Net Zero: Distributional Effects of the Green Transition

(working title)

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”The challenge at the heart of the EU’s green transition is how we can bring (...) benefits to all as quickly and as fairly as possible.”

European Commission, 2021

Research Question:

- What are the distributional consequences of the Net-zero emissions policy and which role plays the fiscal redistribution?

Motivation

The objectives of the European Green deal are:

- no net emissions of greenhouse gases by 2050 EU CO2 Emissions Projections;
- no person and no place left behind;

But...

- transition to a Net Zero economy could resemble a permanent inflationary (or deflationary?) markup-shock ⇒ policy intervention needed to avoid regressive distributional effects;
- wealth-poor households unable to smooth consumption through savings, the larger the variation of wage income, the stronger the variability of their consumption;
- carbon revenues can be used to offset detrimental effects ⇒ subsidies and transfers (*Energy and Climate Fund*, *Social Climate Fund*).

Who would pay the highest costs?

The transition can have regressive distributional effects:

- it raises goods prices (price effect);
- it alters the return to capital and labor (income effect);
- it affects the asset values (wealth effect).

High-carbon intensive sectors take a higher share of low-income households' expenditure.

Energy by income

Preview

- Carbon tax shock leads to an increase in energy inflation and labor supply;
- redistributing carbon tax revenues to hh reduce income and consumption inequality;
- in perfect foresight, rational agents learn about trajectory of the tax and anticipate fall in income: demand effect prevails, the policy becomes deflationary;
- households transfers and firms subsidies reduce income inequality (but not always consumption inequality);

Additional:

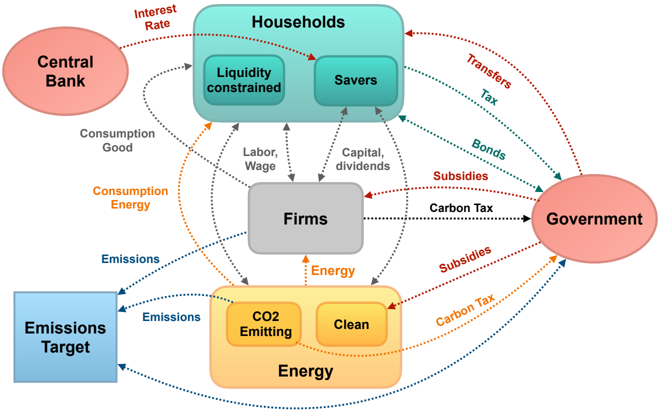
- if only energy sector subject to emission reduction scheme, energy price increases permanently;
- exogenous green growth reduces output fall; expectation errors add noise but dynamics don't change.

Literature

- Macroeconomic effects of environmental policies:
  - Känzig and Konradt (2023) and Metcalf and Stock (2023);
- Distributional effects of carbon tax shocks:
  - Berthold et al. (2023), Eurofound (2021), Känzig (2023), Metcalf (2019), and Zachmann et al. (2018);
- TANK and E-DSGE model :
  - Bilbiie (2008);
  - Annicchiarico and Di Dio (2015, 2017), Carattini et al. (2023), Ferrari and Nispi Landi (2023), and Heutel (2012).

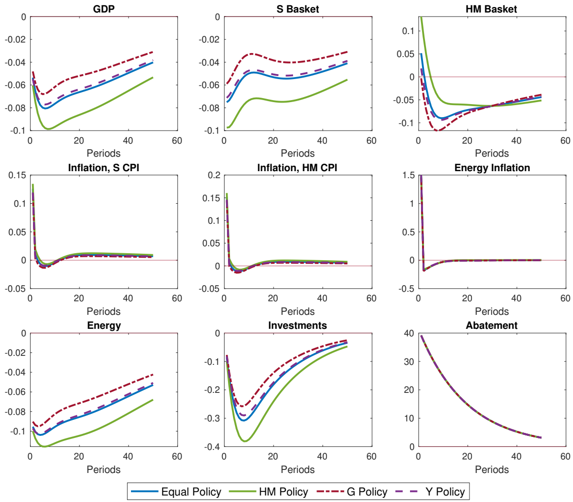
Contribution: E-DSGE for distributional issue; long-run analysis of transition to net zero economy in a general equilibrium framework, comparison of different carbon tax revenues redistribution schemes in terms of inequality. Add: compare diff expectation formation processes.

