Supplementary Material

RICE50+: DICE model at country and regional level

A. Model regions and countries mapping

Table S1: Model regions and corresponding ISO3 countries.

Regions List		
Region	Description	Countries ISO3 code
Arg	Argentina	ARG
Aus	Australia	AUS
Aut	Austria	AUT
Bel	Belgium	BEL
Bgr	Bulgaria	BGR
Blt	Baltic states	EST, LTU, LVA
Bra	Brazil	BRA
Can	Canada	CAN
Che	Switzerland	CHE
Chl	Chile	CHL
Chn	China	CHN
Cze	Czech Republic	CZE
Deu	Germany	DEU
Dnk	Denmark	DNK
Egy	Egypt	EGY
Esp	Spain	ESP
Fin	Finland	FIN
Fra	France	FRA
FSU	Former Soviet Union	ARM, AZE, BLR, GEO, KAZ, KGZ, MDA, TJK, TKM, UZB
GBR	UK	GBR
Gulf	Gulf Countries	ARE, BHR, IRN, IRQ, KWT, OMN, QAT, SAU, YEM
Grc	Greece	GRC
Hrv	Croatia	HRV
Hun	Hungary	HUN
Idn	Indonesia	IDN
Ind	India	IND
Irl	Ireland	IRL
ita	Italy	ITA
jpn	Japan	JPN
Kor	Korea	KOR
MEast	Middle East	ISR, JOR, SYR, LBN, PSE
Mex	Mexico	MEX
Mys	Malaysia	MYS

Nld	Netherlands	NLD
NAfr	North Africa	ESH, TUN, MAR
NWAfr	North-West Africa	LBY, DZA
Nor	Norway	NOR
Ocean	Pacific Island	CXR, COK, HMD, NFK, NIU, NRU, PCN, TKL, TUV, UMI, WLF, FJI, PNG, FSM, GUM, ASM, TLS, PYF, KIR, MNP, MHL, NCL, PLW, WSM, SLB, TON, VUT, NZL
Pol	Poland	POL
Prt	Portugal	PRT
RCAm	Rest Central America	BES, CUW, SXM, ABW, BHS, BLZ, BRB, CRI, CUB, DMA, DOM, GRD, GTM, HND, HTI, JAM, LCA, NIC, PAN, SLV, TTO, VCT, BMU, SGS, TCA, VGB, VIR, AIA, ATG, BLM, CYM, GLP, KNA, MAF, MSR, MTQ, PRI
REur	Rest Europe	CYP, LUX, MLT, LIE, GRL, ISL, FRO, ALA, AND, GGY, GIB, IMN, JEY, MCO, SJM, SMR, VAT, SPM, BIH, ALB, MKD, MNE, SRB, KSV
Rou	Romania	ROU
RSAm	Rest South America	BOL, COL, ECU, FLK, GUF, GUY, PER, PRY, SUR, URY, VEN
RSAs	Rest South Asia	AFG, BGD, BTN, LKA, MDV, NPL, PAK
RSEAs	Rest South-East Asia	BRN, CCK, KHM, LAO, MMR, PHL, SGP, PRK, HKG, MAC, TWN, MNG
Rus	Russia	RUS
SSAfr	Sub-Saharan Africa	AGO, BEN, BWA, BFA, BDI, CMR, CPV, CAF, TCD, COM, COG, COD, CIV, GNQ, ERI, ETH, GAB, GMB, GHA, GIN, GNB, KEN, LSO, LBR, MDG, MWI, MLI, MRT, MUS, MYT, MOZ, NAM, NER, NGA, REU, RWA, STP, SEN, SYC, SHN, SLE, SOM, SSD, SDN, SWZ, TZA, TGO, UGA, ZMB, ZWE, DJI, IOT, BVT, ATF
Slo	Slovenia	SVN
Svk	Slovakia	SVK
Swe	Sweden	SWE
Tha	Thailand	THA
Tur	Turkey	TUR
Ukr	Ukraine	UKR
USA	USA	USA
Vnm	Vietnam	VNM
Zaf	South Africa	ZAF

