **Expected return from renting: See investor buyer and equation 22. Exogenous, assumed to be a fixed rate to housing price, which is taken into account in the calculation of expected investment return.**
  - Model to determine what will be built (developer land buyer)
  - Willingness to Pay

- **Ask price:** See Section 3.1.9, no equation number. Equal to expected price for the next period
  - **Willingness to Accept:** Equal to ask price
  - Bid price
  - **Information sources (i.e. Realtor, listings, neighbours):** Full information of past price. Sellers have no information regarding buyers.
  - Search strategies
  - **Negotiation strategies/negotiation power:** Bargaining power depending on the number of buyers vs sellers. Sellers have more bargaining power in a seller's market, which is implemented by the real estate agent (not directly between seller and buyer).
  - Household composition
  - Partnership status
  - **Location:** Within one of the regional cells
  - Production functions (Developers)
  - Cost functions (Developers)
  - Constraints (i.e. buy/sell, proximity to work—these are likely conditions) **If the market price is lower than the outstanding mortgage of the seller, and the associated costs of default, an investor seller will default on the property.**
2. P -- Decision to participate in the market (become active as a buyer, seller, investor, or renter)
    1. **Decision to participate in the market as a seller. The seller will decide to sell if the expected return from holding the property, taking into account price appreciation, rental income and property tax, is less than the best return they can get elsewhere (exogenous). The property owner can also opt for default on the property if the outstanding debt plus any associated costs of default exceeds the market value of the property.**
      1. Decision to relocate?
      2. Decision to participate in the market as a buyer
      3. Decision to participate in the market as a renter
  3. P – Participate in the market as a buyer
    1. Property budget (includes mortgage decision) – Call from above
    2. Which properties are evaluated (searching strategy):
    3. WTP – call from above
    4. Bid price – call from above
    5. Which property(s) to bid on?
      - i. One per buyer
      - ii. Multiple per buyer
    6. Negotiation strategy / Negotiation power – call from above
    7. Rules if you don't succeed to purchase
      - i. Adjust budget/WTP/bid price (details)
      - ii. Leave market (details)
  4. P – Participate in the market as a renter (renting a residence unit)
    1. Determination of budget
    2. Which properties are evaluated (searching strategy, assume price taker at fixed offer price)

3. WTP (from above)
4. Which property(s) to apply for?
5. Rules if you don't succeed to purchase
  - i. Adjust budget/WTP (details)
  - ii. Leave market (details)
2. P – Participate in the market as a leasor (renting unit to someone else)
5. P – Participate in the market as a seller
  1. **WTA (from above)**
  2. **Ask/List price (What proposed sales price do you post to the market?): ask price equal to WTA**
  3. At what scale are the bids collected?
    - a. Unique unit scale
    - b. **Aggregate market scale: single price for each neighbourhood, which is settled by listing all bids and asks, and find the 'equilibrium' price to maximize transaction volume. If there is no bids or asks in period (so no transaction), price is also adjusted to reflect the market condition.**
  4. Rules for collecting bids: How many bids to you accept?
    - i. One per property up for sale
    - ii. **Multiple per property**
  5. Who to sell to (how to pick the accepted bid)
    - a. Single bid rule (Only relevant if you have chosen 4 i.)
      - i. Accept
      - ii. Accept if  $\geq$  ask price, else reject
      - iii. Accept if  $\geq$  WTA, else reject
      - iv. Other (short text field)
    - b. Multiple bid rule
      - i. Highest price if  $\geq$  ask price
      - ii. Highest price if  $\geq$  WTA
      - iii. Random selection if multiple highest bids
      - iv. Other
    - c. **Custom: Single price for each neighbourhood. Price is settled by listing all bids and asks, and find the 'equilibrium' price to maximise transaction volume. If there is no bids or asks in period (so no transaction), price is also adjusted to reflect the market condition. Sellers with asks/WTA  $\leq$  price will sell; and buyers with bids/WTP  $\geq$  price will buy.**
6. Negotiation strategy No direct negotiation between sellers or buyers, but as sellers stay on the market for longer, they will reduce price.
7. List price/time on market adjustment rules (price decrease/repackage/upgrade)
  - i. **Adjust price (text field for details): Every period a seller fails to sell, they will lowers the price margin by a fixed percentage relative to expected market price**
  - ii. **Take unit off the market (text field for details): if the seller fails to sell for a period that exceeds the maximum set by the model (24 periods or months)**

**Mr. Potatohead Real Estate Market Edition – Agent Decision Template – Non-investor Seller – Ge (2017)**

**Demographic classes (These are agent types. Each agent type could buy, sell, or rent, or rent out. Select your agent type here)**

1. Buyers
  1. Developers – Land buyers
  2. Investors
    - Land
    - Residences
  3. Households
2. **Sellers**
  1. Developers
  2. Investors
    - Land
    - Residences
  3. **Households**
  4. Land owners
3. Renters
  1. People who rent residence units (demand)
  2. People who rent out residence units (supply)
4. Central bank (*For future—not in any current models*)
5. Government (*For future—not in any current models*)

**Decision making class (In MR POTATOHEAD, this is “agent decision model”) (filled out for each land-market agent type, 1-5 from above in current models)**

1. A / P – Attributes (methods/function and parameters) that affect decision real estate decision
  - Budget
  - **Preferences: Non-investor sellers differ in their time-on-market.**
  - **Time horizon/discount rate: Not in terms of discounting future payoffs.**
  - Risk perceptions
  - **Price expectations: Price expectation equals price in the last period.**
  - Commuting/Transportation costs
  - Default decision (See section 3.1.8 and Figure 5)
  - Utility function
  - Expected return from renting
  - Model to determine what will be built (developer land buyer)
  - Willingness to Pay
  - **Ask price: Equal to willingness to accept**
  - **Willingness to Accept: Equal to last period price plus adjustment for time-on-market (TOM) (the longer the TOM, the lower the WTA, which is lowered by a fixed rate) – ask =  $(1+g - d \cdot \text{TOM}_{ht})pg \cdot t - 1$ . See section 3.1.8.**
  - Bid price

- **Information sources** (i.e. Realtor, listings, neighbours) **Full information of past price. Sellers have no information regarding buyers' bids.**
  - Search strategies
  - **Negotiation strategies/negotiation power: Bargaining power depending on the number of buyers vs sellers. Sellers have more bargaining power in a seller's market, which is implemented by the real estate agent (not directly between seller and buyer).**
  - Household composition
  - Partnership status
  - **Location. See Landscape class. Seller households have a regional cell location only (See section 31.8).**
  - Production functions (Developers)
  - Cost functions (Developers)
  - **Constraints** (i.e. buy/sell, proximity to work—these are likely conditions) **If the market price is lower than the outstanding mortgage of the seller, and the associated costs of default, an investor seller will default on the property.**
2. P -- Decision to participate in the market (become active as a buyer, seller, investor, or renter)
    1. Decision to participate in the market as a seller. **In each time period each previously successful home buyer will decide to default on their property, list, or hold. Non-investor home owners can default if the outstanding debts exceeds the market value of the house plus costs associated with default, which is heterogeneous across sellers. If they default the house goes to the bank. They list only in the case of an exogenous move event (see below). Otherwise they hold the property.**
      1. **Decision to relocate? Non-investor sellers decide to sell for exogenous reasons (e.g. job move).. “Moreover, there is a small probability that any homeowner will need to sell the house for exogenous reasons such as job move. If that happens, homeowner he will list the property” See table 1 for parameters.**
    2. Decision to participate in the market as a buyer
    3. Decision to participate in the market as a renter
  3. P – Participate in the market as a buyer
    1. Property budget (includes mortgage decision) – Call from above
    2. Which properties are evaluated (searching strategy):
    3. WTP – call from above
    4. Bid price – call from above
    5. Which property(s) to bid on?
      - i. One per buyer
      - ii. Multiple per buyer
    6. Negotiation strategy / Negotiation power – call from above
    7. Rules if you don't succeed to purchase
      - i. Adjust budget/WTP/bid price (details)
      - ii. Leave market (details)
  4. P – Participate in the market as a renter (renting a residence unit)
    1. Determination of budget

2. Which properties are evaluated (searching strategy, assume price taker at fixed offer price)
3. WTP (from above)
4. Which property(s) to apply for?
5. Rules if you don't succeed to purchase
  - i. Adjust budget/WTP (details)
  - ii. Leave market (details)
2. P – Participate in the market as a leasor (renting unit to someone else)
5. P – Participate in the market as a seller
  1. **WTA (from above)**
  2. **Ask/List price (What proposed sales price do you post to the market?): ask price equal to WTA**
  3. At what scale are the bids collected
    - a. Unique unit scale
    - b. **Aggregate market scale: Single price for each neighbourhood, which is settled by listing all bids and asks, and find the 'equilibrium' price to maximise transaction volume. If there is no bids or asks in period (so no transaction), price is also adjusted to reflect the market condition. Note the individual homeowner does not collect bids.**
  4. Rules for collecting bids: How many bids to you accept?
    - i. One per property up for sale
    - ii. **Multiple per property: See Figure 3.**
  5. Who to sell to (how to pick the accepted bid)
    - a. Single bid rule (Only relevant if you have chosen 4 i.)
      - i. Accept
      - ii. Accept if  $\geq$  ask price, else reject
      - iii. Accept if  $\geq$  WTA, else reject
      - iv. Other (short text field)
    - b. Multiple bid rule
      - i. Highest price if  $\geq$  ask price
      - ii. Highest price if  $\geq$  WTA
      - iii. Random selection if multiple highest bids
      - iv. Other (short text field).
    - c. **Custom: Single price for each neighbourhood. Price is settled by listing all bids and asks, and find the 'equilibrium' price to maximize transaction volume. If there is no bids or asks in period (so no transaction), price is also adjusted to reflect the market condition. Sellers with asks/WTA  $\leq$  price will sell; and buyers with bids/WTP  $\geq$  price will buy. See Section 3.1.5 and Figure 3.**
  6. **Negotiation strategy No direct negotiation between sellers or buyers, but as sellers stay on the market for longer, they will reduce price.**
  7. List price/time on market adjustment rules (price decrease/repackage/upgrade)
    - i. **Adjust price (text field for details): Every period a seller fails to sell, they will lower the price margin by a fixed percentage relative to expected market price**

- ii. **Take unit off the market (text field for details): if the seller fails to sell for a period that exceeds the maximum set by the model (24 periods or months)**

**Mr. Potatohead Real Estate Market Edition – Agent Decision Template – Investor Buyer – Ge (2017)**

**Demographic classes (These are agent types. Each agent type could buy, sell, or rent, or rent out. Select your agent type here)**

1. Buyers
  1. Developers – Land buyers
  2. Investors (0-thousands, set by “speculation index”) See 3.1.7 in Ge (2017)
    - Land
    - Residences
  3. Households
2. Sellers
  1. Developers
  2. Investors
    - Land
    - Residences
  3. Households
  4. Land owners
3. Renters
  1. People who rent residence units (demand)
  2. People who rent out residence units (supply)
4. Central bank (*For future—not in any current models*)
5. Government (*For future—not in any current models*)

**Decision making class (In MR POTATOHEAD, this is “agent decision model”) (filled out for each land-market agent type, 1-4 from above in current models)**

1. A / P – Attributes (methods/function and parameters) that affect decision real estate decision
  - **Budget:** There are two constraints in their budget: down payment and monthly payment. Savings are initialised to be positively correlated with monthly income with a random factor. Monthly income follows a log normal distribution. Household’s savings should be more than the down payment required by the regulator. Their monthly payment as a percentage of income should be below the upper limit set by the regulator, too.
  - **Preferences:** “a speculative buyer is looking for the highest expected annual return he/she can find, which is determined by the expected price inflation in the region and the mortgage rate.” (section 3.1.7, see equation 22). The speculator compares all buying options to the risk-free rate of return.
  - **Time horizon/discount rate:** “where  $y_b$  is the discount rate that speculative buyer  $b$  assigns to price appreciation, which is heterogeneous across buyers and  $y_b \in (0, 1)$ .” See Table 1. Mortgage rate is endogenously determined at the market scale by perceived default risks, which equals discount rate. See Equation 10. Time horizon is 20 years, the length of the mortgage duration.
  - **Risk perceptions:** Risk averse in that investors apply a discount rate to past price appreciation, which serves as a ‘cautionary principle’.

- **Price expectations:** “We assume a speculator’s expectation regarding future price appreciation to be a fraction of the past price appreciation. In other words, we assume that speculators are backward looking and adopt an adaptive expectation for future housing price.” (Section 3.1.7). Price expectation depends on past price appreciation in the neighbourhood, which is heterogeneous across neighbourhoods. A discount rate is applied to past price appreciation to dampen the circle, or to account for the ‘cautionary principle’. Investor buyers differ in their expectation formation for future price appreciation. They apply a different discount (or trend dampening) rate to the past price appreciation/depreciation. Specifically the expected returns from a given property are given in Equation 22, where return depend on the speculator’s expectation of annual price appreciation in that region, the mortgage carrying costs, and expected net rental income (assumed to be a fixed percent of the property’s value).
- Commuting/Transportation costs
- Utility function
- **Expected return from renting:** Assumed to be a fixed percentage of housing price, which is taken into account in the calculation of expected investment return.
- Model to determine what will be built (developer land buyer)
- **Willingness to Pay:** See Equation 24. Equal to the expected price for the next period.
- Ask price
- Willingness to Accept
- **Bid price:** Equal to willingness to pay
- **Information sources (i.e. Realtor, listings, neighbours):** Assumed to have perfect information about prices
- **Search strategies:** Speculative/investor buyers are assumed to have perfect information to be able to identify neighbourhoods prices and appreciation rates.
- **Negotiation strategies/negotiation power Bargaining power** depending on the number of buyers vs sellers. Buyers have more bargaining power in a buyer’s market, which is implemented by the real estate agent.
- Household composition
- Partnership status
- Location (note this will be read by the landscape initialization algorithms)
- Production functions (Developers)
- Cost functions (Developers)
- Constraints (i.e. buy/sell, proximity to work—these are likely conditions)
- 2. P -- Decision to participate in the market (become active as a buyer, seller, investor, or renter)
  1. Decision to participate in the market as a seller
    1. Decision to relocate?
  2. **Decision to participate in the market as a buyer: if the highest expected return from the housing market exceeds that from the outside (assumed to be fixed)**
  3. Decision to participate in the market as a renter

3. P – Participate in the market as a buyer

1. **Property budget (includes mortgage decision) – Call from above**

**Which properties are evaluated (searching strategy): “During month t, speculative buyer b searches each region in the feasible choice set, and chooses  $g^*$ , the region that gives him/her the highest expected return” (section 3.17.)**

1. **WTP – call from above**

2. **Bid price – call from above**

3. **Which property(s) to bid on?**

i. **One per buyer**

ii. **Multiple per buyer**

4. **Negotiation strategy / Negotiation power – call from above**

5. **Rules if you don’t succeed to purchase**

i. **Adjust budget/WTP/bid price (details)**

ii. **Leave market (details): investor buyers are always there to look for profitable opportunities. If there is none in this period or their bids are not accepted, they will wait for the next period.**

4. P – Participate in the market as a renter (renting a residence unit)

1. **Determination of budget**

2. **Which properties are evaluated (searching strategy, assume price taker at fixed offer price)**

3. **WTP (from above)**

4. **Which property(s) to apply for?**

5. **Rules if you don’t succeed to purchase**

i. **Adjust budget/WTP (details)**

ii. **Leave market (details)**

2. P – Participate in the market as a leasor (renting unit to someone else)

5. P – Participate in the market as a seller

1. **WTA (from above)**

2. **Ask/List price (What proposed sales price do you post to the market?)**

3. **At what scale are the bids collected?**

a. **Unique unit scale**

b. **Aggregate market scale**

4. **Rules for collecting bids: How many bids to you accept?**

i. **One per property up for sale**

ii. **Multiple per property**

5. **Who to sell to (how to pick the accepted bid)**

a. **Single bid rule (Only relevant if you have chosen 4 i.)**

i. **Accept**

ii. **Accept if  $\geq$  ask price, else reject**

iii. **Accept if  $\geq$  WTA, else reject**

iv. **Other (short text field)**

b. **Multiple bid rule**

i. **Highest price if  $\geq$  ask price**

ii. **Highest price if  $\geq$  WTA**

iii. **Random selection if multiple highest bids**

- iv. Other
  - c. Custom
- 6. Negotiation strategy
- 7. List price/time on market adjustment rules (price decrease/repackage/upgrade)
  - i. Adjust price
  - ii. Take unit off the market
  - iii. Default on loan

**Mr. Potatohead Real Estate Market Edition – Agent decision template – Non-investor Buyer – Ge (2017)**

**Demographic classes (These are agent types. Each agent type could buy, sell, or rent, or rent out. Select your agent type here)**

1. Buyers
  1. Developers – Land buyers
  2. Investors
    - Land
    - Residences
  3. **Households**
2. Sellers
  1. Developers
  2. Investors
    - Land
    - Residences
  3. Households
  4. Land owners
3. Renters
  1. People who rent residence units (demand)
  2. People who rent out residence units (supply)
4. Central bank (*For future—not in any current models*)
5. Government (*For future—not in any current models*)

**Decision making class (In MR POTATOHEAD, this is “agent decision model”) (filled out for each land-market agent type, 1-5 from above in current models)**

1. A / P – Attributes (methods/function and parameters) that affect decision real estate decision
  - **Budget:** There are two constraints in budget: down payment and monthly payment. Savings are initialised to be positively correlated with monthly income with a random factor. Monthly income follows a log normal distribution. Household’s savings should be more than the down payment required by the regulator. Their monthly payment as a percentage of income should be below the upper limit set by the regulator, too.
  - **Preferences:** Non-investor buyers differ in their preferences (weights) for neighbourhood quality, location and price/affordability. There is no equation number for the utility function but see section 3.1.6. Non-investor buyers gain utility from neighbourhood location (fixed), quality (endogenous), and non-housing consumption.
  - **Time horizon/discount rate:** Mortgage rate is endogenous determined by perceived default risks, which equals discount rate. Time horizon is 20 years, the length of the mortgage duration. This is described in Section 3.1.2. However, the implication is that the buyer faces a fixed mortgage rate: “Agent i\_s mortgage rate equals bank’s mortgage rate at the time the mortgage is issued

and it does not change throughout the mortgage maturity (we assume fixed-rate mortgage)”

- Risk perceptions
  - **Price expectations:** Price expectation equals price in the last period plus expected appreciation/depreciation.
  - **Commuting/Transportation costs:** Embedded in location index.
  - **Utility function:** Cobb-Douglas utility function of neighbourhood quality, location and price/affordability, with heterogeneous weights on each element for different buyers. No equation but see section 3.1.6.
  - Expected return from renting
  - Model to determine what will be built (developer land buyer)
  - **Maximum time-on-market:** See 3.1.6.
  - **Willingness to Pay:** Equal to past price adjusted for expected price appreciation/depreciation, and adjusted for the number of rounds a bidder has not had a bid accepted. See equation 21. Note that buyers originally bid below last period’s price but then increase their bids in each time period.
  - Ask price
  - Willingness to Accept
  - **Bid price:** Equal to willingness to pay
  - **Information sources** (i.e. Realtor, listings, neighbours): **Imperfect information about neighbourhoods-Assumed to only have full knowledge of a subset of cells**
  - **Search strategies** Search a random subset of all neighborhoods (due to imperfect information) See section 3.1.6, the buyer selects a house in a region only, then market clearing happens
  - **Negotiation strategies/negotiation power:** Bargaining power depending on the number of buyers vs sellers, more bargaining power in a buyer’s market (price adjusted down by a central real estate agent)
  - Household composition
  - Partnership status
  - Location (note this will be read by the landscape initialization algorithms)
  - Production functions (Developers)
  - Cost functions (Developers)
  - Constraints (i.e. buy/sell, proximity to work—these are likely conditions)
2. P -- Decision to participate in the market (become active as a buyer, seller, investor, or renter)
    1. Decision to participate in the market as a seller
      1. Decision to relocate?
    2. **Decision to participate in the market as a buyer: exogenous, non-investor buyer always look to buy in a market 3.1.6, a few thousand buyers are activated to search for properties.**
    3. Decision to participate in the market as a renter
  3. P – Participate in the market as a buyer
    1. **Property budget (includes mortgage decision) – Call from above**
    2. **Which properties are evaluated (searching strategy) - selected subset of cells.**
    3. **WTP – call from above**

