Appendix B - Additional tables and figures

Table B1. Coefficient values and initial values of lagged variables and stocks (in 2008)

Symbol	Description	Value	Remarks / Sources
a_f	Real product per unit of capital	0.64	Calibrated such that the model generates the baseline scenario presented in section 3.4
a_n	Hourly product per unit of labour input	0.012	Calibrated such that the model generates the baseline scenario presented in section 3.4
ad_K^c	Adaptation coefficient of conventional capital stock	0.75	Based on Dafermos et al. (2017)
ad_K^g	Adaptation coefficient of green capital stock	0.75	Based on Dafermos et al. (2017)
ad_{lf}	Adaptation of labour force to global warming	0.95	Based on Dafermos et al. (2017)
ad_P	Sensitivity of capital depreciation rate to sustainability gap	0.50	Based on Dafermos et al. (2017)
B_d	Demand for T-bills (and other government securities)	11.71	Calibrated such that the model generates the baseline scenario presented in section 3.4
C	Total consumption	47.70	Based on World Bank data, 2019
c_0^w	Coefficient of green consumption share of LC	0.15	Calibrated such that the model generates the baseline scenario presented in section 3.4
c_0^π	Coefficient of green consumption share of UC	0.15	Calibrated such that the model generates the baseline scenario presented in section 3.4
c_1^w	Coefficient of green consumption share of LC	0.50	Calibrated such that the model generates the baseline scenario presented in section 3.4
c_1^π	Coefficient of green consumption share of UC	0.50	Calibrated such that the model generates the baseline scenario presented in section 3.4
c_2^w	Coefficient of green consumption share of LC	0.50	Calibrated such that the model generates the baseline scenario presented in section 3.4
c_2^π	Coefficient of green consumption share of UC	0.50	Calibrated such that the model generates the baseline scenario presented in section 3.4
c_{aw}	LC's propensity to consume out of wealth	0.02	Calibrated such that the model generates the baseline scenario presented in section 3.4
$c_{a\pi}$	UC's propensity to consume out of wealth	0.0125	Calibrated such that the model generates the baseline scenario presented in section 3.4
C_{INT}	Intermediate consumption	10.68	Based on World Bank data, 2019
c_w	LC's propensity to consume out of income	0.90	Calibrated such that the model generates the baseline scenario presented in section 3.4. Note: 0.88 = average value worldwide
C_w	LC's consumption	31.95	Calibrated such that the model generates the baseline scenario presented in section 3.4
