The green metamorphosis of a Small Open Economy

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*Views are our own and do not necessarily reflect those of the Board of Governors or the Federal Reserve System.

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- **Low fiscal incentives to adopt greener technology** data
- Even though small open economies may not individually make a sizeable contribution to global CO2 emissions, they certainly affect them as a whole
- Studying the transition in such economies provides useful insights for portraying the **macroeconomic dynamics of the green transition**

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Canonical model to study the macroeconomic impact of **green transition in a small open economy** and alternative fiscal policies

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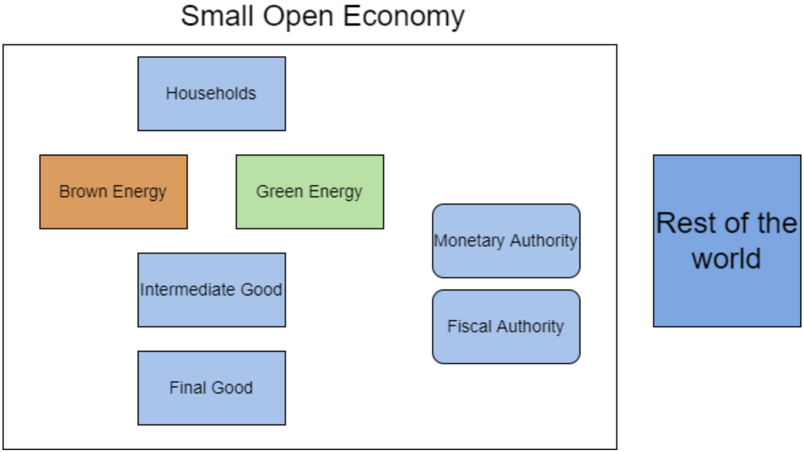
- Calibrate it to Chile and study policy-induced green transitions: 1) carbon taxes; 2) green subsidies; 3) public investment in green capital
- Offer laboratory for policy evaluations and welfare implications

NK-SOE Model with Endogenous growth



Household problem

$$\max_{c_t, i_t, i_t^G, B_{t+1}, B_{t+1}^*, k_{t+1}, s_{t+1}^G} \sum_{t=0}^{\infty} \beta^t U\left(c_t\right)$$

$$i_t^G + i_t + c_t + \frac{B_{t+1}}{P_t} + FX_t \frac{B_{t+1}^*}{P_t} = \frac{B_t}{P_t} R_{t-1} + FX_t \frac{B_t^*}{P_t} R_{t-1}^* \Phi_t(\tilde{B}_t^*) + w_t \bar{h} + \frac{R_t^k}{P_t} k_t + \frac{R_t^G}{P_t} s_t^G + \Gamma_t - \tau_t$$

$$s_{t+1}^G = \left(1-\delta\right) s_t^G + i_t^G + \Phi_s(s_{t+1}^G, s_t^G) s_t^G$$

$$k_{t+1} = (1-\delta) k_t + i_t + \Phi_k(k_{t+1}, k_t) k_t$$

Γ_t are profits and τ_t lump sum taxes
i_t^G, s_t^G are green capital investment and stock

Intermediate goods producers

- Monopolistic competition
- Choose factors and prices, subject to Rotemberg adjustment costs
- Technology:

$$y_{H,i,t} = \left[\left(A_t \left(k_{i,t} \right)^{\alpha} \bar{h}_i^{(1-\alpha)} \right)^{\frac{\epsilon-1}{\epsilon}} + \left(A_{e,t} e_{i,t} \right)^{\frac{\epsilon-1}{\epsilon}} \right]^{\frac{\epsilon}{\epsilon-1}}$$

with:

$$e_{i,t} = \bar{E} \left[(1-\zeta) \left(e^G_{i,t} \right)^{\xi} + \zeta \left(e^B_{i,t} \right)^{\xi} \right]^{\frac{1}{\xi}}$$

k capital, $\bar{h}$ labor, e total energy, e^G and e^B green and brown energy

- The government taxes brown energy by a carbon tax τ^e

Directed technical change (Hassler et al (2021))

The proportion of researchers (n) in each sector affects the productivity $A_{e,t}$, A_t:

$$g_t^A = \frac{A_t}{A_{t-1}} = 1 + Bn_t^{\phi}$$

$$g_t^{Ae} = \frac{A_{e,t}}{A_{e,t-1}} = 1 + B_e(1 - n_t)^{\phi}$$

Trade-off in the allocation of researchers

n_t is chosen optimally by the firms

Green energy production

Maximizes profits:

$$\Gamma_t^G = (1 + s)P_t^G e_t^G - R_t^G s_t^G$$

where s is a green subsidy.