4. **Bid price – call from above**
  5. **Which property(s) to bid on?**
    - i. **One per buyer – however the buyers bid on a generic house in a particular cell.**
    - ii. Multiple per buyer
  6. **Negotiation strategy / Negotiation power – call from above to Real Estate market-clearing agent**
  7. **Rules if you don't succeed to purchase**
    - i. Adjust budget/WTP/bid price (details)
    - ii. **Leave market (details): non-investor buyers adjust their bidding price up every period their bid price is not accepted. The longer their time-on-market is, the higher their bid and the higher the chance their bid will be accepted. If they reach a maximum search period/ maximum time on market (set to be two year or 24 months in the model) without buying a house, they exit the market.**
4. P – Participate in the market as a renter (renting a residence unit)
    1. Determination of budget
    2. Which properties are evaluated (searching strategy, assume price taker at fixed offer price)
    3. WTP (from above)
    4. Which property(s) to apply for?
    5. Rules if you don't succeed to purchase
      - i. Adjust budget/WTP (details)
      - ii. Leave market (details)
  2. P – Participate in the market as a leasor (renting unit to someone else)
  5. P – Participate in the market as a seller
    1. WTA (from above)
    2. Ask/List price (What proposed sales price do you post to the market?)
    3. At what scale are the bids collected
      - a. Unique unit scale
      - b. Aggregate market scale
    4. Rules for collecting bids: How many bids to you accept?
      - i. One per property up for sale
      - ii. Multiple per property
    5. Who to sell to (how to pick the accepted bid)
      - a. Single bid rule (Only relevant if you have chosen 4 i.)
        - i. Accept
        - ii. Accept if  $\geq$  ask price, else reject
        - iii. Accept if  $\geq$  WTA, else reject
        - iv. Other (short text field)
      - b. Multiple bid rule
        - i. Highest price if  $\geq$  ask price
        - ii. Highest price if  $\geq$  WTA
        - iii. Random selection if multiple highest bids
        - iv. Other

c. Custom

6. Negotiation strategy
7. List price/time on market adjustment rules (price decrease/repackage/upgrade)
  - i. Adjust price (text field for details)
  - ii. Take unit off the market (text field for details)
  - iii. Default on loan (text field for details)

**Mr. Potatohead Real Estate Market Edition – Landscape Class Template – Valaei Sharif et al. (Working paper)**

1. What is the form of the base landscape (Questions from original MP)?
  - a) Abstract / **Empirical**
  - b) **Vector** or cell-based (uniform tessellation)
  - c) Source of landscape initialization
    - i. Generic grid, uniform tessellation (*Netlogo default*)
    - ii. CSV file? (Y/N) Enter GIS base layer file name here, or provide link (**Data on the sampled population of buyers and number of sellers in each simulation time step.**)
    - iii. **GIS file?** (Y/N) Enter GIS base layer file name here, or provide link (**Property parcel layer in Kitchener-Waterloo, Canada**)
  - d) Define coarse-scale land uses (*Residential*)
2. What unique products are being bought and sold?
  - a) Number of container types. (**One**) For each container provide the following information:
    - i. **Characteristics of the spatial entity** (pick list, multiple)
      1. **Spatial location(s)**, read from GIS
      2. **Entire lot area** (*parcel polygon*)
      3. **Building footprint area** (*building footprint polygon*)
      4. Number of Stories
      5. **Transportation accessibility** – distance to nearest bus stop, cumulative employment access, see Babin (2016) section 3.2.
      6. **Neighbourhood amenities** (*example, sea view index*): open space access and adjacency. Calculated using spatial separation, cumulative opportunities, and gravity-based access models, see Babin (2016) section 3.2.
      7. **Neighbourhood disamenities: regional road adjacency**
      8. **In Central-Transit Corridor**

$$InCTC = \begin{cases} 1: & \text{located in CTC boundry} \\ 0: & \text{outside of CTC} \end{cases}$$
      9. **Rate of appreciation.** See Babin (2016) section 3.2.3.1.
 
$$RoA_{it} = \frac{LAV_{it} - LAV_{it-1}}{LAV_{it-1}} \times 100$$

Where  $RoA_{it}$  is the rate of change in lagged average values between period  $t-1$  to period  $t$  in neighbourhood  $i$ , and  $LAV_{it}$  is the lagged average value in neighbourhood  $i$  at time period  $t$ .
      10. **Education rate**

$$EduRate = \frac{\text{Population with postsecondary}}{\text{Population}} \times 100$$
      11. **Population density**

$$PopDen = \frac{\text{Population}}{\text{Area}}$$
    - ii. Number of different unit categories in the container. **1**
    - iii. Unit category descriptions: (replicate as needed)

1. Number of units of this type **Each is unique**
2. **Property type (single-family)**
3. **Unit area**
4. **Yard/lot size**
5. **Age**

**Mr. Potatohead Real Estate Market Edition – Property Exchange Class Template – Valaei Sharif et al. (Working paper)**

1. Which market is being modelled?
  - a) **Residences**
  - b) Land
2. Who are the market participants?
  - a) **Buyers**
    - i. Developers
    - ii. Investors
    - iii. **Households**
  - b) **Sellers**
    - i. Developers
    - ii. Investors
    - iii. **Households**
    - iv. Land owners
  - c) **Renters**
    - i. People who rent units (demand)
    - ii. People who rent out units (supply)
3. Initialize buyer and seller locations
  - a) **One agent per spatial container**
    - Each seller has its location based on the parcel location.
    - Each external buyer does not have a specific location since new buyers are generated at each time step. Each local buyer has its own location based on the parcel location, and if succeeded to buy, the buyer will list the old property on the market for sale.
  - b) Multiple agents per spatial container
4. **What are your ask and bid price rules for market-based land allocation?**
  - a) How ask prices posted?
    - i. **Public information**
    - ii. Information held by realtor agents
  - b) **Bid submission: How many properties can a buyer bid on?**
    - Each buyer can bid on one property
  - c) **Bid acceptance: How many bids are accepted per property?**
    - Infinite
5. **Matching algorithm: How are buyers matched to purchased properties?**
  - a) Custom rules. **The buyer whose bid offer is accepted is matched to the property.**
  - b) **How units are matched to the seller—subdivision model (many to one) or single property model (one to one). *Call to seller ADM(s).***
  - c) How are buyer bids matched to units? *Call to buyer ADM(s).*
  - d) **How are winning bids selected? (*Call to seller ADM*). The bid with the highest bid price is accepted only if the bid price is greater than the asking price (WTA).**
  - e) **How is the transaction price defined?**

- i. **Bid price if multiple bids (or if one bid). If there is a tie (multiple bids at the same price that are above WTA), the bid that was submitted earlier would be accepted.**
  - ii. Mean of bid and ask if one bid
  - iii. Negotiation process
  - iv. Custom
- 6. What market housekeeping occurs in your model?
  - a) **Change ownership**
  - b) Age homes
  - c) Record sales prices for next round
  - d) Seller adjustments for un-sold units (*call to ADM functions*)
  - e) **Rules for buyers who did not find a home (*call to ADM functions*)**
    - o **Buyers who cannot successfully buy a home will be removed from the market, and every step has new random local and external buyers.**
  - f) **Identify active buyers and sellers for next round (*call to ADM functions*)**
    - i. **Sellers who haven't sold their property will remain on the market for the next step.**
    - ii. **Local potential buyers who succeed in purchasing a property will list their older property on the market and act as a seller in the next steps, until their older property is sold.**
    - iii. **Every step, new random potential local and external buyers are selected to engage in bidding.**
- 7. What are your stopping rules for market activity?
  - a) No market activity in X time periods (numerical entry for number of time periods) (*equilibrium rule*)
  - b) End time periods (numerical entry for number of time periods) (*non-equilibrium rule*) (*"new round"*).
  - c) **Process stops when End time periods (30 steps).**

**Mr. Potatohead Real Estate Market Edition – Agent Decision Template – Household Seller  
– Valaei Sharif et al. (Working paper)**

**Demographic classes (These are agent types. Each agent type could buy, sell, or rent, or rent out. Select your agent type here)**

1. Buyers
  1. Developers – Land buyers
  2. Investors
    - Land
    - Residences
  3. Households
2. Sellers
  1. Developers
  2. Investors
    - Land
    - Residences
  3. Households
  4. Land owners
3. Renters
  1. People who rent residence units (demand)
  2. People who rent out residence units (supply)
4. Central bank (*For future—not in any current models*)
5. Government (*For future—not in any current models*)

**Decision making class (In MR POTATOHEAD, this is “agent decision model”) (filled out for each land-market agent type, 1-4 from above in current models)**

1. A / P – Attributes (methods/function and parameters) that affect decision real estate decision
  - a) Budget: *NA*
  - b) Preferences: *NA*
  - c) Time horizon/discount rate: *NA*
  - d) Risk perceptions: *NA*
  - e) Price expectations: *NA*
  - f) Commuting/Transportation costs: *NA*
  - g) Utility function: *NA*
  - h) Expected return from renting: *NA*
  - i) Model to determine what will be built (developer land buyer): *NA*
  - j) Willingness to Pay: *NA*
  - k) Ask price: ask price is equal to WTA.
  - l) Willingness to Accept:
    - WTA is determined based on a hedonic function developed by Babin (2016) using the assessed value data of 93,371 properties in Kitchener-Waterloo in 2015, where the dependent variable is the property assessment value, and the independent variables are structural attributes (living area, yard size, building age), neighbourhood attributes (education rate, population

**density) and environmental attributes (open space access, transit access, walkability).**

- m) Bid price: NA
  - n) Information sources (i.e. Realtor, listings, neighbours): NA
  - o) Search strategies: NA
  - p) Negotiation strategies/negotiation power: NA
  - q) Household composition: NA
  - r) Partnership status: NA
  - s) **Location (note this will be read by the landscape initialization algorithms**
    - **This is based on the real-world residential parcels in the case study area, the western part of the Kitchener-Waterloo area in Canada.**
    - **Each seller has a parcel with a specific location.**
  - t) Production functions (Developers): NA
  - u) Cost functions (Developers): NA
  - v) Constraints (i.e. buy/sell, proximity to work—these are likely conditions): NA
2. P -- Decision to participate in the market (become active as a buyer, seller, investor, or renter)
- a) **Decision to participate in the market as a seller**
    - 1. Decision to relocate.
      - **For the initial step, a total number of 6,278 households were allocated to the same number of land parcels with single-family dwellings. The population of sellers are randomly selected from the local residents. The number of sellers is estimated based on the data on the number of emigrants who moved out of the region to other areas in Canada (Statistics Canada, 2023b).**
  - b) Decision to participate in the market as a buyer
  - c) Decision to participate in the market as a renter
3. P – Participate in the market as a buyer
- a) Property budget (includes mortgage decision) – Call from above
  - b) Which properties are evaluated (searching strategy)
  - c) WTP – call from above
  - d) Bid price – call from above
  - e) Which property(s) to bid on?
    - i. One per buyer
    - ii. Multiple per buyer
  - f) Negotiation strategy / Negotiation power – call from above
  - g) Rules if you don't succeed to purchase
    - i. Adjust budget/WTP/bid price (details)
    - ii. Leave market (details)
4. P – Participate in the market as a renter (renting a residence unit)
- a) Determination of budget
  - b) Which properties are evaluated (searching strategy, assume price taker at fixed offer price)
  - c) WTP (from above)
  - d) Which property(s) to apply for?
  - e) Rules if you don't succeed to purchase

- i. Adjust budget/WTP
  - ii. Leave market
- 2. P – Participate in the market as a leasor (renting unit to someone else)
- 5. **P – Participate in the market as a seller**
  - a) **WTA (from above)**
  - b) **Ask/List price (What proposed sales price do you post to the market?): from above**
  - c) At what scale are the bids collected?
    - i. **Unique unit scale**
    - ii. Aggregate market scale
  - d) Rules for collecting bids: How many bids do you accept?
    - i. One per property up for sale
    - ii. **Multiple per property (Infinite bids can be collected)**
  - e) **Who to sell to (how to pick the accepted bid)**
    - i. Single bid rule (Only relevant if you have chosen 4 i.)
      - i. Accept
      - ii. Accept if  $\geq$  ask price, else reject
      - iii. Accept if  $\geq$  WTA, else reject
      - iv. Other (short text field)
    - ii. Multiple bid rule
      - i. **Highest price if  $\geq$  ask price**
      - ii. **Highest price if  $\geq$  WTA**
        - **Note that ask price is equal to WTA, and each seller chooses the highest bid, which is equal to or higher than the ask price (or WTA). If there is a tie (multiple bids at the same price that are above WTA), the bid that was submitted earlier would be accepted.**
      - iii. Random selection if multiple highest bids
      - iv. Other
    - iii. Custom
  - f) Negotiation strategy: NA
  - g) List price/time on market adjustment rules (price decrease/repackage/upgrade)
    - i. Adjust price: NA
    - ii. **Take unit off the market: Sellers with successful transactions will take their units off the market, otherwise, they will stay on the market until their unit is sold.**
    - iii. Default on loan: NA

**Mr. Potatohead Real Estate Market Edition – Agent Decision Template – Household Buyer  
– Valaei Sharif et al. (Working paper)**

**Demographic classes (These are agent types. Each agent type could buy, sell, or rent, or rent out. Select your agent type here)**

**1. Buyers**

1. Developers – Land buyers
2. Investors
  - Land
  - Residences

**3. Households**

**2. Sellers**

1. Developers
2. Investors
  - Land
  - Residences

**3. Households**

**4. Land owners**

**3. Renters**

1. People who rent residence units (demand)
2. People who rent out residence units (supply)
4. Central bank (*For future—not in any current models*)
5. Government (*For future—not in any current models*)

**Decision making class (In MR POTATOHEAD, this is “agent decision model”) (filled out for each land-market agent type, 1-5 from above in current models)**

1. **A / P – Attributes** (methods/function and parameters) that affect decision real estate decision

**a) Budget:**

- All the local and external buyers are sampled from the synthetic population dataset (Prédhumeau & Manley, 2023), and they already have household characteristics associated with them, such as income levels, education and family type.
- Budget for housing is calculated based on a budget-income ratio, assumed to be equal tot 0.3.
- Maximum affordable mortgage is calculated based on  $maxAffordableMortgage = monthlyIncome * budgetIncomeRadio * (1 - Math.pow(1 + monthlyInterestRate, -1 * mortgageMonths)) / monthlyInterestRate$ , where *monthlyInterestRate* is set to be 0.03/12 = 0.0025; *mortgateMonths* are 12 \* (25 years) = 300.

**b) Preferences:**

- In the baseline mode, preferences for each property parcel are homogenous in the model, since the WTP for each property is determined by a first-stage hedonic function, which are the same for all buyers. To account for the preference heterogeneity of buyers, we proposed a new

approach using a two-stage hedonic model proposed by Huang et al. (2023) to estimate the WTP of households with different socio-demographic characteristics. See Section 3.4 of the manuscript.

- c) **Time horizon/discount rate:** Mortgage affordability is based on a 25-year horizon and a 3% annual discount rate.
- d) Risk perceptions: NA
- e) **Price expectations**
  - At the end of each simulation time step (each month), the first-stage hedonic regression model of WTP is re-run using the transaction data for the past 4 time steps and the regression coefficients are updated to reflect the buyers' expectations of prices. At each time step, the buyers use the updated hedonic model coefficients to estimate the WTP for different properties.
- f) Commuting/Transportation costs: NA
- g) **Utility function**
  - **Utility = Willingness to Pay (WTP)**
- h) Expected return from renting: NA
- i) Model to determine what will be built (developer land buyer): NA
- j) **Willingness to Pay**
  - WTP is determined by a spatial hedonic model proposed by Babin (2016) using data on sales transactions of 26,873 residential properties in Kitchener-Waterloo from 2005 to 2015, where WTP is a function of structural attributes (living area, yard size, building age), neighbourhood attributes (education rate, population density) and environmental attributes (open space access, transit access, walkability). This is based on the hedonic regression, where the dependent variable is the residential sales price, and the independent variables are those attributes. See Babin (2016).
  - In the scenario with heterogeneous preferences, the WTP estimated using the one-stage hedonic model proposed by Babin (2016) is adjusted using a deviation term which is estimated based on the households' socio-demographic characteristics using Huang et al.'s (2023) second-stage hedonic model. See Section 3.4 of the manuscript.
  - In both scenarios, when the calculated WTP is larger than the budget of the buyer, then the WTP is adjusted to the budget.
- k) Willingness to Accept
- l) **Bid price**
  - **Bid price is equal to WTP**
- m) Information sources (i.e. Realtor, listings, neighbours): NA
- n) **Search strategies**
  - **Buyers create a search list of properties within their budget range.**
- o) Negotiation strategies/negotiation power: NA
- p) Household composition: NA
- q) Partnership status: NA
- r) Location (note this will be read by the landscape initialization algorithms)
  - **No specific location for each external buyer;**

- **Local buyers are located where their associated parcel is located.**
  - **After successful bid, the buyer will be associated with the parcel location and relocate.**
- s) Production functions (Developers): NA
- t) Cost functions (Developers): NA
- u) Constraints (i.e. buy/sell, proximity to work—these are likely conditions): NA
- 2. P -- Decision to participate in the market (become active as a buyer, seller, investor, or renter)
  - a) Decision to participate in the market as a seller
    - 1. Decision to relocate?
  - b) Decision to participate in the market as a buyer: The number of potential local and external buyers in the market is estimated based on census data on local movers and inter- and intra-provincial migration by the census metropolitan area of origin and destination (Statistics Canada, 2023a and 2023b). See sections 1.7 and 2.5 of the ODD.**
  - c) Decision to participate in the market as a renter
- 3. P – Participate in the market as a buyer
  - a) Property budget (includes mortgage decision) – Call from above**
  - b) Which properties are evaluated? (searching strategy) – Call from above to the search list**
  - c) WTP – call from above**
  - d) Bid price – call from above**
  - e) Which property(s) to bid on?**
    - a. One per buyer – the parcel that has the highest utility/WTP. The search list is then sorted from the highest utility to the lowest utility. Then the buyer sets the bid price equal to the WTP and makes a bid on the house.**
    - b. Multiple per buyer
  - f) Negotiation strategy / Negotiation power – NA
  - g) Rules if you don't succeed to purchase**
    - a. Adjust budget/WTP/bid price
    - b. Leave market (details): Potential buyers will stay on the market for 4 months, without changing their budget, and after 4 months, if they do not have any accepted bid offer or no bids, they will be removed from the market.**
- 4. P – Participate in the market as a renter (renting a residence unit)
  - a) Determination of budget
  - b) Which properties are evaluated (searching strategy, assume price taker at fixed offer price)
  - c) WTP (from above)
  - d) Which property(s) to apply for?
  - e) Rules if you don't succeed to purchase
    - i. Adjust budget/WTP
    - ii. Leave market
- 2. P – Participate in the market as a leasor (renting unit to someone else)
- 5. P – Participate in the market as a seller
  - a) WTA (from above)

- b) Ask/List price (What proposed sales price do you post to the market?)
- c) At what scale are the bids collected?
  - i. Unique unit scale
  - ii. Aggregate market scale (market-clearing mechanism)
- d) Rules for collecting bids: How many bids to you accept?
  - i. One per property up for sale
  - ii. Multiple per property
- e) Who to sell to (how to pick the accepted bid)
  - i. Single bid rule (Only relevant if you have chosen 4 i.)
    - i. Accept
    - ii. Accept if  $\geq$  ask price, else reject
    - iii. Accept if  $\geq$  WTA, else reject
    - iv. Other (short text field)
  - ii. Multiple bid rule
    - i. Highest price if  $\geq$  ask price
    - ii. Highest price if  $\geq$  WTA
    - iii. Random selection if multiple highest bids
    - iv. Other
  - iii. Custom
- f) Negotiation strategy
- g) List price/time on market adjustment rules (price decrease/repackage/upgrade)
  - i. Adjust price
  - ii. Take unit off the market
  - iii. Default on loan

**Mr. Potatohead Real Estate Market Edition – Landscape Class Template – Filatova (2015)**

1. What is the form of the base landscape (Questions from original MP)?
  - a. **Abstract** / Empirical
  - b. **Vector** or cell-based (uniform tessellation).
  - c. Source of landscape initialization
    - i. Generic grid, uniform tessellation (*Netlogo default*)
    - ii. CSV file? (Y/N) Enter GIS base layer file name here, or provide link (text entry)
    - iii. GIS file? (Y/N) Enter GIS base layer file name here, or provide link. ***GIS shape files***
  - d. Define coarse-scale land uses: ***Urban, green and water. Also flood-zones.***
2. What unique products are being bought and sold?
  - a. Number of container types. For each container provide the following information:
    - i. Characteristics of the spatial entity
      1. Spatial location(s), if not read from GIS or CSV
      2. **Entire lot area (*parcel polygon*)**
      3. Building footprint area (*building footprint polygon*)
      4. Number of Stories
      5. Transportation accessibility
      6. **Neighbourhood amenities, captured in neighbourhood quality**
      7. **Neighbourhood disamenities (flood risk)**
    - ii. Number of different unit categories in the container.
    - iii. Unit category descriptions:
      1. Number of units of this type
      2. **Unit area (sq. foot)**
      3. **Number of room/bedrooms: *Number of bedrooms***
      4. Number of baths
      5. **Yard/lot size (acres)**
      6. Garage
      7. ***Age***
      8. ***Dummy for being in a flood zone***
      9. ***Neighbourhood quality (measures through kriging of hedonic residuals)***
      10. Etc.