c_π	UC's propensity to consume out of income	0.60	Calibrated such that the model generates the baseline scenario presented in section 3.4. Note: 0.88 = average value worldwide
C_π	UC's consumption	15.74	Calibrated such that the model generates the baseline scenario presented in section 3.4
car	Conversion coefficient of Gt of carbon into Gt of CO_2	3.67	Based on Dafermos et al. (2017)
cen	Carbon mass of the non-renewable energy sources (Gt)	9.8	Based on Dafermos et al. (2017)
$co2_{AT}$	Initial level of atmospheric CO_2 concentration	3,120.00	Based on Dafermos et al. (2017)
$co2_{AT}^{PRE}$	Pre-industrial CO_2 concentration in atmosphere (Gt)	2,156.20	Based on Dafermos et al. (2017)
$co2_{LO}$	Lower ocean CO_2 concentration	36,706.70	Based on Dafermos et al. (2017)
$co2_{UP}$	Upper ocean/biosphere CO_2 concentration	5,628.80	Based on Dafermos et al. (2017)
d_T	Percentage of damages	0.0028	Based on Dafermos et al. (2017)
d_{TF}	Percentage of damages to fund	0.0026	Based on Dafermos et al. (2017)
d_{TP}	Percentage of damages to productivity	0.0003	Based on Dafermos et al. (2017)
D_π	Bank deposits held by UC	23.43	Calibrated such that the model generates the baseline scenario presented in section 3.4

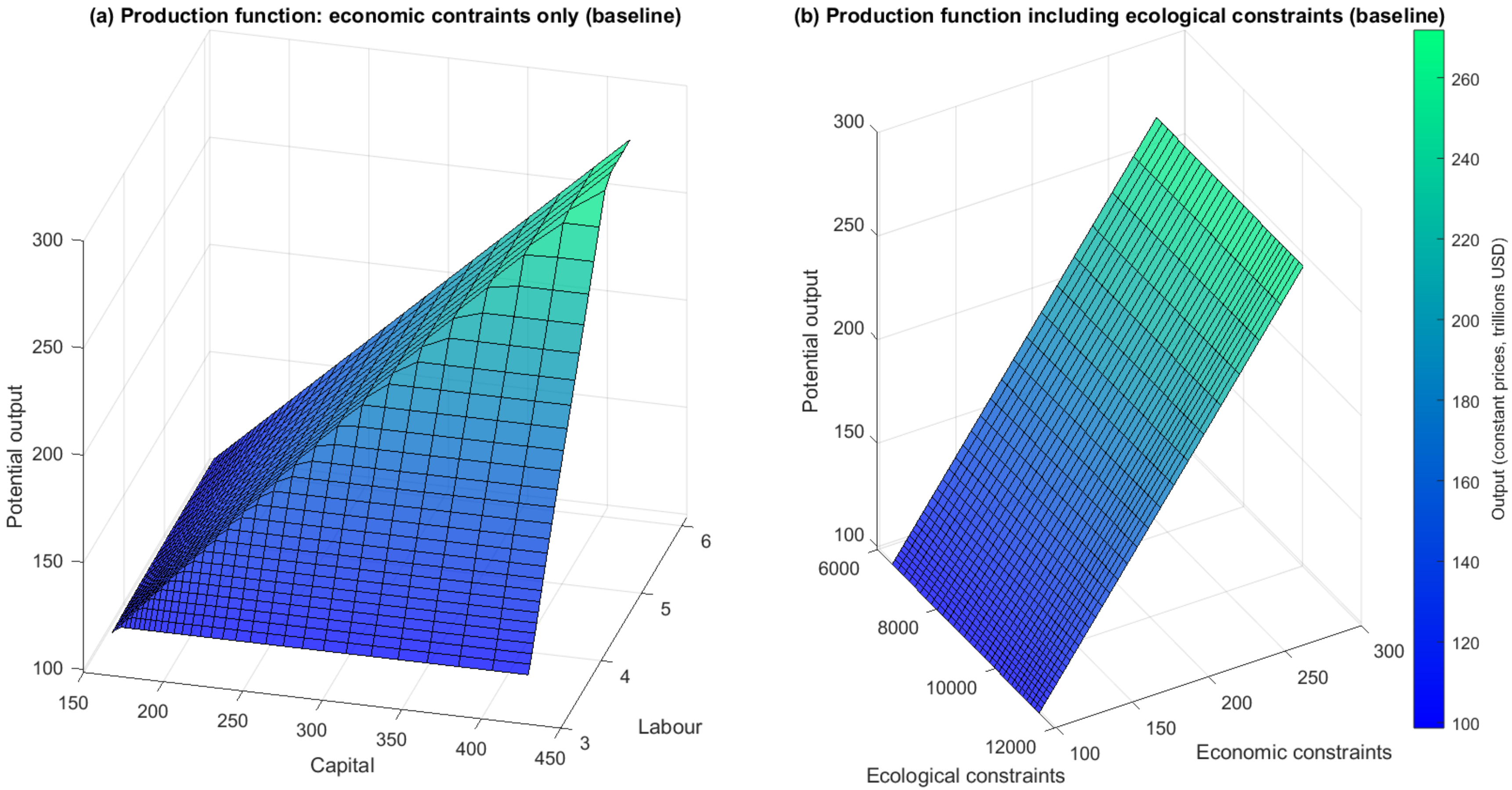
dam_1	Parameter of damage function	0	Based on Dafermos et al. (2017)
dam_2	Parameter of damage function	0.00284	Based on Dafermos et al. (2017)
dam_3	Parameter of damage function	0.000005	Based on Dafermos et al. (2017)
dam_p	Share of productivity damage in total damage due to global warming	0.1	Based on Dafermos et al. (2017)
E_d	Nominal amount of shares held by UC	11.71	Calibrated such that the model generates the baseline scenario presented in section 3.4
em	Employment rate (to total labour force)	0.95	Based on World Bank data, 2019
$emis_{in}$	Land-use CO_2 emissions (Gt)	36.00	Based on Dafermos et al. (2017)
$emis_l$	Land-use CO_2 emissions (Gt)	4.00	Based on Dafermos et al. (2017)
F	Radiative forcing over pre-industrial levels (W/m^2)	2.30	Based on Dafermos et al. (2017)
F_2	Increase in radiative forcing due to doubling of CO_2 concentraton since pre-industrial levels (W/m^2)	3.80	Based on Dafermos et al. (2017)
F_{ex}	Radiative forcing over pre-industrial levels (W/m^2) due to non-CO_2 greenhouse gases (W/m^2)	0.28	Based on Dafermos et al. (2017)
fex	Annual increase in radiative forcing due to non-CO_2 greenhouse gas emissions (W/m^2)	0.005	Based on Dafermos et al. (2017)
G	Total government spending (net of interests)	10.95	Based on World Bank data, 2019
g_{BE}	Growth rate of private innovation	0	Calibrated such that the model generates the baseline scenario presented in section 3.4