B. Proof of simplified impact specification

Lemma1. *In an economic growth model with a Cobb-Douglas production function, stable capital-labor ratios, and "small" exogenous annualized growth rates g_{it}, the Burke et al. (2015) or similar damage function based on temperature-dependent annual growth impacts δ_{it} is approximately equivalent to using a damage function for a model with time step of Δt if I compute Ω_{it} as:*

$$\Omega_{it} = (1 + \Omega_{it-\Delta t})\frac{1}{(1 + \delta_{it})^{\Delta t}} - 1$$

Proof. With GDP given by $Y_{\mathrm{GROSS},it} = \mathrm{TFP}_{it} K_{it}^{\alpha} L_{it}^{1-\alpha}$, as in eq. (1), I have that the per-capita growth factor equals to:

$$\frac{Y_{\mathrm{GROSS},it}/L_{it}}{Y_{\mathrm{GROSS},it-\Delta t}/L_{it-\Delta t}} = \frac{\mathrm{TFP}_{it}}{\mathrm{TFP}_{it-\Delta t}} \frac{(K_{it}/L_{it})^{\alpha}}{(K_{it-\Delta t}/L_{it-\Delta t})^{\alpha}}.$$

Given that historically, the capital-labor ratio in economies can be approximately considered very stable over time, I have that the annualized per-capita growth rate without climate impacts between t and $t + \Delta t$ can be computed as $(1+g_{it})^{\Delta t} \approx \frac{\mathrm{TFP}_{it}}{\mathrm{TFP}_{it-\Delta t}}$. Now, based on the standard damage function in eq. (24), I have that $Y_{\mathrm{NET},it} = \frac{Y_{\mathrm{GROSS},it}}{1+\Omega_{it}}$ and then:

$$\frac{Y_{\mathrm{NET},it}/L_{it}}{Y_{\mathrm{NET},it-\Delta t}/L_{it-\Delta t}} \approx \frac{\mathrm{TFP}_{it}}{\mathrm{TFP}_{it-1}} \frac{1+\Omega^T_{it-\Delta t}}{1+\Omega^T_{it}}.$$

To obtain the equivalence to the annual growth rate impacts given by eq. (26), I need thus to solve the equation $(1+g_{it}+\delta_{it})^{\Delta t} = (1+g_{it})^{\Delta t}\frac{1+\Omega_{it-\Delta t}}{1+\Omega_{it}}$. Looking at the annualized growth rates, and since for growth rates and growth rate impacts of up to, say, 2% or 0.02, $g_{it} \approx 0$ and moreover $\delta_{it} \approx 0$, the left-hand side is close and approximal to $((1+g_{it})(1+\delta_{it}))^{\Delta t}$. Therefore, the baseline growth factor drops out and I have $(1+\delta_{it}) = \left(\frac{1+\Omega_{it-\Delta t}}{1+\Omega_{it}}\right)^{1/\Delta t}$. Solving for Ω_{it} I finally obtain:

$$\Omega_{it} = (1+\Omega_{it-\Delta t})\frac{1}{(1+\delta_{it})^{\Delta t}} - 1,$$

so that the standard damage factor used on consumption or GDP can be used, only in a recursive form.

I compared the resulting country-level impacts in the RCP8.5 with SSP5 baseline GDP projections as in Burke et al. (2015) and found correlations of 0.9998 in 2050 and 0.9858 in 2100 with the approximated implementation based on Lemma 1.