**Mr. Potatohead Real Estate Market Edition – Property Exchange Class Template – Filatova (2015)**

1. Which market is being modelled?
  - a. **Residences**
  - b. Land
2. Who are the market participants?
  - a. **Buyers**
    - i. Developers
    - ii. Investors
    - iii. **Households**
  - b. **Sellers**
    - i. Developers
    - ii. Investors
    - iii. **Households**
    - iv. Land owners
  - c. Renters
    - i. People who rent units (demand)
    - ii. People who rent out units (supply)
  - d. **Real estate agent**
3. Initialize buyer and seller locations (*call to agent's Location field*)
  - a. **One agent per spatial container**
  - b. Multiple agents per spatial container
4. What are your ask and bid price rules for market-based land allocation?
  - a. How ask prices posted?
    - i. Public information
    - ii. **Information held by realtor agents**
  - b. Bid submission: How many properties can a buyer bid on? – **One**
  - c. Bid acceptance: How many bids are accepted per property? – **One**
5. Matching algorithm: How are buyers matched to purchased properties?
  - a. **Custom rule: *the highest bidder whose bid is accepted gets the property.***
  - b. How units are matched to the seller—subdivision model (many to one) or single property model (one to one). *Call to seller ADM(s). A Seller owns one property*
  - c. How are buyer bids matched to units? *Call to buyer ADM(s) see Buyer file for how they search*
  - d. How are winning bids selected? (*Call to seller ADM*) **Max bid. See Negotiations in Buyer/Seller files**
  - e. How is the transaction price defined?
    - i. Bid price if multiple bids
    - ii. Mean of bid and ask if one bid
    - iii. Negotiation process (*describe, calling ADM negotiation strategies*) **See Negotiations in Buyer/Seller files**
    - iv. Custom
6. What market housekeeping occurs in your model?
  - a. **Change ownership**

- b. Age homes
  - c. **Record sales prices for next round**
  - d. **Seller adjustments for un-sold units** (*call to ADM functions*). *See Seller file (reduces price)*
  - e. **Rules for buyers who did not find a home** (*call to ADM functions*)
  - f. **Identify active buyers and sellers for next round**
7. What are your stopping rules for market activity?
- a. No market activity in X time periods (numerical entry for number of time periods) (*equilibrium rule*) *Used this one in some simulations as well*
  - b. **End time periods** (numerical entry for number of time periods) (*non-equilibrium rule*) (*“new round”*)

**Mr. Potatohead Real Estate Market Edition – Agent Decision Template – Household Seller  
– Magglioca et al. (2011)**

**Demographic classes (These are agent types. Each agent type could buy, sell, or rent, or rent out. Select your agent type here)**

1. Buyers
  1. Developers – Land buyers
  2. Investors
    - Land
    - Residences
  3. Households
2. Sellers
  1. Developers
  2. Investors
    - Land
    - Residences
  3. Households
  4. Land owners
3. Renters
  1. People who rent residence units (demand)
  2. People who rent out residence units (supply)
4. Central bank (*For future—not in any current models*)
5. Government (*For future—not in any current models*)
6. Real estate agent

**Decision making class (In MR POTATOHEAD, this is “agent decision model”) (filled out for each land-market agent type, 1-5 from above in current models)**

1. A / P – Attributes (methods/function and parameters) that affect a real estate decision
  - Budget: The ‘budget’ of households in the RHEA model is parameterized based on the empirical data on the annual income distribution in the US (Statista, 2017). As with Buyers, each Seller has an individual ‘housing budget’ ( $Y_H$ ) – the maximum share of his annual income ( $Y$ ) to be spent on housing – which is heterogeneous among agents, with low income households spending a larger share of their incomes on housing compared to affluent ones (de Koning, Filatova, 2020) . This share in the model is estimated using Eq.1 as based on our survey data, and is validated on the U.S. national statistics data (Statista, 2017):
$$Y_H = e^{4.96+0.63 \cdot \ln(Y)} \quad (\text{Eq. 1})$$

Since RHEA was developed to study housing markets in flood prone areas (Filatova, 2015), the housing budget covers mortgage and eventual flood insurance, in case the latter is mandatory. When applicable, flood insurance costs are defined based on the U.S. FEMA insurance premiums quantification. Sellers hardly use their budget attributes in their role as Seller (they mainly use it actively only when deciding to relocate and taking a role of a Buyer).

- **Preferences:** Sellers have heterogeneous preferences for houses (see Buyers file for description). These are not actively used when trading in the role of a Seller, i.e. only when Sellers decide to relocate and become Buyers.
- **Time horizon/discount rate:** Sellers make decisions considering their annual mortgage costs and incomes remain stable, with mortgage spread evenly over 30 years. There is no discounting in the current version.
- **Risk perceptions:** When talking about risks in RHEA we mean risk of flood hazards, not financial/investment risk. Risk enters households decisions in a number of ways in RHEA. Firstly, Sellers may develop 'fear' towards flooding. Fear is subjective and is updated during simulations using Bayesian conditional probability function constructed based on the survey data. Since our survey was run separately among Buyers and Sellers, we were able to define the decision heuristics separately for each of the two groups of market players (de Koning et al, 2019). For Sellers fear (a 4-point scale score) depends on their experience of flood damage in the past and information about flood risk in the news . Secondly, homeowners may decide to move out of flood zone. In this case they become Sellers and start relocating. This decision is triggered by several factors based on Bayesian conditional probability. Based on our survey, these factors include: fear, flood experience, costs of moving and costs of flood insurance, and perceived likelihood of damage that depends on the information Sellers collect from their neighbors (within 2000 feet radius). Lastly, Sellers of flood-prone properties reduce ask prices after a flood event (by 13.8% in 1:500 zone and by 15.7% in 1:100 flood zone, according to the survey data). This is also commonly observed in empirical hedonic literature as well: market value of houses drop after a hazard event, at times irrespectively of whether houses suffer physical damage.
- **Price expectations:** Price expectations are modelled in an elaborate way. Since the housing good in the RHEA market are highly heterogeneous matching the empirical realistic market, we model adaptive learning about prices as the main activity of the Real-Estate Agent (described separately).
- Commuting/Transportation costs
- Utility function
- Expected return from renting
- Model to determine what will be built (developer land buyer)
- Willingness to Pay
- **Ask price:** Sellers use the current market information from the Realtor agent to form own ask prices. Realtor bases his predictions on the hedonic analysis of the past simulated transaction, which account for any market shifts. Sellers apply the latest regression coefficients to their own property considering the following attributes: (1) house age, (2) its size (in sq. footage), (3) size of the land lot (in acres), (4) number of bedrooms (5) dummy on whether a house is flood-prone, and (6) neighborhood quality (captured by kriging of the regression residuals to capture proximity to various amenities and other salient neighborhood characteristics). The estimated ask price could further be adjusted if a property was not sold for two consecutive trade periods (by 4%), or have been flooded (by 15.7% and 13.8% for 1:100 and 1:500 flood zone correspondingly), or if demand

for properties in the neighborhood goes up or down (even if no sales have been there yet; by 10% adjusted by the relative changes in demand in the neighborhood).

- **Willingness to Accept:** Most homeowners have a mortgage paid linearly over 30 years; a few are cash buyers (share based on U.S. national statistics (Statista, 2017)). When a homeowner becomes a Seller, he compares bid prices/anticipated market price with his mortgage dept. If his mortgage debt is higher than what a house is worth on a current market (may happen after a flood), then it serves as Sellers' WTA below which he cannot go.
- Bid price
- **Information sources (i.e. Realtor, listings, neighbours):** Realtor agent that analyses previous simulated transactions (see the separate file) .  
Sellers also get some information from their neighbors (e.g. on flood damage, demand for neighboring properties) within 2000 feet radius.
- Search strategies
- **Negotiation strategies/negotiation power:** Negotiations are modelled explicitly, see (Filatova, 2015) for details and the Figure below. If a seller has at least one bid submitted he engages in price negotiations with the buyer who offered the highest bid price. Naturally, if her bid price is higher than seller's ask price, then the trade is successful and final transaction price is equal to this bid (box (1), Figure below). If the highest bid is below the original ask price, then the market power of agents plays a role (box (2)). Specifically, if the seller has more than 1 bid offered, then the highest-bid buyer is the first one to reconsider his bid price. The highest-bid buyer checks if the opportunity costs of waiting another half year for another trade attempt (her Dneg) are comparable to the difference between the bid and ask prices (box (3)). Here Dneg of a buyer is operationalized as one half year of renting an average house in the city, which is updated with time as residential housing prices change. If it is beneficial for the buyer to accept the ask price instead of waiting another half year for a trade attempt, then she accepts the ask price and trade is successfully registered. However, if the seller receives only one offer-bid, then he is the one to reconsider his ask price (box (4)). In particular, he compares the difference between bid and ask prices to the opportunity costs of waiting another half year (his Dneg) and accepts the bid price, if comparison is in its favor. The Dneg of a seller is operationalized as one half year of mortgage for his property at the start of sellers trading history and gets updated with every unsuccessful trade attempt. If the seller and the buyer do not agree on a price the negotiation fails.

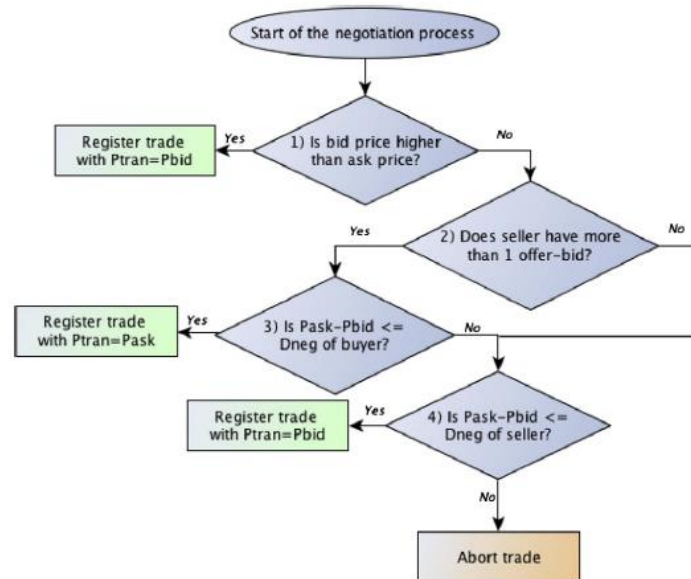


Fig. 3. The simulation flow of the price negotiation process (Section 2.2.6). Here: buyers' opportunity costs of waiting another month for another trade attempt ( $D_{neg}$  of a buyer) are equal to 1 month of rent, seller's opportunity costs of waiting another month ( $D_{neg}$  of a seller) are equal to 1 month of mortgage. Both of them are updated following unsuccessful trades.

- Household composition
  - Partnership status
  - **Location: All properties in RHEA are vector-based polygons (actual GIS data from the US).**
  - Production functions (Developers)
  - Cost functions (Developers)
  - Constraints (i.e. buy/sell, proximity to work—these are likely conditions)
2. P -- Decision to participate in the market (become active as a buyer, seller, investor, or renter)
    1. **Decision to participate in the market as a seller: Homeowners decide to put their house on sale predominantly randomly (with exogenously defined mean and standard deviation; about 10%). Those in the flood zone may decide to become Sellers endogenously (see Relocate).**
      1. Decision to relocate?  
 Some Sellers may decide to look for a house in the same town (fixed %, defined randomly), hence become Buyers and attempt to relocate. In addition, some Sellers decide to relocate because their house is at risk of natural hazards; so they search for another home to evade the hazard.
      2. Decision to participate in the market as a buyer
      3. Decision to participate in the market as a renter
  3. P – Participate in the market as a buyer
    1. Property budget (includes mortgage decision)
    2. Which properties are evaluated (searching strategy)
    3. WTP
    4. Bid price

5. Which property(s) to bid on?
  - i. One per buyer
  - ii. Multiple per buyer
6. Negotiation strategy / Negotiation power
7. Rules if you don't succeed to purchase
  - i. Adjust budget/WTP/bid price
  - ii. Leave market
4. P – Participate in the market as a renter (renting a residence unit)
  1. Determination of budget
  2. Which properties are evaluated (searching strategy, assume price taker at fixed offer price)
  3. WTP (from above)
  4. Which property(s) to apply for?
  5. Rules if you don't succeed to purchase
    - i. Adjust budget/WTP
    - ii. Leave market
2. P – Participate in the market as a leasor (renting unit to someone else)
5. P – Participate in the market as a seller
  1. WTA (from above) – **see above**
  2. Ask/List price (What proposed sales price do you post to the market?) – **see above**
  3. At what scale are the bids collected?
    - a. **Unique unit scale – per property**
    - b. Aggregate market scale
  4. Rules for collecting bids: How many bids to you accept?
    - i. One per property up for sale
    - ii. **Multiple per property – as many as buyers are willing to submit**
  5. Who to sell to (how to pick the accepted bid)
    - a. Single bid rule (Only relevant if you have chosen 4 i.)
      - i. Accept
      - ii. Accept if  $\geq$  ask price, else reject
      - iii. Accept if  $\geq$  WTA, else reject
      - iv. Other (short text field)
    - b. Multiple bid rule
      - i. Highest price if  $\geq$  ask price
      - ii. Highest price if  $\geq$  WTA
      - iii. Random selection if multiple highest bids
      - iv. Other– **in RHEA. see Negotiations above**
    - c. Custom
  6. Negotiation strategy – **see above**
  7. List price/time on market adjustment rules (price decrease/repackage/upgrade)
    - i. **Adjust price– Sellers adjust ask price on 3 occasions. The estimated ask price is adjusted if (i) a property was not sold for two consecutive trade periods (by 4%), (ii) or have been flooded (by 15.7% and 13.8% for 1:100 and 1:500 flood zone**

**correspondingly), (iii) or if demand for properties in the neighborhood goes up or down (even if no sales have been there yet; by 10% adjusted by the relative changes in demand in the neighborhood).**

- ii. Take unit off the market –if the anticipated market price is below own mortgage debt**
- iii. Default on loan

**Mr. Potatohead Real Estate Market Edition – Agent Decision Template – Household Buyer – Filatova (2015)**

**Demographic classes (These are agent types. Each agent type could buy, sell, or rent, or rent out. Select your agent type here)**

1. **Buyers**
  1. Developers – Land buyers
  2. Investors
    - Land
    - Residences
  3. **Households**
2. **Sellers**
  1. Developers
  2. Investors
    - Land
    - Residences
  3. Households
  4. Land owners
3. **Renters**
  1. People who rent residence units (demand)
  2. People who rent out residence units (supply)
4. Central bank (*For future—not in any current models*)
5. Government (*For future—not in any current models*)
6. Real estate agent

**Decision making class (In MR POTATOHEAD, this is “agent decision model”) (filled out for each land-market agent type, 1-5 from above in current models)**

1. A / P – Attributes (methods/function and parameters) that affect a real estate decision
  - **Budget:** the ‘budget’ of households in the RHEA model is parameterized based on the empirical data on the annual income distribution in the US (Statista, 2017). Each Buyers has an individual ‘housing budget’ ( $Y_H$ ) – the maximum share of his annual income ( $Y$ ) to be spent on housing – which is heterogeneous among agents, with low income households spending a larger share of their incomes on housing compared to affluent ones (de Koning, Filatova, 2020) . This share in the model is estimated using Eq.1 as based on our survey data, and is validated on the U.S. national statistics data (Statista, 2017):
$$Y_H = e^{4.96+0.63 \cdot \ln(Y)} \quad (\text{Eq. 1})$$

Since RHEA was developed to study housing markets in flood prone areas (Filatova, 2015), the housing budget covers mortgage and eventual flood insurance, in case the latter is mandatory. When applicable, flood insurance costs are defined based on the U.S. FEMA insurance premiums quantification.

- **Preferences:** Buyers have heterogeneous preferences for houses. They differ in the preferences for the (1) house age, (2) its size (in sq. footage), (3) size of the land lot (in acres), (4) number of bedrooms and (5) neighbourhood quality (capturing proximity to various amenities and other salient neighbourhood

characteristics). These preferences are defined from the empirical housing transactions dataset (Bin and Landry 2013) using ANOVA (Table 3 in the ODD+D RHEA description available online:

<https://www.comses.net/codebases/8e6c8883-d618-4286-808f-8632adf4f1e0/releases/1.0.0/> ).

Out of all the housing attributes that were present in the dataset, including environmental amenities measured as distance to nature or proximity measured as distance to major roads or CBD, we have chosen only those four that were statistically significant. Therefore, amenities and proximity are captured in the residual estimated using kriging (de Koning et.al. 2018). The relative importance of each variable in explaining a variation in housing prices elicited serves as a weight ( $A_{ij}$ ) in the multi-attribute utility function that each buyer  $j$  uses to choose the house.

- **Time horizon/discount rate:** Buyers make decisions considering their annual housing costs and incomes remain stable, with mortgage spread evenly over 30 years. There is no discounting in the current version.
- **Risk perceptions:** When talking about risks in RHEA we mean risk of flood hazards, not financial/investment risk. Risk enters households decisions in a number of ways in RHEA. Firstly, Buyers may develop ‘fear’ towards flooding. Fear is subjective and is updated during simulations using Bayesian conditional probability function constructed based on the survey data. Since our survey was run separately among Buyers and Sellers, we were able to define the decision heuristics separately for each of the two groups of market players (de Koning et al, 2019). For Buyers fear (a 4-point scale score) depends on three Boolean variables: their experience of flood damage in the past, information about flood risk in the news, and whether Buyers are informed about flood risk in general. Secondly, when searching for a house Buyers may choose to avoid flood zone (a 4 point scale score, separately for 1:100 and 1:500 flood zone). At initialization a fixed % (from the survey) of Buyers is assigned to ‘avoid flood zone’. As the model runs, the Buyers tendency to avoid flood zone is updated using Bayesian conditional probability that depends on their initial intention to avoid/not and the evolving fear score.

Lastly, these attitudes towards flood risks influence individual Buyers demand, and eventually market demand for flood-prone properties. Therefore, subjective dynamics risk perceptions capitalize in property values as the market evolves, driving the dynamics of flood-prone properties up or down over time.

- **Price expectations:** Price expectations are modelled in an elaborate way. Since the housing good in the RHEA market are highly heterogeneous matching the empirical realistic market, we model adaptive learning about prices as the main activity of the Real-Estate Agent (described separately).
- **Commuting/Transportation costs:** Transport costs got excluded from the empirical version since our dataset revealed no statistically significant preferences for this attribute. Perhaps this is case-dependent since the data for our case study comes from small coastal towns, where commuting distance does not vary that much across different locations within towns.
- **Utility function:** In the empirical version of RHEA we use multi-attribute utility function, which depends on a bundle of property attributes, neighborhood

quality and a potential exposure to flood hazards. The base multi-attribute utility function ( $U_{0L}$ , Eq.4.1 in the ODD+D) for a house in a safe area is parameterized using weights ( $A_{ij}$ ) that reflect relative importance of each characteristic ( $X_{i,norm}$ ) for each individual agent  $j$ :

$$U_{0L} = A_{ij} * X_{i,norm} \quad (\text{Eq. 2})$$

- Expected return from renting
- Model to determine what will be built (developer land buyer)
- **Willingness to Pay:** WTP of a buyer is not specified explicitly; indirectly their housing budget is the max WTP they can pay for a house. Namely, buyers search for houses within their housing budget and select N most expensive affordable properties. They identify which of these N gives them the highest utility and bid on it.
- Ask price
- Willingness to Accept
- **Bid price:** Bid price of a buyer is anchored to the seller's ask price, as revealed from our semi-structured interviews with realtors (2 x 2 hour in-depth interviews and 19 x half-hour to one hour follow-up interviews with real estate agents to specify the main architecture of the market, e.g. how ask and bid prices are formed, how agents negotiate prices, how they adjust prices, how learning on price expectations is happening).

These real-estate guidelines suggest that buyers may bid between 3-5% and up to 7-10% below/above the ask price, depending on the situation on the market. Buyers in the RHEA model estimate their bid price ( $H_{bid}$ ) following Eq.3:

$$H_{bid} \in [(H_{ask} \pm h); H_{ask}] \quad (\text{Eq. 3})$$

where  $h$  is a random number between 0-5% of the ask price of a seller ( $H_{ask}$ ). Buyer's bid price cannot exceed her housing budget.

