# Sraffian Supermultiplier, Mission-Oriented Innovation Policies and Ecological Sustainability

## A Stock-Flow Dynamic Model

Matteo Deleidi (Università Roma Tre)

Riccardo Pariboni (Università Roma Tre)

Marco Veronese Passarella (University of Leeds)

# Research questions

An analytical tool to address four questions:

a) What is the impact of different types of fiscal policies 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 matter and 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 = 115, X = 73)
c) Add government's mission oriented investment policies (MOIPs)
d) Add ecosystem: depletion of matter and energy reserves
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: physical stock-flow and flow matrices

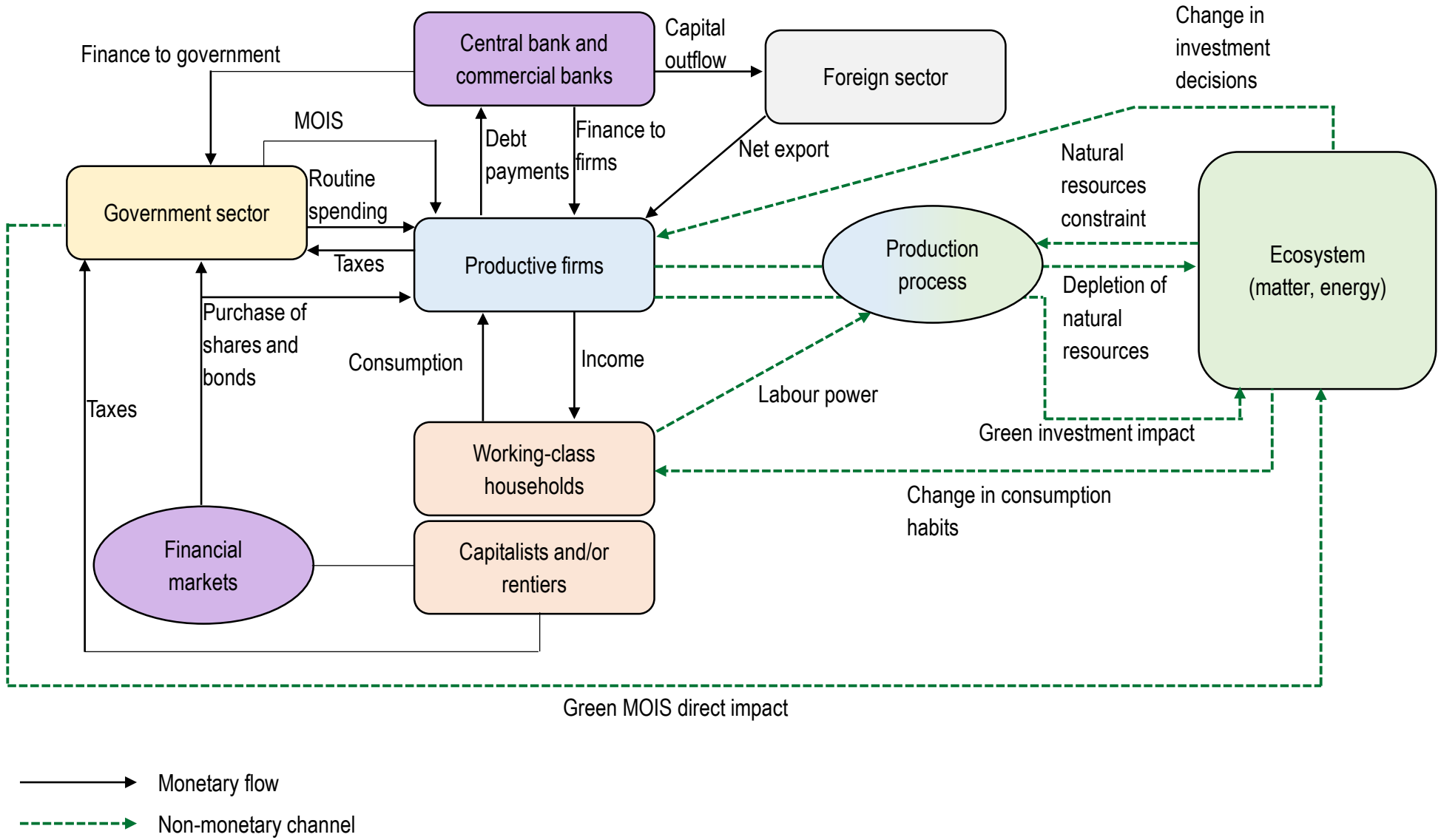
(*a*)

| | **Material reserves** | **Energy reserves** | **Socio-economic stock** |
|---|---|---|---|
| **Initial stock** | $k_{m,-1}$ | $k_{en,-1}$ | $k_{se,-1}$ |
| Resources converted into reserves | $+conv_m$ | $+conv_{en}$ | |
| Production of material goods | | | $+y_{mat}$ |
| Extraction/use of matter/energy | $-mat$ | $-en$ | |
| Destruction of s.e.s. | | | $-des$ |
| **Final stock** | $k_m$ | $k_e$ | $k_{se}$ |

(*b*)

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

# 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) $des = \mu \cdot \frac{DA_f}{p}$

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

17) $wa = mat - \Delta k_{se}$

# Key equations: matter reserves (cont'd)

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

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

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

21) $p_m = p_m^0 + p_m^1 \cdot \left(mat_{-1} - \sigma_{m,-1} \cdot res_{m,-1}\right)$

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

# Key equations: energy reserves

23) $en = \varepsilon \cdot y_s$

24) $ed = en$

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

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

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

28) $p_{en} = p_{en}^0 + p_{en}^1 \cdot \left(en_{-1} - \sigma_{en,-1} \cdot res_{en,-1}\right)$

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

# Key equations: feedback mechanisms

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

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

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

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

# Key equations: feedback mechanisms (cont'd)

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

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

36) $\delta_c = \delta_0 + \delta_1 \cdot (g_{ac,-1} - g_{su,-1})$

37) $h_0 = h_{00} + h_{01} \cdot (g_{ac,-1} - g_{su,-1})$

38) $c_w = c_{w0} + c_{w1} \cdot (g_{ac,-1} - g_{su,-1})$

# Production function

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

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

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

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

# Production function (cont'd)

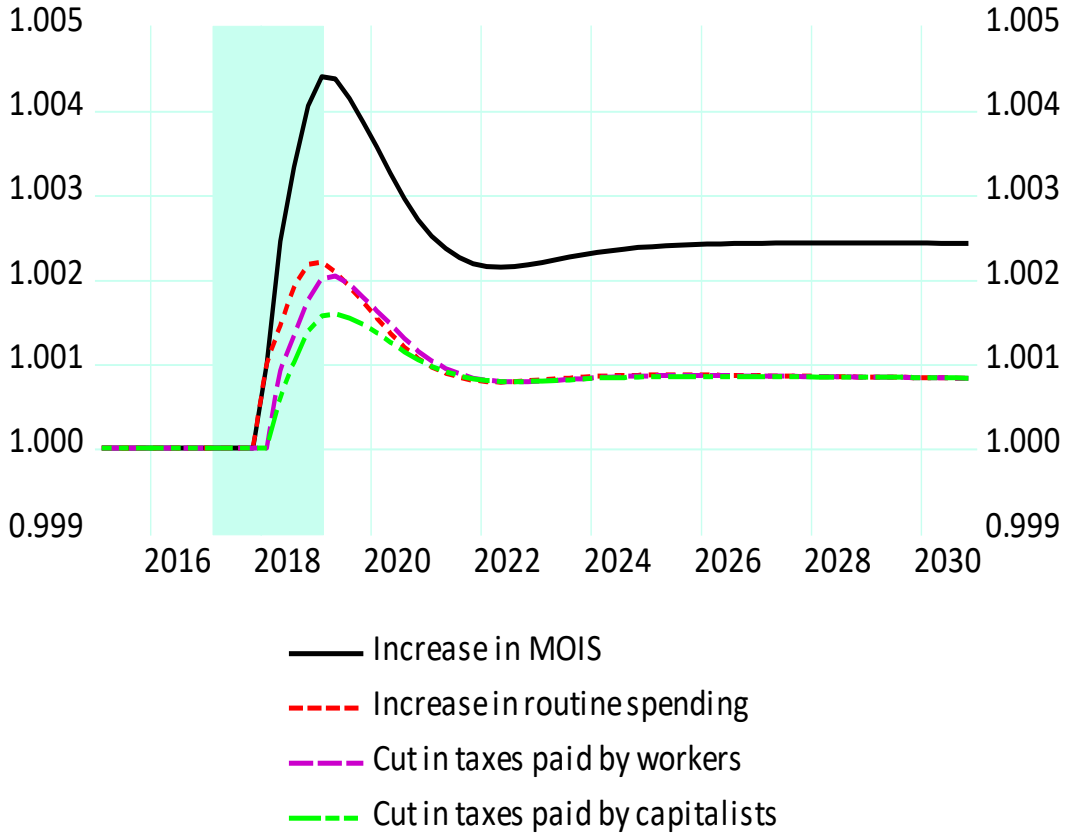
43) $\mu = \mu_{gr} \cdot \frac{K_{gr}}{K_f} + \mu_c \cdot \frac{K_c}{K_f}$