g_{f0}	Baseline value of growth rate of real product per unit of capital before global warming damages	0.001	Based on Dafermos et al. (2017)
g_{f1}	Sensitivity of growth rate of real product per unit of capital to innovative spending growth rate	0	Calibrated such that the model generates the baseline scenario presented in section 3.4
g_G^{mois}	Growth rate of mission-oriented government spending	0.04	Calibrated such that the model generates the baseline scenario presented in section 3.4
g_G^{rout}	Routine government expenditure growth rate	0.04	Calibrated such that the model generates the baseline scenario presented in section 3.4
g_l	Rate of decline of land-use CO2 emissions	0.044	Based on Dafermos et al. (2017)
g_{lf}	Labour force growth rate before global warming	0.012	Based on United Nations data, 2019
G_{mois}	Mission-oriented government spending (MOIS)	5.47	Calibrated such that the model generates the baseline scenario presented in section 3.4
g_{n0}	Autonomous growth rate of labour productivity	0.029	Based on Dafermos et al. (2017)
g_{n1}	Additional component of autonomous growth rate of labour productivity	0	Calibrated such that the model generates the baseline scenario presented in section 3.4
g_{n2}	Sensitivity of labour productivity growth rate to growth rate of output	0.6	Based on Dafermos et al. (2017)
g_{n3}	Rate of decline of autonomous (absolute) growth rate of labour productivity	0.007	Based on Dafermos et al. (2017)
G_{rout}	Routine government spending	5.47	Calibrated such that the model generates the baseline scenario presented in section 3.4
$GDEB$	Government debt (non-consolidated)	15.62	Calibrated such that the model generates the baseline scenario presented in section 3.4
h	Investment share	0.237	Based on World Bank data, 2019
H	Annual working hours per employee	1,800.00	Based on Penn World, Table 8.1
h_1	Sensitivity of working day length to output gap	100	Calibrated such that the model generates the baseline scenario presented in section 3.4
H_d^B	Reserve requirement (demand)	11.80	Calibrated such that the model generates the baseline scenario presented in section 3.4
haz	Hazardous waste ratio (Gt/million km^2)	0.03	Based on Dafermos et al. (2017)
haz	Proportion of hazardous waste to total waste	0.04	Based on Dafermos et al. (2017)
hws	Hazardous waste stock (Gt)	14.00	Based on Dafermos et al. (2017)
k_{en}	Stock of energy reserves	37,000.00	Based on Dafermos et al. (2017)
K_f	Total capital stock	124,26	Based on World Bank data, 2019

K_c	Conventional capital stock	94.78	Based on World Bank data, 2019, and Dafermos et al. (2017)
