Supermultiplier, Innovation and the Ecosystem

A Stock-Flow Dynamic Model

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Research questions

An analytical tool to help address four questions:

a) What is the impact of different types of fiscal policy on innovation and green spending?

b) What is the impact of innovation and green spending on economic growth and the ecosystem?

c) What is the impact of ecological feedback mechanisms on fiscal policy effectiveness?

d) What is the indirect impact of climate change (and matter & energy reserves' depletion) on the stock market?

Literature review

Four strands:

a) Sraffian supermultiplier (e.g. Serrano 1995, Cesaratto et al. 2003, Freitas and Serrano 2015)

b) Schumpeterian innovation and entrepreneurial role of the State (e.g. Mazzucato 2016, 2017, 2018, Deleidi and Mazzucato 2018)

c) Ecological PK economics (e.g. Fontana and Sawyer 2016, Dafermos et al. 2017, 2018)

d) SFC dynamic modelling (e.g. Godley and Lavoie 2007)

Method

Five steps:

a) Develop (analytically) a reduced supermultiplier model
b) Implant it in a 6-sector SFC model (En = 122, X = 82)
c) Add government's mission-oriented investment policies (MOIPs)
d) Add ecosystem: climate change + matter & energy depletion + feedbacks
e) Calibrate the model and perform numerical simulations

Table 1: nominal balance-sheet

	Households		Production firms	Banks & CB	Government	Foreign	Σ
	Workers	**Capitalists**					
Money	$+H_w$	$+H_\pi$		$-H_s$			0
Deposits	$+D_w$	$+D_\pi$		$-D_s$			0
Loans			$-L_d$	$+L_s$		$-L_{row}$	0
Conventional capital			$+K_c$				$+K_c$
Green capital			$+K_{gr}$				$+K_{gr}$
Shares		$+e_d \cdot p_e$	$-e_s \cdot p_e$				0
Gov. bonds		$+B_d$		$+B_{cb}$	$-B_s$		0
Balance (net worth)	$-NW_w$	$-NW_\pi$	$+NW_f$	0	$+GDEB$	$+ROWDEB$	$-K_f$
Σ	0	0	0	0	0	0	0

Table 2: transactions-flow matrix

	Workers	Capitalists	Production firms		Banks & CB	Government	Foreign	Σ
			Current	Capital				
Consumption	$-C_w$	$-C_\pi$	$+C_s$					0
Investment in conventional capital			$+I_{c,s}$	$-I_{c,d}$				0
Innovation spending (*BE*):								
- Green investment			$+I_{gr,s}$	$-I_{gr,d}$				0
- Other			$+BE_{tech,s}$	$-BE_{tech,d}$				0
Gov. routine spending			$+G_{rout}$			$-G_{rout}$		0
Gov. innovative sp. (G_{mois}):								
- Green spending			$+G_{gr}$			$-G_{gr}$		0
- Other			$+G_{tech}$			$-G_{tech}$		0
Taxes on income	$-T_w$	$-T_\pi$				$+T$		0
Net export			$+NX$				$-NX$	0
Wage bill	$+\omega \cdot Y$		$-\omega \cdot Y$					0
Depreciation allowances (and amortisation funds)			$-DA_c - DA_{gr}$	$+AF$				0
Interest on loans			$-r_{l,-1} \cdot L_{d,-1}$		$+r_{l,-1} \cdot L_{s,-1}$		$-r_{l,-1} \cdot L_{row,-1}$	0
Interest on deposits	$+r_{d,-1} \cdot D_{w,-1}$	$+r_{d,-1} \cdot D_{\pi,-1}$			$-r_{d,-1} \cdot D_{s,-1}$			0
Return on gov. bonds		$+r_{b,-1} \cdot B_{\pi,-1}$				$-r_{b,-1} \cdot B_{d,-1}$		0
Entrepreneurial profit		$+F$	$-F$					0
Change in money	$-\Delta H_w$	$-\Delta H_\pi$			$+\Delta H_s$			0
Change in loans				$+\Delta L_f$	$-\Delta L_s$		$+\Delta L_{row}$	0
Change in deposits	$-\Delta D_w$	$-\Delta D_\pi$			$+\Delta D_s$			0
Change in shares		$-\Delta e_d \cdot p_e$		$+\Delta e_s \cdot p_e$				0
Change in gov. bonds		$-\Delta B_d$			$-\Delta B_{cb}$	$+\Delta B_s$		0
Σ	0	0	0	0	0	0	0	0
Memo: capital gains		$-\Delta p_e \cdot e_{s,-1}$						

Table 3: ecosystem matrices

Physical flow matrix

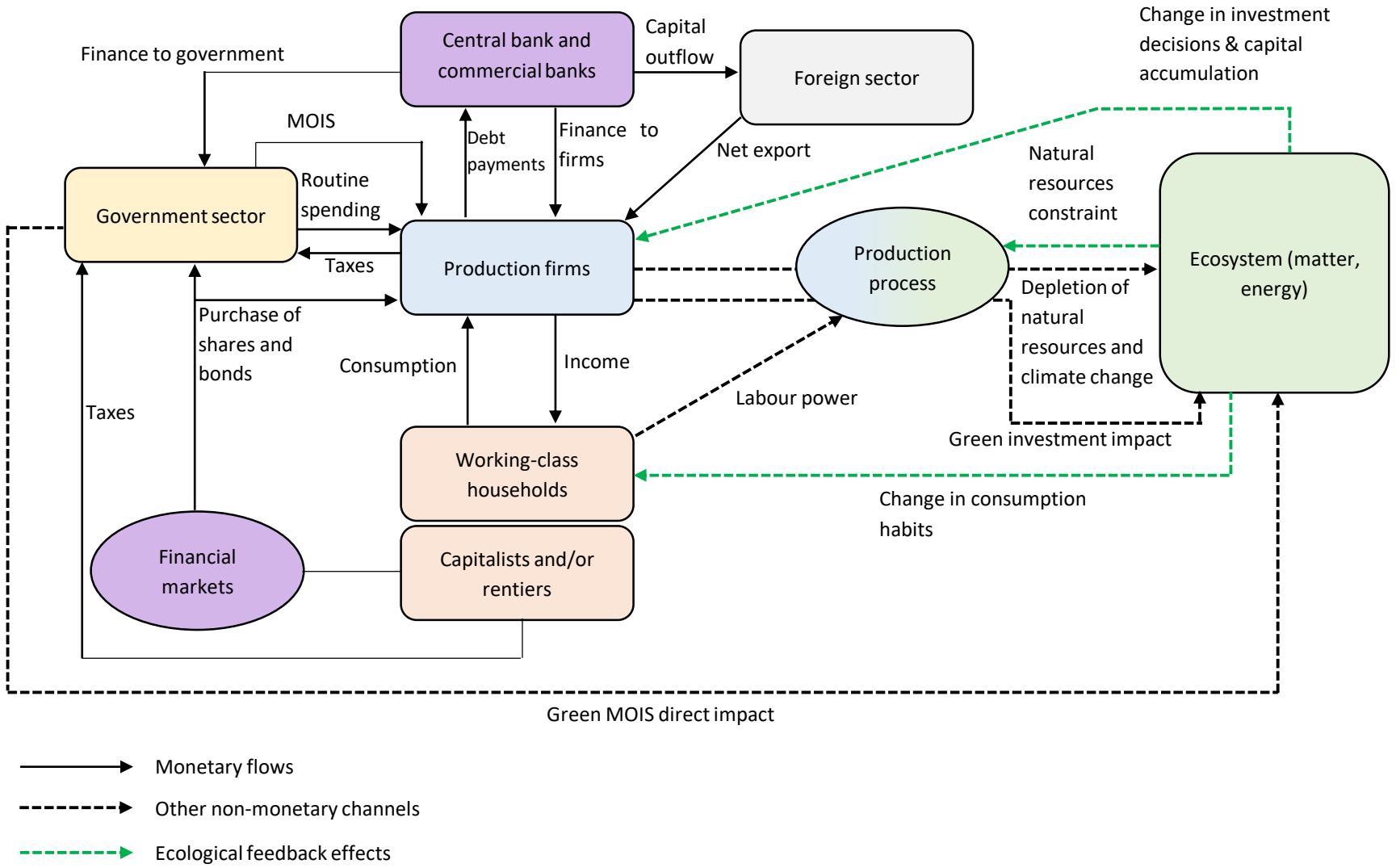
	Material balance	**Energy balance**
Inputs		
Extracted matter	$+mat$	
Non-renewable energy	$+cen$	$+en$
Oxygen	$+O2$	
Outputs		
Industrial emissions	$-emis$	
Waste and emissions	$-wa$	
Dissipated energy		$-ed$
Change in s.e.s.	$-\Delta k_{se}$	
Σ	0	0

Table 3: ecosystem matrices (cont'd)

Physical stock-flow matrix

	Material reserves	**Energy reserves**	**Atmospheric CO2 concentrat.**	**Socio-economic stock**
Initial stock	$k_{m,-1}$	$k_{en,-1}$	$CO2_{-1}$	$k_{se,-1}$
Resources turned into reserves	$+conv_m$	$+conv_{en}$		
Emissions			$+emis$	
Production of material goods				$+y_{mat}$
Extraction/use of matter/energy	$-mat$	$-en$		
Net transfer to oceans/biosph.			$-(1-\Psi_1)\cdot CO2_{-1}$	
Destruction of s.e.s.				$-des$
Final stock	k_m	k_e	$CO2$	k_{se}