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Technology:

$$e_t^G = \Omega[(1-\gamma)(s_t^G)^\omega + \gamma(s_t^{G,P})^\omega]^{(\mu/\omega)}$$

Ω productivity level in the production of clean energy

s_t^G and $s_t^{G,P}$ are green private and public capital.

ω determines the complementarity/substitutability between private and public capital

Brown energy sector

- Endowment of brown energy, traded internationally at price $p_t^{B,*}$
- Law of one price, then the domestic price is:

$$p_t^B = rer_t p_t^{B,*}$$

rer is the real exchange rate, $p_t^{B,*}$ is exogenous

The government

Central bank

Follows a Taylor rule to set the short-term interest rate

$$\frac{R_t}{R} = \left(\frac{R_{t-1}}{R}\right)^{\rho_R} \left[\left(\frac{\pi_t}{\bar{\pi}}\right)^{\phi_\pi} \left(\frac{y_t}{\bar{y}}\right)^{\phi_y}\right]^{1-\rho_R}$$

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Fiscal Authority

Collects lump sum taxes from households and issues debt subject to a budget constraint:

$$\tau_t + \tau^e p_t^B e_t^B + b_{t+1} = s p_t^G e_t^G + \frac{b_t}{\pi_t} R_{t-1} + i_t^P$$

"green policies": brown taxes, green subsidies, public investment

The tax rule is

$$\tau_t = \bar{\tau} + \phi_\tau \left(b_t - \bar{b}\right)$$

Solution and calibration

- We solve for the **perfect foresight** solution

- Calibration: target business cycle first-order moments on NIPA accounts and energy production and use for Chile, in the initial steady state

Calibration

	Parameter	Target/source	Value
β	Discount factor	Av. Inflation Chile	0.987
σ	CES elasticity in utility	Standard	1
θ	Subst. H & F in consumption	JP (2011)	0.85
χ	Share F goods in consumption	JP (2011)	0.24
δ	Depreciation capital	Standard	0.12
κ_P	Adj. cost of prices	Standard	19
ϵ_P	Elasticity between varieties	Av. Markup 11%	10
α	Capital share in production	Standard	0.26
R^*	Gross risk free rate	3 months Tbill USA	1.03
$\bar{b}$	Public debt at initial steady state	Debt-to-GDP 16%	0.14
τ^*	Lump sum taxes at initial SS	Public spending/GDP	0.12
ρ_R	Interest rate smoothing parameter	Standard	0.9
ϕ_π	Interest rate response to inflation	Martinez et al (2020)	1.12
ϕ_y	Interest rate response to output	Standard	0.2
ϕ_τ	Tax response to debt	Standard	0.07
ϕ_A	Sovereign spread parameter	Country spread Chile	0.009

Calibration

	Energy parameters	Target/source	Value
$e^{B,d}$	e^B Domestic endowment	Imported/total energy	0.5
ξ	Subst. energy inputs	Papageorgiou et al (2015)	0.67
μ	Green capital share in e^G	Standard	0.33
ϵ	Subst. energy and K	Jointly calibrated	0.48
ζ	Share of brown energy	Jointly calibrated	0.3
Ω	TFP in e^G	Jointly calibrated	0.03
B	Prod. coef researchers	Jointly calibrated	0.021
Be	Prod. coef researchers	Av. Growth 2.5%	0.11
ϕ	Prod. coef researchers	Hassler et al (2021)	0.92
γ	Green public and private K	An and Kangur (2019)	0.44
ω	Public inv. share in e^G	Substitutes	0.66