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

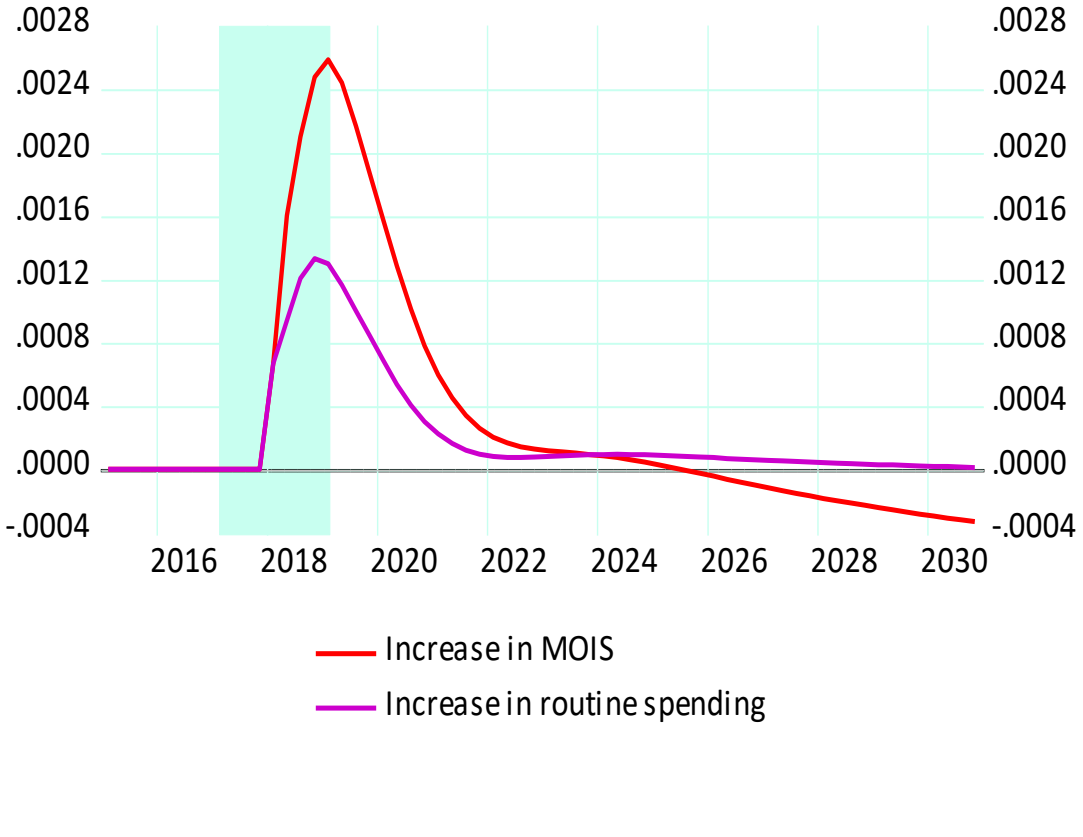
45) $p = p_0 + p_1 \cdot (y_{-1} - y^*_{-1})$

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

(a) GDP (ratio to baseline)

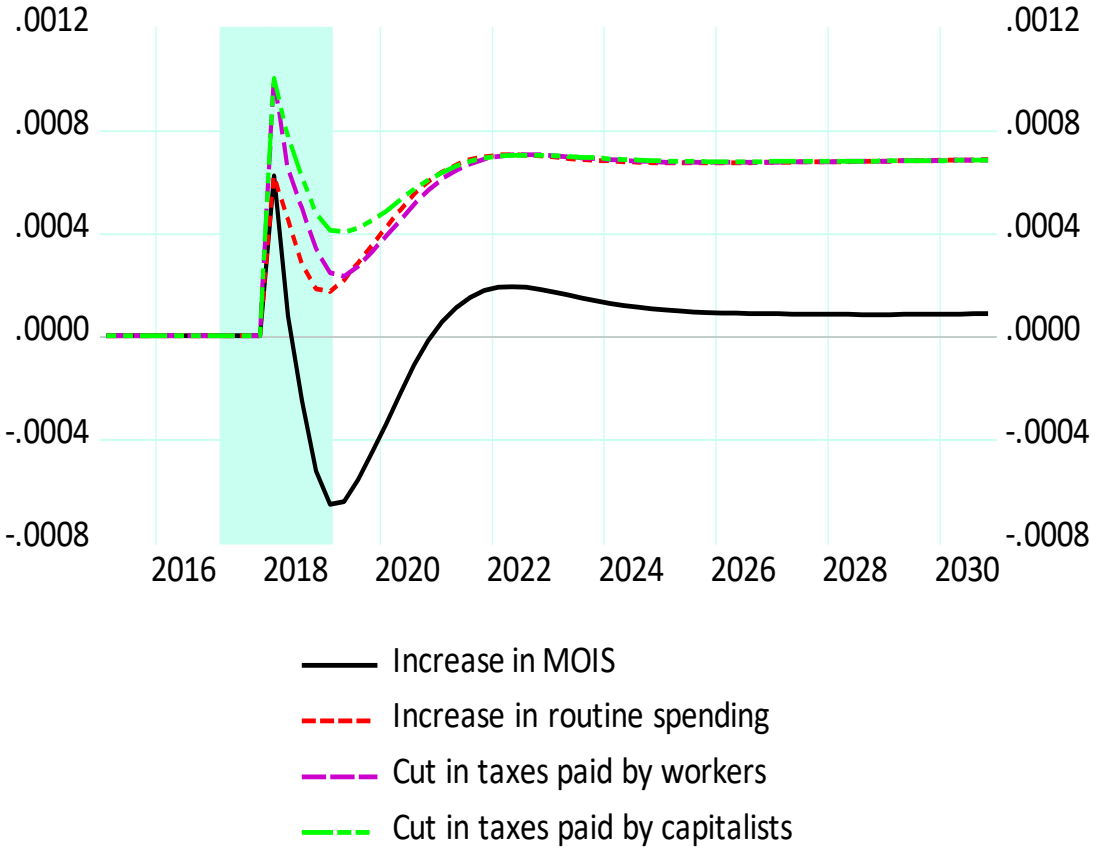



(b) Capacity utilisation (difference with baseline)