Model's main interactions



Key equations: conventional investment

1) $K_c = K_{c,-1} + I_c - DA_c$
2) $I_f = h \cdot E(Y)$
3) $h = h_{-1} + h \cdot \phi \cdot (u_{-1} - u_n) + h_0$
4) $I_c = I_f - I_{gr}$
5) $u = u_{-1} + u_{-1} \cdot (g_y - g_k)$
6) $DA_c = \delta_c \cdot K_{c,-1}$

Key equations: green investment

7) $G_{gr} = \alpha \cdot G_{mois}$

8) $I_{gr} = \gamma_{gr} \cdot G_{gr,-1} + DA_{gr}$

9) $K_{gr} = K_{gr,-1} + I_{gr} - DA_{gr}$

10) $DA_{gr} = \delta_{gr} \cdot K_{gr,-1}$

11) $Z_{gr} = I_{gr} + G_{gr}$

Key equations: matter reserves

12) $y_{mat} = \mu \cdot y_s$

13) $mat = y_{mat} - rec$

14) $rec = \rho_{rec} \cdot des$

15) $des = \mu \cdot \left(DA_f + C_{-1}\right) \cdot \frac{1}{p_{-1}}$

16) $k_{se} = k_{se,-1} + y_{mat} - des$

17) $wa = mat + cen + o2 - emis - \Delta k_{se} = mat - \Delta k_{se}$

Key equations: matter reserves (cont'd)

18) $cen = \frac{emis}{car}$

19) $o2 = emis - cen$

20) $k_m = k_{m,-1} + conv_m - mat$

21) $conv_m = \max(\sigma_m \cdot res_{m,-1}, mat_{-1})$

22) $res_m = res_{m,-1} - conv_m$

23) $p_m = p_m^0 + p_m^1 \cdot \frac{mat_{-1}}{\sigma_{m,-1} \cdot res_{m,-1}}$

24) $\sigma_m = \sigma_m^0 + \sigma_m^1 \cdot E(p_m)$

Key equations: energy reserves

25) $en = \varepsilon \cdot y_s$

26) $ed = en$

27) $k_{en} = k_{en,-1} + conv_{en} - en$

28) $conv_{en} = \max(\sigma_{en,-1} \cdot res_{en,-1}, en_{-1})$

29) $res_{en} = res_{en,-1} - conv_{en}$

30) $p_{en} = p_{en}^0 + p_{en}^1 \cdot \frac{en_{-1}}{\sigma_{en,-1} \cdot res_{en,-1}}$

31) $\sigma_{en} = \sigma_{en}^0 + \sigma_{en}^1 \cdot E(p_{en})$

Key equations: emissions and climate change

32) $emis = \beta \cdot en$

33) $co2 = \psi_1 \cdot co2_{-1} + emis$

34) $temp = temp_{-1} + \psi_2 \cdot co2$

Key equations: feedback mechanisms

35) $\rho_m = \frac{mat}{k_{m,-1}}$

36) $\rho_{en} = \frac{en}{k_{en,-1}}$

37) $g_m = \frac{conv_m}{k_{m,-1}}$

38) $g_{en} = \frac{conv_{en}}{k_{en,-1}}$

Key equations: feedback mechanisms (cont'd)

39) $g_{ac} = \max(\rho_m, \rho_{en})$

40) $g_{su} = \min(g_m, g_{en})$

41) $\delta_c = \delta_0 + \delta_1 \cdot \left(g_{ac,-1} - g_{su,-1}\right) + \delta_2 \cdot \Delta temp$

42) $h_0 = h_{00} + h_{01} \cdot (g_{ac,-1} - g_{su,-1}) + h_{02} \cdot \Delta temp$

43) $c_w = c_{w0} + c_{w1} \cdot (g_{ac,-1} - g_{su,-1}) + c_{w2} \cdot \Delta temp$

Production function

44) $y_f^* = a_f \cdot k_{f,-1}$

45) $y_m^* = \frac{k_{m,-1}+rec}{\mu}$

46) $y_{en}^* = \frac{k_{en,-1}}{\varepsilon}$

47) $y^* = \min\left(y_f^*, y_m^*, y_{en}^*\right)$

Production function (cont'd)

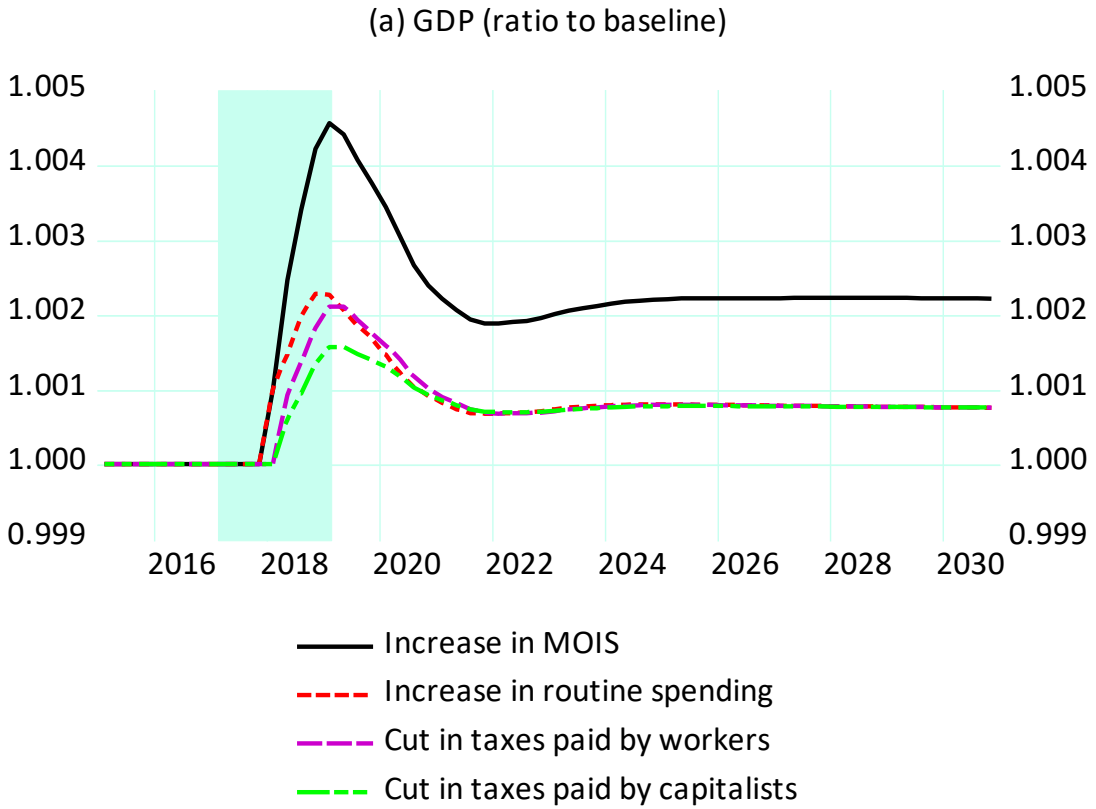
48) $\mu = \mu_{gr} \cdot \frac{K_{gr}}{K_f} + \mu_c \cdot \frac{K_c}{K_f}$

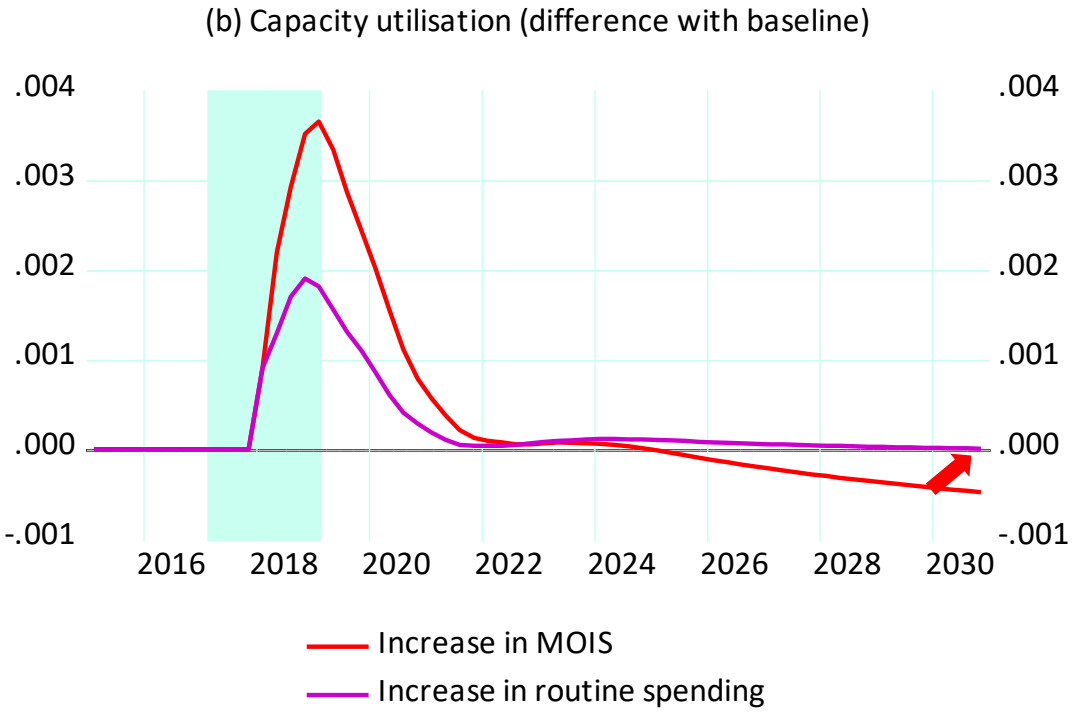
49) $\varepsilon = \varepsilon_{gr} \cdot \frac{K_{gr}}{K_f} + \varepsilon_c \cdot \frac{K_c}{K_f}$