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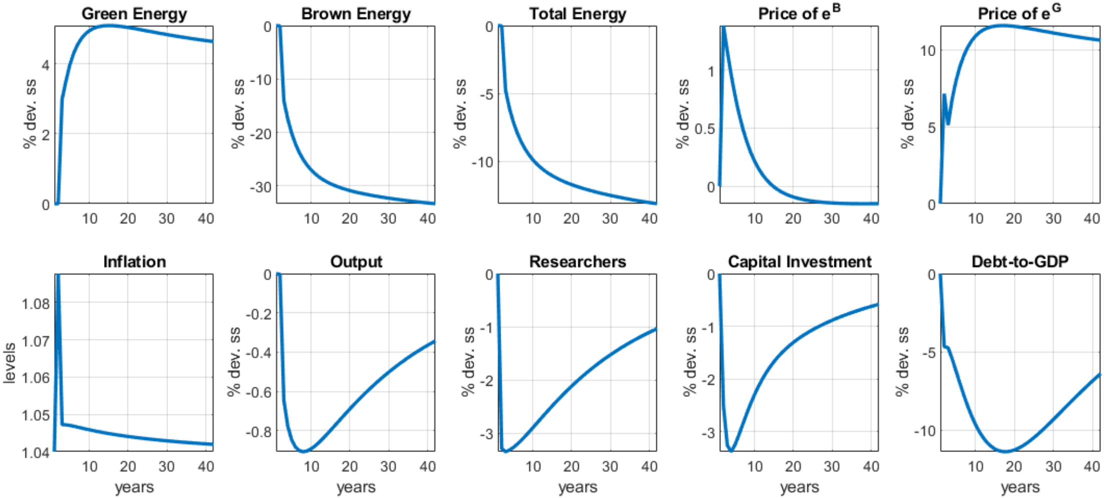
e^B/e	$(i + i^G + i^{G,P})/y$	$(i^G + i^{G,P})/y$	$e^B/e + e^G/e$
0.72	0.20	0.01	1.00

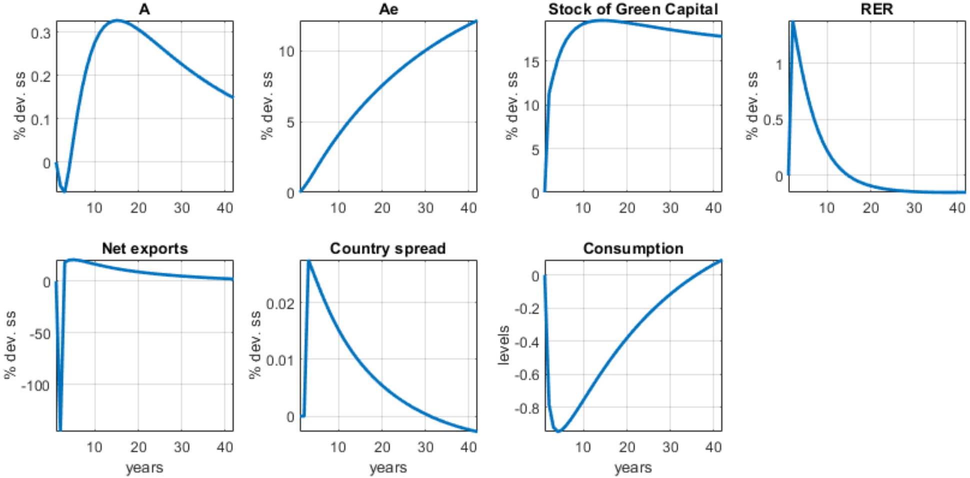
Baseline transition

- **Green transition**
  - **Carbon tax hike from \$5/t to \$35/t** as in Chile´s Climate Plan.
  - Starting from the initial steady state, we assume a 40-year transition
  - Transition results in a **35% decrease in brown energy usage**

A transition with an increase in carbon taxes



A Transition with an increase in carbon taxes



Sensitivity

- Supply frictions Go
- Production structure for energy inputs Go
- Speed of transition Go
- Exporter country Go
- Substitution or complementarity in green capital Go