- **Information sources** (i.e. Realtor, listings, neighbours): Realtor agent that analyses previous simulated transactions (see the separate file).
- **Search strategies:** Firstly, buyers 'sort' all vacant affordable houses according to their price. Secondly, out of the top most expensive ones they randomly choose N and proceed with this set further to estimate utility and bid price. We commonly use N=5 in RHEA (based on the sensitivity analysis).
- **Negotiation strategies/negotiation power:** Negotiations are modelled explicitly, see (Filatova, 2015) for details and the Figure below. If a seller has at least one bid submitted he engages in price negotiations with the buyer who offered the highest bid price. Naturally, if her bid price is higher than seller's ask price, then the trade is successful and final transaction price is equal to this bid (box (1), Figure below). If the highest bid is below the original ask price, then the market power of agents plays a role (box (2)). Specifically, if the seller has more than 1 bid offered, then the highest-bid buyer is the first one to reconsider his bid price. The highest-bid buyer checks if the opportunity costs of waiting another half year for another trade attempt (her Dneg) are comparable to the difference between the bid and ask prices (box (3)). Here Dneg of a buyer is operationalized

as one half year of renting an average house in the city, which is updated with time as residential housing prices change. If it is beneficial for the buyer to accept the ask price instead of waiting another half year for a trade attempt, then she accepts the ask price and trade is successfully registered. However, if the seller receives only one offer-bid, then he is the one to reconsider his ask price (box (4)). In particular, he compares the difference between bid and ask prices to the opportunity costs of waiting another half year (his Dneg) and accepts the bid price, if comparison is in its favor. The Dneg of a seller is operationalized as one half year of mortgage for his property at the start of sellers trading history and gets updated with every unsuccessful trade attempt. If the seller and the buyer do not agree on a price the negotiation fails.

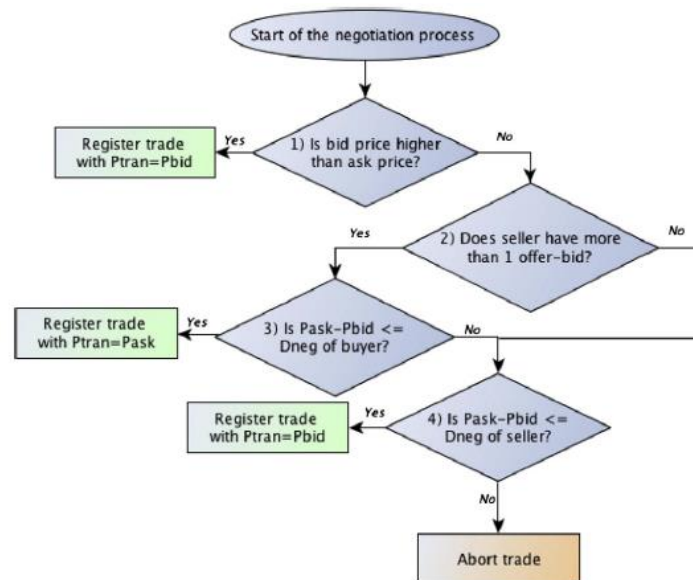


Fig. 3. The simulation flow of the price negotiation process (Section 2.2.6). Here: buyers' opportunity costs of waiting another month for another trade attempt ( $D_{neg}$  of a buyer) are equal to 1 month of rent, seller's opportunity costs of waiting another month ( $D_{neg}$  of a seller) are equal to 1 month of mortgage. Both of them are updated following unsuccessful trades.

- Household composition
  - Partnership status
  - **Location: All properties in RHEA are vector-based polygons (actual GIS data from the US).**
  - Production functions (Developers)
  - Cost functions (Developers)
  - Constraints (i.e. buy/sell, proximity to work—these are likely conditions)
2. P -- Decision to participate in the market (become active as a buyer, seller, investor, or renter)
    1. **Decision to participate in the market as a seller: At initialization agents are assigned a status of Buyer or Seller. Buyer who bought a house, i.e. become homeowners, may decide later on to sell. Every time step a fraction of properties goes for sale (with exogenously defined mean and standard deviation).**

1. Decision to relocate?  
**Some Sellers may decide to look for a house in the same town (fixed %, defined randomly), hence become Buyers and attempt to relocate. In addition, some Sellers decide to relocate because their house is at risk of natural hazards; so they search for another home to evade the hazard.**
2. **Decision to participate in the market as a buyer**  
**At initialization agents are assigned a status of Buyer or Seller. Some Sellers may decide to look for a house in the same town (fixed %, defined randomly), hence become Buyers.**
3. Decision to participate in the market as a renter  
**It is assumed that all Buyers who have not yet secured a house are renting. Rental market is not modelled explicitly. Monthly rental price is anchored to the average property price in the town (specifically in the last version - estimated as an average of the current period housing prices).**
3. P – Participate in the market as a buyer
  1. Property budget (includes mortgage decision) – **Call from above**
  2. Which properties are evaluated (searching strategy) – **see above**
  3. WTP – **call from above**
  4. Bid price – **call from above**
  5. Which property(s) to bid on?
    - i. **One per buyer**
    - ii. **Multiple per buyer**
  6. Negotiation strategy / Negotiation power – **see above**
  7. Rules if you don't succeed to purchase
    - i. **Adjust budget/WTP/bid price (details) – Buyer adjust bid prices during negotiations. After an unsuccessful attempt, they just keep bidding in the next time steps for another property.**
    - ii. **Leave market (details) – after Buyers leave after being unsuccessful on the market > 2 years.**
4. P – Participate in the market as a renter (renting a residence unit)
  1. Determination of budget
  2. Which properties are evaluated (searching strategy, assume price taker at fixed offer price)
  3. WTP (from above)
  4. Which property(s) to apply for?
  5. Rules if you don't succeed to purchase
    - i. **Adjust budget/WTP (details)**
    - ii. **Leave market (details)**
2. P – Participate in the market as a leasor (renting unit to someone else)
5. P – Participate in the market as a seller
  1. WTA (from above)
  2. Ask/List price (What proposed sales price do you post to the market?)
  3. At what scale are the bids collected?
    - a. **Unique unit scale**
    - b. **Aggregate market scale**

4. Rules for collecting bids: How many bids to you accept?
  - i. One per property up for sale
  - ii. Multiple per property
5. Who to sell to (how to pick the accepted bid)
  - a. Single bid rule (Only relevant if you have chosen 4 i.)
    - i. Accept
    - ii. Accept if  $\geq$  ask price, else reject
    - iii. Accept if  $\geq$  WTA, else reject
    - iv. Other (short text field)
  - b. Multiple bid rule
    - i. Highest price if  $\geq$  ask price
    - ii. Highest price if  $\geq$  WTA
    - iii. Random selection if multiple highest bids
    - iv. Other
  - c. Custom
6. **Negotiation strategy – see above**
7. List price/time on market adjustment rules (price decrease/repackage/upgrade)
  - i. **Adjust price - Done on the seller's side, see the other file**
  - ii. Take unit off the market
  - iii. Default on loan

**Mr. Potatohead Real Estate Market Edition – Agent Decision Template – Realtor – Filatova (2015)**

**Demographic classes (These are agent types. Each agent type could buy, sell, or rent, or rent out. Select your agent type here)**

1. Buyers
  1. Developers – Land buyers
  2. Investors
    - Land
    - Residences
  3. Households
2. Sellers
  1. Developers
  2. Investors
    - Land
    - Residences
  3. Households
  4. Land owners
3. Renters
  1. People who rent residence units (demand)
  2. People who rent out residence units (supply)
4. Central bank (*For future—not in any current models*)
5. Government (*For future—not in any current models*)
6. Real estate agent

**Decision making class (In MR POTATOHEAD, this is “agent decision model”) (filled out for each land-market agent type, 1-5 from above in current models)**

1. A / P – Attributes (methods/function and parameters) that affect a real estate decision
  - Budget
  - Preferences
  - Time horizon/discount rate
  - Risk perceptions
  - **Price expectations: Since the housing good in the RHEA market are highly heterogeneous matching the empirical realistic market, forming price expectations based on learning at the level of individual Sellers is not possible. Real-estate agent pursues adaptive learning at the level of the market. He forms prices expectations using the predictions on the hedonic analysis of the past N trade periods, hence accounting for any market shifts (Filatova, 2015). At initialization Realtor relies on the actual transactions data from the US (Bin, Landry, 2013) and runs hedonic-kriging analysis on them. Further on, Realtor relies on simulated transactions, which he records together with all the relevant attributes of a house. Both successful and unsuccessful trades in the RHEA ABM housing market are recorded. According to Hedonic Price Modeling, a house is a bundle of quantitative and qualitative characteristics (Rosen 1974). Hence, a price of a house is as a**

function of its attributes. Marginal implicit prices can be interpreted as marginal willingness to pay of a representative household for specific housing attributes.

$$\ln H_{tran} = \beta_0 + \sum_{i=1}^n \beta_i x_i + \varepsilon$$

Here  $\ln H_{tran}$  is the log of transaction price,  $x_i$  is a variable for the  $i^{\text{th}}$  housing attribute (structural),  $\beta$  are regression coefficients, and  $\varepsilon$  is the error term that captures the value of spatial attributes used for kriging.

Realtor applies a hedonic analysis on successful transactions considering the following GIS attributes: (1) house age, (2) its size (in sq. footage), (3) size of the land lot (in acres), (4) number of bedrooms, (5) dummy on whether a house is flood-prone, and (6) neighborhood quality (captured by kriging of the regression residuals to capture proximity to various amenities and other salient neighborhood characteristics). We limited the number of explanatory variables only to those essential ones that were statistically significant for small samples sizes (i.e. transactions of the past few periods only), see (de Koning et al. 2016) for details. All other traditionally studied influential factors – environmental amenities, distance to highways, to CBD and etc. – are captured through kriging.

- Commuting/Transportation costs
  - Utility function
  - Expected return from renting
  - Model to determine what will be built (developer land buyer)
  - Willingness to Pay
  - Ask price
  - Willingness to Accept
  - Bid price
  - **Information sources (i.e. Realtor, listings, neighbours): Realtor agent that analyses previous simulated transactions. They have access to both successful and failed trade attempts.**
  - Search strategies
  - Negotiation strategies/negotiation power
  - Household composition
  - Partnership status
  - **Location: All properties in RHEA are vector-based polygons (actual GIS data from the US).**
  - Production functions (Developers)
  - Cost functions (Developers)
  - Constraints (i.e. buy/sell, proximity to work—these are likely conditions)
2. P -- Decision to participate in the market (become active as a buyer, seller, investor, or renter)
1. Decision to participate in the market as a seller
    1. Decision to relocate?
  2. Decision to participate in the market as a buyer
  3. Decision to participate in the market as a renter

3. P – Participate in the market as a buyer
  1. Property budget (includes mortgage decision)
  2. Which properties are evaluated (searching strategy)
  3. WTP – call from above
  4. Bid price – call from above
  5. Which property(s) to bid on?
    - i. One per buyer
    - ii. Multiple per buyer
  6. Negotiation strategy / Negotiation power
  7. Rules if you don't succeed to purchase
    - i. Adjust budget/WTP/bid price
    - ii. Leave market (details)
4. P – Participate in the market as a renter (renting a residence unit)
  1. Determination of budget
  2. Which properties are evaluated (searching strategy, assume price taker at fixed offer price)
  3. WTP (from above)
  4. Which property(s) to apply for?
  5. Rules if you don't succeed to purchase
    - i. Adjust budget/WTP (details)
    - ii. Leave market (details)
2. P – Participate in the market as a leasor (renting unit to someone else)
5. P – Participate in the market as a seller
  1. WTA (from above)
  2. Ask/List price (What proposed sales price do you post to the market?)
  3. At what scale are the bids collected?
    - a. Unique unit scale
    - b. Aggregate market scale
  4. Rules for collecting bids: How many bids to you accept?
    - i. One per property up for
    - ii. Multiple per property
  5. Who to sell to (how to pick the accepted bid)
    - a. Single bid rule (Only relevant if you have chosen 4 i.)
      - i. Accept
      - ii. Accept if  $\geq$  ask price, else reject
      - iii. Accept if  $\geq$  WTA, else reject
      - iv. Other (short text field)
    - b. Multiple bid rule
      - i. Highest price if  $\geq$  ask price
      - ii. Highest price if  $\geq$  WTA
      - iii. Random selection if multiple highest bids
      - iv. Other
    - c. Custom
  6. Negotiation strategy
  7. List price/time on market adjustment rules (price decrease/repackage/upgrade)
    - i. Adjust price

- ii. Take unit off the market
- iii. Default on loan

**Mr. Potatohead Real Estate Market Edition – Landscape Class Template – Prunetti et al. (2025)**

1. What is the form of the base landscape?
  - a. **Abstract** / Empirical
  - b. Vector or **cell-based**
  - c. Source of landscape initialization
    - i. **Generic grid, uniform tessellation** (*Netlogo default*)
    - ii. CSV file? (Y/N) Enter GIS base layer file name here, or provide link (*text entry*)
    - iii. GIS file? (Y/N) Enter GIS base layer file name here, or provide link (*text entry*)
  - d. Define coarse-scale land uses
    - i. **Residential**
2. What unique products are being bought and sold?
  - a. Number of container types (**1**). For each container provide the following information:
    - i. Characteristics of the spatial entity
      - 1. Spatial location(s), if not read from GIS or CSV**
        - a. **Cells are characterized by distance from amenities**
      2. Entire lot area
      3. Building footprint area
      4. Number of Stories
      - 5. Transportation accessibility**
        - a. **Daily cost of transportation to and from house location and CBD at a rate of €0.5404 by km.**
      - 6. Neighbourhood amenities**
        - a. **Distance to the beach  $dB_i$ , distance to the nearest Central Business District  $dCBD_i$ , sea-view-index: (estimated) access to sea-view (0-100)  $SVI_i$**
      7. Neighbourhood disamenities
    - ii. Number of different unit categories in the container.
      - 1. 1 (single residence)**
    - iii. Unit category descriptions:
      1. Number of units of this type
      - 2. Unit area**
        - a. **Square meters**
      3. Number of room/bedrooms
      4. Number of baths
      5. **Yard/lot size**
      6. Garage
      7. Etc.

**Mr. Potatohead Real Estate Market Edition – Land Exchange Class Template – Prunetti et al. (2025)**

1. Which market is being modeled?
  - (a) Residences
  - (b) **Land**
2. Who are the market participants?
  - (a) **Buyers**
    - i. **Developers**
    - ii. Investors
    - iii. Households
  - (b) **Sellers**
    - i. Developers
    - ii. Investors
    - iii. Households
    - iv. **Land owners: Household Landowner Agents**
  - (c) Renters
    - i. People who rent units (demand)
    - ii. People who rent out units (supply)
3. What unique products are being bought and sold?
  - (a) **Generic grid, uniform tessellation (Netlogo default)**
  - (b) CSV file? (Y/N) Enter GIS base layer file name here, or provide link (text entry)
  - (c) GIS file? (Y/N) Enter GIS base layer file name here, or provide link (text entry)
  - (d) Define coarse-scale land uses (*undeveloped land: water, open space; zoning, etc.*)
  - (e) Number of container types. (text numeric) For each container provide the following information: one per parcel. **NA in the land market**
    - i. **Characteristics of the spatial entity**
      - A. Spatial location(s), if not read from GIS or CSV: see GIS files
      - B. **Entire lot area (land area)**
      - C. Building footprint area (building footprint polygon)
      - D. Number of Stories
      - E. Transportation accessibility
      - F. **Neighbourhood amenities (example, distance to the beach  $dB_L$ , distance to the nearest Central District Business  $dCDB_L$ ), sea-view-index: (estimated) access to sea-view (0-100)  $SVI_L$**
      - G. Neighbourhood disamenities
    - ii. Number of different unit categories in the container.
    - iii. Unit category descriptions:
      - A. Number of units of this type
      - B. Unit area
      - C. Number of room/bedrooms
      - D. Number of baths
      - E. Yard/lot size
      - F. Garage
      - G. Flood risk
4. Initialize buyer and seller locations (call to agent's Location field)

- (a) **One agent per spatial container undeveloped**
  - (b) Multiple agents per spatial container
5. What are your ask and bid price rules for market-based land allocation?
- (a) **How ask prices posted?**
    - i. **Public information**
    - ii. Information held by realtor agents
  - (b) **Bid submission: How many properties can a buyer bid on? (numerical field)** Developers have a building capacity constraint. One developer  $m$  only bid on  $n_m = n - \sigma_m$  parcels of land, where  $\sigma_m$  is the number of construction site in progress for this developer.
  - (c) **Bid acceptance: How many bids are accepted per property? (numerical field)** All bids.
6. Matching algorithm: How are buyers matched to purchased properties?
- (a) **Custom rule: The buyer who purchased the land is the one which the higher Bid.**
  - (b) **How units are matched to the seller**—subdivision model (many to one) or **single property model (one to one)**. *Call to seller ADM(s).*
  - (c) **How are buyer bids matched to units?** *Call to buyer ADM(s): Only one.*
  - (d) **How are winning bids selected?** (*Call to seller ADM*)  
**The buyer who have the highest bid is matched to the seller if  $WTP \geq WTA$ . (if 2 or more buyers have the same WTP, the winning buyer is randomly selected).**
  - (e) **How is the transaction price defined?**
    - i. Bid price if multiple bids
    - ii. Mean of bid and ask if one bid
    - iii. Negotiation process (describe, calling ADM negotiation strategies)
    - iv. **Custom (long text field): call to ADM functions**  
**For sellers:**  $Askprice_{HA} = (1 + \psi_{HA})WTA_{HA}$   
**For buyers:**  $Bidprice_m = (1 - \psi_m)WTP_m(z_L)$   
 $\psi_j; j = \{HA; m\}$ : maximum expected leeway on the selling price
      - A. **If there are some bid prices such as  $Bidprice_m \geq Askprice_{L,t}$ , an efficient-rationing rule applied: the developers with the highest bid price buy the land parcel.**  
**The transaction price is then equal to the Ask price of the landowner, with no negotiations:**  
 $P(z_L) = AskPrice_{HA}$
      - B. **If no  $Bidprice_{Max}$  exceeds the  $AskPrice_{HA}$ , no direct sale occurs. Yet, if the  $WTP_m$  for a parcel is greater than its  $WTA_{HA}$ , negotiations are initiated. The highest WTP from Developer Agent is matched with the landowner's  $WTA_{HA}$ . The final transaction price is then negotiated between  $WTP_{Max}$  and  $WTA_{HA}$ , influenced by market conditions. A higher demand for a parcel raises its price, empowering the seller:**

$$\bar{P}(z_L) = WTA_{HA}(z_L) + \frac{ND_L}{\chi} [WTP_{Max} - WTA_{HA}(z_L)]$$

where  $ND_L$  represents potential demand and  $\chi$  denotes the count of Developer Agents with  $n_{m'} \geq 0$ , such that  $m' \in \{1, \dots, \chi\}$  and  $ND_L \leq \chi$ .
      - C. **A transaction is void if a landowner's WTA for parcel  $L$  is more than the Developer Agent's WTP, or if developers have reached their construction capacity ( $\chi = 0$ ).**
7. What market housekeeping occurs in your model?
- (a) **Change ownership.**

- (b) **Age developments (building homes).**
  - (c) **Record sales prices for next round.**
  - (d) Seller adjustments for un-sold units (call to ADM functions)
  - (e) **Rules for buyers who did not find a home (call to ADM functions): Buyers who did not find undeveloped parcels of land stay in the market and continue to bid on next time step.**
  - (f) **Identify active buyers and sellers for next round.**
8. What are your stopping rules for market activity?
- (a) All lands are sold.
  - (b) **End time periods: 40 discrete time steps (one time step = one quarter, i.e. 10 years)**

**Mr. Potatohead Real Estate Market Edition – Property Exchange Class Template – Prunetti et al. (2025)**

1. Which market is being modeled?
  - (a) **Residences**
  - (b) Land
2. Who are the market participants?
  - (a) **Buyers**
    - i. Developers
    - ii. **Investor**
    - iii. **Households**
  - (b) **Sellers**
    - i. **Developers**
    - ii. Investors
    - iii. Households
    - iv. Land owners
  - (c) Renters
    - i. People who rent units (demand)
    - ii. People who rent out units (supply)
3. What unique products are being bought and sold?
  - (a) **Generic grid, uniform tessellation (Netlogo default)**
  - (b) CSV file? (Y/N) Enter GIS base layer file name here, or provide link (text entry)
  - (c) GIS file? (Y/N) Enter GIS base layer file name here, or provide link (text entry)
  - (d) Define coarse-scale land uses
  - (e) **Number of container types. (text numeric) For each container provide the following information: one per parcel.**
    - i. **Characteristics of the spatial entity**
      - A. Spatial location(s), if not read from GIS or CSV: see GIS files
      - B. **Entire lot area (parcel polygon)**
      - C. Building footprint area (building footprint polygon)
      - D. Number of Stories
      - E. Transportation accessibility
      - F. **Neighbourhood amenities (example, distance to the beach  $dB_L$ , distance to the nearest Central District Business  $dCDB_L$ , Sea View Index  $SVI_L$ ).**
      - G. Neighbourhood disamenities (example, flood risk)
    - ii. Number of different unit categories in the container.
    - iii. **Unit category descriptions: (replicate as needed)**
      - A. Number of units of this type
      - B. **Unit area**
      - C. Number of room/bedrooms
      - D. Number of baths
      - E. **Size area**
      - F. Garage
      - G. Flood risk
4. Initialize buyer and seller locations (call to agent's Location field)
  - (a) **One agent per spatial container undeveloped.**