C. Additional figures for qualitative calibrations

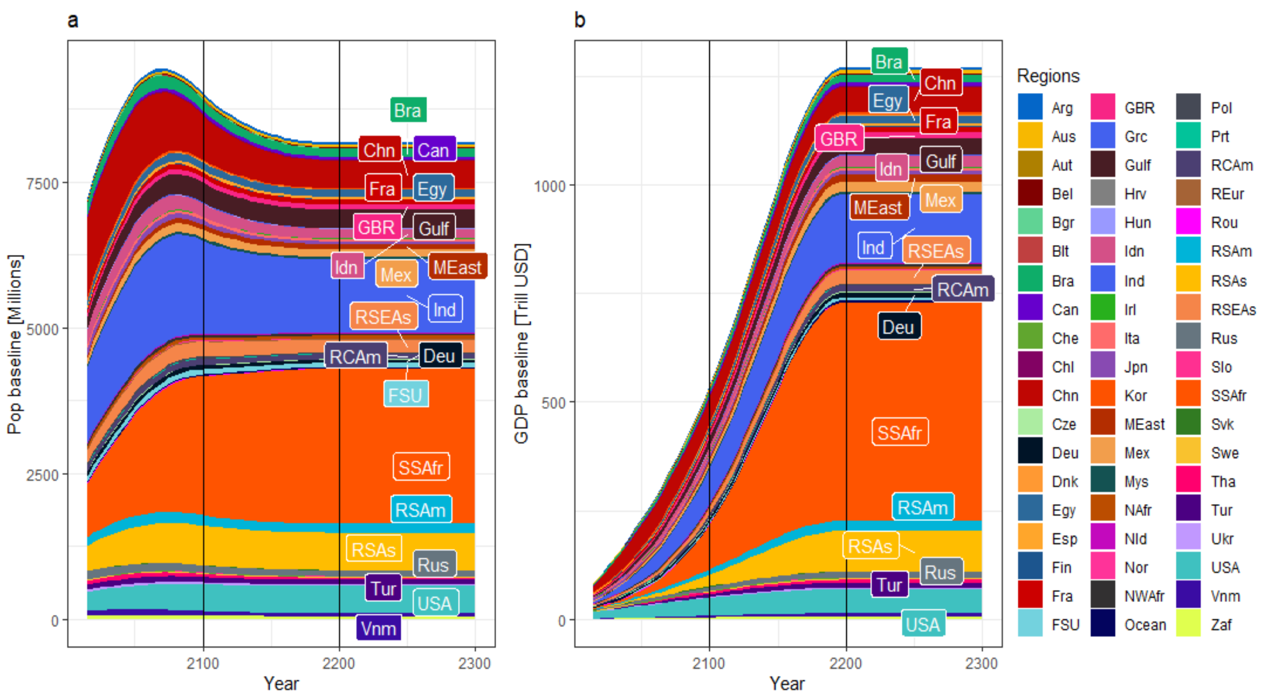

Figure S1: SSP2 scenario projections for regional population (a) and gross GDP [PPP] (b) over the full time-horizon. Values from 2015 to 2100 are extracted from SSP dataset. Values beyond 2100 are estimated according to the conservative approach described.