Two-agents E-DGE: Model Overview

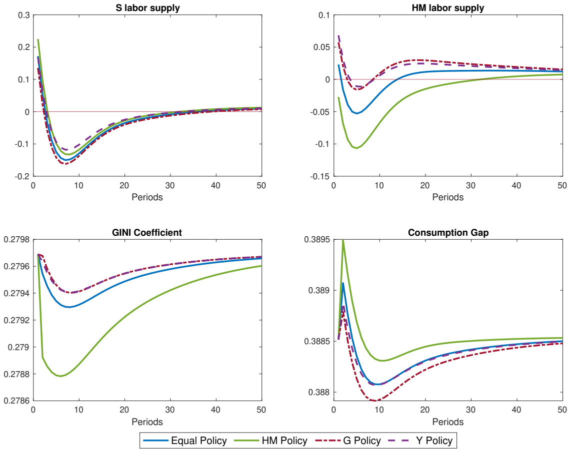


HH | HH basket | non-energy firm | aggr. energy | energy producers | climate | market clearing

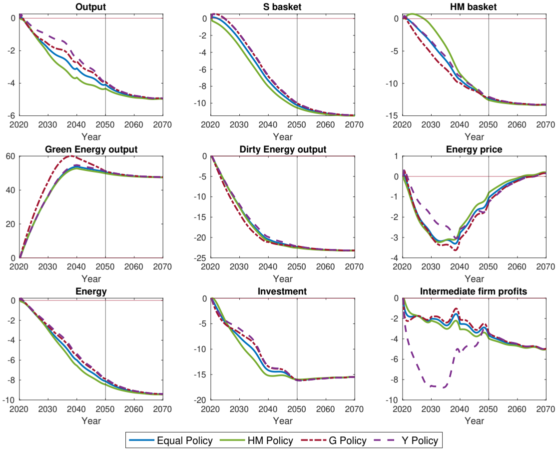
IRF: Temporary Carbon Tax Shock



IRF: Temporary Carbon Tax Shock

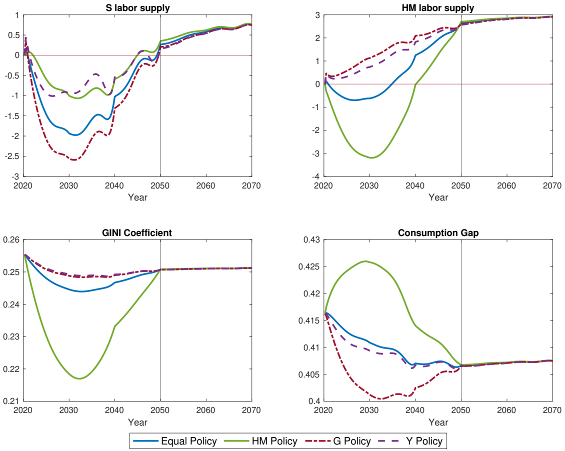


The Net Zero Policy: Transition Dynamic



◂ Energy Prices ◂ Sectoral Labor & Capital ◂ Expectation Errors ◂ Exogenous Green Growth ◂ τ_D only

Labor Supply and Inequality Measures, Transition Dynamics



Conclusion

- Carbon tax shock: temporary increase in energy inflation; lasting slump in production and consumption;
- redistributing carbon tax revenues to HM reduces income and consumption inequality (only temporary); but it's the most detrimental to output and inflation;
- in perfect foresight, rational agents learn about the full trajectory of the tax and anticipate fall in income: demand effect prevails and soon the policy becomes deflationary;
- only HM transfers reduce (temporary) income and consumption inequality;
- other redistribution schemes (firms subsidies in particular) have little to no effect on income and negative on consumption inequality.