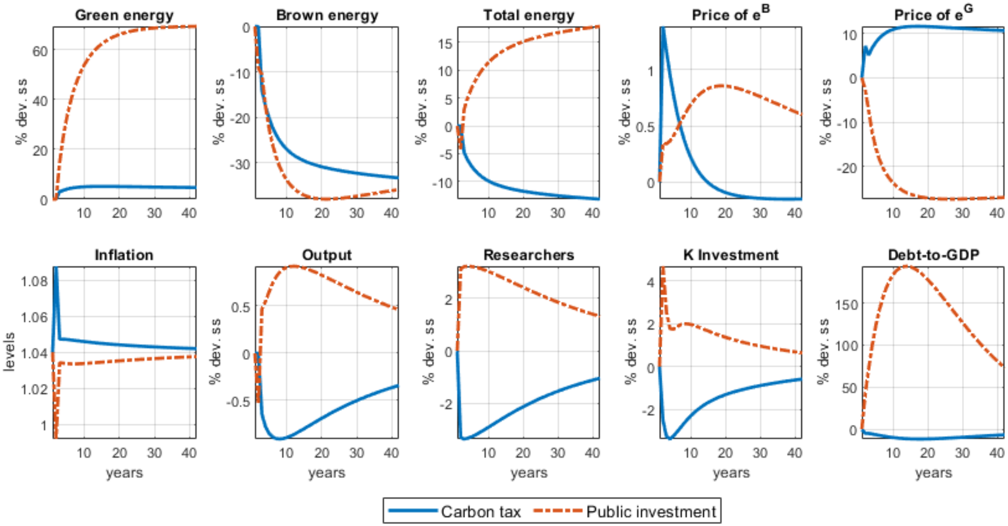
Alternative fiscal instruments

Carbon taxes decrease brown energy usage by 35%. What about other instruments?

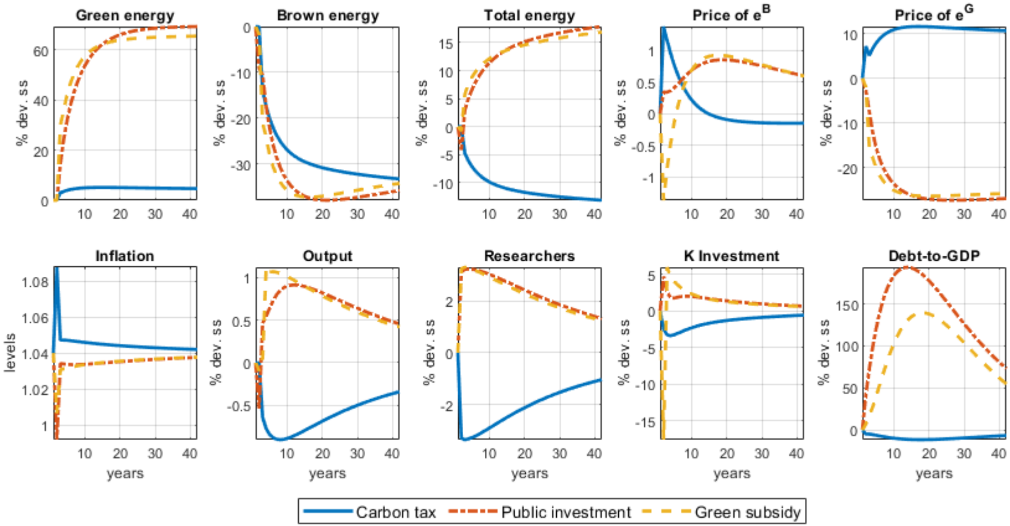
1. **Green subsidies** can achieve a similar decrease in brown energy usage only if raised to 300% (12% of GDP)

2. **Public investment in green capital** can do it with an increase in public green investment from zero to 7% of GDP (large fiscal expansion!)

Transitions with different fiscal instruments



Transitions with different fiscal instruments



Comparing Policy tools

Costs of transition depend on the fiscal policy instrument

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- **Policy mix:** combining carbon taxes with other fiscal instrument can alleviate the unintended consequences mix

Welfare

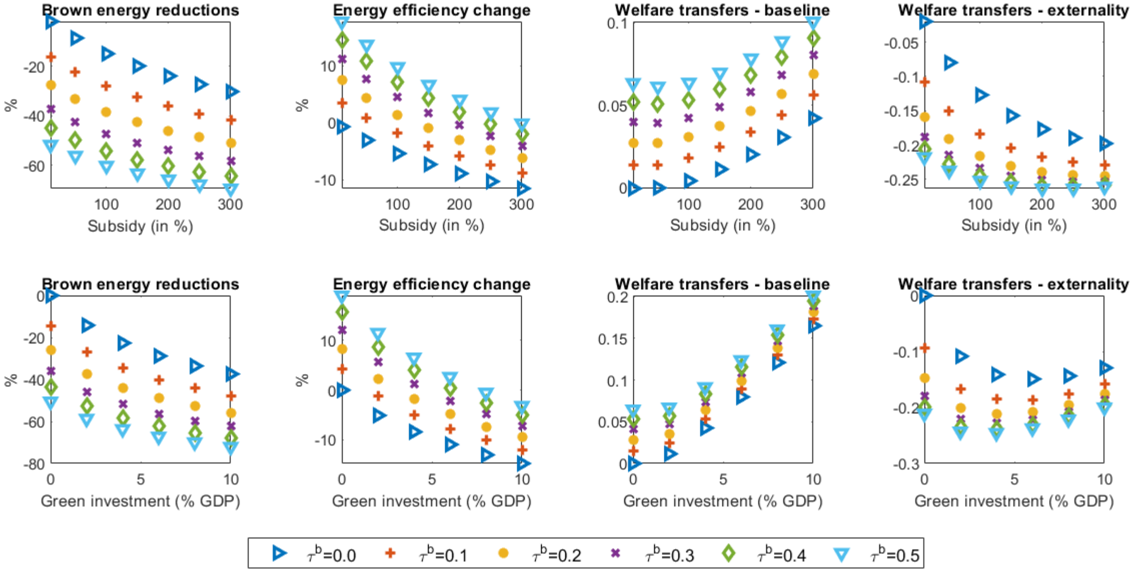
- We study welfare as consumption equivalence from the initial steady state
- **Carbon tax is the best policy** in terms of welfare
- **The green transition implies welfare losses** in the baseline model more