K_{gr}	Green capital stock	29.48	Based on World Bank data, 2019, and Dafermos et al. (2017)
k_m	Stock of material reserves	6,000.00	Based on Dafermos et al. (2017)
k_{se}	Socio-economic stock	1,135.60	Based on Dafermos et al. (2017)
LF	Labour force (billion people)	3.12	Based on World Bank data, 2019
lf_0	Coefficient of labour force growth rate function	0.022	Calibrated such that the model generates the baseline scenario presented in section 3.4
lf_1	Coefficient of labour force growth rate function	0.022	Calibrated such that the model generates the baseline scenario presented in section 3.4
lf_2	Coefficient of labour force growth rate function	0.2	Based on Dafermos et al. (2017)
lf_3	Coefficient of labour force growth rate function	0.001	Based on Dafermos et al. (2017)
lf_4	Deceleration rate of labour force	0.018	Based on Dafermos et al. (2017)
N	Employment (billion people)	2.96	Based on World Bank data, 2019
NW	Total net wealth	156.20	Based on World Bank data, 2019
NW_w	Total net wealth of LC	78.10	Calibrated such that the model generates the baseline scenario presented in section 3.4
NW_π	Total net wealth of UC	78.10	Calibrated such that the model generates the baseline scenario presented in section 3.4
p	Price level (GDP deflator, 2010 = 100)	0.98	Based on World Bank data, 2019
p_1	Sensitivity of price level to output gap	0.05	Calibrated such that the model generates the baseline scenario presented in section 3.4
p_2	Sensitivity of price level to price of energy	0.05	Calibrated such that the model generates the baseline scenario presented in section 3.4
p_3	Sensitivity of price level to price of matter	0.05	Calibrated such that the model generates the baseline scenario presented in section 3.4
p_e	Unit price of shares	1.00	Normalisation condition
p_{en}^0	Autonomous component of energy price	1.00	Calibrated such that the model generates the baseline scenario presented in section 3.4
p_{en}^1	Sensitivity of energy price to demand-supply gap	0.20	Calibrated such that the model generates the baseline scenario presented in section 3.4
p_m^0	Autonomous component of matter price	1.00	Calibrated such that the model generates the baseline scenario presented in section 3.4
p_m^1	Sensitivity of matter price to demand-supply gap	0.20	Calibrated such that the model generates the baseline scenario presented in section 3.4
r_{cb}	Interest rate set by central bank	0.015	Based on World Bank data, 2019
r_d	Interest rate on bank deposits	0.00	Calibrated such that the model generates the baseline scenario presented in section 3.4