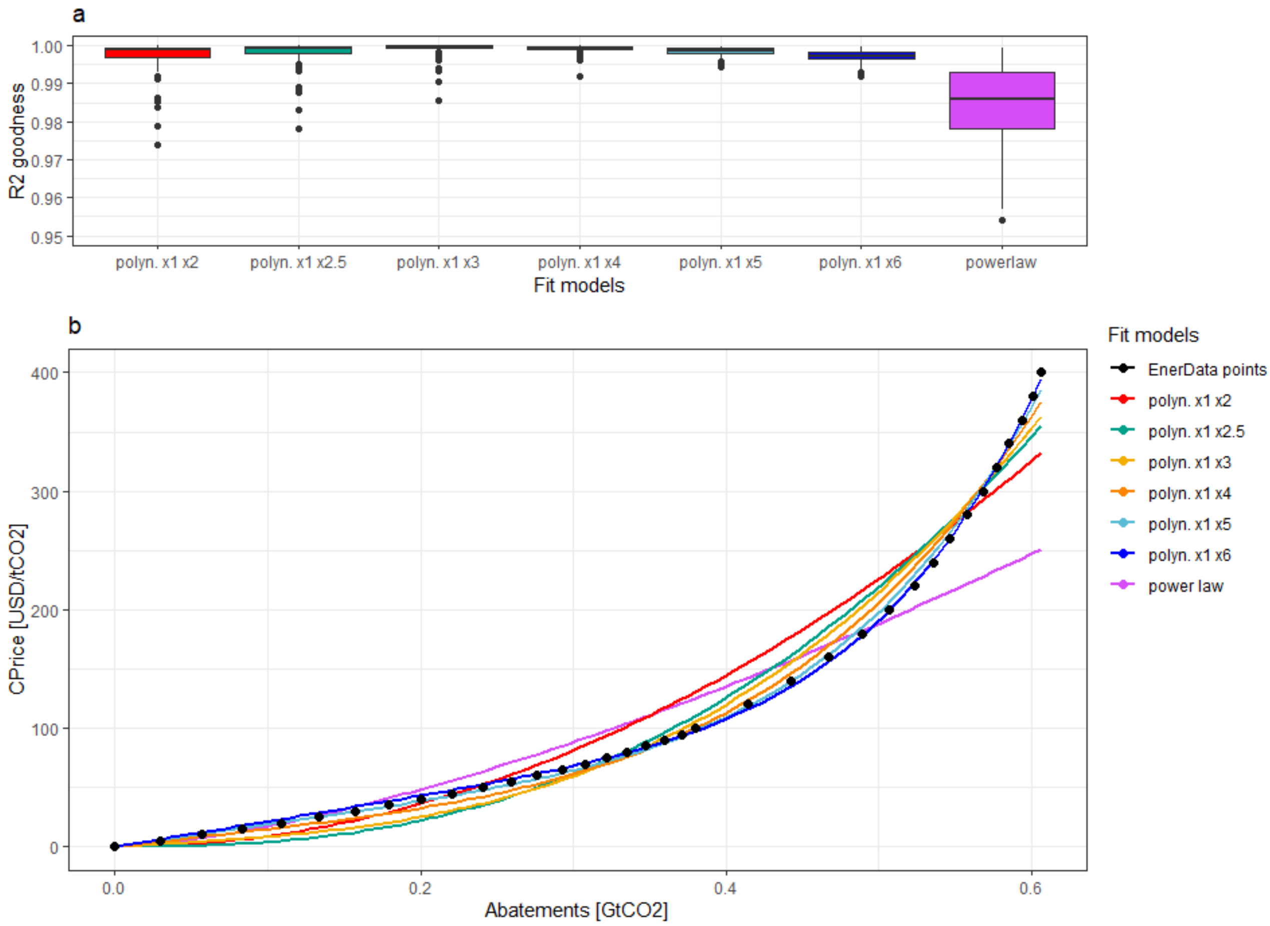

Figure S2: Panel (a) shows MACC fitting goodness (R-squared) distribution for all the candidate models and across all regions. Panel (b) shows the resulting curves for the China region for all the fitting models considered. It is a representative example of the extra qualitative check performed for the most influential economies.