50) $\beta = \beta_{gr} \cdot \frac{K_{gr}}{K_f} + \beta_c \cdot \frac{K_c}{K_f}$

51) $p = p_0 + p_1 \cdot (y_{-1} - y^*_{-1})$

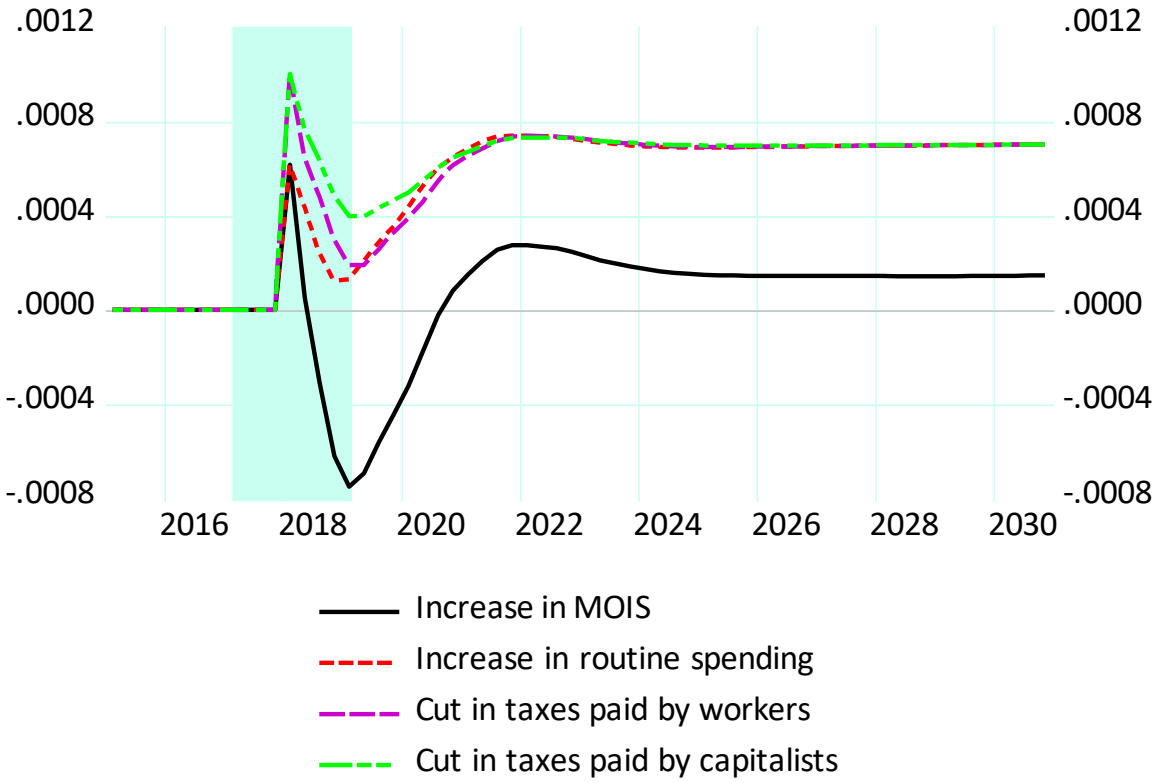
Impact of fiscal policy (+0.1% GDP) to output



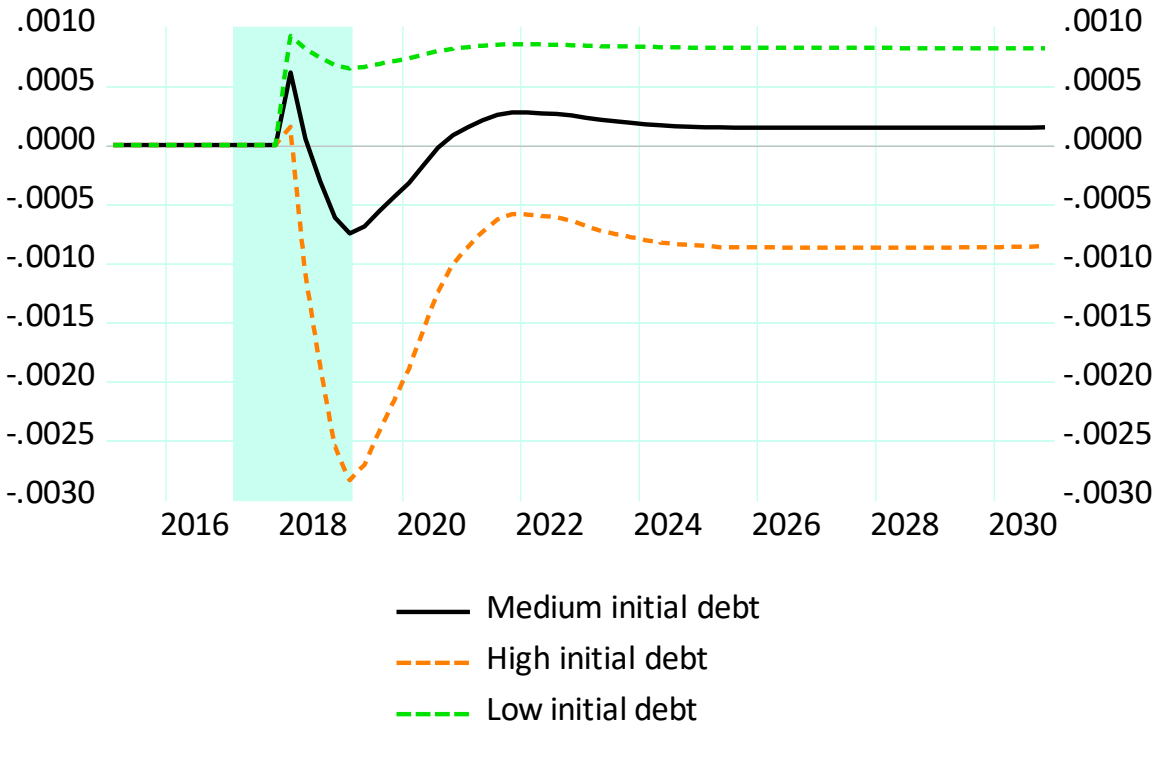


Impact of fiscal policy on government budget

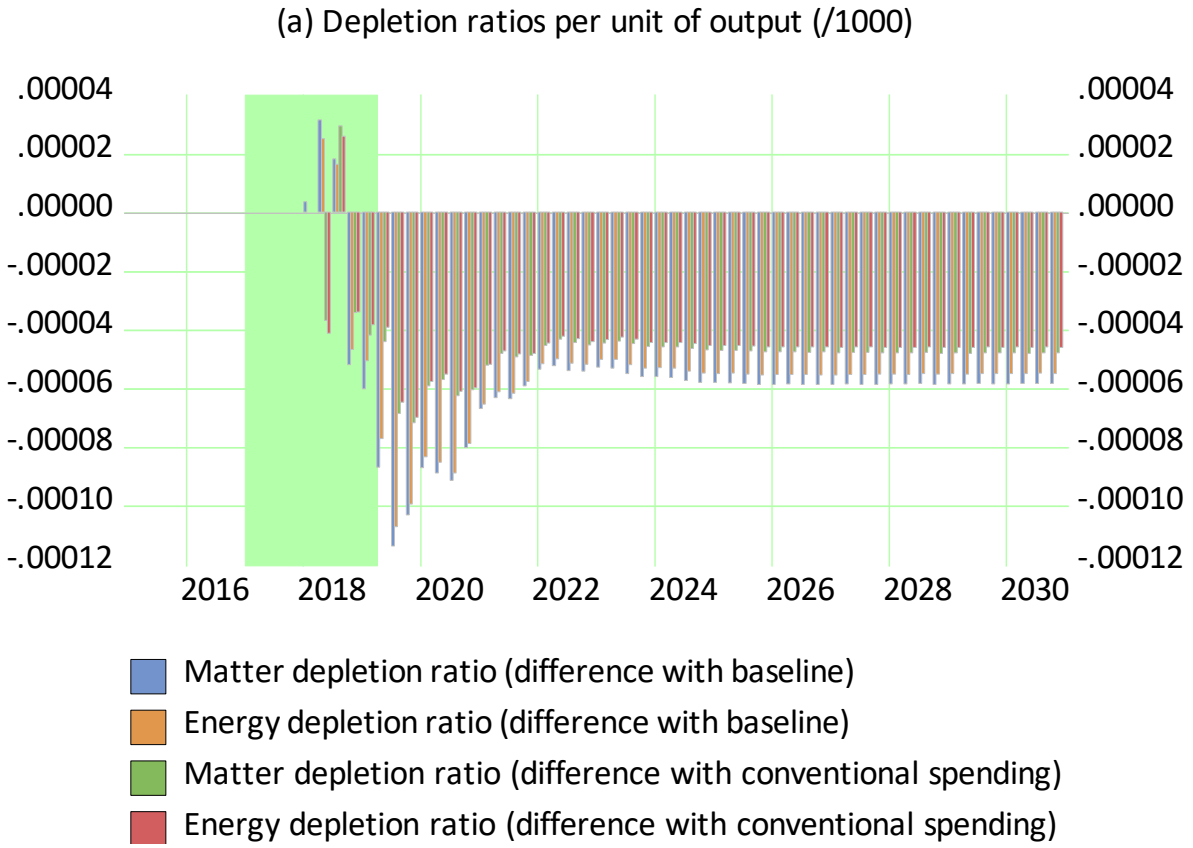
(a) Impact on gov. debt to GDP (difference with baseline)