Policy mix

Alternative combination of policies

- Public opposition to carbon taxation (see Carattini et al. (2018))
- Combine lower increase in carbon taxes with the other two fiscal instruments
  1. Increase in taxation from 5 to 25% and increase in green subsidies from 0 to 40%
  2. Increase in taxation from 5 to 15% and increase in green public investment from 0 to 2.8% of GDP
- Both policies reduce inflationary/output and fiscal costs of transition
- **Welfare improvements through a policy mix**

Different policy mix and welfare more



Some concluding remarks

- Increases in **carbon taxes** decrease the usage of brown energy but do not significantly expand the green sector. They improve energy efficiency use, surging firms' marginal costs, leading to greenflation and output losses.
- Public investment/subsidies avoid inflation and recession. However, they generate losses in terms of energy efficiency and high fiscal costs.
- Policy combination of carbon tax increases and green subsidies or public green investment can alleviate the unintended consequences.
- Monetary policy can shape greenflation in the short run at the cost of higher fiscal stress.

The End

Thank you!

Motivation back

Low fiscal incentives to adopt greener technology

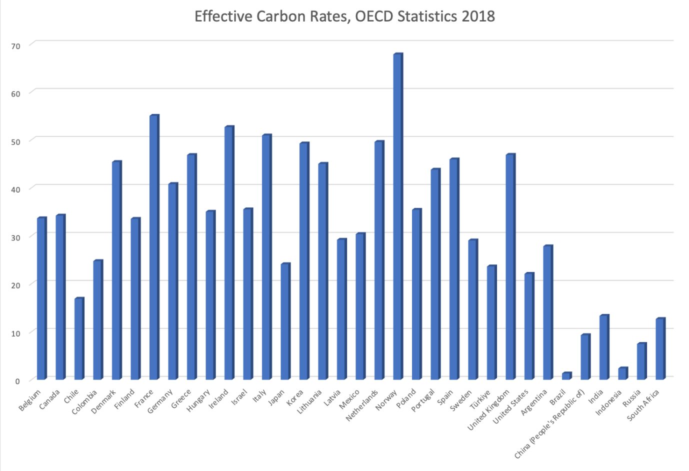


Figure 1: Carbon Pricing Score, (wrt 60 euros per metric ton of CO2-equivalent).

Welfare externality back

Welfare as consumption equivalence from initial steady state:

$$\sum_{t=1}^{T} \beta^t log\,(c_0) = \sum_{t=1}^{T} \beta^t log\,(c_{t,k} + \Lambda_k)$$

where $\tilde{c}_t$ is the detrended value of consumption more

$$c_t = \tilde{c}_t X_{t-1}$$

and k is the scenario under study

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Externality scenario

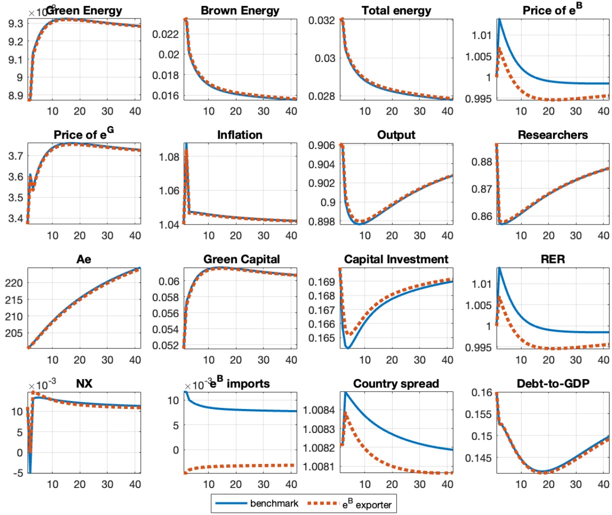
$$\hat{c}_t = c_t - \tilde{\gamma}(e_t^B)^2$$