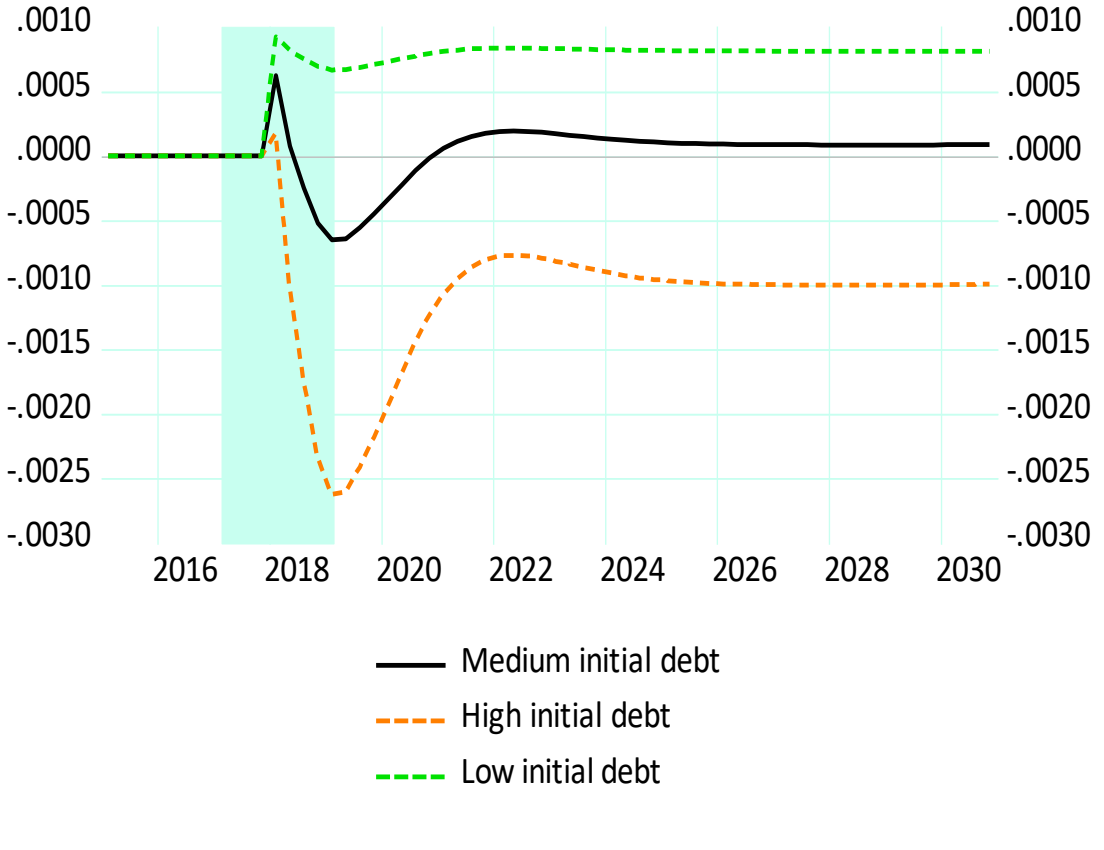


# Impact of fiscal policy on government budget

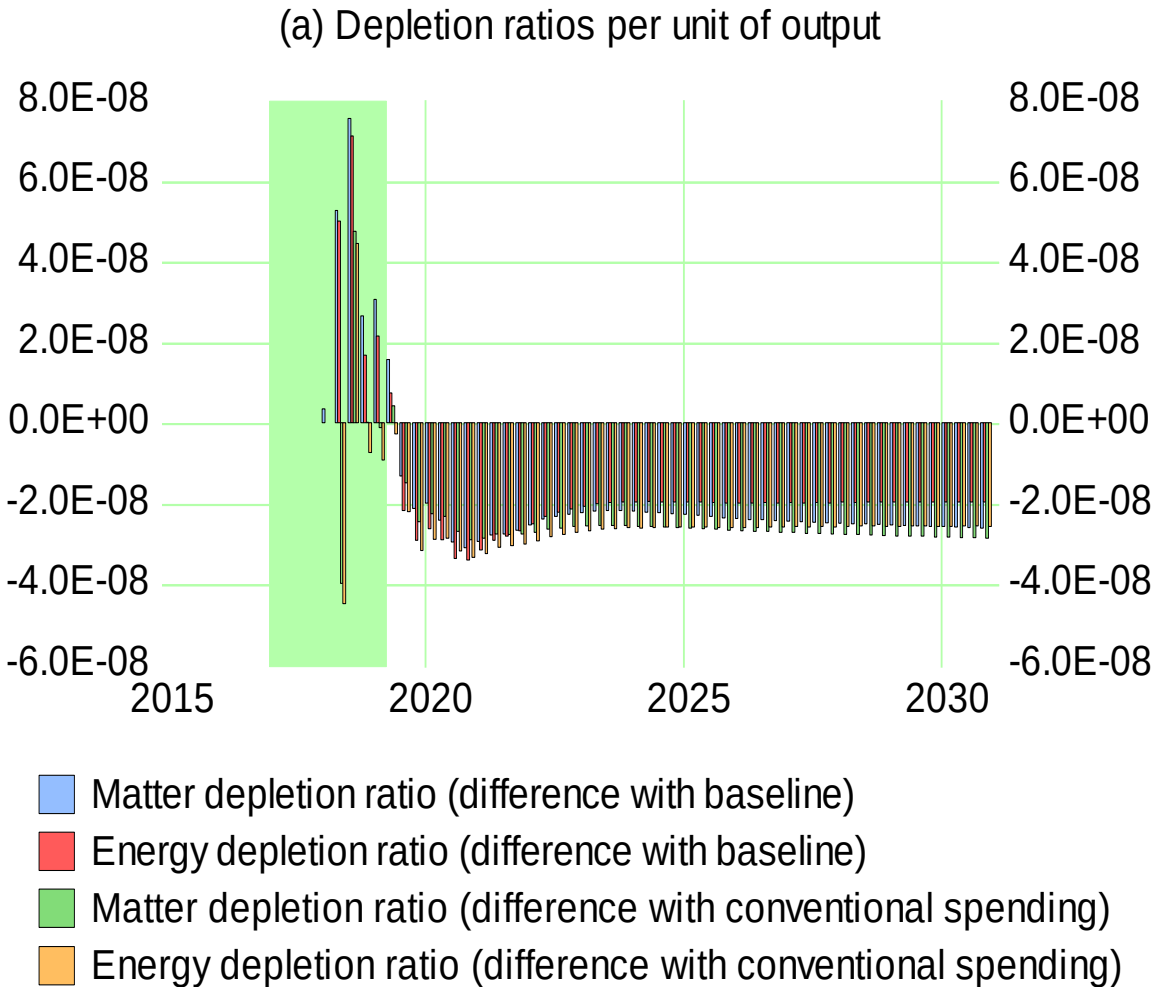
(a) Impact on gov. debt to GDP (difference with baseline)

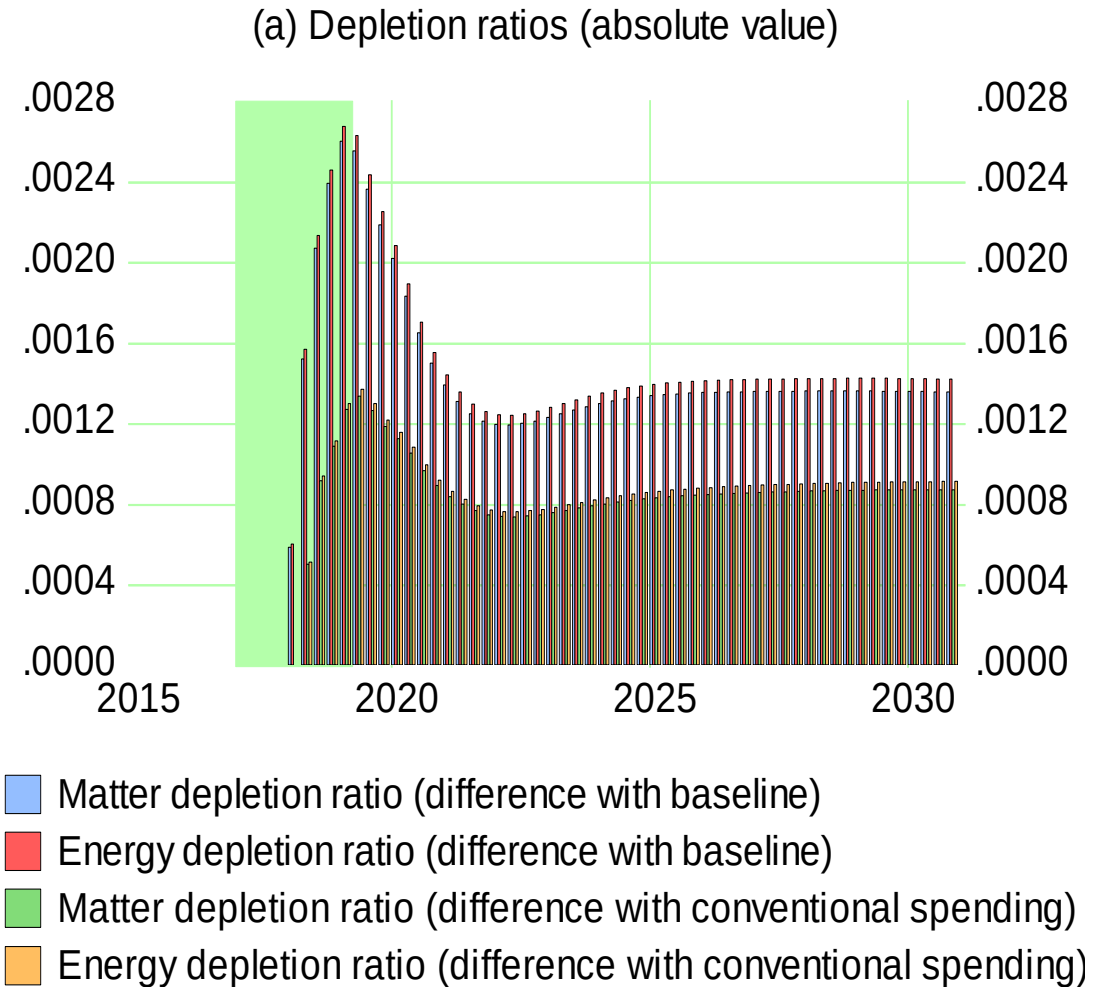



(b) Impact of gov. MOIS on debt to GDP (difference with baseline)