- (b) Multiple agents per spatial container
5. What are your ask and bid price rules for market-based land allocation?
- (a) **How ask prices posted?**
- i. **Public information**
- ii. Information held by realtor agents
- (b) **Bid submission: How many properties can a buyer bid on? Households bid on one property by step in a time step and the investor can bid on all properties.**
- (c) **Bid acceptance: How many bids are accepted per property? All bids.**
6. Matching algorithm: How are buyers matched to purchased properties?
- (a) **Custom rule:**
- The buyer who purchased the land is the one which the higher Bid.**
- (b) **How units are matched to the seller**—subdivision model (many to one) or **single property model (one to one)**. *Call to seller ADM(s).*
- (c) **How are buyer bids matched to units?** *Call to buyer ADM(s): Only one.*
- (d) **How are winning bids selected?** *(Call to seller ADM):*
- The buyer who have the highest bid is matched to the seller if  $WTP \geq WTA$ . (if 2 or more buyers have the same WTP, the winning buyer is randomly selected).**
- (e) **How is the transaction price defined?**
- i. Bid price if multiple bids.
- ii. Mean of bid and ask if one bid.
- iii. Negotiation process (describe, calling ADM negotiation strategies)
- iv. **Custom (long text field):**
- For sellers  $\bar{m}$ :  $Askprice_{\bar{m}} = (1 + \psi_{\bar{m}})WTA_{\bar{m}}$ ;  $\psi_{\bar{m}}$ : maximum expected leeway on the selling price**
- For buyers  $m$ :  $Bidprice_m = (1 - \psi_m)WTP_m(\eta)$ ;  $\psi_m$ : maximum expected leeway on the selling price**
- **The sellers (Developer Agent) scrutinize all bids and identify the highest Bidprice. If this highest bid,  $Bidprice_{Max}$ , exceeds the seller's asking price,  $AskPrice_{\bar{m}}$ , a sale is finalized at the asking price. Hence, the transaction price is:**  

$$\bar{P}(\bar{m}) = AskPrice_{\bar{m}}$$
  - **If no bid surpasses the  $AskPrice_{\bar{m}}$ , there is no direct sale. Yet, if a buyer's  $WTP(\bar{m})$  exceeds the  $WTA(\bar{m})$  of the Developer Agent, a negotiation ensues. The Developer Agent determines the highest  $WTP(\bar{m})_{Max}$ , matching it accordingly. The transaction price is then settled between the highest  $WTP$  and the  $WTA$  based on market conditions. The more demand exists for an item, the higher the transaction price and the seller's bargaining power. The transaction price is:**  

$$\bar{P}(\bar{m}) = WTA(\bar{m}) + \frac{ND_{\bar{m}}}{C+1} [WTP(\bar{m})_{Max} - WTA(\bar{m})]$$
**where  $ND_{\bar{m}}$  is the number of potential demands (number of household agents bidding for the house plus one if the Investor bids), and  $C$  represents the number of active Household Agents on the Housing Market.**
  - **If the Developer Agent's  $WTA$  for a house  $\bar{m}$  surpasses the highest  $WTP$  of the bidders, no transaction takes place.**
7. What market housekeeping occurs in your model?
- (a) **Check for new home supply.**
- (b) **Change ownership.**
- (c) **Age homes**

- (d) **Record sales prices for next round.**
  - (e) **Seller adjustments for un-sold units:**  
*AskPrice* is reduced in the subsequent period to match the construction cost, forgoing profit.  
**If, over two consecutive periods, the agent fails to make any positive sales, the Developer Agent is deemed bankrupt and is replaced by another developer agent. Otherwise, the Developer Agent remains in the Housing Market.**
  - (f) **Rules for buyers who did not find a home (call to ADM functions): Buyers who did not find properties stay in the market and continue to bid on next time step.**
  - (g) **Identify active buyers and sellers for next round.**
8. **What are your stopping rules for market activity?**
- (a) **End time periods: 40 discrete time steps (one time step = one quarter, i.e. 10 years)**

**Mr. Potatohead Real Estate Market Edition – Agent Decision Template – Household Landowner  
– Prunetti et al. (2025)**

**Demographic classes (These are agent types. Each agent type could buy, sell, or rent, or rent out.  
Select your agent type here)**

1. Buyers
  - (a) Developers – Land buyers
  - (b) Investors
    - i. Land
    - ii. Residences
  - (c) Households
2. **Sellers**
  - (a) Developers
  - (b) Investors
    - i. Land
    - ii. Residences
  - (c) Households
  - (d) **Land owners: Household Landowner Agents**
3. Renters
  - (a) People who rent residence units (demand)
  - (b) People who rent out residence units (supply)
4. Central bank
5. Government

**Decision making class (In MR POTATOHEAD, this is “agent decision model”) (filled out for each  
land-market agent type, 1-5 from above in current models)**

1. **A / P – Attributes (methods/function and parameters) that affect decision real estate decision**
  - (a) Budget
  - (b) Preferences
  - (c) Time horizon/discount rate
  - (d) Risk perceptions
  - (e) **Price expectations:**  
 $\ln(P_{t-1}) = \alpha_L + \beta_{1L} \ln(LA_L) + \beta_{2L} [\ln(LA_L)]^2 + \beta_{3L} / dB_L + \beta_{4L} / dCDB_L + \beta_{5L} SVI_L + \beta_{6L} t + \beta_{7L} CD_L + \epsilon_{1L}$ : **price of a parcel of land based on previous prices for parcel of land with the same characteristics  $z_L$ . It will be given by the results of a linear regression with spatial fixed effects using the PERVAL dataset (produced by the Chamber of Notaries on property transactions) on land market transactions.**
  - (f) Commuting/Transportation costs
  - (g) Utility function
  - (h) Expected return from renting
  - (i) Model to determine what will be built (developer land buyer)
  - (j) **Location (note this will be read by the landscape initialization algorithms): vector of characteristics of the (unbuilt) parcel of land ( $z_L$ ): land area  $LA_L$ , distance to the CDB  $dCDB_L$ , distance to the beach  $dB_L$ , sea-view-index: (estimated) access to sea-view (0-100)  $SVI_L$ .**
  - (k) Willingness to Pay
  - (l)  $Askprice_{HA} = (1 + \psi_{HA}) WTA_{HA}$ ;  $\psi_{HA}$ : **maximum expected leeway on the selling price.**

- (m) **Willingness to Accept:**  $WTA_{HA}(z_L) = P_{t-1}(z_L)$ .
  - (n) Bid price
  - (o) **Information sources (i.e. Realtor, listings, neighbours):** They have information about the past prices of parcel sold as a common knowledge.
  - (p) Search strategies
  - (q) Negotiation strategies/negotiation power
  - (r) Household composition
  - (s) Partnership status
  - (t) Production functions (Developers)
  - (u) Cost functions (Developers)
  - (v) Constraints (i.e. buy/sell, proximity to work – these are likely conditions)
2. **P – Decision to participate in the market (become active as a buyer, seller, investor, or renter)**
    - (a) **Decision to participate in the market as a seller: Parcels landowners are always on the market.**
      - i. **Decision to relocate? A certain percentage of land sellers relocate buying houses on the residence market.**
    - (b) Decision to participate in the market as a buyer
    - (c) Decision to participate in the market as a renter
  3. **P – Participate in the market as a buyer**
    - (a) Property budget (includes mortgage decision) – Call from above
    - (b) Which properties are evaluated (searching strategy)
    - (c) WTP – call from above
    - (d) Bid price – call from above
    - (e) Which property(s) to bid on?
      - i. One per buyer
      - ii. Multiple per buyer
    - (f) Negotiation strategy / Negotiation power – call from above
    - (g) Rules if you don't succeed to purchase
      - i. Adjust budget/WTP/bid price (details)
      - ii. Leave market (details)
  4. **P – Participate in the market as a renter (renting a residence unit)**
    - (a) Determination of budget
    - (b) Which properties are evaluated (searching strategy, assume price taker at fixed offer price)
    - (c) WTP (from above)
    - (d) Which property(s) to apply for?
    - (e) Rules if you don't succeed to purchase
      - i. Adjust budget/WTP (details)
      - ii. Leave market (details)
  5. **P – Participate in the market as a leasor (renting unit to someone else)**
  6. **P - Participate in the market as a seller**
    - (a) **WTA (from above).**
    - (b) **Ask/List price (What proposed sales price do you post to the market?):**  $Askprice_{HA} = (1 + \psi_{HA})WTA_{HA}$ ;  $\psi_{HA}$ : maximum expected leeway on the selling price.
    - (c) **At what scale are the bids collected?**
      - i. **Unique unit scale: at parcel scale.**
      - ii. Aggregate market scale

- (d) **Rules for collecting bids: How many bids to you accept?**
- One per property up for sale
  - Multiple per property.**
- (e) **Who to sell to (how to pick the accepted bid)**
- Single bid rule
    - Accept
    - Accept if  $\geq$  ask price, else reject
    - Accept if  $\geq$  WTA, else reject
    - Other (short text field)
  - Multiple bid rule**
    - Highest price if  $\geq$  ask price
    - Highest price if  $\geq$  WTA
    - Random selection if multiple highest bids.**
    - Other (short text field: Cf. Negotiation strategy / Negotiation power).
  - Custom (long text field): Cf. Negotiation strategy hereafter.**
- (f) **Negotiation strategy: see land exchange template**
- For sellers:**  $Askprice_{HA} = (1 + \psi_{HA})WTA_{HA}$ .
- For buyers:**  $Bidprice_m = (1 - \psi_m)WTP_m(z_i)$ .
- $\psi_j$ ;  $j = \{HA; m\}$ : **maximum expected leeway on the selling price.**
- If there are some bid prices such as  $Bidprice_m \geq Askprice_{HA}$ , an efficient-rationing rule applied: the developers with the highest bid price buy the land parcel.**  
**The transaction price is then equal to the Ask price of the landowner, with no negotiations:**  

$$P(z_L) = AskPrice_{HA}$$
  - If no  $Bidprice_{Max}$  exceeds the  $AskPrice_{HA}$ , no direct sale occurs. Yet, if the  $WTP_m$  for a parcel is greater than its  $WTA_{HA}$ , negotiations are initiated. The highest  $WTP$  from Developer Agent is matched with the landowner's  $WTA_{HA}$ . The final transaction price is then negotiated between  $WTP_{Max}$  and  $WTA_{HA}$ , influenced by market conditions. A higher demand for a parcel raises its price, empowering the seller:**  

$$\bar{P}(z_L) = WTA_{HA}(z_L) + \frac{ND_L}{\chi} [WTP_{Max} - WTA_{HA}(z_L)]$$
**where  $ND_L$  represents potential demand and  $\chi$  denotes the count of Developer Agents with  $n_{m'} \geq 0$ , such that  $m' \in \{1, \dots, \chi\}$  and  $ND_L \leq \chi$ .**
  - A transaction is void if a landowner's  $WTA$  for parcel  $L$  is more than the Developer Agent's  $WTP$ , or if developers have reached their construction capacity ( $\chi = 0$ ).**
- (g) **List price/time on market adjustment rules (price decrease/repackage/upgrade)**
- Adjust price (text field for details)
  - Take unit off the market (text field for details)
  - Default on loan (text field for details)

**Mr. Potatohead Real Estate Market Edition – Agent Decision Template - Developer Home Seller – Prunetti et al. (2025)**

**Demographic classes (These are agent types. Each agent type could buy, sell, or rent, or rent out. Select your agent type here)**

1. Buyers
  - (a) Developers – Land buyers
  - (b) Investors
    - i. Land
    - ii. Residences
  - (c) Households
2. Sellers
  - (a) **Developers**
  - (b) Investors
    - i. Land
    - ii. Residences
  - (c) Households
  - (d) Land owners
3. Renters
  - (a) People who rent residence units (demand)
  - (b) People who rent out residence units (supply)
4. Central bank
5. Government

**Decision making class (In MR POTATOHEAD, this is “agent decision model”) (filled out for each land-market agent type, 1-5 from above in current models)**

1. **A / P – Attributes (methods/function and parameters) that affect decision real estate decision**
  - (a) Budget
  - (b) Preferences
  - (c) Time horizon/discount rate
  - (d) Risk perceptions
  - (e) Price expectations
  - (f) Commuting/Transportation costs
  - (g) Utility function
  - (h) Expected return from renting
  - (i) Model to determine what will be built (developer land buyer)
  - (j) Willingness to Pay
  - (k) **Ask price:**  $Askprice_{L,m} = (1 + \psi_m) WTA_{L,m}$ ;  $\psi_m$  represents the margin that a developer might incorporate to potentially achieve a transaction price exceeding the WTA.
  - (l) **Margin rate of the developer  $\pi_m$ .**
  - (m) **Cost functions (Developers):**  $C_{LivA}(z_L, LivA_m) = C_{LivA} LivA_m$  is the construction cost to build a house of type  $m$ ;  $C_{LivA}$  is a constant.
  - (n) **Willingness to Accept:**  
 $WTA_{L,m}(z_L, LivA_m) = (1 + \pi_m) (\bar{P}_L(z_L) + C_{LivA} \times LivA_m)$   
Where  $\bar{P}_L(z_L)$  is the price paid for the land.
  - (o) Bid price

- (p) Information sources (i.e. Realtor, listings, neighbours)
  - (q) Search strategies
  - (r) Negotiation strategies/negotiation power
  - (s) Household composition
  - (t) Partnership status
  - (u) **Location (note this will be read by the landscape initialization algorithms): vector of characteristics of the (unbuilt) parcel of land ( $z_L$ ): land area  $LA_L$ , distance to the CDB  $dCDB_L$ , distance to the beach  $dB_L$ , sea-view-index: (estimated) access to sea-view (0-100)  $SVI_L$ .**
  - (v) **Characteristics of houses: total surface: in square meters  $LivA_m$ .**
  - (w) Production functions (Developers)
  - (x) **Constraints (i.e. buy/sell, proximity to work—these are likely conditions): Constraint of construction time, between 8 and 11 trimesters.**
2. **P – Decision to participate in the market (become active as a buyer, seller, investor, or renter)**
    - (a) **Decision to participate in the market as a seller: All houses ready for development go on the market.**
      - i. Decision to relocate?
    - (b) Decision to participate in the market as a buyer
    - (c) Decision to participate in the market as a renter
  3. **P – Participate in the market as a buyer**
    - (a) Property budget (includes mortgage decision) – Call from above
    - (b) Which properties are evaluated (searching strategy)
    - (c) WTP – call from above
    - (d) Bid price – call from above
    - (e) Which property(s) to bid on?
      - i. One per buyer
      - ii. Multiple per buyer
    - (f) Negotiation strategy
    - (g) Rules if you don't succeed to purchase
      - i. Adjust budget/WTP/bid price (details)
      - ii. Leave market (details)
      - iii. Stay in the market
  4. **P – Participate in the market as a renter (renting a residence unit)**
    - (a) Determination of budget
    - (b) Which properties are evaluated (searching strategy, assume price taker at fixed offer price)
    - (c) WTP (from above)
    - (d) Which property(s) to apply for?
    - (e) Rules if you don't succeed to purchase
      - i. Adjust budget/WTP (details)
      - ii. Leave market (details)
  5. **P – Participate in the market as a leasor (renting unit to someone else) (rules need to be constructed)**
  6. **P – Participate in the market as a seller**
    - (a) **WTA (from above): Developers decide to sell their house if at least one buyer's bids are greater than their WTA.**
    - (b) **Ask/List price (What proposed sales price do you post to the market?):  $Askprice_{L,m} = (1 + \psi_m) WTA_{L,m}$ ;  $\psi_m$ : maximum expected leeway on the selling price.**

- (c) **At what scale are the bids collected? (pick list) (This is related to the container issues. You might have a container of units, but still list each one separately.)**
- Unique unit scale: at house scale.**
  - Aggregate market scale
- (d) **Rules for collecting bids: How many bids to you accept?**
- One per property up for sale
  - Multiple per property.**
- (e) **Who to sell to (how to pick the accepted bid)**
- Single bid rule
    - Accept
    - Accept if  $\geq$  ask price, else reject
    - Accept if  $\geq$  WTA, else reject
    - Other (short text field)
  - Multiple bid rule**
    - Highest price if  $\geq$  ask price
    - Highest  $Bidprice_m$  if  $\geq Askprice_{i,m}$
    - Highest price if  $\geq$  WTA
    - Random selection if multiple highest bids.**
    - Other (short text field: Cf. Negotiation strategy / Negotiation power).
  - Custom (long text field): Cf. Negotiation strategy hereafter**
- (f) **Negotiation strategy / negotiation power: see property exchange template:**  
**For sellers  $\bar{m}$ :  $Askprice_{\bar{m}} = (1 + \psi_{\bar{m}})WTA_{\bar{m}}$ ;  $\psi_{\bar{m}}$ : maximum expected leeway on the selling price**  
**For buyers  $m$ :  $Bidprice_m = (1 - \psi_m)WTP_m(\eta)$ ;  $\psi_m$ : maximum expected leeway on the selling price**
- The sellers (Developer Agents) scrutinize all bids and identify the highest  $Bidprice$ . If this highest bid,  $Bidprice_{Max}$ , exceeds the seller's asking price,  $AskPrice_{\bar{m}}$ , a sale is finalized at the asking price. Hence, the transaction price is:  

$$\bar{P}(\bar{m}) = AskPrice_{\bar{m}}$$
  - If no bid surpasses the  $AskPrice_{\bar{m}}$ , there is no direct sale. Yet, if a buyer's  $WTP(\bar{m})$  exceeds the  $WTA(\bar{m})$  of the Developer Agent, a negotiation ensues. The Developer Agent determines the highest  $WTP(\bar{m})_{Max}$ , matching it accordingly. The transaction price is then settled between the highest  $WTP$  and the  $WTA$  based on market conditions. The more demand exists for an item, the higher the transaction price and the seller's bargaining power. The transaction price is:  

$$\bar{P}(\bar{m}) = WTA(\bar{m}) + \frac{ND_{\bar{m}}}{C+1} [WTP(\bar{m})_{Max} - WTA(\bar{m})]$$
 where  $ND_{\bar{m}}$  is the number of potential demands (number of household agents bidding for the house plus one if the Investor bids), and  $C$  represents the number of active Household agents on the Housing Market.
  - If the Developer Agent's  $WTA$  for a house  $\bar{m}$  surpasses the highest  $WTP$  of the bidders, no transaction takes place.
- (g) **List price/time on market adjustment rules (price decrease/repackage/upgrade)**
- Adjust price (see above).
  - Take unit off the market if bankruptcy (see above)
  - Default on loan (text field for details): Keep trying to sell the house to new buyers.**

**Mr. Potatohead Real Estate Market Edition – Agent Decision Template – Developers Land Buyer  
– Prunetti et al. (2025)**

**Demographic classes (These are agent types. Each agent type could buy, sell, or rent, or rent out.  
Select your agent type here)**

1. **Buyers**
  - (a) **Developers – Land buyers**
  - (b) Investors
    - i. Land
    - ii. Residences
  - (c) Households
2. **Sellers**
  - (a) Developers
  - (b) Investors
    - i. Land
    - ii. Residences
  - (c) Households
  - (d) Land owners
3. **Renters**
  - (a) People who rent residence units (demand)
  - (b) People who rent out residence units (supply)
4. **Central bank**
5. **Government**

**Decision making class (In MR POTATOHEAD, this is “agent decision model”) (filled out for each  
land-market agent type, 1-5 from above in current models)**

**1. A / P – Attributes (methods/function and parameters) that affect decision real estate decision**

- (a) Budget
- (b) Preferences
- (c) Time horizon/discount rate
- (d) Risk perceptions
- (e) **Price expectations:**  
 $\ln(P_{H,t-1}) = \alpha_H + \beta_{1H} \text{Liv}A_L + \beta_{2H} \text{Liv}A_L^2 + \beta_{3H} \text{Liv}A_L^3 + \beta_{4H} \text{Liv}A_L^4 + \beta_{5H} LA_L + \beta_{6H} / dB_L + \beta_{7H} / dCDB_L + \beta_{8H} SVI_L + \beta_{9H} t + \varepsilon_H$ : **where  $\text{Liv}A_L$  is the living area of the house;  $LA_L$  is the land area;  $dB_L$  is the distance to the nearest beach;  $dCDB_L$  is the distance to the nearest city centre;  $SVI_L$  is the Sea View Index and  $\varepsilon_H$  is the error term. The polynomial terms capture the nonlinear relation between the living area and housing prices. It will be given by the results of a spatial regression using the PERVAL dataset (produced by the Chamber of Notaries on property transactions) on the detached house market transactions.**
- (f) Commuting/Transportation costs
- (g) Utility function
- (h) Expected return from renting
- (i) **Margin rate of the developer  $\pi_m$ .**
- (j) **Location (note this will be read by the landscape initialization algorithms): vector of characteristics of the (unbuilt) parcel of land : distance to the CDB  $dCDB_L$ , distance to the beach  $dB_L$ , sea-view-index: (estimated) access to sea-view (0-100)  $SVI_L$ .**