Calibrate $\tilde{\gamma}$ to get damages as 5% and 20% of GDP.

Welfare comparisons back

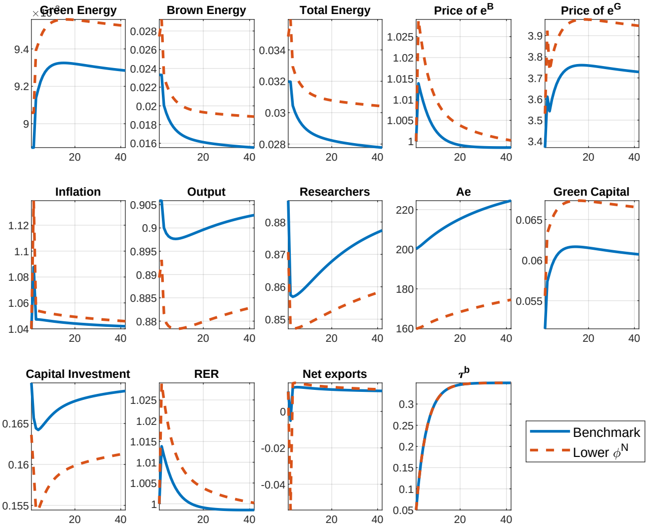
	No externality	**Low Externality** e^B	**High Externality** e^B
Carbon Tax	0.041	-0.023	-0.179
Green Subsidy	0.042	-0.023	-0.198
Public Investment	0.101	0.034	-0.148