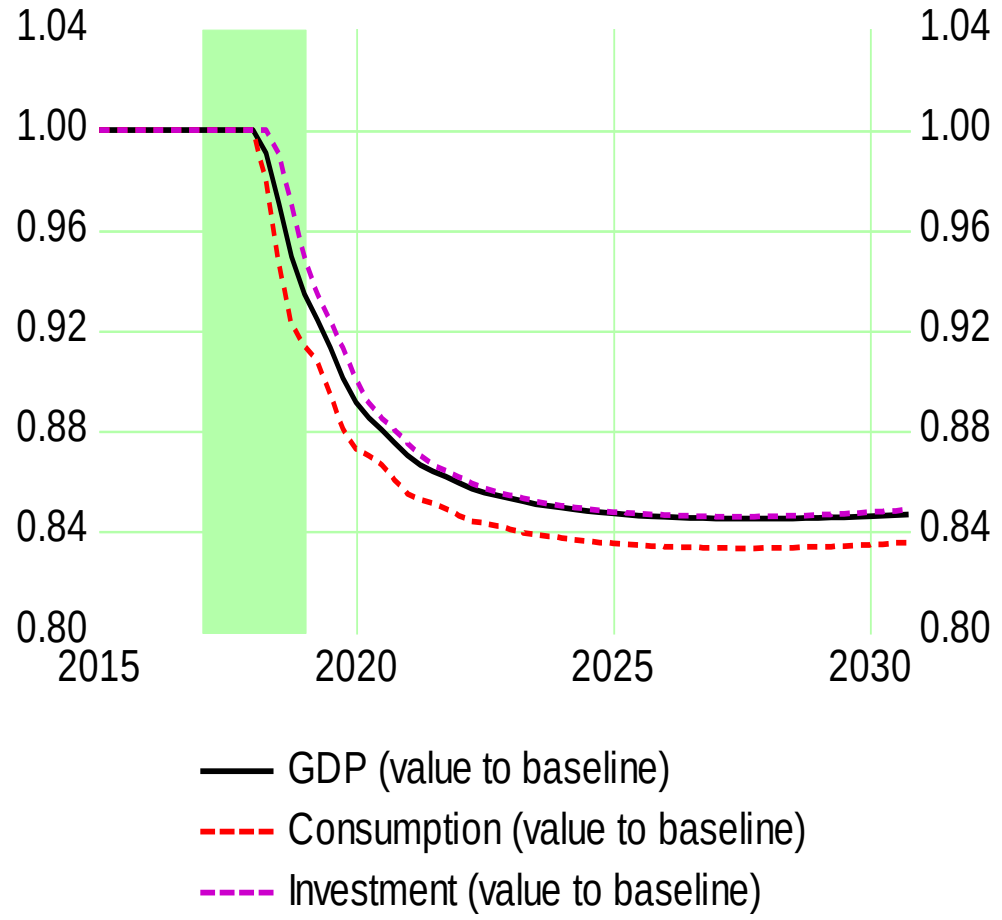
# Impact of MOIS on depletion rates



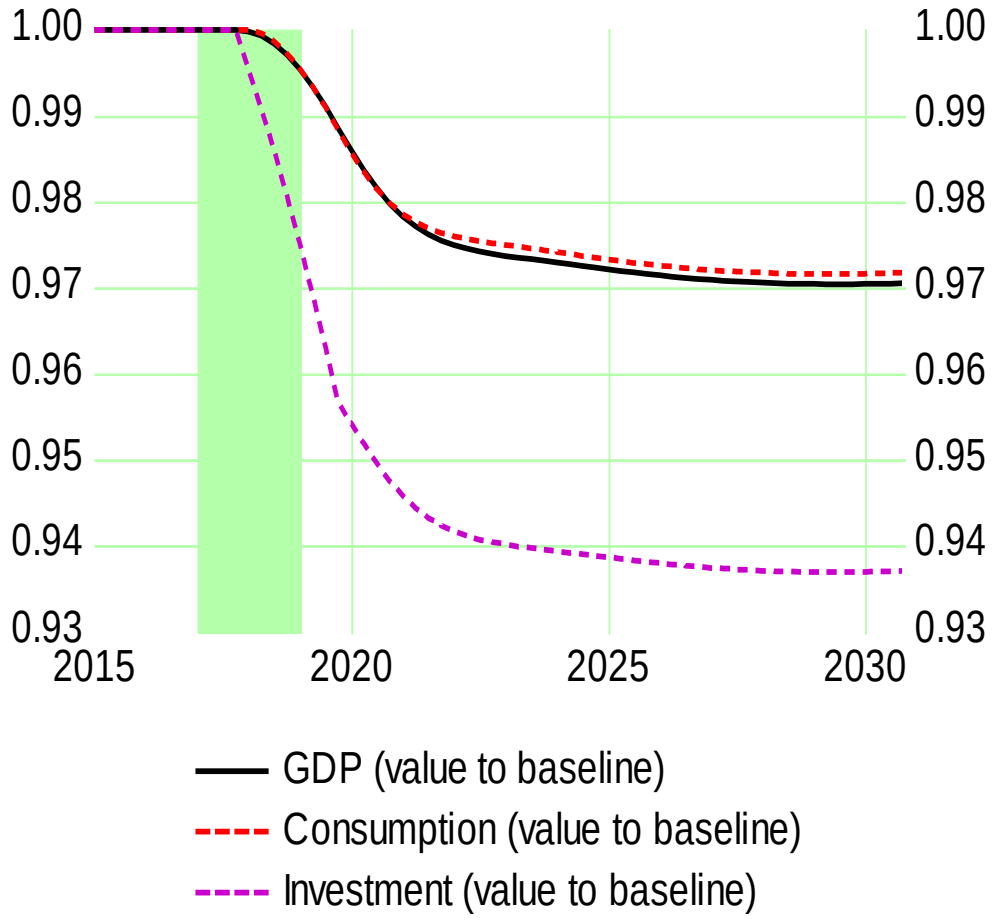



# Eco feedbacks on GDP

(a) GDP components when unsustainability boosts capital depreciation

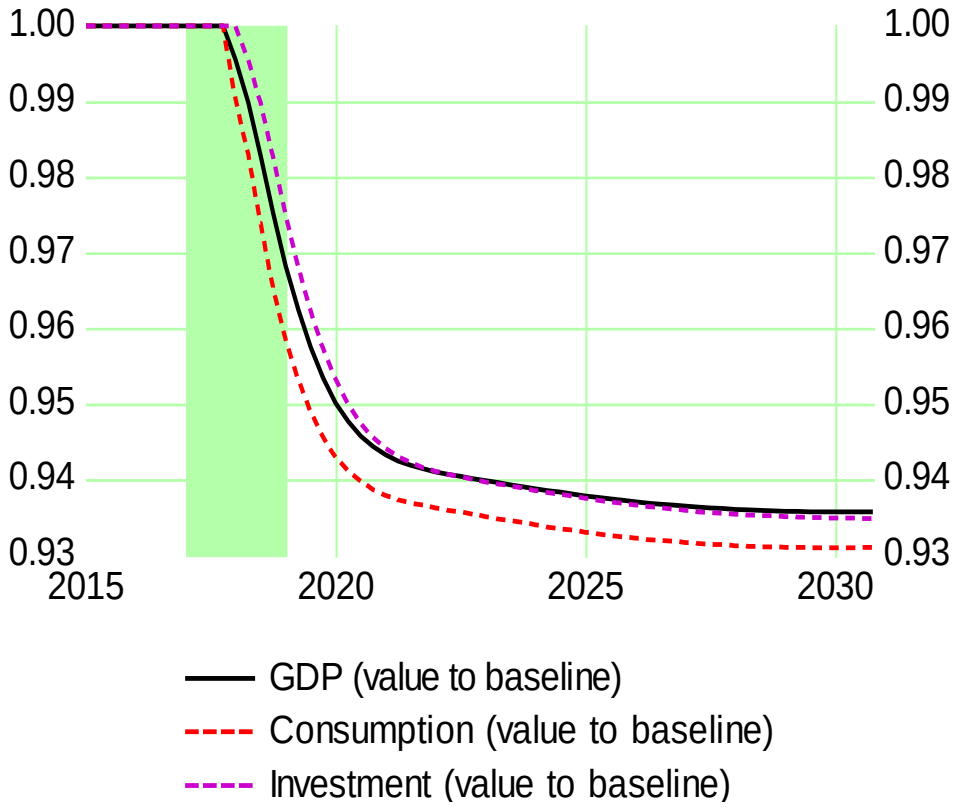



(b) GDP components when unsustainability affects investment share

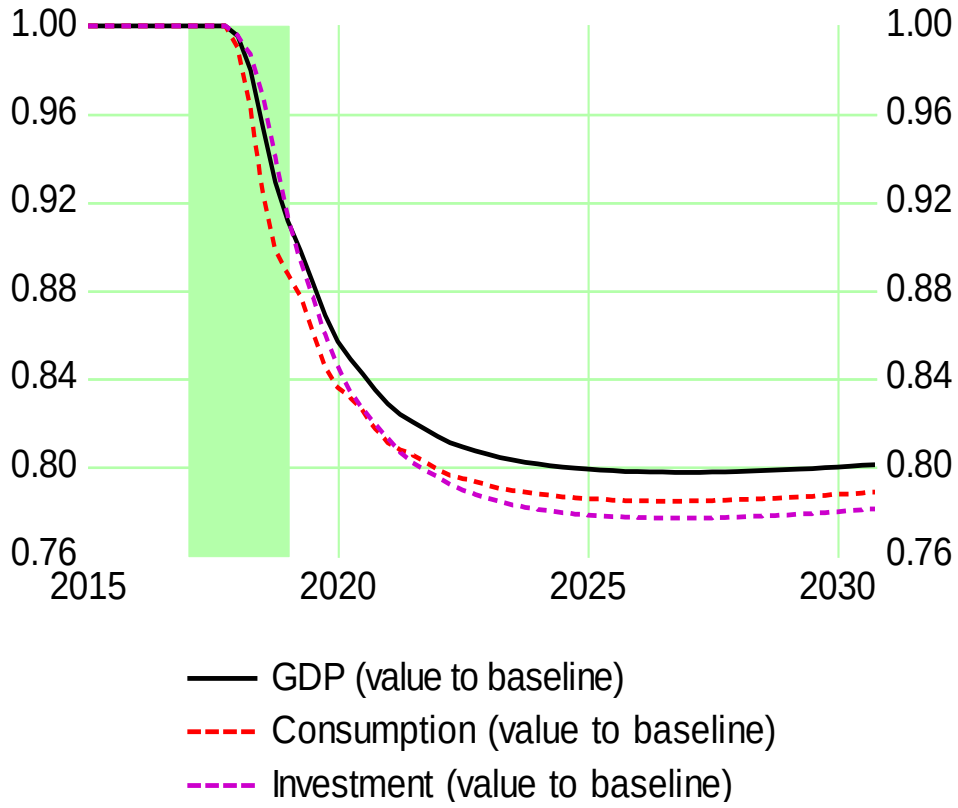


# Eco feedbacks on GDP (cont'd)

(a) GDP components when unsustainability affects consumption

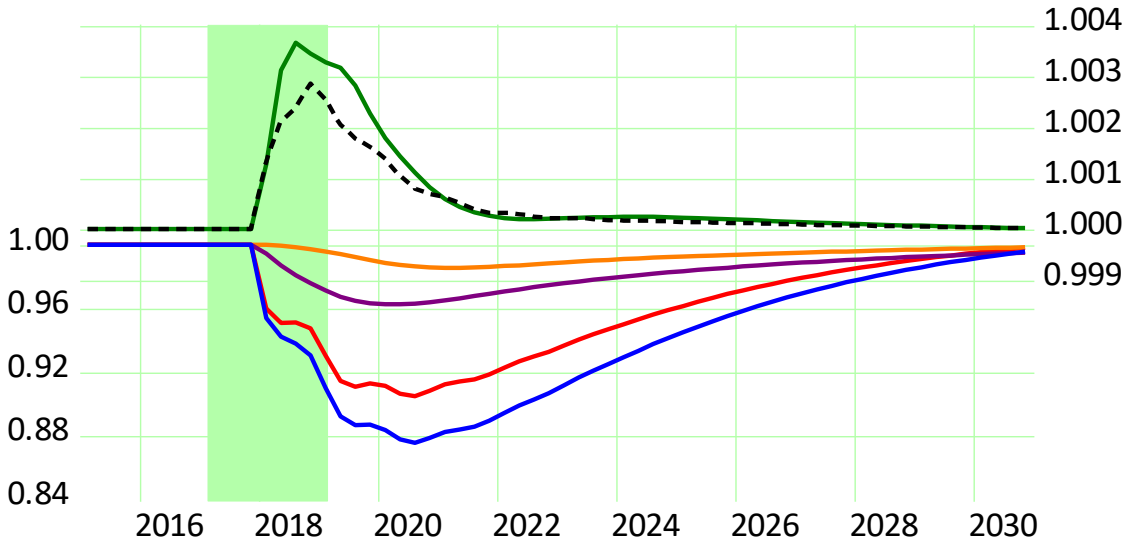