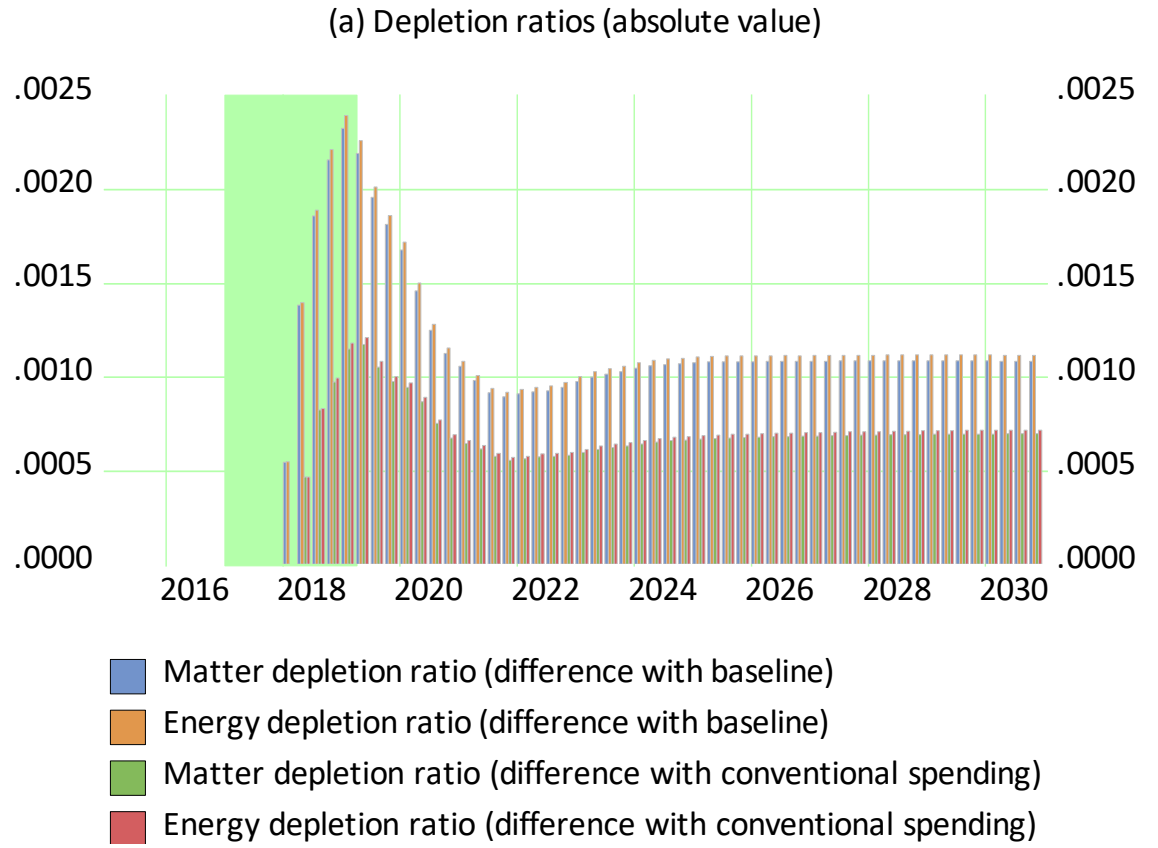


(b) Impact of gov. MOIS on debt to GDP (difference with baseline)



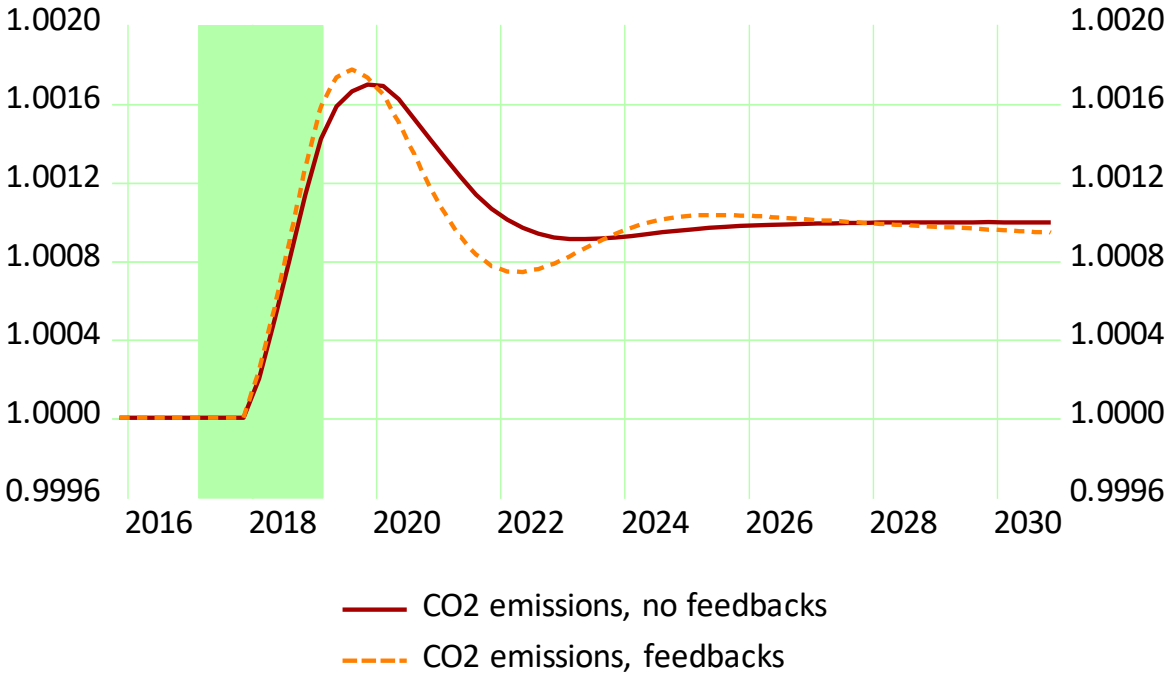
Impact of MOIS on depletion rates



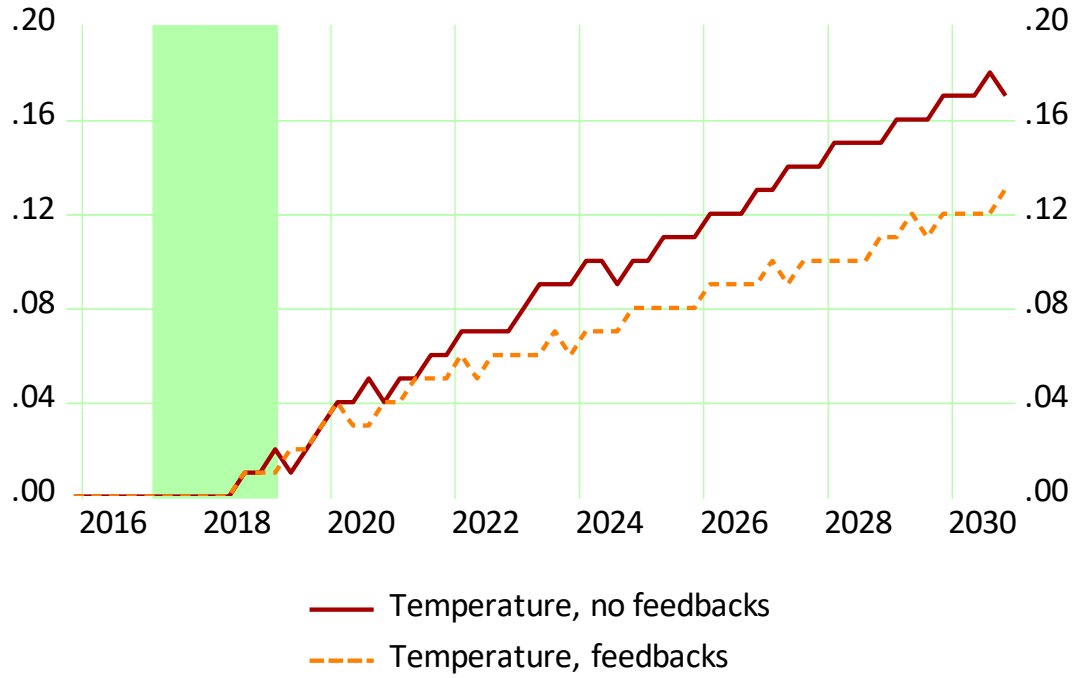


Impact of MOIS on climate change

(a) Impact of increase in MOIS on CO2 emissions (to baseline)