The case of a brown energy exporter back

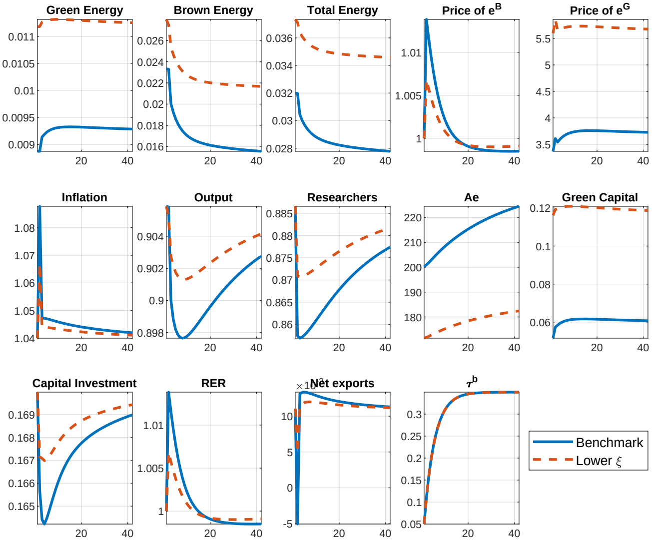


The role of supply frictions

back

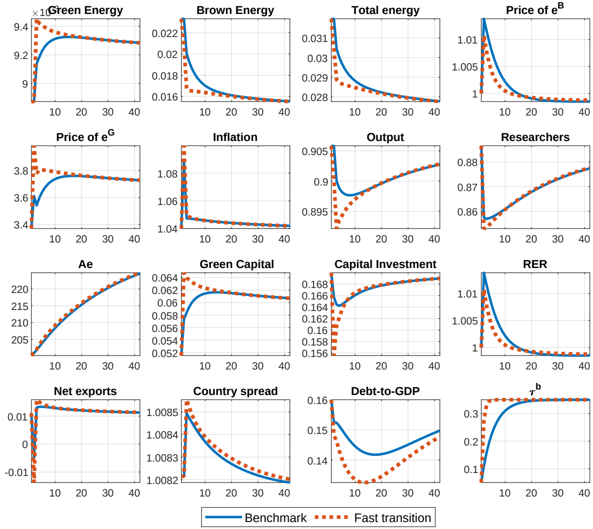


The role of substitutability between energy inputs back

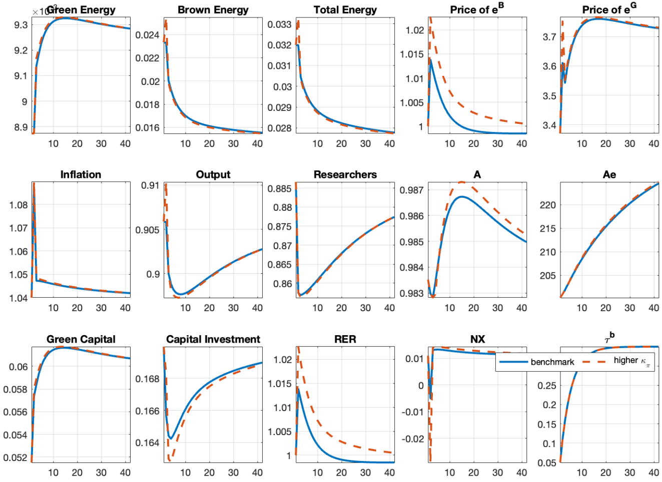


The speed of transition

back

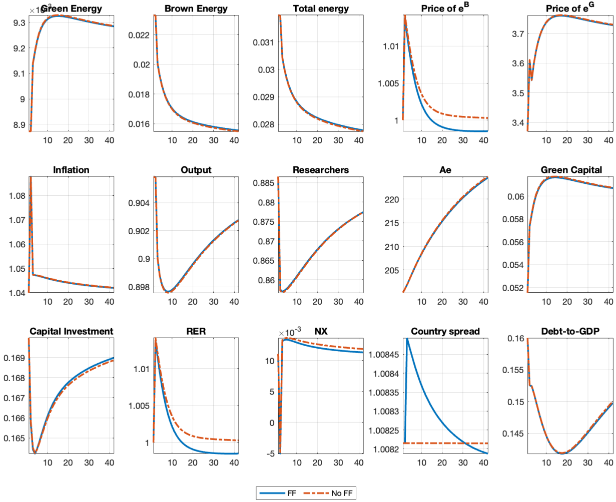


Sensitivity: Stickier Prices back

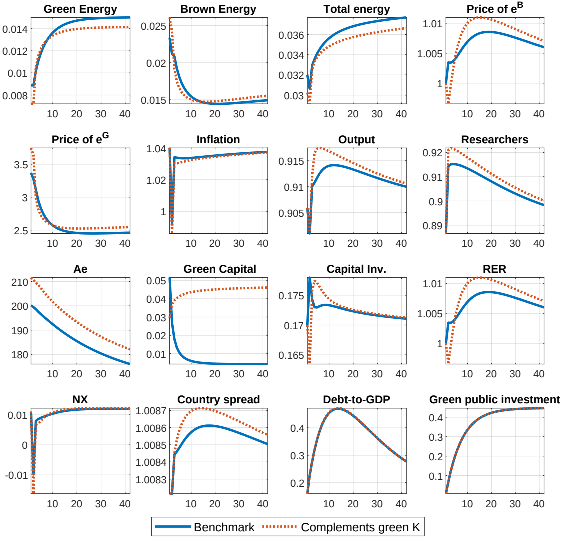


Sensitivity: Financial Frictions

back

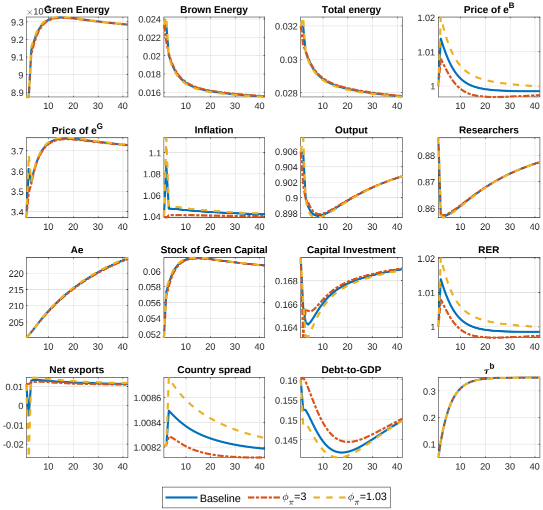


Public and private green capital complementarity
back

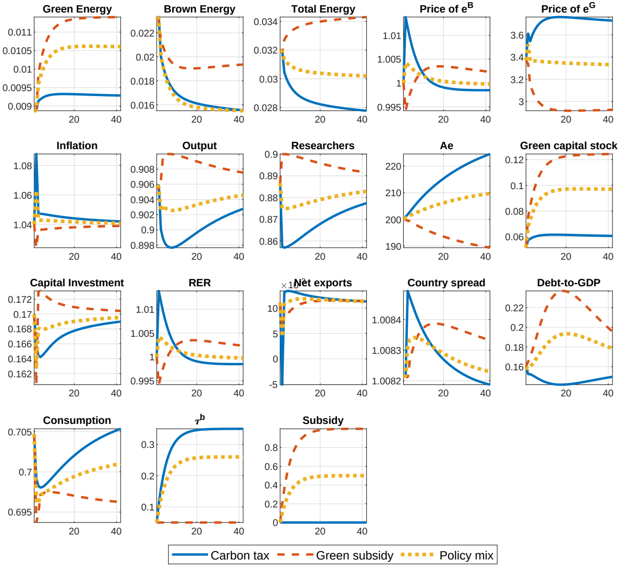


The role of monetary policy

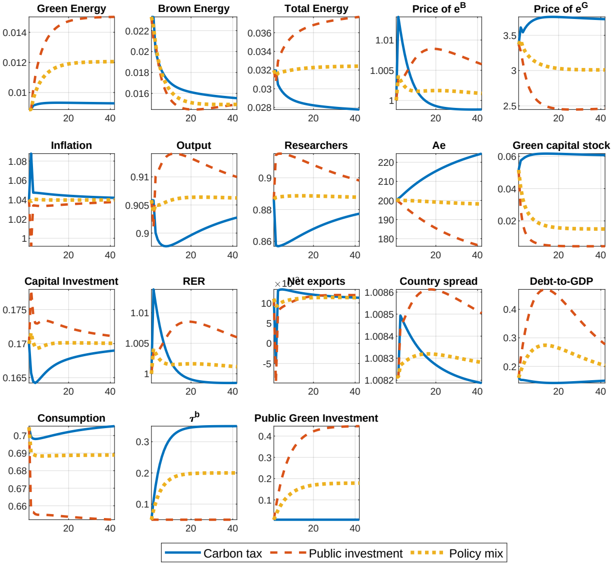
back



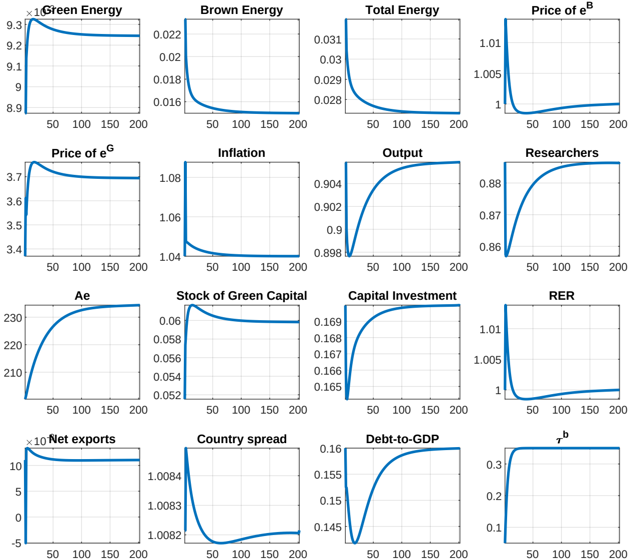
Policy mix brown taxes and green subsidies back



Policy mix brown taxes and green investment back



The whole transition path 200 years back



Welfare comparisons back

- Increase in carbon taxes from 5% to 35%
- Increase in Green Public Infrastructure by 7% of GDP
- Policy mix 1: Increase in carbon taxes from 5% to 25% by 7% and subsidies from zero to 40%
- Policy mix 2: Increase in carbon taxes from 5% to 15% by 7% and public investment from zero to 2.8% of GDP

Table 1: Welfare Comparisons

	No externality	**Low Externality** e^B	**High Externality** e^B
Carbon Tax	0.041	-0.023	-0.179
Green Subsidy 300%	0.042	-0.023	-0.198
Public Infrastructure	0.101	0.034	-0.148
Carbon Tax-Sub Mix	0.028	-0.036	-0.194
Carbon Tax-IG Mix	0.040	-0.027	-0.194