(b) GDP components when all parameters are affected



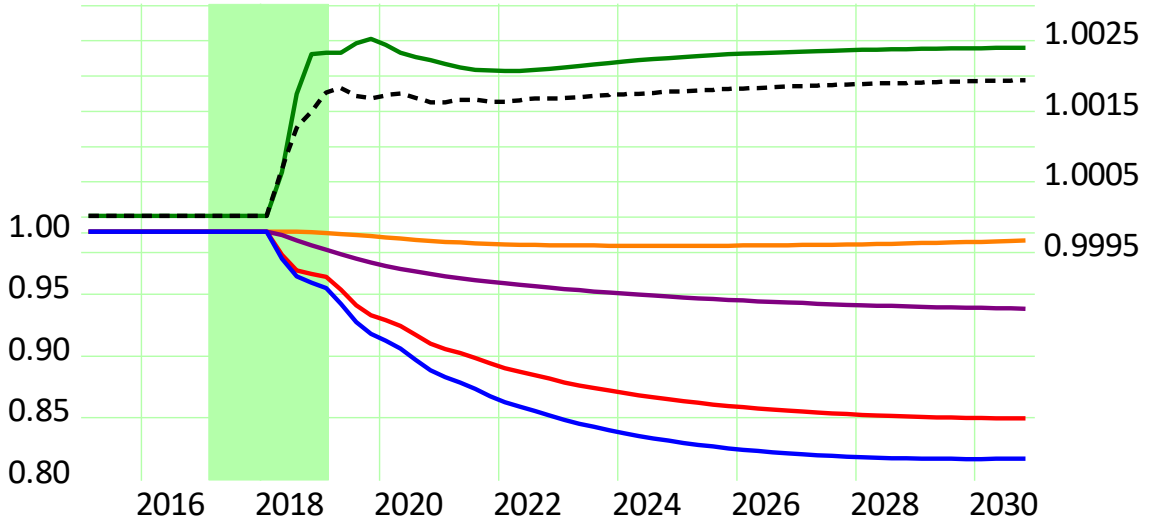
# Eco feedbacks on financial structure

(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)

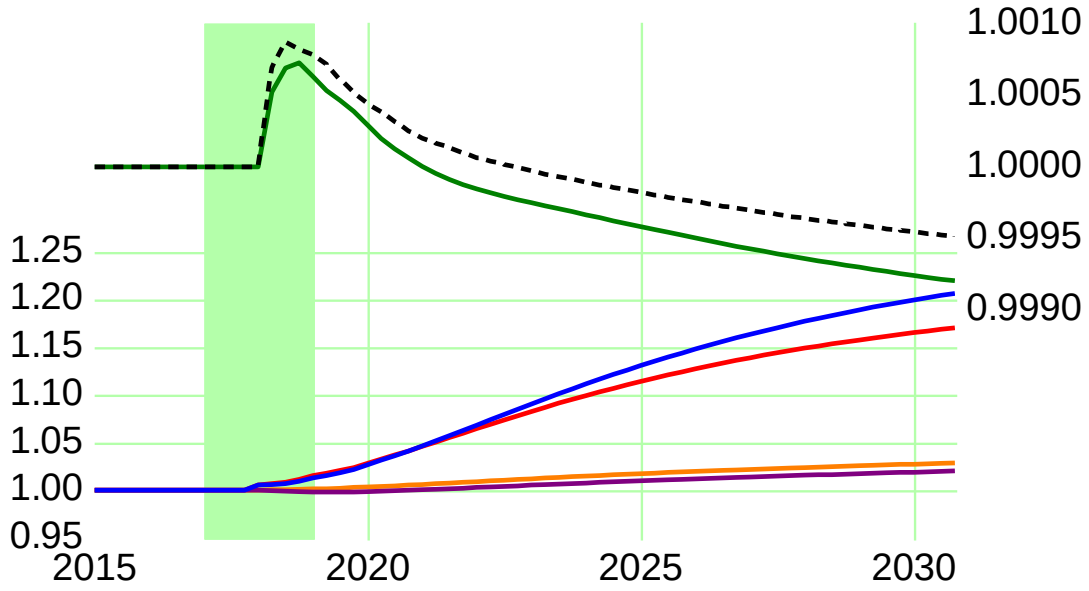
(b) Normalised market value of equity and shares when...




...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)

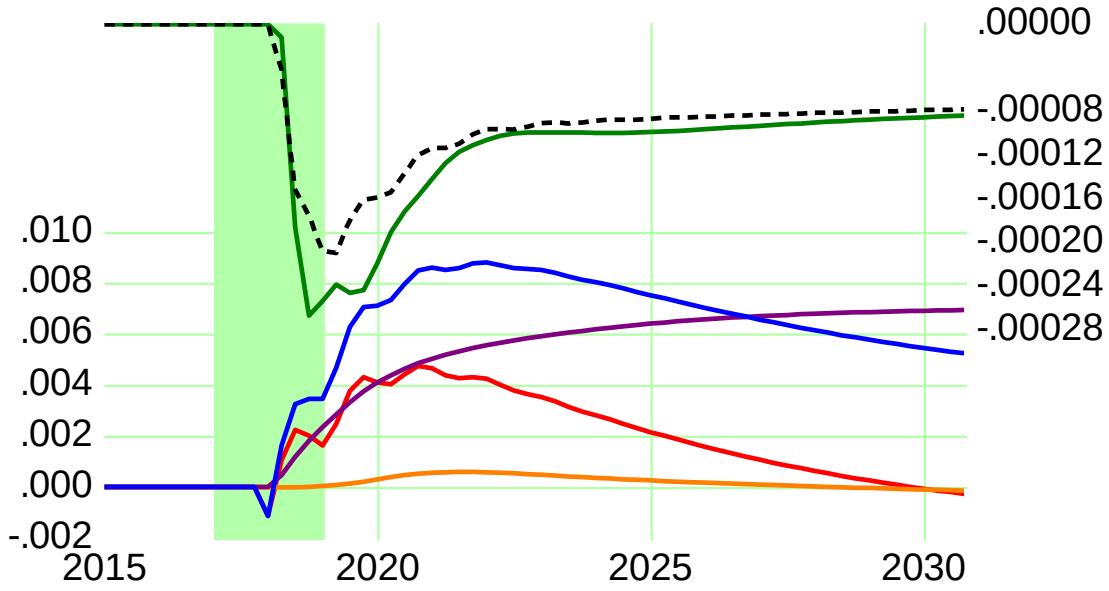
# Eco feedbacks on financial structure (cont'd)

(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)