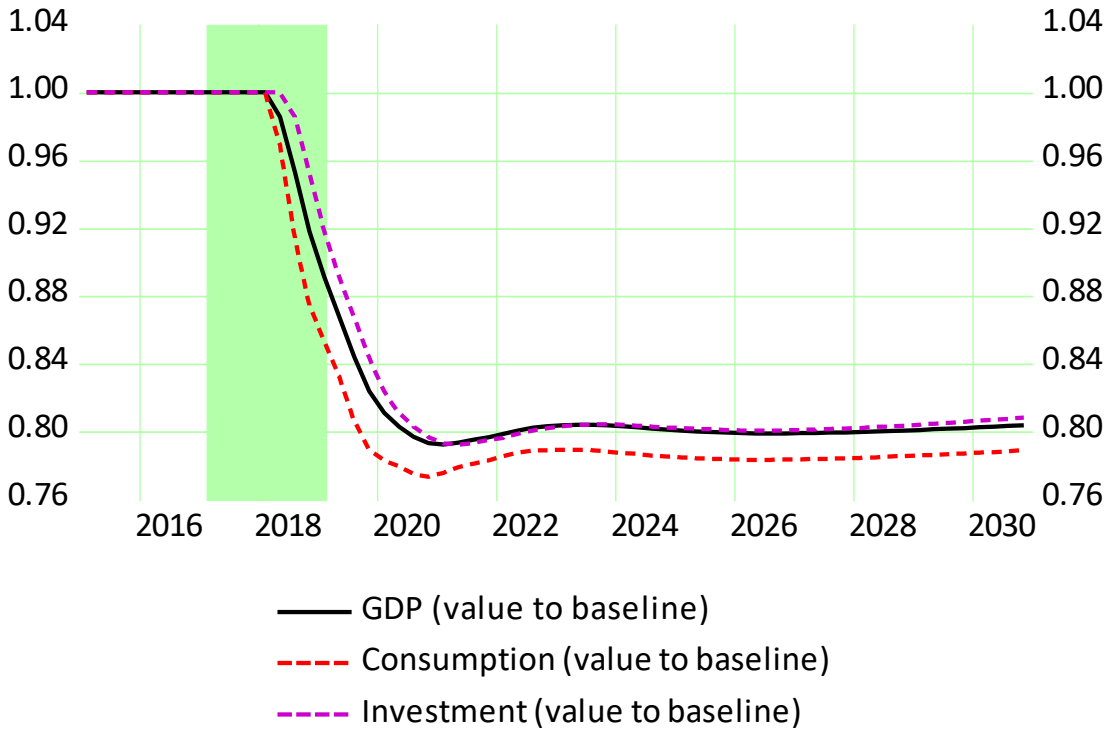


(b) Impact of increase in MOIS on atmospheric temperature (difference with baseline, /1000)

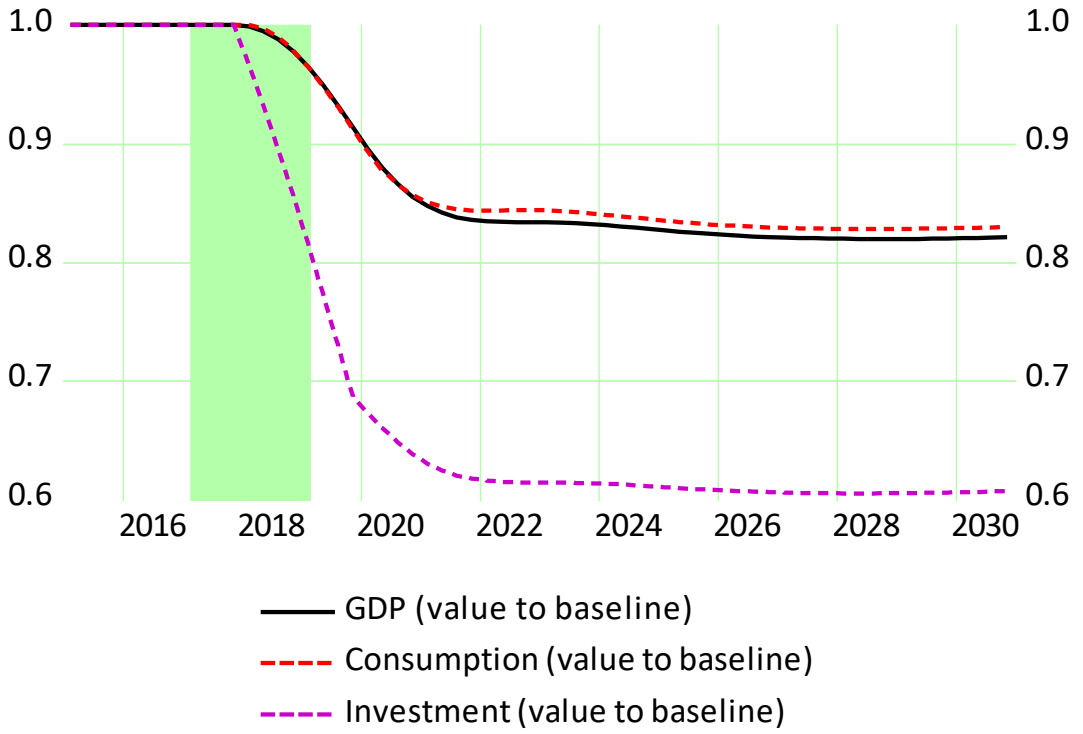


Eco feedbacks on GDP

(a) GDP components when climate change boosts capital depreciation

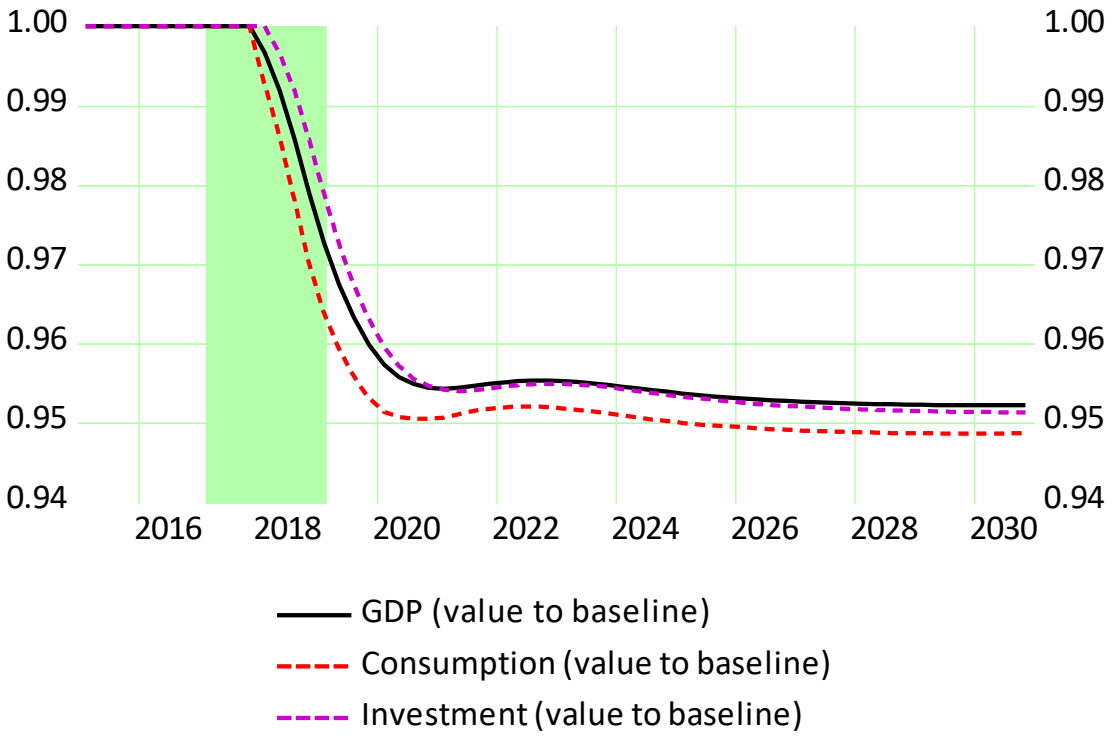


(b) GDP components when climate change affects investment share

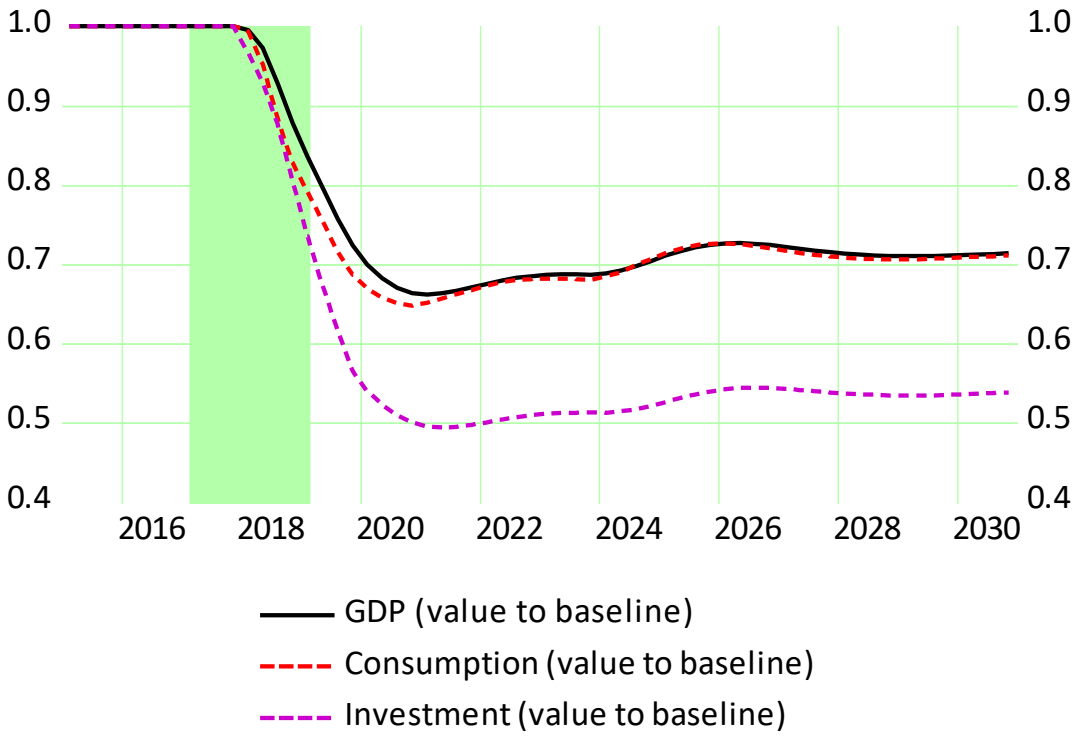


Eco feedbacks on GDP (cont'd)