rep	Repayment rate of LC's loans	0.60	Calibrated such that the model generates the baseline scenario presented in section 3.4
res_{en}	Stock of non-renewable energy resources in 2010	542,000.00	Based on Dafermos et al. (2017)
res_m	Stock of material resources in 2010	388,889.00	Based on Dafermos et al. (2017)
$sens$	Equilibrium climate sensitivity	3	Based on Dafermos et al. (2017)
$surf$	Earth surface (million km^2)	510.10	Based on Google data, 2019
t_1	Speed of adjustment parameter in atmospheric temperature function	0.027	Based on Dafermos et al. (2017)
t_2	Coefficient of heat loss from the atmosphere to the lower ocean in atmospheric temperature function	0.0018	Based on Dafermos et al. (2017)
t_3	Coefficient of heat loss from the atmosphere to the lower ocean in lower ocean temperature function	0.005	Based on Dafermos et al. (2017)
T_{AT}	Atmospheric temperature over pre-industrial levels (C)	1	Based on Dafermos et al. (2017)
T_{LO}	Lower ocean temperature over pre-industrial levels (C)	0.0068	Based on Dafermos et al. (2017)
u	Actual utilisation rate of plants	0.72	Based on World Bank data, 2019

u_n	Normal utilisation rate of plants	0.90	Calibrated such that the model generates the baseline scenario presented in section 3.4
vat_c	VAT rate on brown consumption goods	0.02	Calibrated such that the model generates the baseline scenario presented in section 3.4
vat_{gr}	VAT rate on green consumption goods	0.02	Calibrated such that the model generates the baseline scenario presented in section 3.4
w	Wage rate per hour (trillion USD / annual working hours)	0.0088	Calibrated such that the model generates the baseline scenario presented in section 3.4
wa	Waste generated by production activities (Gt)	11.00	Based on Dafermos et al. (2017)
WB	Wage bill	41.82	Based on World Bank data, 2019
Y	Total output (trillion USD, constant prices)	64.35	Based on World Bank data, 2019
YD_w	Total disposable income of LC	35.79	Calibrated such that the model generates the baseline scenario presented in section 3.4
YD_π	Total disposable income of UC	28.55	Calibrated such that the model generates the baseline scenario presented in section 3.4
α	Percentage of MOIS devoted to green innovation	0.44	Calibrated such that the model generates the baseline scenario presented in section 3.4
β_c	Parameter defining CO_2 intensity coefficient of conventional capital	0.09	Calibrated such that the model generates the baseline scenario presented in section 3.4
β_{gr}	Parameter defining CO_2 intensity coefficient of green capital	0.05	Based on Dafermos et al. (2017)
γ_0^{tech}	Autonomous component of firms' innovative spending	0.0328	Based on Deloitte's 2016-2017 Global CIO Survey