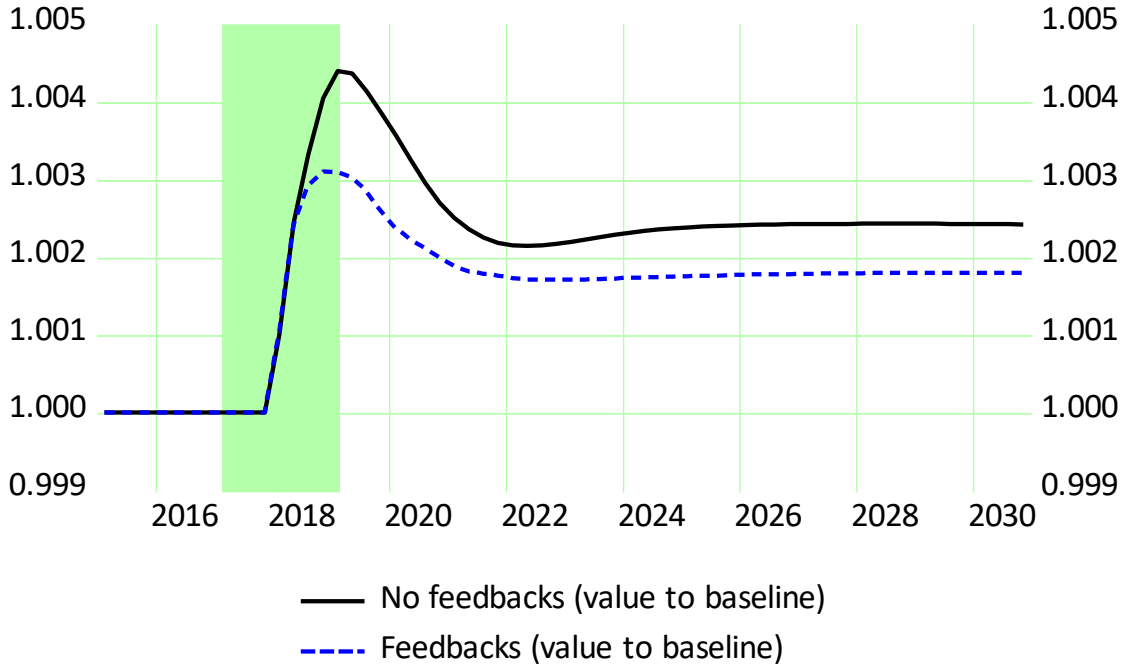
(b) Change in firms leverage ratio...



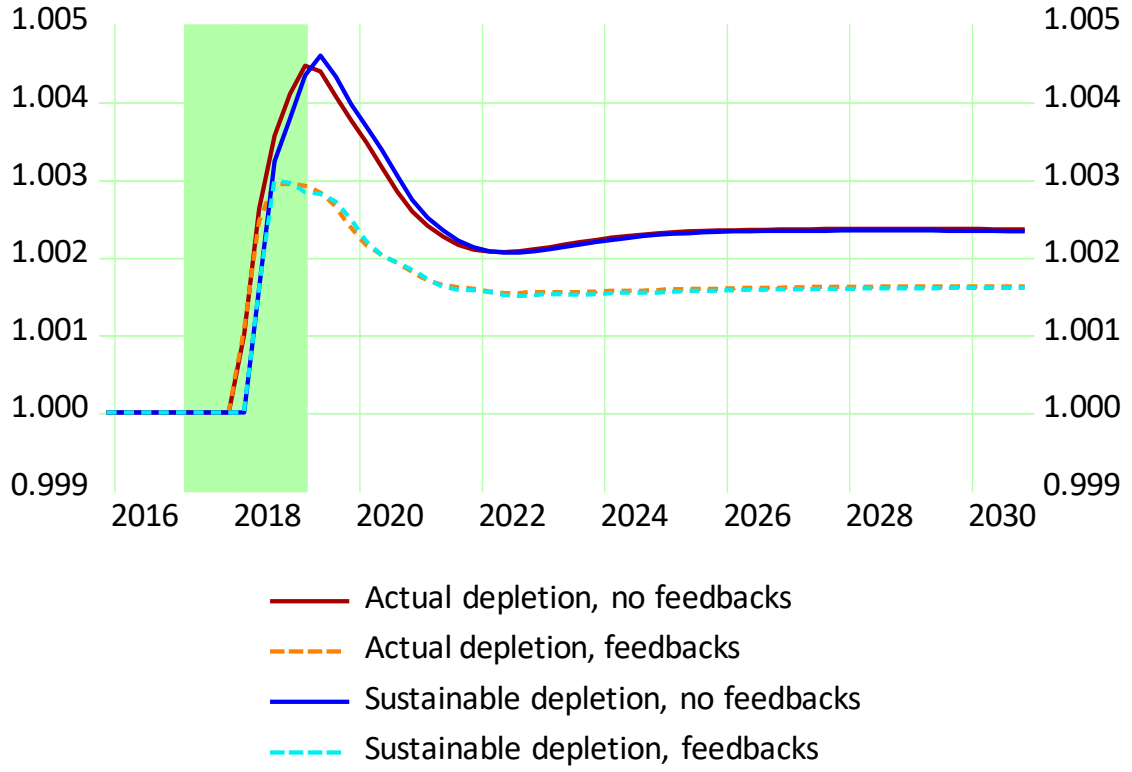

...MOIS is increased (right axis)
...capital depreciation is affected
...share of investment is affected
...propensity to consume is affected
...all the above
...MOIS and feedbacks (right axis)