- (k) **Characteristics of houses: total surface: in square meters  $LivA_L$ .**
  - (l) **Cost functions (Developers):  $C_{LivA}(z_L)$  is the construction cost to build a house ;  $C_{LivA}$  is a constant.**
  - (m) **Model to determine what will be built (developer land buyer): There are  $M$  developers, each of them buy a parcel and build a house of type  $m$ , with  $m = \{1, \dots, M\}$ .**
  - (n) **Willingness to Pay: They determine these WTP by requiring that the selling price allow them to generate a margin  $\pi_m$  on the total cost of the house built on the parcel of land  $L$  (sum of the price paid for buying the parcel of land  $L$  and the construction cost to build a house). They build only one house by parcel. Finally, The willingness to pay (WTP) for a developer  $m$  for a given parcel with the vector characteristics  $z_L$ , is given by the following expression:**

$$WTP_m(z_L) = \frac{P_{H,L,t-1}(z_L, LivA_m) - C_{LivA}(z_L)LivA_m}{1 + \pi_m}$$
  - (o) Ask price
  - (p) Willingness to Accept
  - (q) **Bid price:  $Bidprice_m = (1 - \psi_m)WTP_m(z_L)$ ;  $\psi_m$ : maximum expected leeway on the selling price.**
  - (r) **Information sources (i.e. Realtor, listings, neighbours): They have information about the past prices of parcel and houses built on a parcel sold as a common knowledge.**
  - (s) Search strategies
  - (t) Negotiation strategies/negotiation power
  - (u) Household composition
  - (v) Partnership status
  - (w) Production functions (Developers)
  - (x) **Constraints (i.e. buy/sell, proximity to work—these are likely conditions): Developers have a building capacity constraint which means that they can only build  $n$  houses during a period  $t$ . Thus, one developer  $m$  only bid on  $n_m = n - \sigma_m$  parcels of land, where  $\sigma_m$  is the number of construction site in progress for this developer.**
2. **P – Decision to participate in the market (become active as a buyer, seller, investor, or renter)**
- (a) Decision to participate in the market as a seller
    - i. Decision to relocate?
  - (b) **Decision to participate in the market as a buyer: They bid according to their building capacity constraint.**
  - (c) Decision to participate in the market as a renter
3. **P – Participate in the market as a buyer**
- (a) Property budget (includes mortgage decision) – Call from above
  - (b) **Which properties are evaluated (searching strategy) : All properties are evaluated.**
  - (c) **WTP – call from above.**
  - (d) **Bid price – call from above.**
  - (e) **Which property(s) to bid on?**
    - i. One per buyer
    - ii. **Multiple per buyer: By respect of their building capacity constraints.**
  - (f) **Negotiation strategy: see land exchange template**

**For sellers:  $Askprice_{HA} = (1 + \psi_{HA})WTA_{HA}$**   
**For buyers:  $Bidprice_m = (1 - \psi_m)WTP_m(z_L)$**   
 **$\psi_j$ ;  $j = \{HA, m\}$ : maximum expected leeway on the selling price**

- i. **If there are some bid prices such as  $Bidprice_m \geq Askprice_{HA}$ , an efficient-rationing rule applied: the developers with the highest bid price buy the land parcel. The transaction price is then equal to the Ask price of the landowner, with no negotiations:**  

$$P(z_L) = AskPrice_{HA}$$
  - ii. **If no  $Bidprice_{Max}$  exceeds the  $AskPrice_{HA}$ , no direct sale occurs. Yet, if the  $WTP_m$  for a parcel is greater than its  $WTA_{HA}$ , negotiations are initiated. The highest  $WTP$  from Developer Agent is matched with the landowner's  $WTA_{HA}$ . The final transaction price is then negotiated between  $WTP_{Max}$  and  $WTA_{HA}$ , influenced by market conditions. A higher demand for a parcel raises its price, empowering the seller:**  

$$\bar{P}(z_L) = WTA_{HA}(z_L) + \frac{ND_L}{\chi} [WTP_{Max} - WTA_{HA}(z_L)]$$
**where  $ND_L$  represents potential demand and  $\chi$  denotes the count of Developer Agents with  $n_{m'} \geq 0$ , such that  $m' \in \{1, \dots, \chi\}$  and  $ND_L \leq \chi$ .**
  - iii. **A transaction is void if a landowner's  $WTA$  for parcel  $L$  is more than the Developer Agent's  $WTP$ , or if developers have reached their construction capacity ( $\chi = 0$ ).**
- (g) **Rules if you don't succeed to purchase**
- i. Adjust budget/WTP/bid price (details)
  - ii. Leave market (details)
  - iii. **Stay in the market, commencing house construction to later sell in the housing market, unless they face bankruptcy.**
4. P – Participate in the market as a renter (renting a residence unit)
- (a) Determination of budget
  - (b) Which properties are evaluated (searching strategy, assume price taker at fixed offer price)
  - (c) WTP (from above)
  - (d) Which property(s) to apply for?
  - (e) Rules if you don't succeed to purchase
    - i. Adjust budget/WTP (details)
    - ii. Leave market (details)
5. P – Participate in the market as a leasor (renting unit to someone else)
6. P – Participate in the market as a seller
- (a) WTA (from above)
  - (b) Ask/List price (What proposed sales price do you post to the market?)
  - (c) At what scale are the bids collected?
    - i. Unique unit scale
    - ii. Aggregate market scale
  - (d) Rules for collecting bids: How many bids to you accept?
    - i. One per property up for sale
    - ii. Multiple per property
  - (e) Who to sell to (how to pick the accepted bid)
    - i. Single bid rule
      - A. Accept
      - B. Accept if  $\geq$  ask price, else reject
      - C. Accept if  $\geq$  WTA, else reject
      - D. Other (short text field)
    - ii. Multiple bid rule

- A. Highest price if  $\geq$  ask price
    - B. Highest price if  $\geq$  WTA
    - C. Random selection if multiple highest bids
    - D. Other.
  - iii. Custom
- (f) Negotiation strategy
- (g) List price/time on market adjustment rules (price decrease/repackage/upgrade)
  - i. Adjust price
  - ii. Take unit off the market
  - iii. Default on loan

**Mr. Potatohead Real Estate Market Edition – Agent Decision Template – Household Buyer – Prunetti et al. (2025)**

**Demographic classes (These are agent types. Each agent type could buy, sell, or rent, or rent out. Select your agent type here)**

1. **Buyers**
  - (a) Developers – Land buyers
  - (b) Investors
    - i. Land
    - ii. Residences
  - (c) **Households**
2. **Sellers**
  - (a) Developers
  - (b) Investors
    - i. Land
    - ii. Residences
  - (c) Households
  - (d) Land owners
3. **Renters**
  - (a) People who rent residence units (demand)
  - (b) People who rent out residence units (supply)
4. **Central bank**
5. **Government**

**Decision making class (In MR POTATOHEAD, this is “agent decision model”) (filled out for each land-market agent type, 1-5 from above in current models)**

**1. A / P – Attributes (methods/function and parameters) that affect decision real estate decision**

**(a) Budget:**

The budget constraint of Household Agent  $c$  is given by the following equation:  $Y_c - Tr(D) + \frac{W}{T} = x + P(\eta)$  where  $Y_c$  is the income of the household  $c$ ;  $Tr(D)$  is the commuting cost for a house located at a distance  $D$  to the CDB;  $W$  represents the household's wealth, excluding the agent's wage income, if it has sold one or more parcels of land on the land market. If this is not the case,  $W = 0$ . In the case where  $W > 0$  and the Household Agent is looking for a house, we assume that  $W$  is devoted exclusively to the purchase of a house: if the Household Agent is unable to buy a house in a given period, it invests this amount in the financial market, and its wealth excluding wage income increases by  $W(1+r)$  in the following period. In this case, we assume that the Household Agent devotes a fixed share of the income from the sale(s) made in  $\tau$  over the interval  $\tau = \{\tau, \dots, \tau + T - 1\}$  to house and consume the composite good, so if the selling price of the parcel of land is  $P(z_L)$  the amount  $\frac{P(z_L)}{T}$  is added to this wage income for each period over this interval;  $x$  is the amount of money spent for the composite good;  $P(\eta)$  is the expected price of house and the corresponding parcel of land with characteristics  $\eta$ ,  $\eta = \{\eta_1, \dots, \eta_n\}$ .

- (b) **Preferences:**  $\alpha_k(s_c)$  reflects the preference of a household belonging to class  $c$  for the characteristic  $\eta_k$ . It will be noted that  $\sum_{k=1}^K \alpha_k(s_c) = 1$ .

- (c) **Time horizon/discount rate:** discount rate for the agent  $c$  is  $\delta_c$ ;  $\delta_c \in [0.01, 0.1]$ . The time horizon is  $T = 20$ . It is the same for all agents and corresponds to the mean duration of a loan.
- (d) Risk perceptions
- (e) Price expectations
- (f) **Commuting/Transportation costs:** Households bid on house according to their budget constraint which includes the commuting cost for the distance to the CDB:  $T(dCDB_L) = 0.5404 \times dCDB_L$  (Tax data).
- (g) **Utility function:** The utility function of the households for the house is given by the following expression:  

$$W_c(\eta) = \sum_{j=1}^n \alpha_j \eta_j + Y_c + \frac{W}{T} - T(D) - e^{\eta_0 + \sum_{j=1}^n \beta_j \eta_j}$$

$$\eta_j = (db_L, dCDB_L, SV_L, LivA_\mu)$$
 is the vector of characteristics of the parcel  $L$  and of the house.
- (h) Expected return from renting
- (i) Model to determine what will be built (developer land buyer)
- (j)  $b$  controls the steepness of the WTP function.
- (k) **Willingness to Pay:** Household  $c$  considers all the house available on the market at time  $t$  and computes his maximal utility and bid only on this house. Then he determines his bid function (periodical WTP) for this house. This function is given by the following equation:  

$$\theta_c(\eta) = \frac{YD_c (V_c^{Max})^2}{b^2 + (V_c^{Max})^2}$$

where  $YD_c$  is the amount of money that the  $HA$  spends on housing each period and  $b$  is the slope of the bid function.

In our model,  $YD_c = \omega Y_c + \frac{W}{T} - T(D)$ ; where  $\omega$  = is the rate corresponding to the household's borrowing capacity in relation to its wage income.

Hence, the total WTP in  $t$  for house  $\eta$  is given by:

$$WTP_c(\eta) = \sum_{t=1}^T (1 + \delta_c)^t \theta_c(\eta) = \frac{(1 + \delta_c)[(1 + \delta_c)^T - 1]}{\delta_c} \theta_c(\eta)$$
- (l) Ask price
- (m) Willingness to Accept
- (n) **Bid price:**  $Bidprice_c = (1 - \psi_c) WTP_c(\eta)$ ;  $\psi_c$ : maximum expected leeway on the selling price.
- (o) Information sources (i.e. Realtor, listings, neighbours)
- (p) Search strategies
- (q) Negotiation strategies/negotiation power
- (r) Household composition
- (s) Partnership status
- (t) **Location (note this will be read by the landscape initialization algorithms):** vector of characteristics of the (unbuilt) parcel of land ( $z_L$ ): distance to the CDB  $dCDB_L$ , distance to the beach  $db_L$ , sea-view-index: (estimated) access to sea-view (0-100)  $SVI_L$ .
- (u) **Characteristics of houses:** total surface: in square meters  $LivA_m$ .
- (v) Production functions (Developers)
- (w) Cost functions (Developers)
- (x) **Wealth:**  $W$  comes from the sale of land on the land market.
- (y) Constraints (i.e. buy/sell, proximity to work—these are likely conditions)
- 2. **P – Decision to participate in the market (become active as a buyer, seller, investor, or renter)**
  - (a) Decision to participate in the market as a seller

- i. Decision to relocate?
  - (b) **Decision to participate in the market as a buyer:** As long as he doesn't have a house, the household is always an active buyer.
  - (c) Decision to participate in the market as a renter
3. **P – Participate in the market as a buyer**
  - (a) **Property budget (includes mortgage decision) – Call from above**
  - (b) **Which properties are evaluated (searching strategy) :** all houses are evaluated.
  - (c) **WTP – call from above.**
  - (d) **Bid price – call from above:**  $Bidprice_c = (1 - \psi_c) WTP_c(\eta)$ ;  $\psi_c$ : maximum expected leeway on the selling price.
  - (e) **Which property(s) to bid on?**
    - i. **One per buyer:** Household  $c$  considers all the house available on the market at time  $t$  and computes his maximal utility and bid only on this house.
    - ii. **Multiple per buyer:** He bids on all houses if WTP is positive and can buy multiple houses
  - (f) **Negotiation strategy / negotiation power: see property exchange template:**  
**For sellers  $\bar{m}$ :**  $Askprice_{\bar{m}} = (1 + \psi_{\bar{m}}) WTA_{\bar{m}}$ ;  $\psi_{\bar{m}}$ : maximum expected leeway on the selling price  
**For buyers  $m$  :**  $Bidprice_m = (1 - \psi_m) WTP_m(\eta)$ ;  $\psi_m$ : maximum expected leeway on the selling price
    - **The sellers (Developer Agents) scrutinize all bids and identify the highest  $Bidprice$ . If this highest bid,  $Bidprice_{Max}$ , exceeds the seller's asking price,  $AskPrice_{\bar{m}}$ , a sale is finalized at the asking price. Hence, the transaction price is:**  

$$\bar{P}(\bar{m}) = AskPrice_{\bar{m}}$$
    - **If no bid surpasses the  $AskPrice_{\bar{m}}$ , there is no direct sale. Yet, if a buyer's  $WTP(\bar{m})$  exceeds the  $WTA(\bar{m})$  of the Developer Agent, a negotiation ensues. The Developer Agent determines the highest  $WTP(\bar{m})_{Max}$ , matching it accordingly. The transaction price is then settled between the highest  $WTP$  and the  $WTA$  based on market conditions. The more demand exists for an item, the higher the transaction price and the seller's bargaining power. The transaction price is:**  

$$\bar{P}(\bar{m}) = WTA(\bar{m}) + \frac{ND_{\bar{m}}}{C+1} [WTP(\bar{m})_{Max} - WTA(\bar{m})]$$
**where  $ND_{\bar{m}}$  is the number of potential demands (number of household agents bidding for the house plus one if the Investor bids), and  $C$  represents the number of active Household agents on the Housing Market.**
    - **If the Developer Agent's  $WTA$  for a house  $\bar{m}$  surpasses the highest  $WTP$  of the bidders, no transaction takes place.**
  - (g) **Rules if you don't succeed to purchase**
    - i. Adjust budget/WTP/bid price (details)
    - ii. Leave market (details)
    - iii. **Stay in the market**
4. **P – Participate in the market as a renter (renting a residence unit)**
  - (a) Determination of budget
  - (b) Which properties are evaluated (searching strategy, assume price taker at fixed offer price)
  - (c) WTP (from above)
  - (d) Which property(s) to apply for?
  - (e) Rules if you don't succeed to purchase

- i. Adjust budget/WTP (details)
  - ii. Leave market (details)
- 5. P – Participate in the market as a leasor (renting unit to someone else)
- 6. P - Participate in the market as a seller
  - (a) WTA (from above)
  - (b) Ask/List price (What proposed sales price do you post to the market?)
  - (c) At what scale are the bids collected?
    - i. Unique unit scale
    - ii. Aggregate market scale
  - (d) Rules for collecting bids: How many bids to you accept?
    - i. One per property up for sale
    - ii. Multiple per property
  - (e) Who to sell to (how to pick the accepted bid)
    - i. Single bid rule
      - A. Accept
      - B. Accept if  $\geq$  ask price, else reject
      - C. Accept if  $\geq$  WTA, else reject
      - D. Other (short text field)
    - ii. Multiple bid rule
      - A. Highest price if  $\geq$  ask price
      - B. Highest price if  $\geq$  WTA
      - C. Random selection if multiple highest bids
      - D. Other (short text field).
    - iii. Custom (long text field)
  - (f) Negotiation strategy
  - (g) List price/time on market adjustment rules (price decrease/repackage/upgrade)
    - i. Adjust price (text field for details)
    - ii. Take unit off the market (text field for details)
    - iii. Default on loan (text field for details)

**Mr. Potatohead Real Estate Market Edition – Agent Decision Template – Residence Investor – Prunetti et al. (2025)**

**Demographic classes (These are agent types. Each agent type could buy, sell, or rent, or rent out. Select your agent type here)**

1. **Buyers**
  - (a) Developers – Land buyers
  - (b) **Investor**
    - i. Land
    - ii. **Residences**
  - (c) Households
2. **Sellers**
  - (a) Developers
  - (b) Investors
    - i. Land
    - ii. Residences
  - (c) Households
  - (d) Land owners
3. **Renters**
  - (a) People who rent residence units (demand)
  - (b) People who rent out residence units (supply)
4. **Central bank**
5. **Government**

**Decision making class (In MR POTATOHEAD, this is “agent decision model”) (filled out for each land-market agent type, 1-5 from above in current models)**

1. A / P – Attributes (methods/function and parameters) that affect decision real estate decision
  - (a) **Budget: The investor is assumed to have a limited budget, denoted as  $\Omega$ , which represents the total investment in the home market over a specified period.**
  - (b) Preferences
  - (c) **Time horizon/discount rate: T corresponds to the mean of a loan.**
  - (d) Risk perceptions
  - (e) **Price expectations:  $P_t(\eta)$  is the previous price of a housing  $m$  on the parcel of land  $L$  and  $\varphi(\eta)$  is the previous tourist rental price of a housing  $m$  on the parcel of land  $L$ . These price expectations are given by a spatial regression using a dataset provided by AirDNA, a commercial company that collects short-term vacation rental data.**
  - (f)  **$\gamma$  is the coefficient of net return on rental (net of maintenance costs...).**
  - (g)  **$\eta$  represent the significant variables for determining the price of rents for tourist residences.**
  - (h)  **$\rho(1+r)^{-T}P_t(\eta)$  is the house’s residual value after  $T$  years, with  $\rho \in [0, 1]$ .**
  - (i)  **$\zeta$  is the duration of the tourist season in days.**
  - (j) Commuting/Transportation costs
  - (k) Utility function
  - (l) **Financial market interest rate:  $r \in ]0, 1[$ .**

- (m) **Expected return from renting:** the investor decisions are based only on objective criteria: their expected returns if she buys the house  $\mu$  built on a given land  $i$  at  $P_I(\eta)$ , that is  $R_{fi}(\eta) = -P_I(\eta) + \sum_{t=1}^T \left[ P_I(\eta) - \frac{P_I(\eta)}{(1+r)^{-t}} \right] = (T-1)P_I(\eta) - \frac{1-(1+r)^{-T}}{r}P_I(\eta)$ .  
**The investment choice leans towards a tourist residence over the financial market if:**  $R_{tour}(\eta) \geq R_{fin}(\eta) \Leftrightarrow \frac{\gamma\zeta\varphi(\eta)[1-(1+r)^{-T}]}{r(1-\rho)(1+r)^{-T} + rT-1+(1+r)^{-T}} \geq P_I(\eta)$
- (n) Model to determine what will be built (developer land buyer)
- (o) **Willingness to Pay of the investor for a housing  $m$  on a parcel of land  $L$  is:**  
 $WTP_I(\eta) = \frac{1-(1+r)^{-T}}{r(1-\rho)(1+r)^{-T} + rT-1+(1+r)^{-T}} \gamma\zeta\varphi(\eta)$
- (p) Ask price
- (q) Willingness to Accept
- (r) **Bid price:**  $Bidprice_I = (1 - \psi_I)WTP_I$ ;  $\psi_I$ : the margin reserved for negotiation.
- (s) **Information sources (i.e. Realtor, listings, neighbours):** They have information about the previous tourist rental price of a housing as a common knowledge and the previous tourist rental price of a housing  $m$  on the parcel of land  $i$ .
- (t) Search strategies
- (u) Negotiation strategies/negotiation power
- (v) Household composition
- (w) Partnership status
- (x) **Location (note this will be read by the landscape initialization algorithms):** vector of characteristics of the (unbuilt) parcel of land ( $z_L$ ): land area  $LA_L$ , distance to the CDB  $dCDB_L$ , distance to the beach  $dB_L$ , sea-view-index: (estimated) access to sea-view (0-100)  $SVI_L$ .
- (y) **Characteristics of houses: total surface: in square meters**  $LivA_m$ .
- (z) Production functions (Developers)
- (aa) Cost functions (Developers)
- (ab) Constraints (i.e. buy/sell, proximity to work—these are likely conditions)
2. **P – Decision to participate in the market (become active as a buyer, seller, investor, or renter)**
- (a) Decision to participate in the market as a seller
- i. Decision to relocate?
- (b) **Decision to participate in the market as a buyer: the investor will invest in a tourist rental house if:**  
 $R_{tour}(\eta) \geq R_{fin}(\eta) \Leftrightarrow \frac{\gamma\zeta\varphi(\eta)[1-(1+r)^{-T}]}{r(1-\rho)(1+r)^{-T} + rT-1+(1+r)^{-T}} \geq P_I(\eta)$  and the investor participate to the market.
- (c) Decision to participate in the market as a renter
3. **P – Participate in the market as a buyer**
- (a) Property budget (includes mortgage decision) – Call from above
- (b) **Which properties are evaluated (searching strategy) : all houses are evaluated.**
- (c) **WTP – call from above.**
- (d) **Bid price – call from above:**  $Bidprice_I = (1 - \psi_I)WTP_I$ .
- (e) **Which property(s) to bid on?**
- i. One per buyer
- ii. **Multiple per buyer: She bids on all houses if WTP is positive and can buy multiple houses.**

