Supplementary Material

RICE50+: DICE model at country and regional level

A. Model regions and countries mapping

Table S1: Model regions and corresponding ISO3 countries.

| 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                 |
| Country | Region | Code |
|---------|--------|------|
| Nld     | Netherlands | NLD  |
| NAfr    | North Africa | ESH, TUN, MAR |
| NWAfr   | North-West Africa | LBY, DZA |
| Nor     | Norway | NOR |
| Ocean   | Pacific Island | COK, COC, HMD, NFK, NIU, NRU, PCN, TKL, TUV, UMI, WLF, FJI, PNG, FGM, GUM, ASM, TSL, 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, CUR, 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, SIM, 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 |
| RSAAs   | 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, GQ, ERI, ETH, GAB, GMB, GHA, GIN, GNB, KEN, LSO, LBR, MDG, MWI, ML, MRT, MUS, MYT, MOZ, NAM, NER, NGA, NRE, RWA, STP, SEN, SYC, SHN, SLE, SOM, SSD, SDN, SWZ, TZA, TGO, UGA, ZMB, ZWE, DJI, IOT, BVT, AT |
| 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

**Lemma 1.** 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 $\delta_{it}$ is approximately equivalent to using a damage function for a model with time step of $\Delta t$ if I compute $\Omega_{it}$ as:

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

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

$$\frac{Y_{GROSS,lt}}{Y_{GROSS,lt-\Delta t}} = \frac{TFP_{lt}K_{lt}^{\alpha}L_{lt}^{1-\alpha}}{TFP_{lt-\Delta t}K_{lt-\Delta t}^{\alpha}L_{lt-\Delta t}^{1-\alpha}}$$

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 \((1 + g_{it})^{dt} \approx \frac{\text{TFP}_{it}}{\text{TFP}_{it - dt}}\). Now, based on the standard damage function in eq. (24), I have that

\[ Y_{\text{NET},it} = \frac{Y_{\text{GROSS},it}}{1 + \Omega_{it}} \]

and then:

\[
\frac{Y_{\text{NET},it}/L_{it}}{Y_{\text{NET},it - dt}/L_{it - dt}} \approx \frac{\text{TFP}_{it}}{1 + \Omega_{it - dt}} / \frac{\text{TFP}_{it - 1}}{1 + \Omega_{it}}.
\]

To obtain the equivalence to the annual growth rate impacts given by eq. (26), I need thus to solve the equation \((1 + g_{it} + \delta_{it})^{dt} = (1 + g_{it})^{dt} \frac{1 + \Omega_{it - dt}}{1 + \Omega_{it}}\). 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 approximally to \(((1 + g_{it})(1 + \delta_{it}))^{dt}\). Therefore, the baseline growth factor drops out and I have \((1 + \delta_{it})^{(1/dt)} = (1 + \Omega_{it - dt})^{1/dt - 1}\). Solving for \(\Omega_{it}\) I finally obtain:

\[ \Omega_{it} = (1 + \Omega_{it - dt}) \frac{1}{(1 + \delta_{it})^{1/dt - 1}} - 1, \]

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](image_url): 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.
### 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 |
| $TTP_i(t)$ | Regional total factor productivity |
| $L_i(t)$ | Regional labor |
| $I_i(t)$ | Regional investments |
| $S_i(t)$ | Regional savings rate |
| $Y_{GROSS,i}(t)$ | Regional GDP gross |
| $Y_{NET,i}(t)$ | Regional GDP net of climate impacts and abatement costs |
| $Y_i(t)$ | Regional GDP net of climate impacts |
| $\sigma_i(t)$ | Regional carbon intensity on production |
| $E_{IND,i}(t)$ | Regional emissions from production |
| $E_{LU,i}(t)$ | 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 |
| $A_i(t,\mu_i)$ | Regional abatement costs |
| $MAC_i(t,\mu_i)$ | Regional marginal abatement cost curve |
| $BT(t)$ | Global backstop curve |
| $T_i(t)$ | Regional temperature increase |
| $GMT(t)$ | Global mean temperature increase (from pre-industrial level) |
| $RF(t)$ | Global radiative forcing |
| $W$ | Welfare |
| $d_k$ | Depreciation rate on capital per year |
| $\alpha$ | Capital elasticity in production function |
| $\zeta$ | Elasticity of output to capital |
| $\eta$ | Elasticity over the marginal utility of consumption |
| $\rho$ | Pure rate of social time preference (i.e., discount rate) |
| $\gamma$ | Inequality aversion |