Allen, Myles R., Opha Pauline Dube, and William Solecki (2018). *Chapter 1: Framing and Context. In: Global Warming of 1.5 ℃ an IPCC special report on the impacts of global warming of 1.5 ℃ above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change. Intergovernmental Panel on Climate Change.*

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Appendix

Net Zero: Distributional Effects of the Green Transition

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Households: ”Hand-to-mouth” vs ”savers”

Utility maximization problem: maximize w.r.t consumption and labor, s.t. budget balance and law of motion of capital:

$$u\left(x_{j,t}, l_{j,t}\right) = \frac{x_{j,t}^{1-\varphi_c} - 1}{1-\varphi_c} - \psi \frac{l_{j,t}^{1+\varphi_l}}{1+\varphi_l} \quad \text{where j=\{HM,S\}} \tag{1}$$

HM budget:

$$p_{HM,t} x_{HM,t} = w_t l_{HM,t} + \mathcal{T}_t^{HM} \tag{2}$$

S budget:

$$b_t + p_{s,t} x_{s,t} + i_t = b_{t-1} \frac{r_{t-1}}{\pi_t} + r_t^k K_{t-1} + w_t l_{s,t} + \mathcal{T}_t^S \tag{3}$$

back

Households' consumption basket

CES basket: final good and energy consumption:

$$x_{j,t} = \left[\gamma_j^{\frac{1}{\epsilon}} c_{j,t}^{\frac{\epsilon-1}{\epsilon}} + (1-\gamma_j)^{\frac{1}{\epsilon}} E_{j,t}^{c\ \frac{\epsilon-1}{\epsilon}} \right]^{\frac{\epsilon}{\epsilon-1}} \tag{4}$$

Demand:

$$c_{j,t} = \gamma_j \left(\frac{1}{p_{j,t}} \right)^{-\epsilon} x_{j,t} \tag{5}$$

$$E^c{}_{j,t} = (1-\gamma_j) \left(\frac{p^E{}_t}{p_{j,t}} \right)^{-\epsilon} x_{j,t} \tag{6}$$

back

Non-energy producers

Final good production:

$$y_t(i) = TFP_t \left[\upsilon^{\frac{1}{\xi_y}} \left(VA_t(i)\right)^{\frac{\xi_y - 1}{\xi_y}} + (1-\upsilon)^{\frac{1}{\xi_y}} \left(A_{E,t} E_{y,t}(i)\right)^{\frac{\xi_y - 1}{\xi_y}} \right]^{\frac{\xi_y}{\xi_y - 1}}, \tag{7}$$

$$\text{where } VA_t(i) = A_{y,t}(i) \left(k_{y,t-1}(i)\right)^{\alpha} \left(l_{y,t}(i)\right)^{1-\alpha} \quad \text{with} \quad \alpha \leq 1 \tag{8}$$

$$\text{and} \quad TFP_t(i) = \left(1 - D_t(e_{s,t})\right) \tag{9}$$

Profit function:

$$\Pi_t^y = p_t y_t - w_t l_t^y - r_t^k k_{t-1}^y - \left(\tau_t^y - \mathcal{T}_{\mu,t}^Y\right) e_t^y - \theta_1 \left(\mu_t^y\right)^{\theta_2} y_t - p_t^E E_t^y \tag{10}$$

back

Energy Firms

Energy good E_t is a CES aggregator combining renewable and non-renewable energy:

$$E_t = \left[\nu^{\frac{1}{\chi}} \left(E_t^G \right)^{\frac{\chi-1}{\chi}} + (1-\nu)^{\frac{1}{\chi}} \left(E_t^D \right)^{\frac{\chi-1}{\chi}} \right]^{\frac{\chi}{\chi-1}} \tag{11}$$

Demand functions for the two energy products are:

$$E_t^G = \nu \left(\frac{p_t^G}{p_t^E} \right)^{-\chi} E_t, \qquad E_t^D = (1-\nu) \left(\frac{p_t^D}{p_t^E} \right)^{-\chi} E_t$$

back

Energy producers

Non-renewable Energy production:

$$E_t^D = A_t^D \left(k_{t-1}^D\right)^{\alpha_E} \left(l_t^D\right)^{1-\alpha_E}, \tag{12}$$

$$s.t. \quad \Pi_t^D = p_t^D E_t^D - \tau_t^D e_t^D - \theta_1 \left(\mu_t^D\right)^{\theta_2} E_t^D - w_t l_t^D - r_t^k k_{t-1}^D \tag{13}$$

Non-renewable energy firms face a trade-off between paying an environmental tax on their polluting emissions or sacrifice a share of their output to abate emissions.