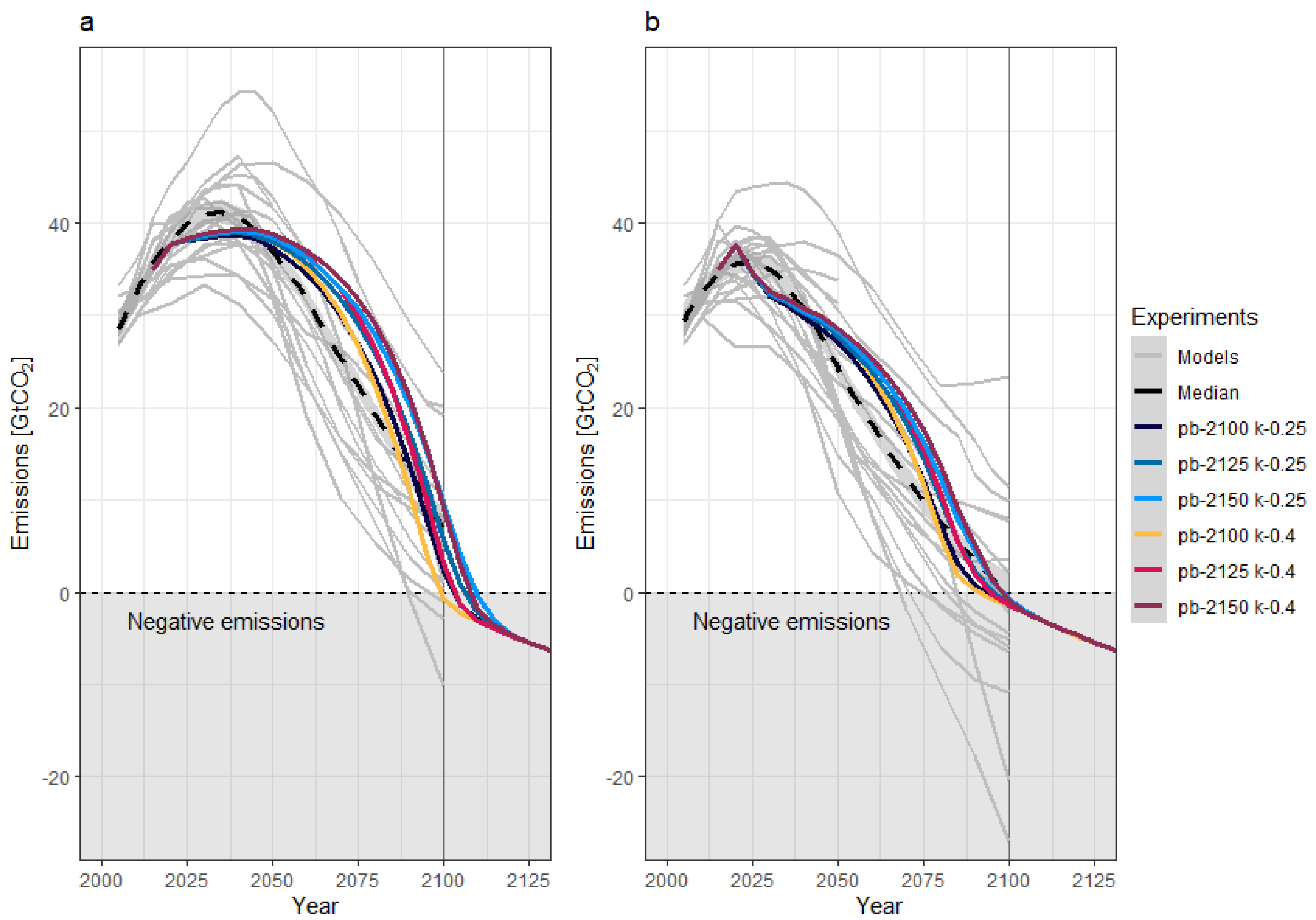

Figure S3: Figure showing qualitative analysis examples for MAC curves long-term transition towards backstop values. Resulting world emissions are compared with SSP-models references under same carbon-tax policies. In panel (a) carbon tax starts in 2020 from 30 US$ with 5% yearly growth. In panel (b) carbon tax starts from 80 US$ with 5% yearly growth. Experiments reported vary backstop converging time (pb-values) and transition smoothness (k-values).