γ_1^{gr}	Autoregressive component of green investment	0.20	Calibrated such that the model generates the baseline scenario presented in section 3.4
γ_1^{tech}	Private non-green innovative spending following government MOIS	0.25	Calibrated such that the model generates the baseline scenario presented in section 3.4
γ_2^{gr}	Sensitivity of green investment to government MOIS	0.35	Calibrated such that the model generates the baseline scenario presented in section 3.4
γ_3^{gr}	Sensitivity of green investment to environmental damages	0.5	Calibrated such that the model generates the baseline scenario presented in section 3.4
γ_4^{gr}	Sensitivity of green investment to green consumption	0.02	Calibrated such that the model generates the baseline scenario presented in section 3.4
δ_c	Conventional capital depreciation rate	0.11	Based on World Bank data, 2019
δ_{gr}	Green capital depreciation rate	0.11	Based on World Bank data, 2019
ϵ	Energy intensity coefficient (initial value)	7.92	Based on Dafermos et al. (2017)
ϵ_{gr}	Energy intensity coefficient on green production	6.65	Based on Dafermos et al. (2017)
ζ	Portion of durable goods discarded every year	0.015	Based on Dafermos et al. (2017)
η_0	Initial value of risk premium	0.055	Calibrated such that the model generates the baseline scenario presented in section 3.4
η_1	Sensitivity of risk premium to global warming	0.05	Calibrated such that the model generates the baseline scenario presented in section 3.4
η_{en}	Share of renewable energy (initial value)	0.14	Based on Dafermos et al. (2017)
η_{gr}	Share of renewable energy linked with green production	0.4	Based on Dafermos et al. (2017)
θ	Profit retention rate of firms	0.2	Calibrated such that the model generates the baseline scenario presented in section 3.4
λ_{10}	Parameter in portfolio equation for equity and shares	0.30	Calibrated such that the model generates the baseline scenario presented in section 3.4
λ_{11}	Parameter in portfolio equation for equity and shares	0.00	Calibrated such that the model generates the baseline scenario presented in section 3.4
λ_{12}	Parameter in portfolio equation for equity and shares	0.00	Calibrated such that the model generates the baseline scenario presented in section 3.4
λ_{13}	Parameter in portfolio equation for equity and shares	0.00	Calibrated such that the model generates the baseline scenario presented in section 3.4
λ_{14}	Parameter in portfolio equation for equity and shares	0.00	Horizontal constraint on coefficients for rates of return