Renewable Energy production:

$$E_t^G = A_t^G \left(k_{t-1}^G\right)^{\alpha_E} \left(l_t^G\right)^{1-\alpha_E}, \tag{14}$$

$$s.t. \quad \Pi_t^G = p_t^G E_t^G - (w_t - \mathcal{T}_{l,t}^G) l_t^G - r_t^k k_{t-1}^G \tag{15}$$

back

Climate Module and Redistribution scheme

- The climate module describes the interconnection between
  - Final good y_t, non-renewable energy production E_t^D
  - Emissions $e_t^{y,E}$
  - Abatement effort $g(\mu_t^{y,E})$

$$e_t^y = (1 - \mu_t^y)\, \gamma_y (y_t)\,, \quad e_t^E = \left(1 - \mu_t^E\right) \gamma_E \left(E_t^D\right) \tag{16}$$

$$g\left(\mu_t^{y,E}\right) = \theta_1 \left(\mu_t^{y,E}\right)^{\theta_2}, \quad \mu_t^{y,E} \in [0,1] \tag{17}$$

- Carbon tax revenues are redistributed to households (transfers) or Green energy firms (capital/labor subsidies):

$$\mathcal{T}_t^{HM} + \mathcal{T}_t^{S} + \mathcal{T}_{l,t}^{G} + \mathcal{T}_{\mu,t}^{Y} = \tau_t^y e_t^y + \tau_t^D e_t^D \tag{18}$$

back

Market clearing

Capital market:

$$K_{t-1} = \left({k_Y}_t^{1+\phi_h} + {k_D}_t^{1+\phi_h} + {k_G}_t^{1+\phi_h} \right)^{\frac{1}{1+\phi_h}} \tag{19}$$

Labor market:

$$\left({l_Y}_t^{1+\phi_h} + {l_D}_t^{1+\phi_h} + {l_G}_t^{1+\phi_h} \right)^{\frac{1}{1+\phi_h}} = \Delta l_{HM,t} + (1-\Delta) l_{S,t} \tag{20}$$

Energy market:

$$E_t = E_t^c + E_t^y \tag{21}$$

Aggregate consumption:

$$x_t = \Delta x_{HM,t} + (1-\Delta) x_{S,t} \tag{22}$$

Calibration back

Calibration

Table: Model parameters

Parameter	Description	Value	Source
Households			
β	Discount factor	0.995	Drygalla et al. (2018)
φ_c	Inverse elasticity of intertemporal sub.	1.5	–
φ_l	Inverse Frisch elasticity	1.5	–
φ_h	Inverse elasticity of labor sub. between sectors	1.5	–
ϵ_{HM}	Elasticity of subs energy/non-energy good, HM	0.05	Känzig (2023)
ϵ_S	Elasticity of subs energy/non-energy good, S	0.275	–
γ_{HM}	Distribution parameter HM	0.0543	Energy share $\omega_{HM} = 7.6\%$, EU-SILC
γ_S	Distribution parameter S	0.0455	Energy share $\omega_S = 5.9\%$, EU-SILC
ϕ_i	Investment adjustment cost	4	Standard value
Δ	Share of HM households	40%	–
Firms			
ξ_y	Elasticity of sub. between VA and energy	$\{0.02, 0.38\}$	Hassler et al. (2021), van der Werf (2008)
ξ	Elasticity of sub. between intermediate goods	6	Standard value
α	Share of capital in value added	1/3	Eurostat
$1-\upsilon$	Share of energy in non-energy production	0.09	–
ϕ_p	Price adjustment cost	58.2524	Implied from Ascari and Rossi (2012)
χ	Elasticity of sub. between energy sources	10	Hassler et al. (2021)
ι	Weight of renewable energy	0.20	Eurostat
ν	Weighting parameter of renewable energy	0.11	Implied from ι
α_E	Share of capital in energy production	2/3	–
Q_{Ec}	Share of energy used for consumption by HH	28%	–
Q_E	Energy sector share of total emissions	30%	–