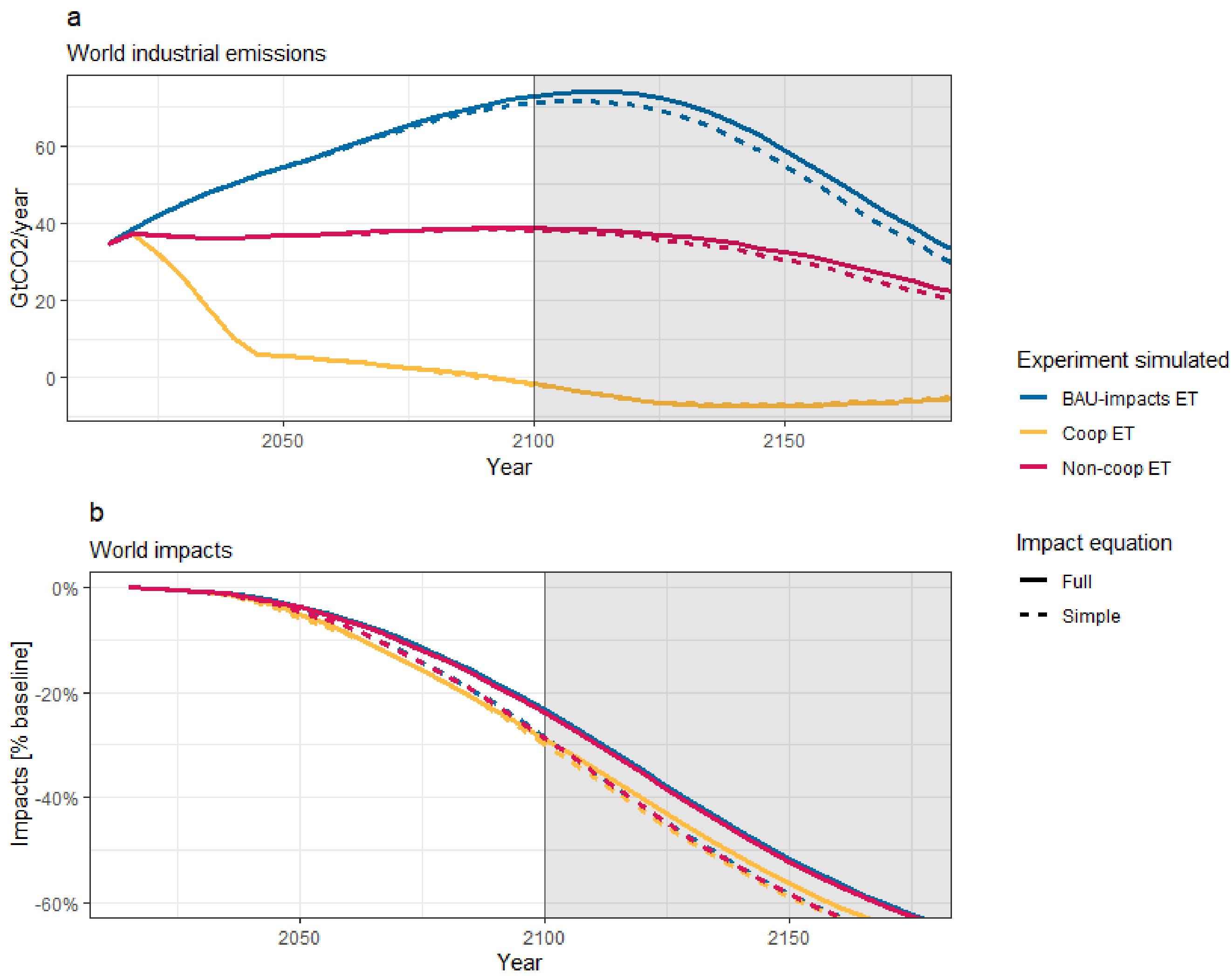

Figure S4: Comparison between Omega-Full (cf. eq. (27)) and Omega-Simple (cf. eq. (28)): Panel (a) shows emissions trajectories; Panel (b) shows world impacts as a percentage of baseline GDP. Experiments simulate the model under BAU (no-mitigation), Coop and Non-coop policy trajectories (with all the other variables at their default level). To better isolate the contribution of the different Omega definitions, local temperatures trajectories are provided exogenously as well (consistently with policy trajectories; this is highlighted with ET in the legend).