λ_{20}	Parameter in portfolio equation for T-bills	0.30	Calibrated such that the model generates the baseline scenario presented in section 3.4

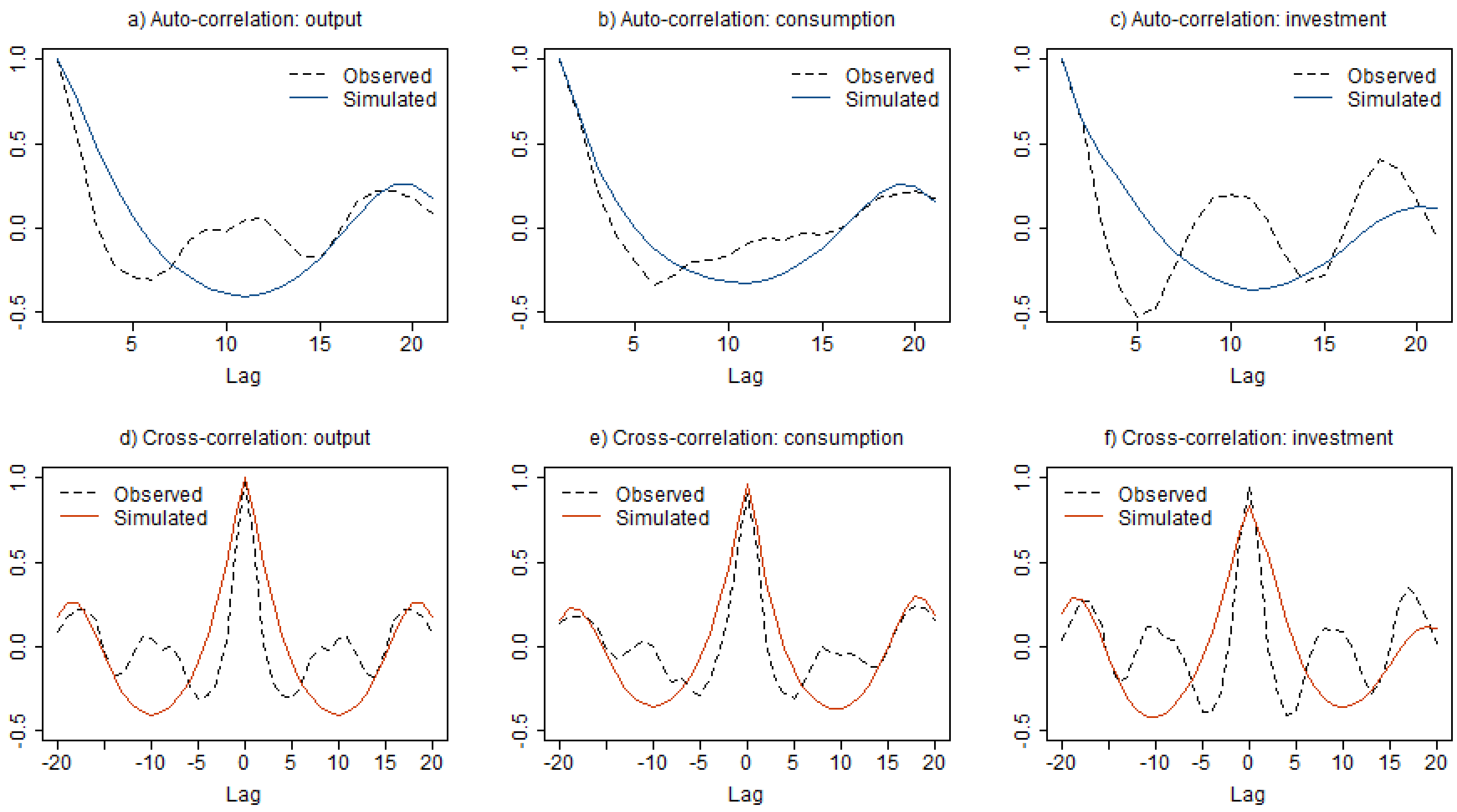
λ_{21}	Parameter in portfolio equation for T-bills	0.00	Calibrated such that the model generates the baseline scenario presented in section 3.4
λ_{22}	Parameter in portfolio equation for T-bills	0.00	Calibrated such that the model generates the baseline scenario presented in section 3.4
λ_{23}	Parameter in portfolio equation for T-bills	0.00	Calibrated such that the model generates the baseline scenario presented in section 3.4
λ_{24}	Parameter in portfolio equation for T-bills	0.00	Horizontal constraint on coefficients for rates of return
λ_{30}	Parameter in portfolio equation for bank deposits	0.30	Calibrated such that the model generates the baseline scenario presented in section 3.4
λ_{31}	Parameter in portfolio equation for bank deposits	0.00	Calibrated such that the model generates the baseline scenario presented in section 3.4
λ_{32}	Parameter in portfolio equation for bank deposits	0.00	Calibrated such that the model generates the baseline scenario presented in section 3.4
λ_{33}	Parameter in portfolio equation for bank deposits	0.00	Calibrated such that the model generates the baseline scenario presented in section 3.4
λ_{34}	Parameter in portfolio equation for bank deposits	0.00	Horizontal constraint on coefficients for rates of return
λ_w	Percentage of cash held by LC	010	Calibrated such that the model generates the baseline scenario presented in section 3.4
μ_b	Risk premium on T-bills	0.055	Calibrated such that the model generates the baseline scenario presented in section 3.4
μ_c	Matter intensity coefficient on conventional production	0.76	Based on Dafermos et al. (2017)
μ_{gr}	Matter intensity coefficient on green production	0.61	Based on Dafermos et al. (2017)
μ_l	Mark-up on interest rate for bank loans	0.055	Based on World Bank data, 2019
π	Adjustment coefficient of price expectations	0	Calibrated such that the model generates the baseline scenario presented in section 3.4
ρ_B	Percentage of reserve requirement	0.03	Calibrated such that the model generates the baseline scenario presented in section 3.4
ρ_{rec}	Recycling rate of discarded goods	0.24	Based on Dafermos et al. (2017)
σ_{en}^0	Autonomous component of non-renewable energy conversion rate	0.003	Based on Dafermos et al. (2017)
σ_{en}^1	Sensitivity of energy conversion rate to energy price	0.00001	Based on Dafermos et al. (2017)
σ_m^0	Autonomous component of matter conversion rate	0.0005	Based on Dafermos et al. (2017)