# How eco feedbacks affect MOIS effectiveness

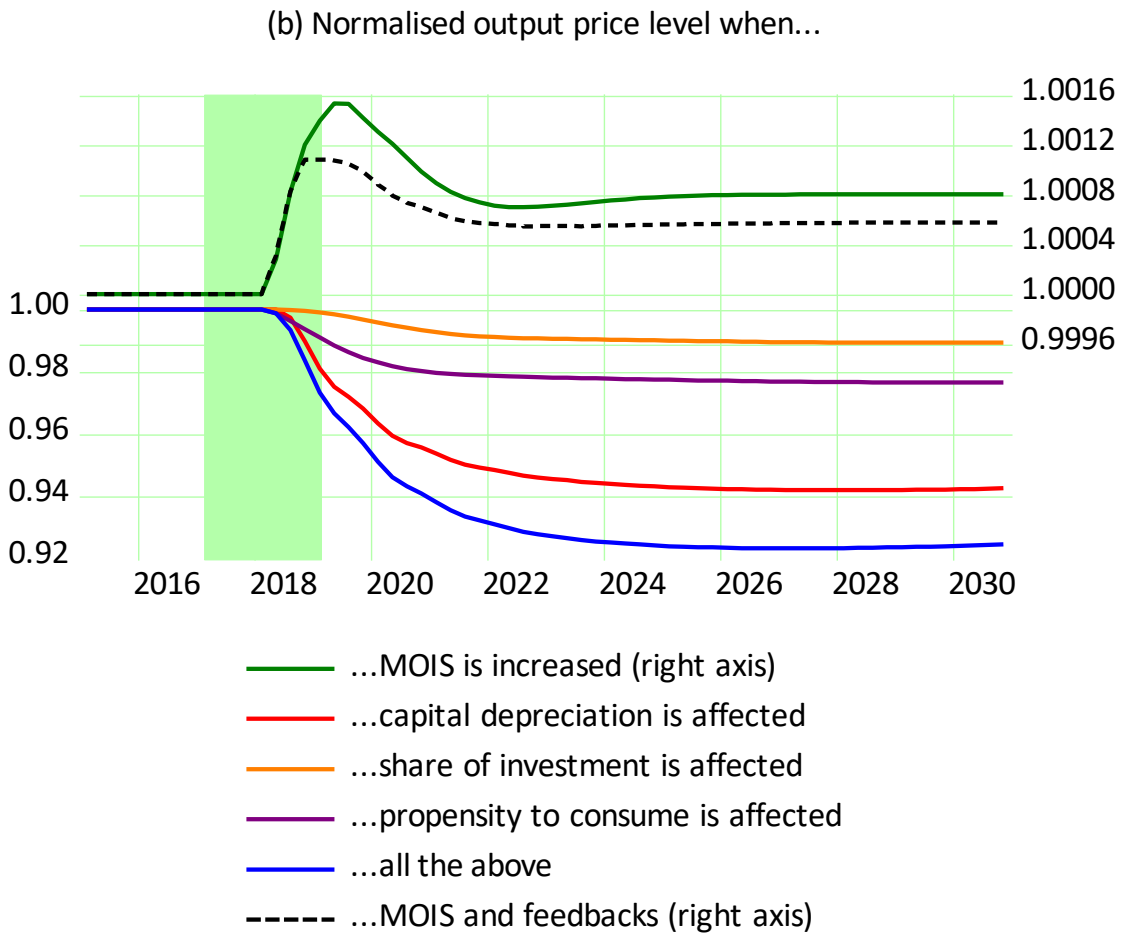
(a) Impact of increase in MOIS on GDP

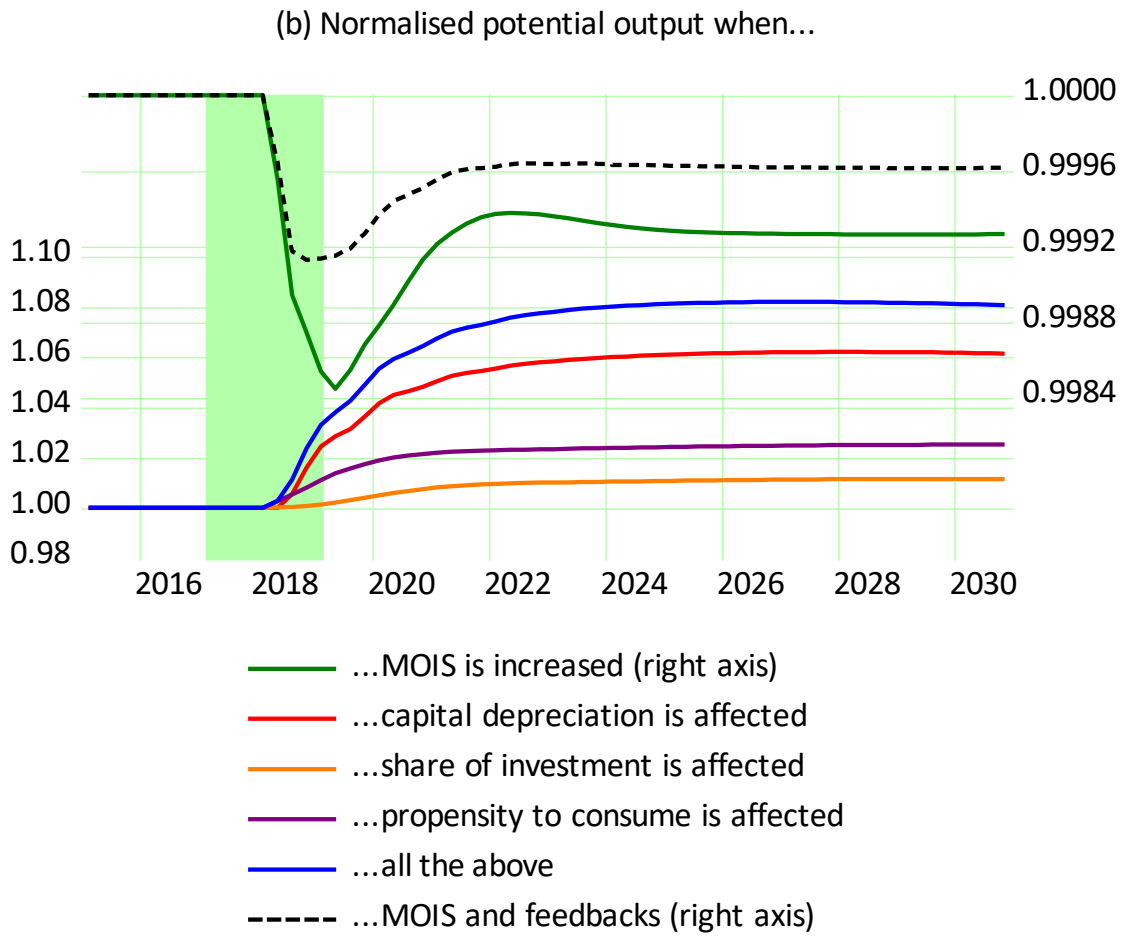



(b) Impact of increase in MOIS on depletion rate (to baseline)



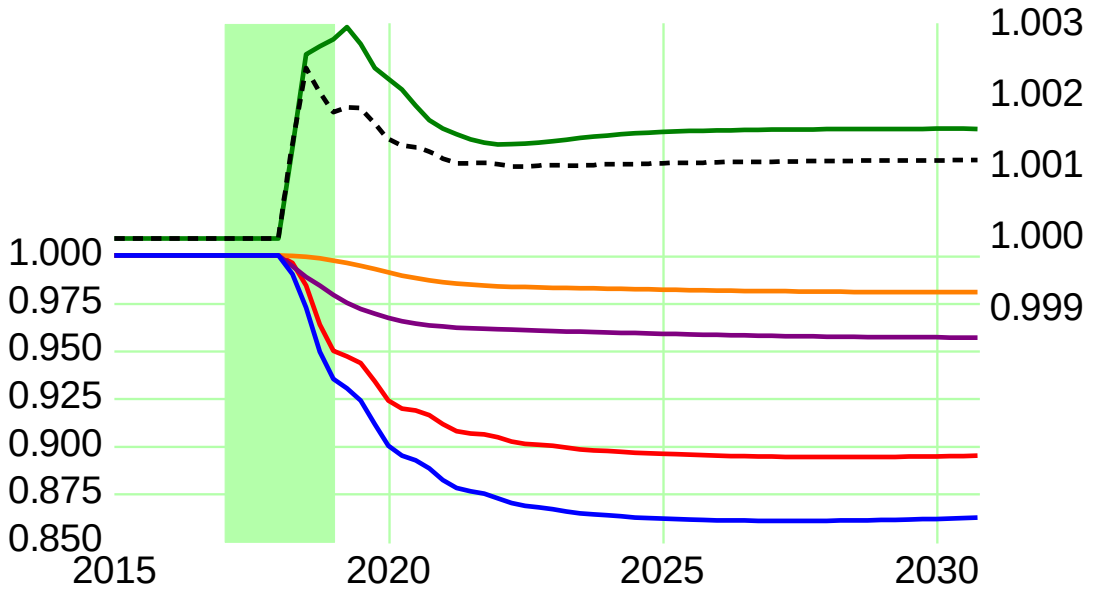
# Price of products and potential output



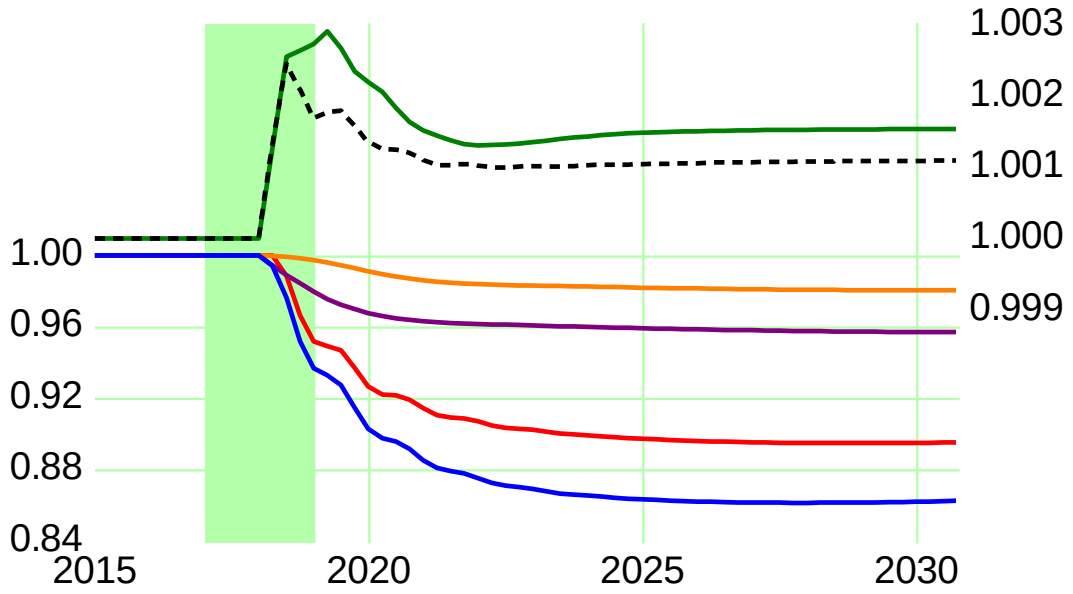
# Matter and energy prices

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




...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)

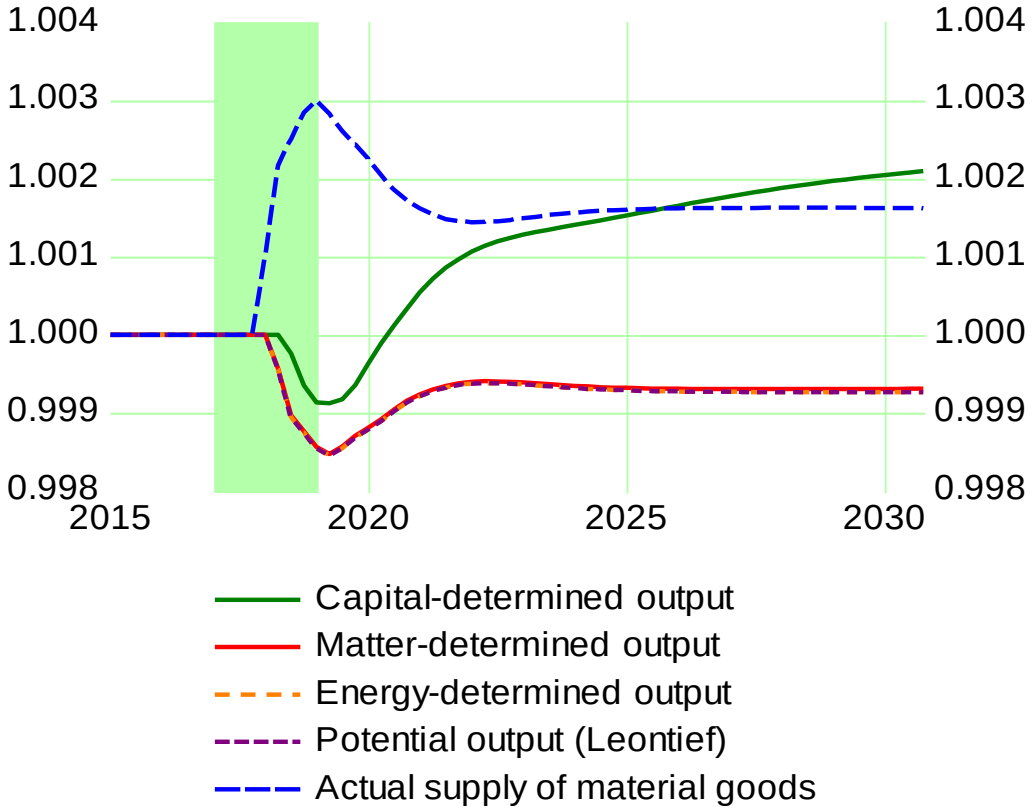
(b) Unit price of energy (relative to baseline)