Calibration

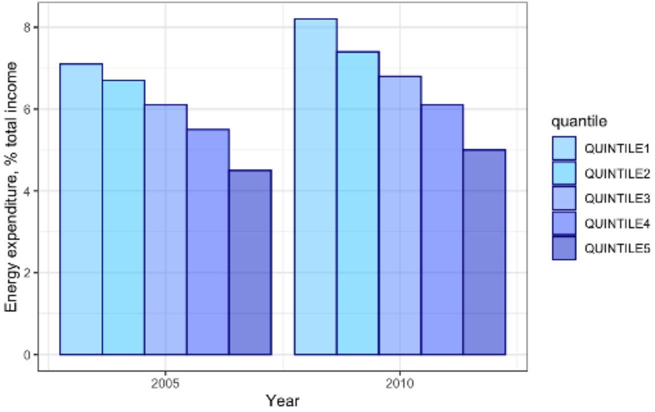
Table: Model parameters

Parameter	Description	Value	Source
Environment			
γ_D	Energy sector emissions intensity	0.6058	Implied from Q_E
γ_y	Non-energy sector emissions intensity	0.1196	Implied from Q_E
d_0	Damage function constant	-0.0076	Gibson and Heutel (2023)
d_1	Damage function linear parameter	8.1e-6	–
d_2	Damage function quadratic parameter	1.05e-8	–
θ_1	Abatement cost function coefficient	0.074	–
θ_2	Abatement cost function exponent	2.6	–
η	Pollution decay rate	0.9965	Allen et al. (2018)
Other			
ϕ_π	Mon. pol. response to inflation	1.5	Standard value
ρm	Monetary policy inertia	0.9	–

back

Electricity, Gas and Other Fuels Consumption Expenditure by Income Quintile, EU-27, %

Sources: Eurostat, EU-SILC



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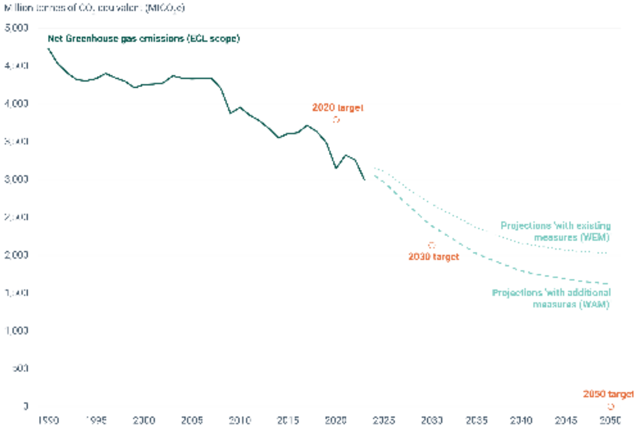
EU CO_2 Emissions Projections and EU Targets, % of 1990

Sources: European Environment Agency (EEA), 2024



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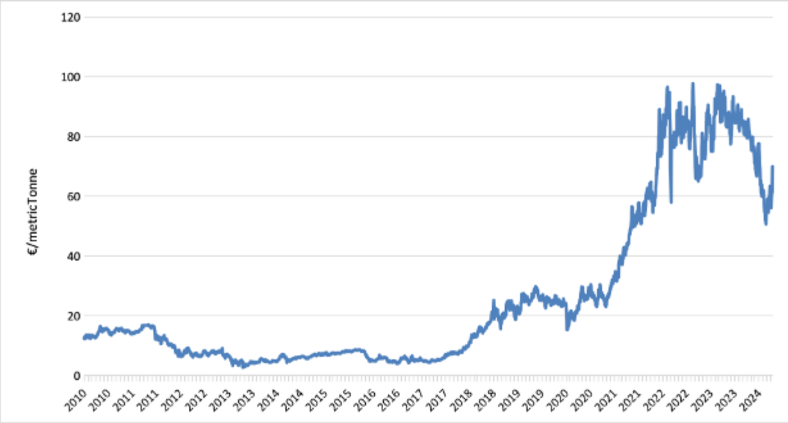
ETS Spot Price, e/metric Tonne, 2010-2025

Sources: Datastream. Available: LSEG Workspace



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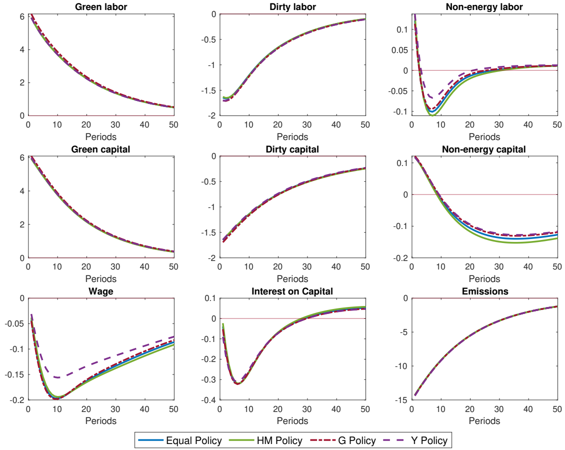
IRF:Temporary Carbon Tax Shock cont.