(f) **Negotiation strategy: see property exchange template:**

**For sellers  $\bar{m}$ :  $Askprice_{\bar{m}} = (1 + \psi_{\bar{m}})WTA_{\bar{m}}$ ;  $\psi_{\bar{m}}$ : maximum expected leeway on the selling price**

**For buyers  $m$ :  $Bidprice_m = (1 - \psi_m)WTP_m(\eta)$ ;  $\psi_m$ : maximum expected leeway on the selling price**

- **The sellers (Developer Agents) scrutinize all bids and identify the highest  $Bidprice$ . If this highest bid,  $Bidprice_{Max}$ , exceeds the seller's asking price,  $AskPrice_{\bar{m}}$ , a sale is finalized at the asking price. Hence, the transaction price is:**

$$\bar{P}(\bar{m}) = AskPrice_{\bar{m}}$$

- **If no bid surpasses the  $AskPrice_{\bar{m}}$ , there is no direct sale. Yet, if a buyer's  $WTP(\bar{m})$  exceeds the  $WTA(\bar{m})$  of the Developer Agent, a negotiation ensues. The Developer Agent determines the highest  $WTP(\bar{m})_{Max}$ , matching it accordingly. The transaction price is then settled between the highest  $WTP$  and the  $WTA$  based on market conditions. The more demand exists for an item, the higher the transaction price and the seller's bargaining power. The transaction price is:**

$$\bar{P}(\bar{m}) = WTA(\bar{m}) + \frac{ND_{\bar{m}}}{C+1} [WTP(\bar{m})_{Max} - WTA(\bar{m})]$$

**where  $ND_{\bar{m}}$  is the number of potential demands (number of household agents bidding for the house plus one if the Investor bids), and  $C$  represents the number of active Household agents on the Housing Market.**

- **If the Developer Agent's  $WTA$  for a house  $\bar{m}$  surpasses the highest  $WTP$  of the bidders, no transaction takes place.**

(g) **Rules if you don't succeed to purchase**

- Adjust budget/WTP/bid price (see above).**
- Leave market (details)
- Continue to bid on the next time step.**

4. P – Participate in the market as a renter (renting a residence unit)

- Determination of budget
- Which properties are evaluated (searching strategy, assume price taker at fixed offer price)
- WTP (from above)
- Which property(s) to apply for?
- Rules if you don't succeed to purchase
  - Adjust budget/WTP (details)
  - Leave market (details)

5. P – Participate in the market as a leasor (renting unit to someone else)

6. P - Participate in the market as a seller

- WTA (from above)
- Ask/List price (What proposed sales price do you post to the market?)
- At what scale are the bids collected?
  - Unique unit scale
  - Aggregate market scale
- Rules for collecting bids: How many bids to you accept?
  - One per property up for sale
  - Multiple per property
- Who to sell to (how to pick the accepted bid)
  - Single bid rule

- A. Accept
    - B. Accept if  $\geq$  ask price, else reject
    - C. Accept if  $\geq$  WTA, else reject
    - D. Other (short text field)
  - ii. Multiple bid rule
    - A. Highest price if  $\geq$  ask price
    - B. Highest price if  $\geq$  WTA
    - C. Random selection if multiple highest bids
    - D. Other (short text field).
  - iii. Custom (long text field)
- (f) Negotiation strategy
- (g) List price/time on market adjustment rules (price decrease/repackage/upgrade)
- i. Adjust price (text field for details)
  - ii. Take unit off the market (text field for details)
  - iii. Default on loan (text field for details)

**Mr. Potatohead Real Estate Market Edition – Landscape Class Template –  
Magliocca et al. 2011**

1. What is the form of the base landscape?
  - a. **Abstract** / Empirical
  - b. Vector or **cell-based** (uniform tessellation of **1-acre resolution**)
  - c. Source of landscape initialization
    - i. **Generic grid**, uniform tessellation
    - ii. CSV file? (Y/N) Enter GIS base layer file name here, or provide link
    - iii. GIS file? (Y/N) Enter GIS base layer file name here, or provide link
  - d. Define coarse-scale land uses
    - i. **Residential and agricultural/undeveloped (10 acre/cell parcels)**
    - ii. **User-specified minimum lot size zoning (e.g., 2-acre, 5-acre or flood risk-based zoning)**
2. What unique products are being bought and sold?
  - a. Number of container types. **4 (1, 2, 5, and 10 acre lots)**. For each container provide the following information:
    - i. Characteristics of the spatial entity (**housing parcel**)
      1. **Spatial location(s)**, if not read from GIS or CSV
        - a. **Each cell in the landscape is characterized by travel cost to the central business district (CBD), proximity to the coastline, a proximity-based coastal amenity level, and flood risk**
      2. **Entire lot area (1-acre cells to 10 acre / cell polygons)**
      3. Building footprint area
      4. Number of Stories
      5. **Transportation accessibility**
        - a. **Annual cost of transportation to and from house location and CBD at a rate of \$25. 85 per cell (\$1.30/mile, 0.0395 miles per cell, and 500 miles travelled per year; Magliocca et al., 2011).**
      6. **Neighbourhood amenities (Unit-free amenity level that decays with distance from the coast (Eq. 2). For baseline settings, the amenity level at the coast ( $A_0$ ) is 500,000, and the rate of amenity decline with distance from the coast ( $r$ ) is 0.08.)**
      7. **Neighbourhood disamenities (Categorization of locations based on potential damages from storms. Classifications are waterfront (immediately adjacent to coast), waterview (within 0.2 miles from coast), and inland).**
    - ii. Characteristics of the spatial entity (**land/residence parcel**)
      1. **Spatial location(s)**, if not read from GIS or CSV
        - a. **Each cell in the landscape is characterized by travel cost to the central business district (CBD),**

2. **Entire lot area (For the land market model: 100 1-acre cells.** The spatial location and total size of the land parcels owned by a landowner agent. Each landowner is assigned 100 acres each (10-by-10 cells). **For the residence market model: 1-10 acres.)**
3. Building footprint area
4. Number of Stories
5. **Transportation accessibility**
  - a. **Annual cost of transportation to and from house location and CBD at a rate of \$25. 85 per cell (\$1.30/mile, 0.0395 miles per cell, and 500 miles travelled per year; Magliocca et al., 2011).**
6. **Proximity to the coastline**
7. **A proximity-based coastal amenity level**
8. **Flood risk**
- iii. Number of different unit categories in the container **(3)**
- iv. Unit category descriptions: (replicate as needed)
  1. **Number of units of this type-4- ¼ acre lots; 2-1/2 acre lots; 1-1,2,5, or 10 acre lots.**
  2. Unit area **(1, 2, 5, or 10 acre)**
  3. Number of room/bedrooms
  4. Number of baths
  5. **Yard/lot size (1/4-10 acres)**
  6. Garage
  7. **Square footage (Square footage of house built on one land parcel: 1500-2,500 ft<sup>2</sup>)**

**Mr. Potatohead Real Estate Market Edition – Property Exchange Class Template – Magliocca et al. (2011)**

1. Which market is being modelled?
  - a. Residences
  - b. Land**
2. Who are the market participants?
  - a. Buyers
    - i. Developers**
    - ii. Investors
    - iii. Households
  - b. Sellers
    - i. Developers
    - ii. Investors
    - iii. Households
    - iv. Landowners**
  - c. Renters
    - i. People who rent units (demand)
    - ii. People who rent out units (supply)
3. Initialize buyer and seller locations
  - a. One agent per spatial container**
  - b. Multiple agents per spatial container
4. What are your ask and bid price rules for market-based land allocation?
  - a. How ask prices posted?
    - i. Public information**
    - ii. Information held by realtor agents
  - b. Bid submission: How many properties can a buyer bid on?
  - c. Bid acceptance: How many bids are accepted per property?
    - i. One, if conditions are met—there is only one developer bidder in the model.**
5. Matching algorithm: How are buyers matched to purchased properties?
  - a. Custom rule
  - b. How units are matched to the seller—subdivision model (many to one) or **single property model** (one to one). *Call to seller ADM(s).*
  - c. How are buyer bids matched to units? *Call to buyer ADM(s)*
  - d. How are winning bids selected? (*Call to seller ADM*)
  - e. How is the transaction price defined?
    - i. Bid price if multiple bids
    - ii. Mean of bid and ask if one bid
    - iii. **Negotiation process. See section 3.3.1 in Magliocca et al. (2011); weighted average (by market power). If the developer's WTP for a given farm is greater than the farmer's WTA for his land, then the two enter into bilateral negotiation to determine the final transaction price of each parcel.**  
**Bargaining power is defined as  $\varepsilon = \frac{d_{Land} - A_{F*}}{d_{Land} - A_{F*}}$ , where  $d_{Land}$  is the acreage demanded by the developer and  $A_{F*}$  is the acreage**

supplied by participating farmers. If the developer demands more land than the farmers supply,  $e$  is positive and farmers bid above their WTA (Section 3.2.3). If farmers supply more land than is demanded by the developer,  $e$  is negative and the developer will bid below his initial WTP (Section 3.2.1).

iv. Custom

6. What market housekeeping occurs in your model?
  - a. **Change ownership – resulting from randomly assigned residence time being met and/or relocation due to perceived disutility of dynamic flood risk**
  - b. Age homes
  - c. **Record sales prices for the next round**
  - d. Seller adjustments for un-sold units (*call to ADM functions*)
  - e. Rules for buyers who did not find a home (*call to ADM functions*)
  - f. **Identify active buyers and sellers** for the next round
7. What are your stopping rules for market activity?
  - a. No market activity in X time periods (*equilibrium rule*)
  - b. **End time periods (30 time steps) (*non-equilibrium rule*)**

**Mr. Potatohead Real Estate Market Edition – Property Exchange Class Template – Magliocca et al. (2011)**

1. Which market is being modelled?
  - a. **Residences**
  - b. Land
2. Who are the market participants?
  - a. Buyers
    - i. Developers
    - ii. Investors
    - iii. **Households**
  - b. Sellers
    - i. **Developers**
    - ii. Investors
    - iii. Households
    - iv. **Landowners**
  - c. Renters
    - i. People who rent units (demand)
    - ii. People who rent out units (supply)
3. Initialize buyer and seller locations (*call to agent's Location field*)
  - a. **One agent per spatial container**
  - b. Multiple agents per spatial container
4. What are your ask and bid price rules for market-based land allocation?
  - a. How ask prices posted?
    - i. Public information
    - ii. **Information held by realtor agents**
  - b. Bid submission: How many properties can a buyer bid on?
    - i. **A given housing consumer will bid on the set of houses for which their WTP is greater than or equal to the developer's asking price, and the house generates a positive utility given the asking price.**
  - c. Bid acceptance: How many bids are accepted per property?
    - i. **All bids above the asking price are accepted.**
5. Matching algorithm: How are buyers matched to purchased properties?
  - a. **Custom rule**
    - i. **After the bidding process is completed, the highest bidder for each house is identified. For each consumer in the set of winning bidders, the set of houses for which the consumer owns the highest bid is identified. The consumer's utility is recalculated for each of these houses using the winning bid instead of the initial asking price. Given these new levels of utility, the consumer is matched with the house that produces the highest utility. Once a consumer is matched with a house, both the consumer and house are removed from the market. The matching process is reiterated with the remaining bids, which are kept constant, until all consumers are matched, all**

houses are occupied, or all positive bids are exhausted. This process ensures consumers are matched to houses that generate their maximum possible utility levels given competitive bids from other consumers and discrete housing options provided by the developer. If there is a tie between buyer's bids, the buyer with the higher utility is awarded the house. If there is still a tie, then a 'coin flip' decides it.

- b. How units are matched to the seller—subdivision model (many to one) or **single property model** (one to one). *Call to seller ADM(s).*
- c. How are buyer bids matched to units? *Call to buyer ADM(s)*
- d. How are winning bids selected? (*Call to seller ADM*) – **housing consumer with the highest bid on a given house**
- e. How is the transaction price defined?
  - i. **Bid price if multiple bids**
  - ii. Mean of bid and ask if one bid
  - iii. Negotiation process (*describe, calling ADM negotiation strategies*)
  - iv. Custom
6. What market housekeeping occurs in your model?
  - a. **Change ownership – resulting from randomly assigned residence time being met and/or relocation due to perceived disutility of dynamic flood risk**
  - b. Age homes
  - c. **Record sales prices for next round**
  - d. **Seller adjustments for un-sold units** (*call to ADM functions*)
  - e. **Rules for buyers who did not find a home** (*call to ADM functions*)
  - f. **Identify active buyers and sellers for next round**
7. What are your stopping rules for market activity?
  - a. No market activity in X time periods (*equilibrium rule*)
  - b. **End time periods (30 time steps)** (*non-equilibrium rule*)

**Mr. Potatohead Real Estate Market Edition – Agent Decision Template – Developer  
Residence Seller – Magglioca et al. (2011)**

**Demographic classes (These are agent types. Each agent type could buy, sell, or rent, or rent out. Select your agent type here)**

1. Buyers
  1. Developers – Land buyers
  2. Investors
    - Land
    - Residences
  3. Households
2. Sellers
  1. **Developers**
  2. Investors
    - Land
    - Residences
  3. Households
  4. Landowners
3. Renters
  1. People who rent residence units (demand)
  2. People who rent out residence units (supply)
4. Central bank (*For future—not in any current models*)
5. Government (*For future—not in any current models*)

**Decision making class (In MR POTATOHEAD, this is “agent decision model”) (filled out for each land-market agent type, 1-5 from above in current models)**

1. A / P – Attributes (methods/function and parameters) that affect decision real estate decision
  - Budget
  - Preferences
  - **Time horizon/discount rate**
    - Discount rate of 5% is used to annualize all land or housing prices, costs, and price expectations. All prices/costs are annualized assuming a 30-yr mortgage and similar loan rate for development/construction costs.
    - Price expectations (land owners, developer, see below) have a maximum of 10 years of past price information from which to form expectations
  - **Risk perceptions**
    - Loss-aversion is taken into account using the prediction error,  $\sigma$ , associated with the most successful rent prediction model for each housing type. High and low estimates of expected returns are then considered in a risk-aversion framework modified from Ligmann-Zielinska (2009) to conform to prospect theory. Potential gains (potgain) and losses (potloss) are calculated relative to a reference point of zero, which represents meeting the profit target of a normal rate of return applied in the equations.

- **Price expectations**
  - **Developers make pricing decisions informed by expectations of future housing prices. Adapted from price expectation models used in agent-based financial literature (e.g. Arthur, 1994, 2006; Axtell, 2005), agents try to predict next period's price based on current and past price information. An agent is given a set of twenty prediction models. Each prediction model may use one of six different prediction methods, and there may be more than one model applying the same prediction method in the agent's set of twenty models. Some of these prediction methods map past and present prices (P) into the next period using various extrapolation methods.**
- **Commuting/Transportation costs**
- **Utility function**
- **Expected return from renting**
- **Model to determine what will be built**
- **Willingness to Pay**
- **Ask price**
  - **List price is based on the developer's spatially-explicit rent projections. Rent projections are calculated as the weighted combination of local and regional (suburb-wide) expected rents for existing houses (3.4.1. Magliocca et al, 2011). The method of rent projection depends on the level of uncertainty in rent expectations. If a given housing type has been built, a spatially weighted extrapolation is made based on distance and price trends. If the given housing type has not yet been built within the region, the developer relies on a hedonic regression model based on existing housing characteristics. The hedonic regression uses median consumer income ( $x_1$ ) from similar housing types, lot size of the given housing type,  $h$  ( $x_2$ ), and travel costs ( $x_3$ ) to and amenity level ( $x_4$ ) in the given location,  $i$ , to project an expected rent:**

$$R_{proj}(i, h) = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_4 x_4$$
**See section 3.4.1 in Magliocca et al. (2011).**
- **Willingness to Accept**
  - **Based on a profit target equal to normal rate of return on investment, assumed to be 5%, above cost to acquire and develop property.**
- **Bid price**
- **Information sources (i.e. Realtor, listings, neighbours)**
  - **The developer uses housing information, which would be available from a listing service or similar source, to form expectations of annual rental payments for different housing types in the next period. The developer is assumed to have costless access to 10 years of information.**
- **Search strategies**
- **Negotiation strategies/negotiation power**
- **Household composition**
- **Partnership status**
- **Location**

- **Production functions (Developers)** (See section 3.2.2 and costs from Table 1).
  - **Cost functions (Developers)**
    - **Carrying costs are incurred by the developer annually and do not compound over time. Carrying costs represent costs to the developer associated with holding vacant property; for example, interest accrued on loans financing the development project or foregone interest on an alternative safe investment. Carrying costs for vacant land equal 5% interest on the price paid for land. Carrying costs for vacant houses equal 5% interest on the combined price paid for land and annualized construction costs of the particular housing type. Thus, available capital in a given period is constrained by the amount of vacant land or houses the developer owns, which influences how much land the developer can acquire each period.**
    - **Costs of construction and infrastructure by housing types are given in Table 1.**
  - **Constraints (i.e. buy/sell, proximity to work—these are likely conditions)**
    - **Spatial locations and number of land parcels purchased from landowners for development determine the land available for housing supply and the potential profitability of housing types.**
2. P -- Decision to participate in the market (become active as a buyer, seller, investor, or renter)
    1. **Decision to participate in the market as a seller**
    2. Decision to participate in the market as a buyer
    3. Decision to participate in the market as a renter
  3. P – Participate in the market as a buyer
    1. Property budget (includes mortgage decision) – Call from above
    2. Which properties are evaluated (searching strategy)
    3. WTP – call from above
    4. Bid price – call from above
    5. Which property(s) to bid on?
      - i. One per buyer
      - ii. Multiple per buyer
    6. Negotiation strategy / Negotiation power – call from above
    7. Rules if you don't succeed to purchase
      - i. Adjust budget/WTP/bid price (details)
      - ii. Leave market (until the next year)
  4. P – Participate in the market as a renter (renting a residence unit)
    1. Determination of budget
    2. Which properties are evaluated (searching strategy, assume price taker at fixed offer price)
    3. WTP (from above)
    4. Which property(s) to apply for?
    5. Rules if you don't succeed to purchase
      - i. Adjust budget/WTP (details)
      - ii. Leave market (details)
  2. P – Participate in the market as a lessor (renting unit to someone else)

5. P – Participate in the market as a seller
  1. **WTA (from above)**
  2. **Ask/List price (from above)**
    - a. **Equals WTA of developer necessary to meet profit target**
  3. At what scale are the bids collected? (pick list) (This is related to the container issues. You might have a container of units, but still list each one separately.)
    - a. **Unique unit scale (each residential unit)**
    - b. Aggregate market scale
  4. Rules for collecting bids: How many bids to you accept?
    - i. One per property up for sale
    - ii. **Multiple per property**
  5. Who to sell to (how to pick the accepted bid)- See section and the Residence Exchange template, Matching Algorithm
    - a. Single bid rule (Only relevant if you have chosen 4 i.)
      - i. Accept
      - ii. Accept if  $\geq$  ask price, else reject
      - iii. **Accept if  $\geq$  WTA, else reject**
      - iv. Other (short text field)
    - b. Multiple bid rule
      - i. Highest price if  $\geq$  ask price
      - ii. **Highest price if  $\geq$  WTA – but see section 3.4.4., as the residence might ultimately go to another bidder at another sales price.**
      - iii. Random selection if multiple highest bids
      - iv. Other
    - c. Custom
  6. Negotiation strategy
  7. List price/time on market adjustment rules (price decrease/repackage/upgrade)
    - i. **Adjust price**
      1. **For each year on the market, the housing price is decreased by the discount rate.**
      - ii. Take unit off the market (text field for details)
      - iii. Default on loan (text field for details)

**Mr. Potatohead Real Estate Market Edition – Agent Decision Template – Land Owner Seller – Magliocca et al. (2011)**

**Demographic classes (These are agent types. Each agent type could buy, sell, or rent, or rent out. Select your agent type here)**

1. Buyers
  1. Developers – Land buyers
  2. Investors
    - Land
    - Residences
  3. Households
2. Sellers
  1. Developers
  2. Investors
    - Land
    - Residences
  3. Households
  4. **Land owners (farmers)**
3. Renters
  1. People who rent residence units (demand)
  2. People who rent out residence units (supply)
4. Central bank (*For future—not in any current models*)
5. Government (*For future—not in any current models*)