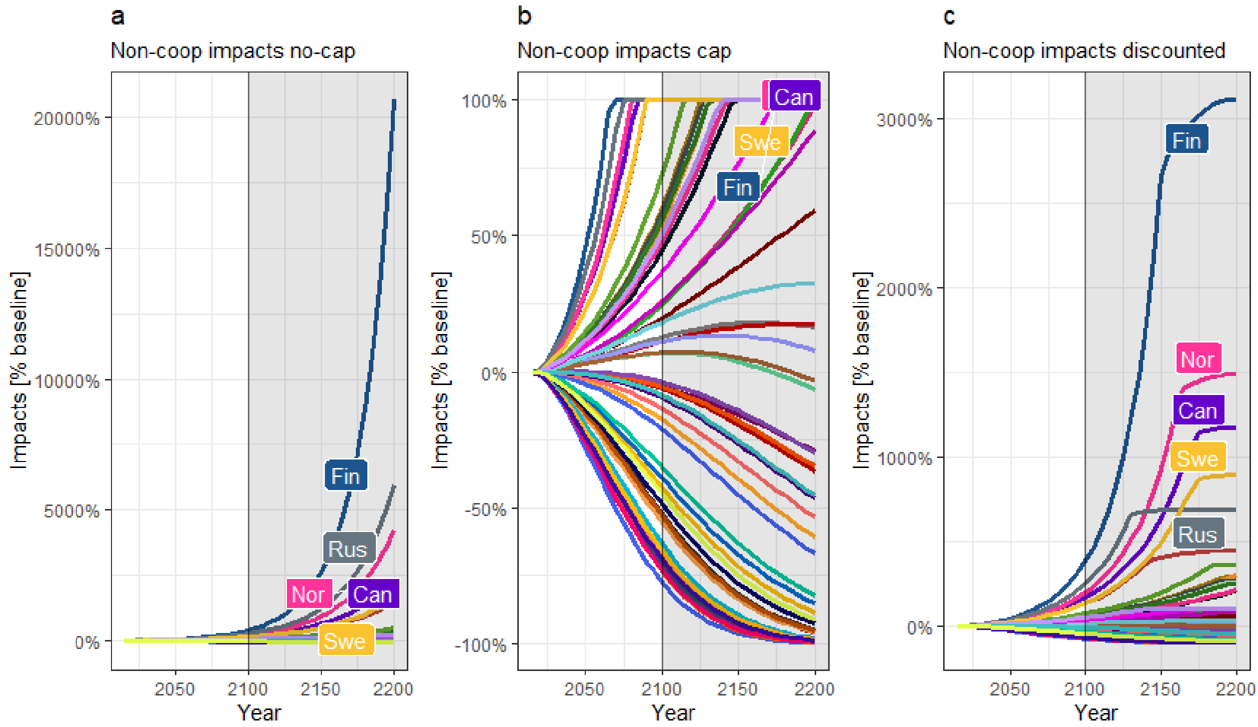

Figure S5: Regional impacts (expressed as percentages of baseline GDP) over time under Non-coop policies (those leading to highest values). Panel (a) shows the degenerating trends of a few countries when the model runs without any cap; Panel (b) shows the regional impacts when the [+100%, -100%) range cap applies (this is the official implementation); Panel (c) shows qualitatively the limited improvements in dampening the degenerating trends when a decay on impact effect is applied.

D. Model variables

Table S2: Most important RICE50+ model variables and parameters: quick reference notation.

Variable	Definition
$K_i(t)$	Regional capital
$C_i(t)$	Regional consumption
$TFP_i(t)$	Regional total factor productivity
$L_i(t)$	Regional labor
$I_i(t)$	Regional investments
$S_i(t)$	Regional savings rate
$Y_{\mathrm{GROSS},i}(t)$	Regional GDP gross
$Y_{\mathrm{NET},i}(t)$	Regional GDP net of climate impacts
$Y_i(t)$	Regional GDP net of climate impacts and abatement costs
$\sigma_i(t)$	Regional carbon intensity on production
$E_{\mathrm{IND},i}(t)$	Regional emissions from production
$E_{\mathrm{LU},i}(t)$	Regional emissions from land use
$\mu_i(t)$	Regional emissions control rate
$\Omega_i(T(t))$	Regional climate impacts on production
$\delta_i(t, T)$	Regional climate impacts on production growth
$\Lambda_i(t, \mu_i)$	Regional abatement costs
$\mathrm{MAC}_i(t, \mu_i)$	Regional marginal abatement cost curve
$\mathrm{BT}(t)$	Global backstop curve
$T_i(t)$	Regional temperature increase
$\mathrm{GMT}(t)$	Global mean temperature increase (from pre-industrial level)
$\mathrm{RF}(t)$	Global radiative forcing
W	Welfare
d_k	Depreciation rate on capital per year
α	Capital elasticity in production function
ζ	Elasticity of output to capital
η	Elasticity over the marginal utility of consumption
ρ	Pure rate of social time preference (i.e., discount rate)
γ	Inequality aversion