σ_m^1	Sensitivity of matter conversion rate to energy price	0.00001	Based on Dafermos et al. (2017)
τ_w	Average tax rate on LC's income	0.14	Based on World Bank data, 2019
τ_π	Average tax rate on UC's income	0.14	Based on World Bank data, 2019
ϕ	Sensitivity of investment share to utilisation gap	0.11	Calibrated such that the model generates the baseline scenario presented in section 3.4
ϕ_{11}	CO_2 transfer coefficient	0.9817	Based on Dafermos et al. (2017)
ϕ_{12}	CO_2 transfer coefficient	0.0183	Based on Dafermos et al. (2017)
ϕ_{21}	CO_2 transfer coefficient	0.0080	Based on Dafermos et al. (2017)
ϕ_{22}	CO_2 transfer coefficient	0.9915	Based on Dafermos et al. (2017)
ϕ_{23}	CO_2 transfer coefficient	0.0005	Based on Dafermos et al. (2017)
ϕ_{32}	CO_2 transfer coefficient	0.0001	Based on Dafermos et al. (2017)
ϕ_{33}	CO_2 transfer coefficient	0.9999	Based on Dafermos et al. (2017)
χ	Equity to capital ratio	0.001	Calibrated such that the model generates the baseline scenario presented in section 3.4
ψ	Gross percentage of new personal loans to disposable income	0.01	Calibrated such that the model generates the baseline scenario presented in section 3.4
ω	Wage share to total output	0.65	Based on World Bank data, 2019

Figure B1. Potential output as determined by equations (153) to (159)



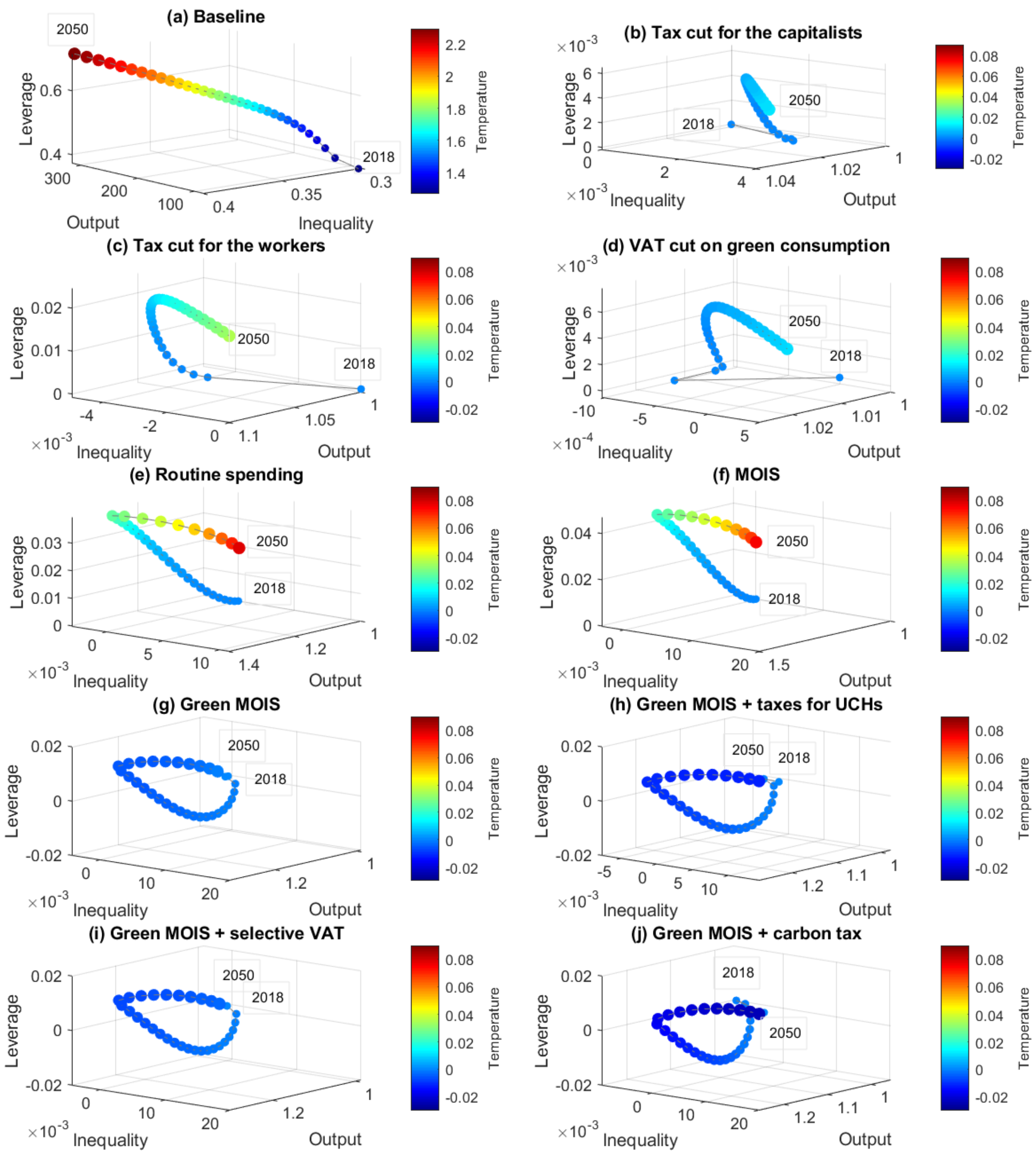
Note: ecologically-constrained output is defined by equation (158); economically-constrained output is defined by equation (157).

Figure B2. Auto- and cross-correlations of main output components: in-sample series vs. out-of-sample (predicted) series



Note: Series are all expressed in logarithms. A Hodrick-Prescott filter (with $\lambda = 100$) was used to separate the cyclical component of each series from its trend. Only the former is considered. Observed data refer to the period 1960-2018. Simulated series cover the period 2018-2050 (out-of-sample predictions).

Figure B3. Differential policy effects: a 5D comparison



Note: The five dimensions considered are: i) the economic sphere, which is expressed by real output (x axis); ii) the financial sphere, which is expressed by the leverage ratio of firms (y axis); iii) the ecosystem, which is expressed by the atmospheric temperature (colour); iv) the society, which is expressed by income inequality (z axis); v) the year of the observation (which determines the size of each marker and is sorted according to an ascending order). Variables in quadrant (a) are at their baseline values. By contrast, variables in quadrants (b) to (j) are calculated as ratios to (or differences with) baseline values.