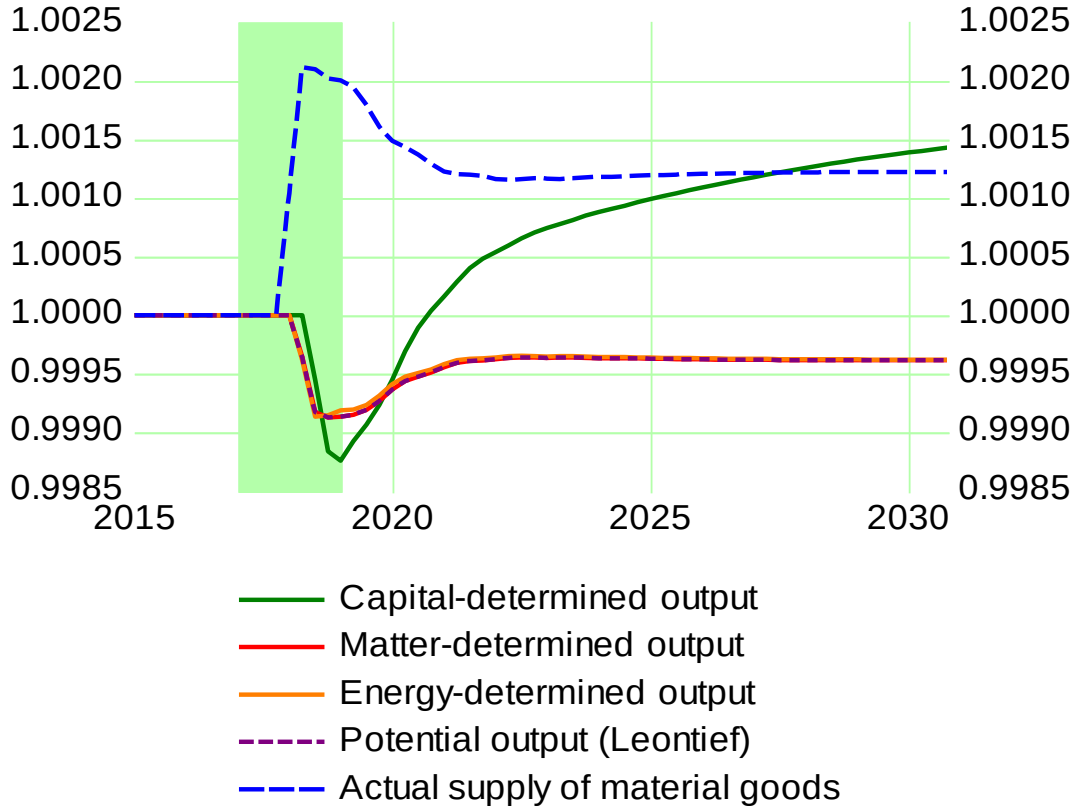

...MOIS is increased (right axis)
...capital depreciation is affected
...share of investment is affected
...propensity to consume is affected
...all the above
...MOIS and feedbacks (right axis)

# Eco feedbacks on production function

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




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



# Final remarks

- Main findings: government can support innovation and growth while limiting reserves' depletion. The latter affects policy effectiveness.
- Limitations:
  - coefficients are not estimated (the model returns us what we assumed)
  - the role of CB and NBFIs is just sketched
  - class struggle is ruled out
  - the ecosystem is highly stylised
- Pros: shedding light on the role of the State in actively promoting green innovation, thus driving a change in the overall economic structure. A simple model to account for the tendency of growth rates to slow down, while facing a progressive erosion of natural capital.
- Two developments: empirical estimation, two-country model

# Thank you

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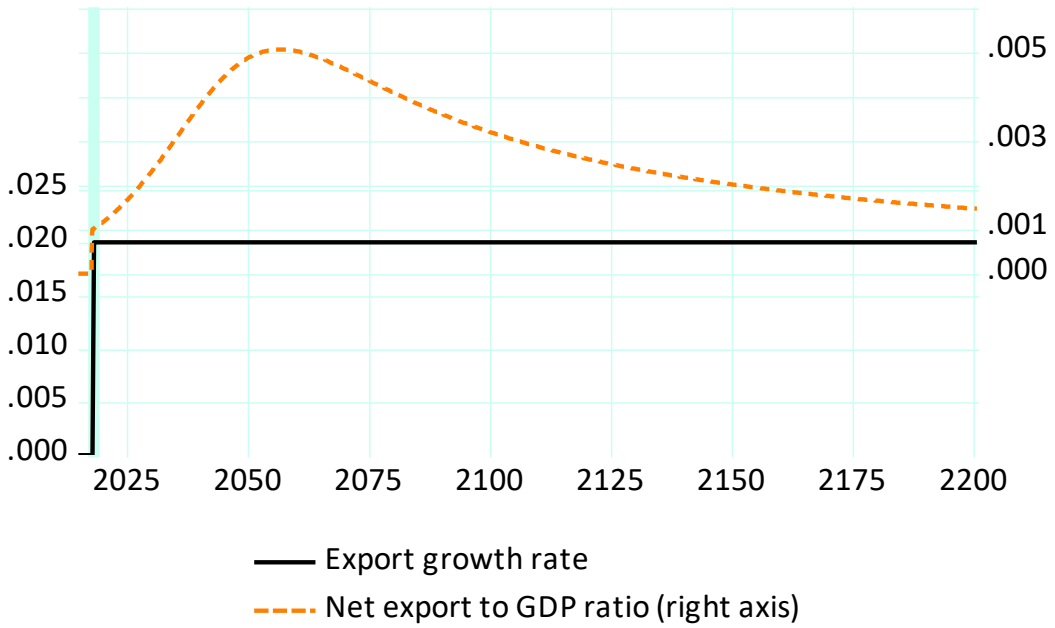
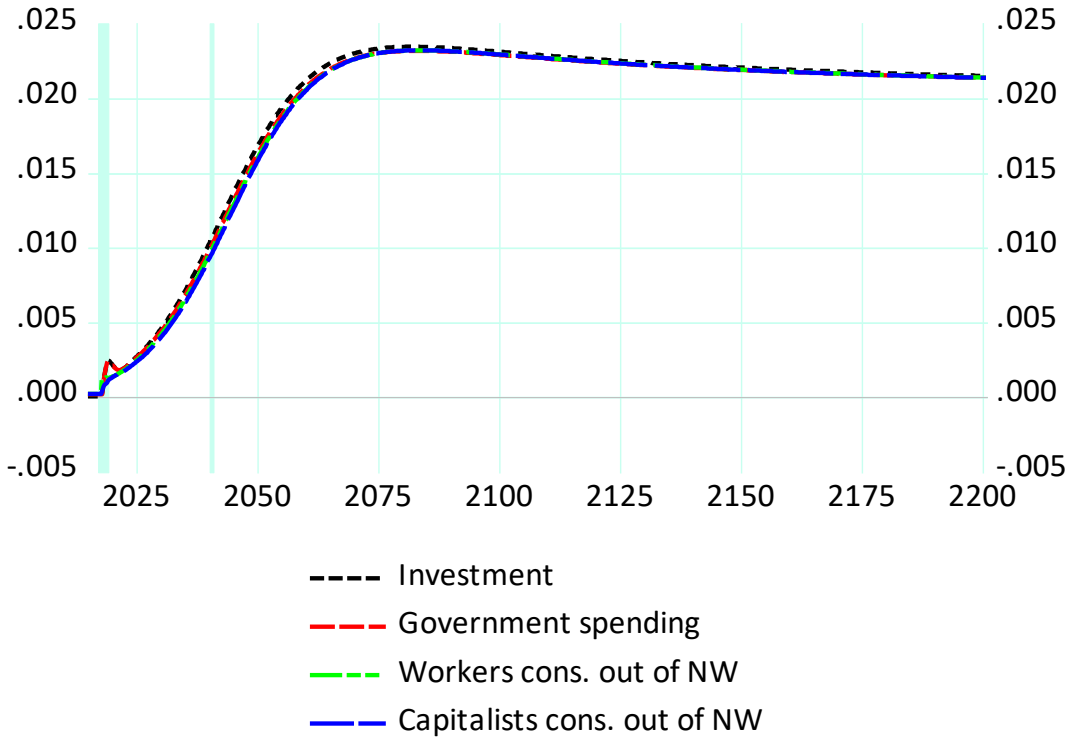
# Appendix 1: convergence to exp. growth rate

(a) Shock to growth rate of net export




(b) Growth rates (shock to NX)



# Appendix 2: long-run GDP and capacity utilis.