(a) GDP components when climate change affects consumption

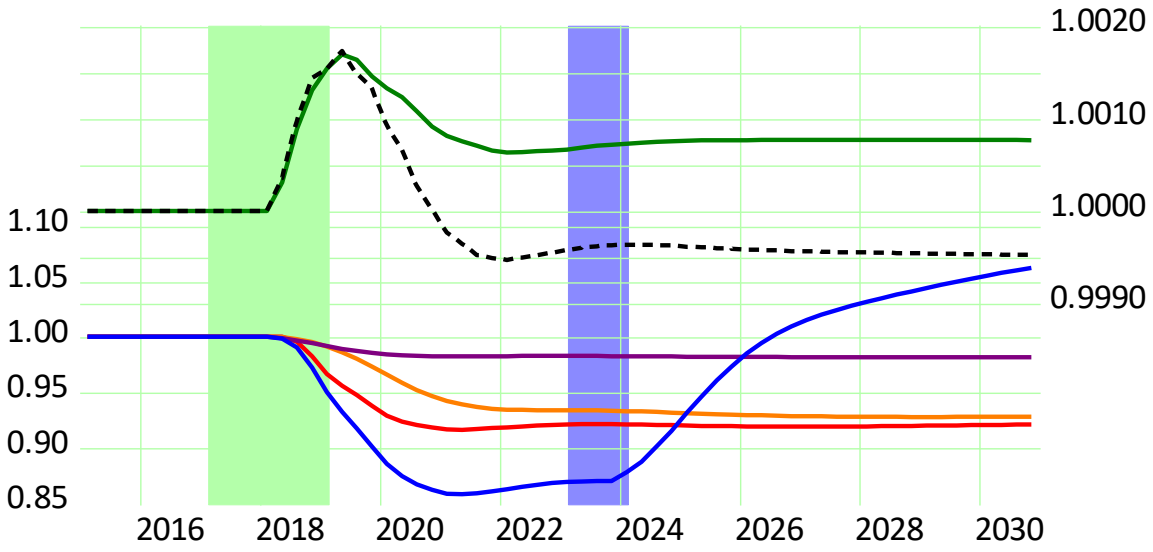


(b) GDP components when all parameters are affected



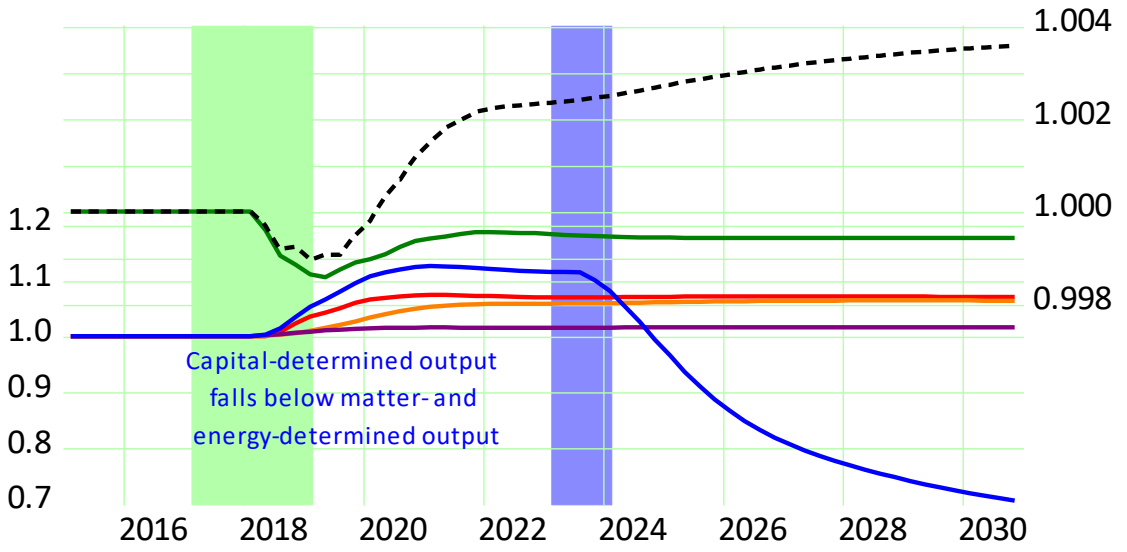
Price of products and potential output

(a) Normalised output price level when...



...MOIS is increased (right axis)
...capital depreciation is affected
...share of investment is affected
...propensity to consume is affected
...all the above
...MOIS and feedbacks (right axis)

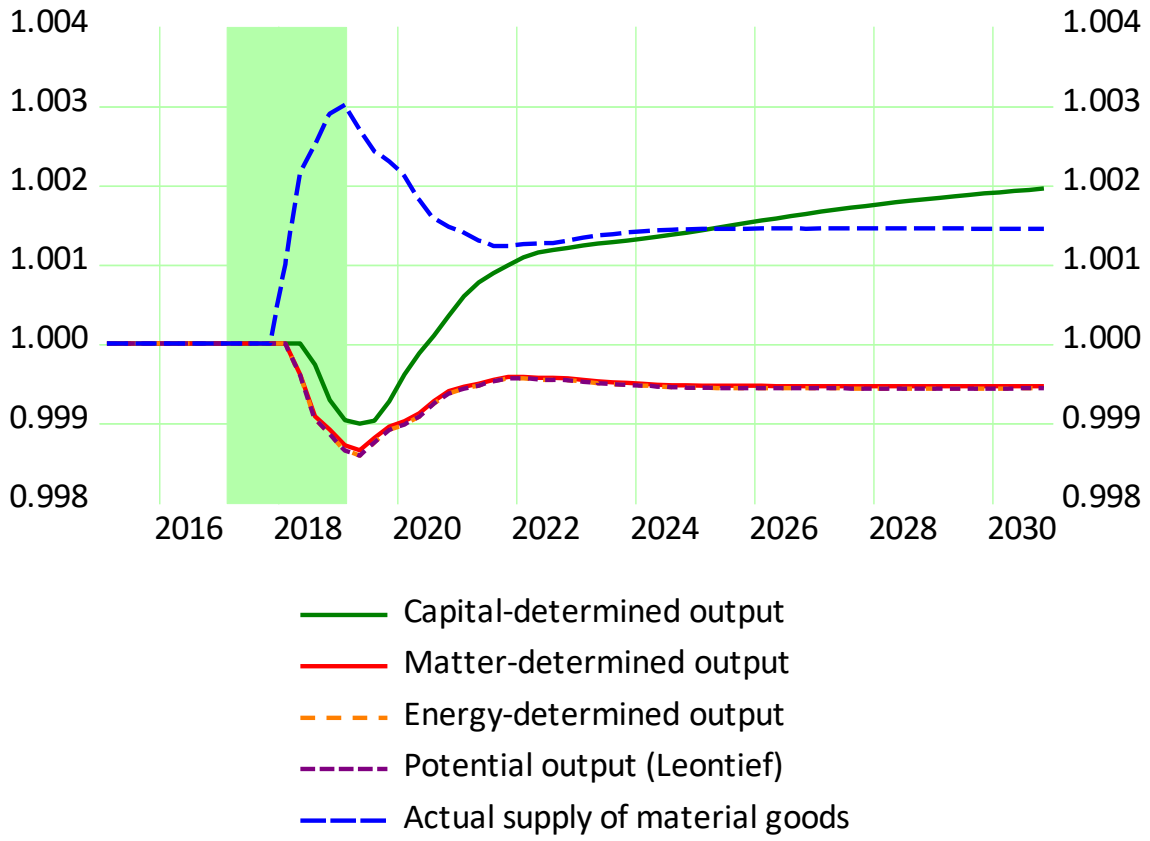
(b) Normalised potential output when...