**Decision making class (In MR POTATOHEAD, this is “agent decision model”) (filled out for each land-market agent type, 1-5 from above in current models)**

1. A / P – Attributes (methods/function and parameters) that affect decision real estate decision
  - Budget
  - Preferences
  - **Time horizon/discount rate**
    - **Discount rate of 5% is used to annualize all land or housing prices, costs, and price expectations. All prices/costs are annualized assuming a 30-yr mortgage and similar loan rate for development/construction costs.**
    - **Price expectations (land owners, developer) have a maximum of 10 years of past price information from which to form expectations**
  - Risk perceptions
  - **Price expectations**
    - **Landowners observe the price and location of one or more land transactions through time. A landowner then attempts to discount the observed transaction price(s) based on the distance from his location. The spatially discounted price(s) accounts for spatially variable land values and enables an adjustment of land prices based solely on trends in the market land price. Price prediction models are detailed in Appendix A of Magliocca et al. 2011.**

- Commuting/Transportation costs
  - Utility function
  - Expected return from renting
  - Model to determine what will be built (developer land buyer)
  - Willingness to Pay
  - **Ask price**
    - **Greater than or equal to WTA subject to land market competition. See Eq. 13 in Magliocca et al. (2011). “The asking price of the market-participating farmer,  $F_i$ , is equal to or greater than the value of his land in agriculture. If the developer demands more land than farmers supply, each farmer will mark up his asking price to potentially maximize gains from trade.” (p. 187)**
  - **Willingness to Accept**
    - **Minimum price per acre that the landowner would be willing to sell to a developer. As development pressure increases, WTA can exceed the reservation price. See section 3.2.3, based on a comparison of returns to agriculture vs. expected sales prices using multiple expectations mechanisms, see equation 11.**
  - Bid price
  - **Information sources (i.e. Realtor, listings, neighbours) Farmers are assumed to have access to data on farming returns plus up to ten years of land prices.**
  - Search strategies
  - **Negotiation strategies/negotiation power**
    - **If the developer’s WTP for a given landowner’s holding is greater than the landowner’s WTA for land, then the two enter into bilateral negotiation to determine the final transaction price. Bargaining power in the land market is adapted from Parker and Filatova (2008) and captures differences in the developer’s demand for, and the landowners’ supply of, land at the initial WTP of the developer. (See section 3.3.1)**
  - Household composition
  - Partnership status
  - **Location Land holdings - the spatial location and total size of the land parcels owned by a landowner agent. Each landowner is assigned 100 acres each (10-by-10 cells).**
  - Production functions (Developers)
  - Cost functions (Developers)
  - **Constraints (i.e. buy/sell, proximity to work—these are likely conditions)**
    - **Reservation price - the economic returns generated from the land parcels in the highest value, undeveloped state. Along the coast, this is equal to the speculative value of the land for development. Further inland, this may be equal to returns from agriculture.**
2. P -- Decision to participate in the market (become active as a buyer, seller, investor, or renter)
1. **Decision to participate in the market as a seller. Farmers compare the returns from farming to expected profit from selling their land to a single**

**representative developer and make the decision each period whether to continue farming or enter the land market.**

1. Decision to relocate?
2. Decision to participate in the market as a buyer
3. Decision to participate in the market as a renter
3. P – Participate in the market as a buyer
  1. Property budget (includes mortgage decision) – Call from above
  2. Which properties are evaluated (searching strategy)
  3. WTP – call from above
  4. Bid price – call from above
  5. Which property(s) to bid on?
    - i. One per buyer
    - ii. Multiple per buyer
  6. Negotiation strategy / Negotiation power – call from above
  7. Rules if you don't succeed to purchase
    - i. Adjust budget/WTP/bid price (details)
    - ii. Leave market (details)
4. P – Participate in the market as a renter (renting a residence unit)
  1. Determination of budget
  2. Which properties are evaluated (searching strategy, assume price taker at fixed offer price)
  3. WTP (from above)
  4. Which property(s) to apply for?
  5. Rules if you don't succeed to purchase
    - i. Adjust budget/WTP (details)
    - ii. Leave market (details)
2. P – Participate in the market as a leasor (renting unit to someone else)
5. P – Participate in the market as a seller
  1. **WTA (from above)**
  2. **Ask/List price**
    - a. **Based on a land owner's reservation price and perceived competition in the land market.**
  3. At what scale are the bids collected?
    - a. **Unique unit scale**
    - b. Aggregate market scale
  4. Rules for collecting bids: How many bids to you accept?
    - i. **One per property up for sale (*becomes a bilateral transaction model*) because CHALMS has only one representative developer; the land market is a series of bilateral negotiations and transactions.**
    - ii. Multiple per property
  5. Who to sell to (how to pick the accepted bid)
    - a. Single bid rule (Only relevant if you have chosen 4 i.)
      - i. Accept
      - ii. **Accept if  $\geq$  ask price, else reject**
      - iii. Accept if  $\geq$  WTA, else reject

- iv. Other (short text field)
  - b. Multiple bid rule
    - i. Highest price if  $\geq$  ask price
    - ii. Highest price if  $\geq$  WTA
    - iii. Random selection if multiple highest bids
    - iv. Other
  - c. Custom
- 6. **Negotiation strategy -See 3.3.1. Implicit negotiation strategy.**
- 7. List price/time on market adjustment rules (price decrease/repackage/upgrade)
  - i. Adjust price**
  - ii. Take unit off the market
  - iii. Default on loan

**Mr. Potatohead Real Estate Market Edition – Agent Decision Template – Developer Land Buyer – Magglioca et al. (2011)**

**Demographic classes (These are agent types. Each agent type could buy, sell, or rent, or rent out. Select your agent type here)**

1. Buyers
  1. **Developers – Land buyers**
  2. Investors
    - Land
    - Residences
  3. Households
2. Sellers
  1. Developers
  2. Investors
    - Land
    - Residences
  3. Households
  4. Landowners
3. Renters
  1. People who rent residence units (demand)
  2. People who rent out residence units (supply)
4. Central bank (*For future—not in any current models*)
5. Government (*For future—not in any current models*)

**Decision making class (In MR POTATOHEAD, this is “agent decision model”) (filled out for each land-market agent type, 1-5 from above in current models)**

1. A / P – Attributes (methods/function and parameters) that affect decision real estate decision
  - Budget
  - Preferences
  - **Time horizon/discount rate**
    - Discount rate of 5% is used to annualize all land or housing prices, costs, and price expectations. All prices/costs are annualized assuming a 30-yr mortgage and similar loan rate for development/construction costs.
    - Price expectations (land owners, developer, see below) have a maximum of 10 years of past price information from which to form expectations
  - **Risk perceptions**
    - Loss-aversion is taken into account using the prediction error,  $\sigma$ , associated with the most successful rent prediction model for each housing type. High and low estimates of expected returns are then considered in a risk-aversion framework modified from Ligmann-Zielinska (2009) to conform to prospect theory. Potential gains (potgain) and losses (potloss) are calculated relative to a reference point of zero, which represents meeting the profit target of a normal rate of return applied in the equations.

- **Price expectations**
  - **Developers make pricing decisions informed by expectations of future housing prices. Adapted from price expectation models used in agent-based financial literature (e.g. Arthur, 1994, 2006; Axtell, 2005), agents try to predict the next period's price based on current and past price information. An agent is given a set of twenty prediction models. Each prediction model may use one of six different prediction methods, and there may be more than one model applying the same prediction method in the agent's set of twenty models. Some of these prediction methods map past and present prices (P) into the next period using various extrapolation methods.**
- **Commuting/Transportation costs**
- **Utility function**
- **Expected return from renting**
- **Model to determine what will be built**
  - **Decision to build is based on expected profits given observed housing prices among contiguous developed land parcels for each housing type to inform future price expectations.**
- **Willingness to Pay**
  - **Maximum price per acre the developer is willing to pay for a landowners holdings based on expected profit from rents of residences. See section 3.2.2 in Magliocca et al. 2011.**
- **Ask price**
- **Willingness to Accept**
- **Bid price**
  - **Equal to net positive return of housing development per acre after accounting for bargaining power in the land market (i.e., land demand relative to supply). See 3.3.3 in Magliocca et al. (2011).**
- **Information sources (i.e. Realtor, listings, neighbours)**
  - **The developer uses housing information, which would be available from a listing service or similar source, to form expectations of annual rental payments for different housing types in the next period. The developer is assumed to have costless access to 10 years of information.**
- **Search strategies. See section 3.3.3 in Magliocca et al. (2011); If farmers supply more land than the developer demands, the developer will mark down his bid price for each farm to maximize both gains from trade and profit from sales of houses in that location.**
- **Negotiation strategies/negotiation power**
  - **If the developer's WTP for a given landowner's holding is greater than the landowner's WTA for land, then the two enter into bilateral negotiation to determine the final transaction price. Bargaining power in the land market is adapted from Parker and Filatova (2008) and captures differences in the developer's demand for, and the landowners' supply of, land at the initial WTP of the developer.**
- **Household composition**
- **Partnership status**

- Location
  - **Production functions (Developers)** (See section 3.2.2 and costs from Table 1).
  - **Cost functions (Developers)**
    - Carrying costs are incurred by the developer annually and do not compound over time. Carrying costs represent costs to the developer associated with holding vacant property; for example, interest accrued on loans financing the development project or foregone interest on an alternative safe investment. Carrying costs for vacant land equal 5% interest on the price paid for land. Carrying costs for vacant houses equal 5% interest on the combined price paid for land and annualized construction costs of the particular housing type. Thus, available capital in a given period is constrained by the amount of vacant land or houses the developer owns, which influences how much land the developer can acquire each period.
    - Costs of construction and infrastructure by housing types are given in Table 1.
  - **Constraints (i.e. buy/sell, proximity to work—these are likely conditions)**
    - Spatial locations and number of land parcels purchased from landowners for development determine the land available for housing supply and the potential profitability of housing types.
2. P -- Decision to participate in the market (become active as a buyer, seller, investor, or renter)
    1. Decision to participate in the market as a seller
    2. **Decision to participate in the market as a buyer**
    3. Decision to participate in the market as a renter
  3. P – Participate in the market as a buyer
    1. Property budget (includes mortgage decision) – Call from above
    2. **Which properties are evaluated (searching strategy)**
      - a. All land parcels with expected positive return
    3. **WTP – call from above**
    4. **Bid price – call from above**
    5. Which property(s) to bid on?
      - i. One per buyer
      - ii. **Multiple per buyer**
    6. **Negotiation strategy / Negotiation power – call from above**
    7. Rules if you don't succeed to purchase
      - i. Adjust budget/WTP/bid price (details)
      - ii. **Leave the market (until the next year)**
  4. P – Participate in the market as a renter (renting a residence unit)
    1. Determination of budget
    2. Which properties are evaluated (searching strategy, assume price taker at fixed offer price)
    3. WTP (from above)
    4. Which property(s) to apply for?
    5. Rules if you don't succeed to purchase
      - i. Adjust budget/WTP (details)

- ii. Leave market (details)
- 5. P – Participate in the market as a leasor (renting unit to someone else)
- 6. P – Participate in the market as a seller
  - 1. WTA (from above)
  - 2. Ask/List price (What proposed sales price do you post to the market?)
  - 3. At what scale are the bids collected?
    - a. Unique unit scale
    - b. Aggregate market scale
  - 4. Rules for collecting bids: How many bids do you accept?
    - i. One per property up for sale
    - ii. Multiple per property
  - 5. Who to sell to (how to pick the accepted bid)
    - a. Single bid rule (Only relevant if you have chosen 4 i.)
      - i. Accept
      - ii. Accept if  $\geq$  ask price, else reject
      - iii. Accept if  $\geq$  WTA, else reject
      - iv. Other (short text field)
    - b. Multiple bid rule
      - i. Highest price if  $\geq$  ask price
      - ii. Highest price if  $\geq$  WTA
      - iii. Random selection if multiple highest bids
      - iv. Other.
    - c. Custom
- 6. Negotiation strategy
- 7. List price/time on market adjustment rules (price decrease/repackage/upgrade)
  - i. Adjust price
  - ii. Take unit off the market (text field for details)
  - iii. Default on loan (text field for details)

**Mr. Potatohead Real Estate Market Edition – Agent Decision Template – Housing Consumer/Residence Buyer – Magliocca et al. (2011)**

**Demographic classes (These are agent types. Each agent type could buy, sell, or rent, or rent out. Select your agent type here)**

1. Buyers
  1. Developers – Land buyers
  2. Investors
    - Land
    - Residences
  3. **Households**
2. Sellers
  1. Developers
  2. Investors
    - Land
    - Residences
  3. Households
  4. Land owners
3. Renters
  1. People who rent residence units (demand)
  2. People who rent out residence units (supply)
4. Central bank (*For future—not in any current models*)
5. Government (*For future—not in any current models*)

**Decision making class (In MR POTATOHEAD, this is “agent decision model”) (filled out for each land-market agent type, 1-5 from above in current models)**

1. A / P – Attributes (methods/function and parameters) that affect decision real estate decision
  - **Budget**
    - Annual household income spent between housing and all other goods (i.e., ‘consumer good’). Incomes are heterogeneous among agents and drawn randomly from a log-normal distribution with  $\mu=\$86,450$  and  $\sigma=\$39,095$  and a range of [40,000, 200,000].
    - Proportion of income spent on housing in Cobb-Douglas utility function. This proportion varies based on income level: \$40-\$80k is .35–.42; \$80-\$120k is .27–.34; and > \$120k is .18–.26. See table 1.
    - A consumer’s budget constraint is given by:
$$I_c = x + P_{ask|i} [1 + \rho(C(d_i) - IP_{d_i}^{cov})] + \psi_i + IP_{d_i}^{cost}$$

$I_c$  is income,  $\psi_i$  is the travel cost from the location  $i$  to the CBD,  $\rho$  is subjective risk perception of the occurrence of a storm (see *Dynamic Subjective Risk Perception*),  $C$  is the expected damage from a storm in location  $i$ , and  $IP^{cov}$  and  $IP^{cost}$  are the amount of coverage and cost of an insurance premium, respectively, in location  $i$  with distance from the coast  $d$ . (Source: Appendix A ODD from Magliocca et al. 2018)
  - **Preferences**

- **Consumer good**
- **House size**
- **Lot size**
- **Environmental amenity (e.g., coastal, open space)** (*Source: Magliocca et al. 2018*)
- **Time horizon/discount rate**
- **Risk perceptions**
  - **Dynamically updated based on direct experience (or lack thereof) of storm events.** The expected annual probability of a storm  $E(p)$ , or subjective risk perception, at time  $t$  is formalized as:
$$E(p|S'_t, t') = \frac{S'_t + \alpha}{t' + \alpha + \beta}$$

where  $\alpha$  and  $\beta$  are parameters of a beta distribution,  $S'_t = \sum_{s=1}^t y_s \delta^{t-s}$  are weighted storm observations, and  $t' = \sum_{s=1}^t \delta^{t-s}$  is the number of yearly observation 'equivalents with time-weighting parameter  $\delta = 0.91$  following the findings of Gallagher (2014). (Magliocca et al. 2018, Appendix A, section 3.4.4)
- **Price expectations**
- **Commuting/Transportation costs**
  - **Annual cost of transportation to and from house location and CBD at a rate of \$25.85 per cell (\$1.30/mile, 0.0395 miles per cell, and 500 miles travelled per year; Magliocca et al., 2011).**
- **Utility function**
  - **Consumer  $c$ 's utility function has a Cobb–Douglas form (see equation 3 from Appendix A, Magliocca et al. 2018)**

$$U(c, i) = x^{\alpha_c} a(d_i)^{\beta_c}$$
- **Expected return from renting**
- **Model to determine what will be built (developer land buyer)**
- **Willingness to Pay**
  - **The willingness to pay (WTP) of a consumer for any given house is equal to the proportion of the consumer's income that goes towards housing (see Equation 5 from Magliocca et al. 2018, Appendix A, section 2.2.1.1:**

$$WTP(c, i) = (I_c - \psi_i - IP_{d_i}^{cost}) \left( \frac{\beta_c}{1 - \rho(C(d_i) - IP_{d_i}^{cov})} \right)$$
- **Ask price**
- **Willingness to Accept**
- **Bid price**
  - **A bid,  $R^*(c, n)$ , for each housing option available for each consumer that reflects the relative utility difference between that option and the one that produces the maximum utility,  $U^*$ :**

$$R^*(c, n) = P_{ask|n} \frac{U(c, n)}{U^*}$$

The consumer's bid for any particular house is then the minimum of their *WTP* or the bid price calculated here (Equation 31 in section 3.4.1 Appendix A, Magliocca et al. 2018).
- **Information sources (i.e. Realtor, listings, neighbours)**

- Housing consumers are assumed to know how many other housing consumers are bidding on the same set of houses. It is assumed that this information is communicated by a real estate agent.
- Search strategies. “Consumer  $c$  will bid on houses for which his WTB is greater than or equal to the developer’s asking prices,  $Pask|j$ , multiplied by the bid level,  $X|t$  for housing type  $lt$ . The bid level is the running average percentage that sale prices have been above/below the original asking prices for houses of type  $lt$  in the past.” Magliocca et al. 2011, section 3.4.2
- Negotiation strategies/negotiation power
  - The housing-market competition factor,  $HMC$ , describes the competition for housing each consumer faces in the housing market:
 
$$HMC_c = \frac{N_C - N_H}{N_C + N_H}$$

where  $N_H$  is the number of houses the consumer bids on and  $N_C$  is the number of other consumers bidding on those same houses (Equation 16, Magliocca et al 2011). Consumer  $c$  then modifies their bid price,  $R^*$ , for each house in response to market conditions using  $HMC$ . Competition is high for a given consumer if there are more bidders for the houses he/she is bidding on than there are houses, and the bid will be increased. Competition is relatively low if there are more houses he/she is bidding on than total bidders for those houses, and the bid is adjusted downward. The adjustment of consumers’ bid prices in response to market conditions allows consumers to attempt to maximize their gains from trade and the likelihood that they will be the highest bidder. (See also 2.6.1 in Appendix A, ODD, 2018)
- Household composition
- Partnership status
- **Location**
- Production functions (Developers)
- Cost functions (Developers)
- Constraints (i.e. buy/sell, proximity to work—these are likely conditions)
- 2. P -- Decision to participate in the market (become active as a buyer, seller, investor, or renter)
  1. Decision to participate in the market as a seller
    1. **Decision to relocate?**
      1. Endogenous relocation can be triggered by updated utility for a given residence and location following a storm event. If higher utility properties exist and decrease in utility exceeds moving costs, then housing consumer will vacate residence and re-enter the housing consumer pool.
    2. **Decision to participate in the market as a buyer.** In Magliocca et al. 2018 (see Appendix A section 2.6.1), consumers have a stochastic residence time, and when their residence time is up, they look for a new home. New consumers are also introduced to the market each year.
    3. Decision to participate in the market as a renter
- 3. P – Participate in the market as a buyer

1. **Property budget (includes mortgage decision) – see Budget above**
  2. Which properties are evaluated (see searching strategy)
  3. **WTP – call from above**
  4. **Bid price – call from above**
  5. Which property(s) to bid on?
    - i. One per buyer
    - ii. **Multiple per buyer (see Equation 15 from Magliocca et al. 2011)**
  6. **Negotiation strategy / Negotiation power – call from above**
  7. Rules if you don't succeed to purchase
    - i. Adjust budget/WTP/bid price (details)
    - ii. **Leave the market (after 3 time steps of unsuccessful bids)**
4. P – Participate in the market as a renter (renting a residence unit)
    1. Determination of budget
    2. Which properties are evaluated (searching strategy, assume price taker at fixed offer price)
    3. WTP (from above)
    4. Which property(s) to apply for?
    5. Rules if you don't succeed to purchase
      - i. Adjust budget/WTP (details)
      - ii. Leave market (details)
  2. P – Participate in the market as a leasor (renting unit to someone else)
  5. P – Participate in the market as a seller
    1. WTA (from above)
    2. Ask/List price (What proposed sales price do you post to the market?)
    3. At what scale are the bids collected?
      - a. Unique unit scale
      - b. Aggregate market scale
    4. Rules for collecting bids: How many bids to you accept?
      - i. One per property up for sale
      - ii. Multiple per property
    5. Who to sell to (how to pick the accepted bid)
      - a. Single bid rule (Only relevant if you have chosen 4 i.)
        - i. Accept
        - ii. Accept if  $\geq$  ask price, else reject
        - iii. Accept if  $\geq$  WTA, else reject
        - iv. Other (short text field)
      - b. Multiple bid rule
        - i. Highest price if  $\geq$  ask price
        - ii. Highest price if  $\geq$  WTA
        - iii. Random selection if multiple highest bids
        - iv. Other
      - c. Custom
    6. Negotiation strategy
    7. List price/time on market adjustment rules (price decrease/repackage/upgrade)
      - i. Adjust price (text field for details)

- ii. Take unit off the market (text field for details)
- iii. Default on loan (text field for details)

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