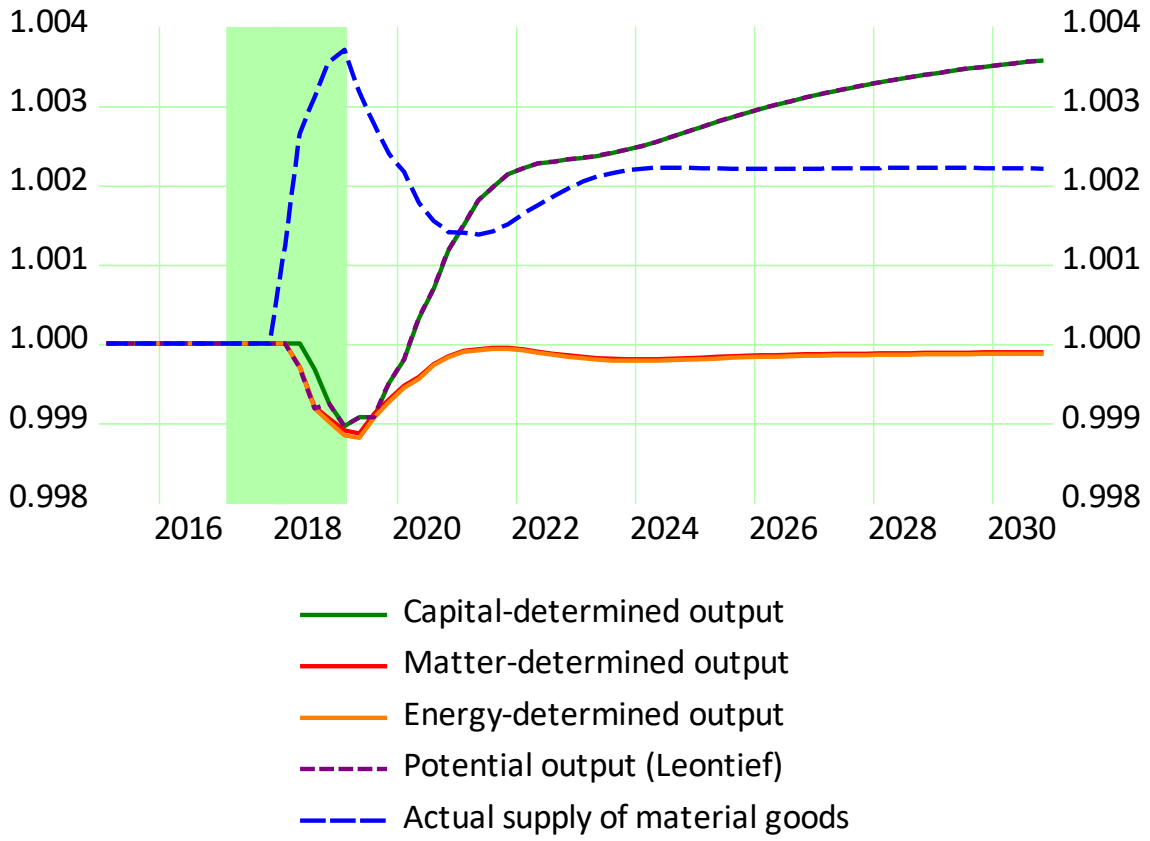
...MOIS is increased (right axis)
...capital depreciation is affected
...share of investment is affected
...propensity to consume is affected
...all the above
...MOIS and feedbacks (right axis)

Eco feedbacks on production function

(a) Production constraints: shock to MOIS (relative to baseline)

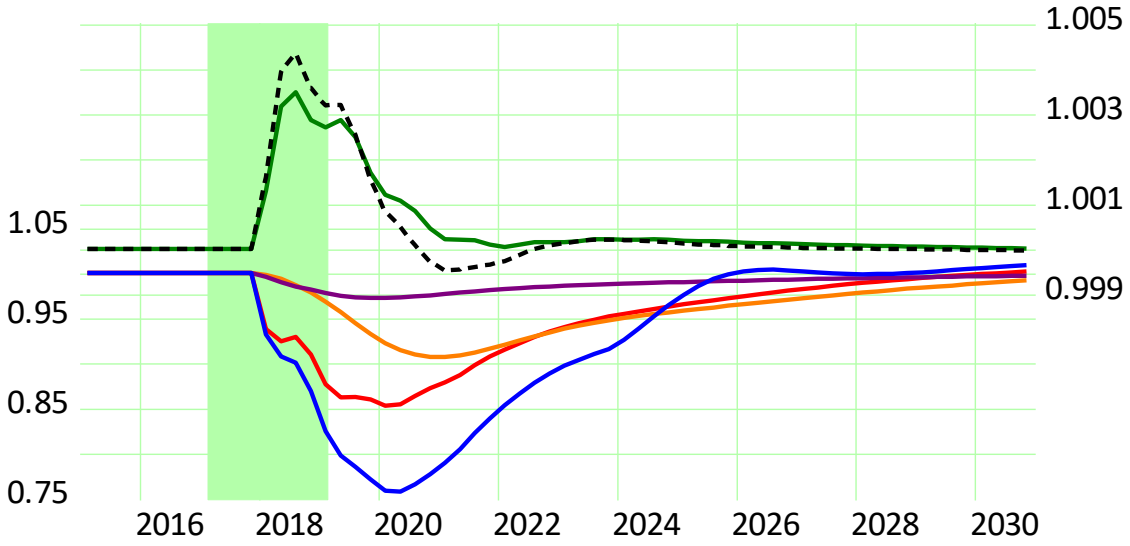


(b) Production constraints: MOIS + all eco. feedbacks (relative to baseline)



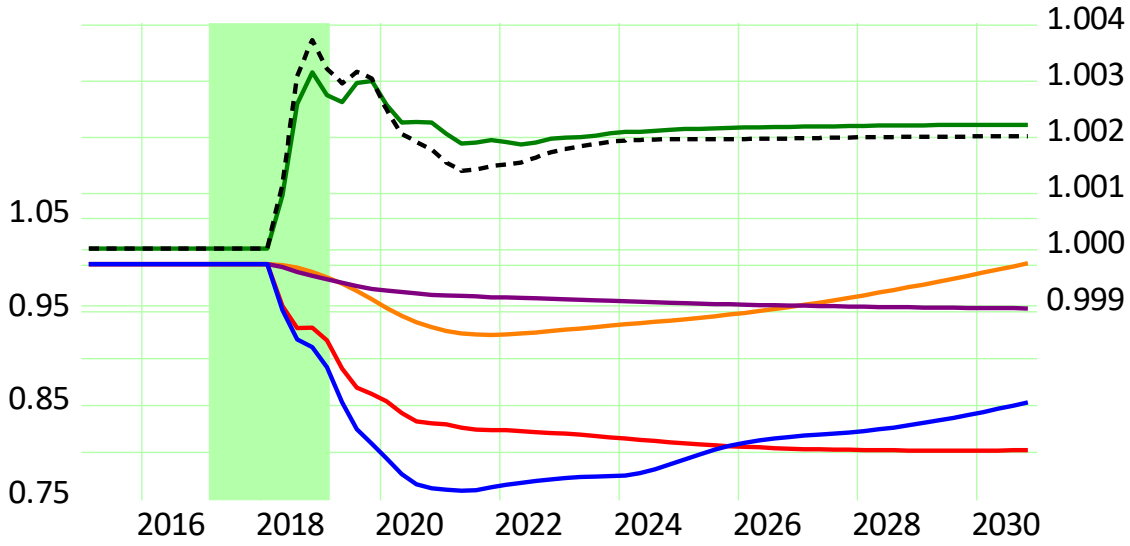
Eco feedbacks on financial structure

(a) Normalised dividend yields when...



...MOIS is increased (right axis)
...capital depreciation is affected
...share of investment is affected
...propensity to consume is affected
...all the above
...MOIS and feedbacks (right axis)

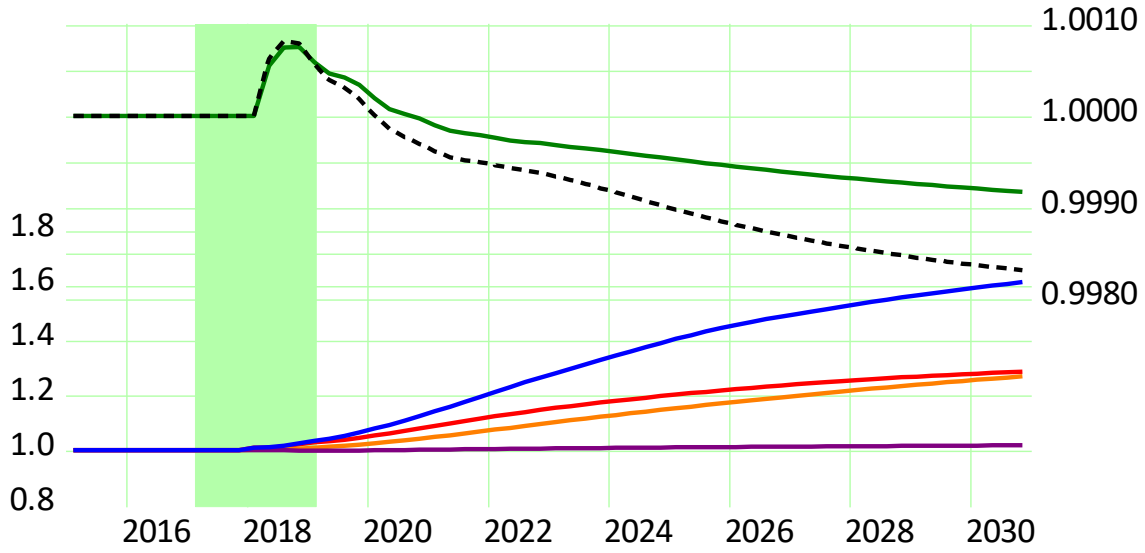
(b) Normalised market value of equity and shares when...



...MOIS is increased (right axis)
...capital depreciation is affected
...share of investment is affected
...propensity to consume is affected
...all the above
...MOIS and feedbacks (right axis)

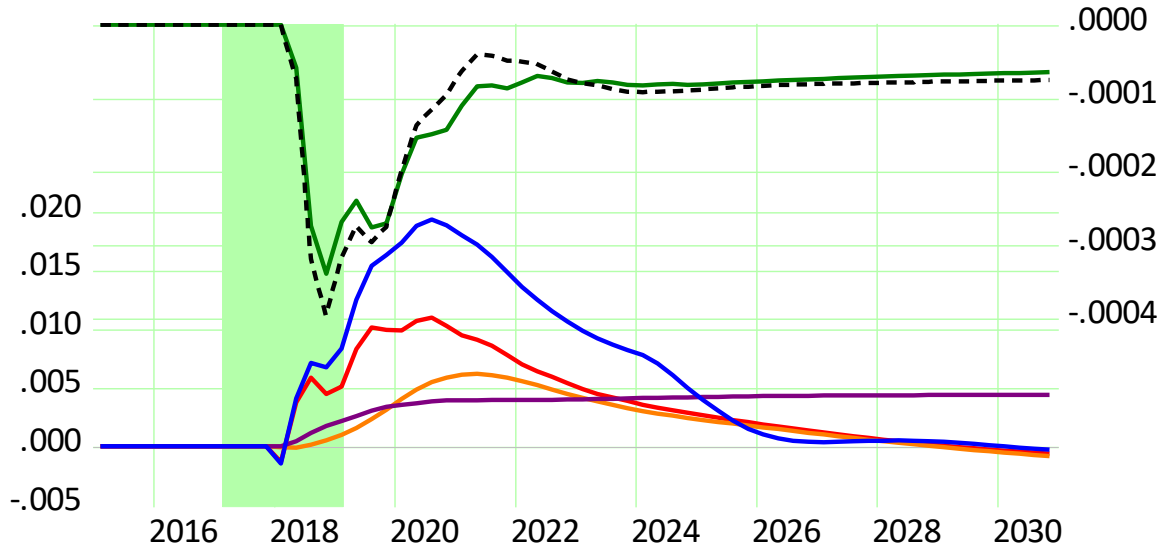
Eco feedbacks on financial structure (cont'd)

(a) Normalised Tobin q when...



...MOIS is increased (right axis)
...capital depreciation is affected
...share of investment is affected
...propensity to consume is affected
...all the above
...MOIS and feedbacks (right axis)

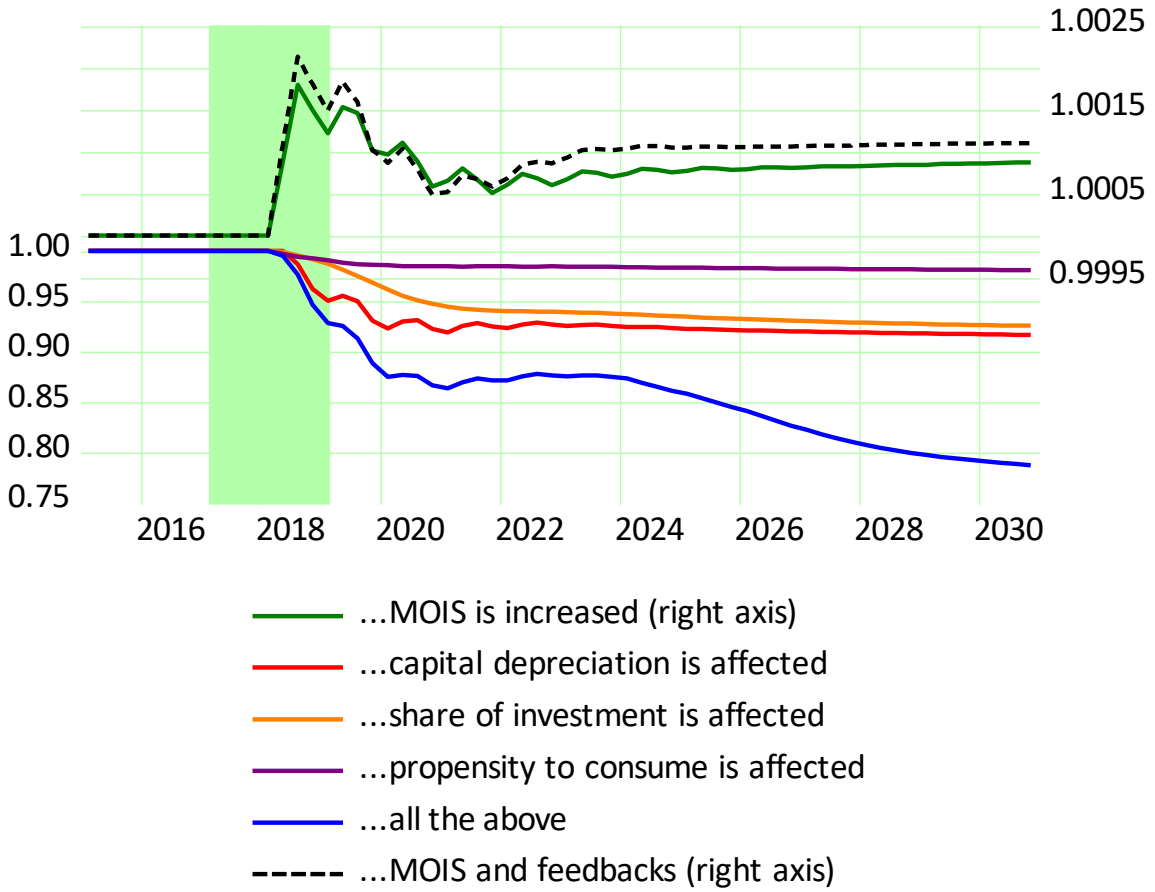
(b) Change in firms leverage ratio...



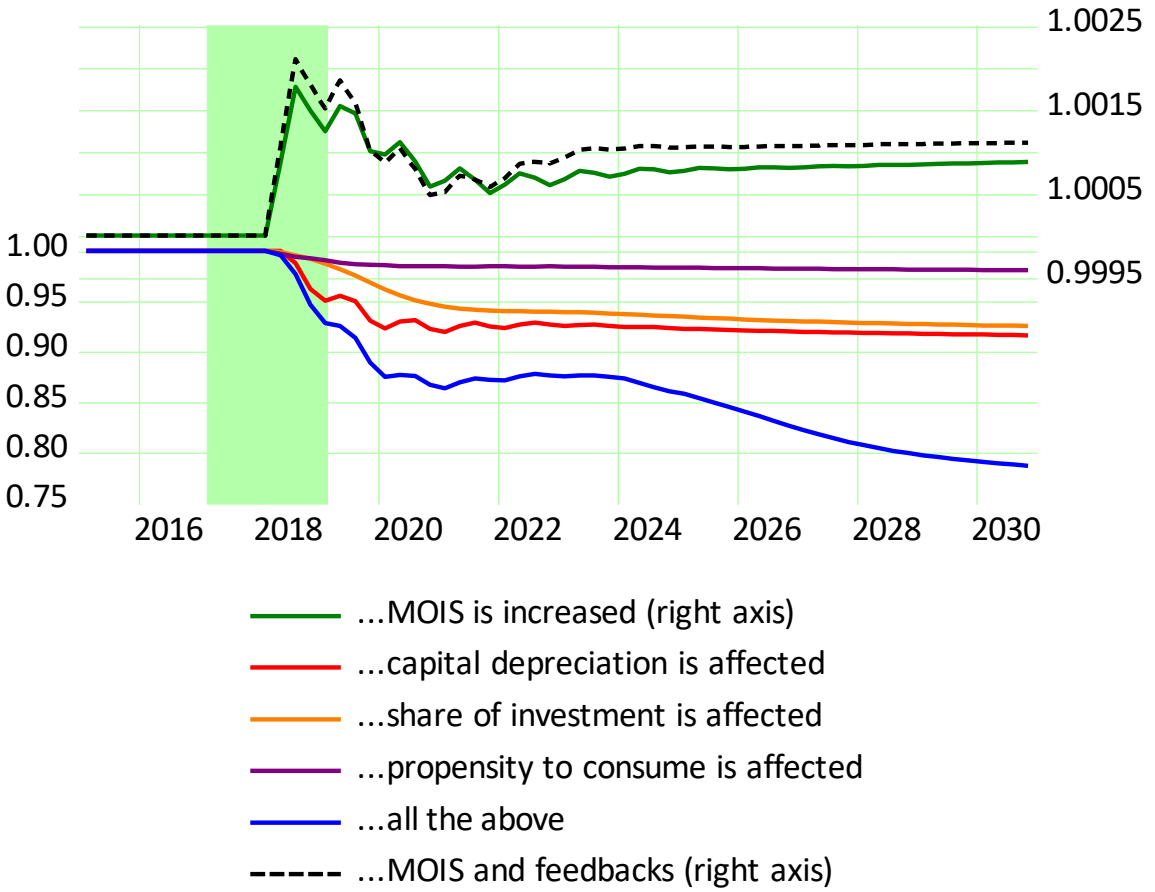
...MOIS is increased (right axis)
...capital depreciation is affected
...share of investment is affected
...propensity to consume is affected
...all the above
...MOIS and feedbacks (right axis)

Matter and energy prices

(a) Unit price of matter (relative to baseline)



(b) Unit price of energy (relative to baseline)



Final remarks

- Main findings (to be tested empirically): some types of government green spending can support growth, while slowing down climate change and reserves' depletion. But ecological feedback effects must be considered…
- Limitations / cons:
  a) neither estimated nor tested (the model returns us what we assumed)
  b) the role of CB is country-specific and class/political struggle is ruled out
  c) the ecosystem is still quite stylised
- Advantages / pros:
  a) sheds light on the role of the State in actively promoting green innovation
  b) conundrum: green innovation leads to higher efficiency but also higher growth…
  c) shows tendency of growth rates to slow down, while facing ecological issues
- Two developments: empirical calibration, two-country model

Thank you

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