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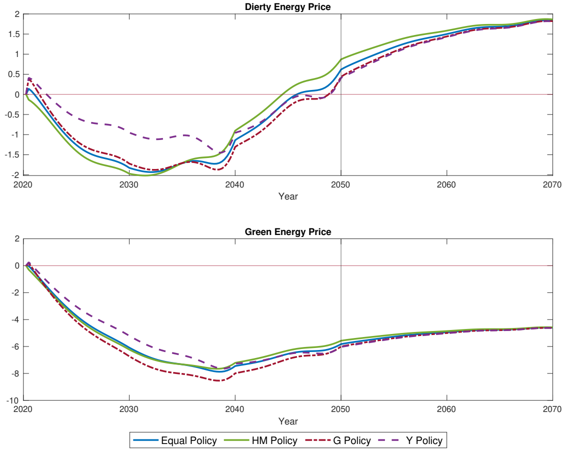
Energy Prices, Transition Dynamics cont.



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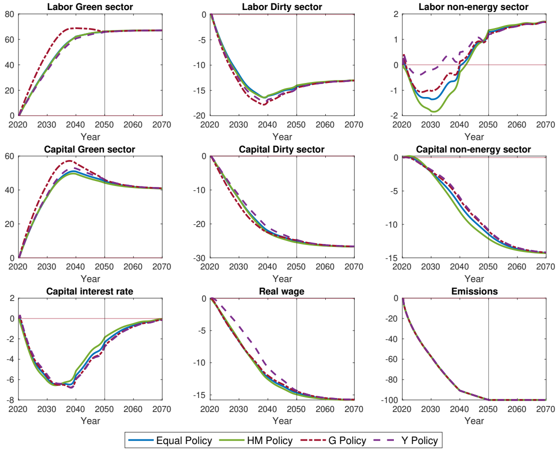
Labor, Capital and Emissions, Transition Dynamics cont.



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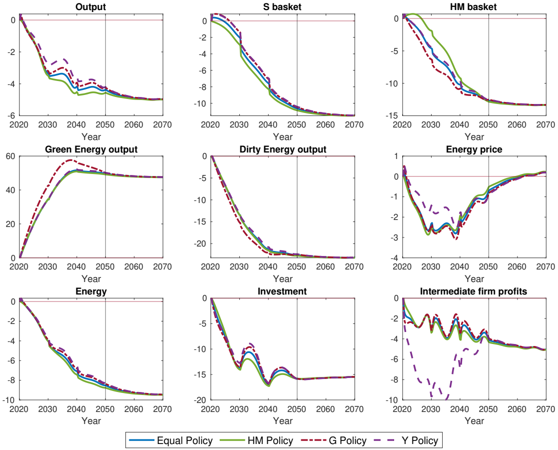
Transition Dynamics with Expectation Errors



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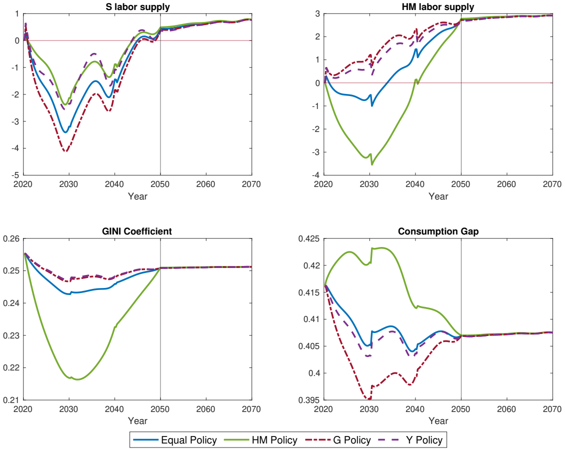
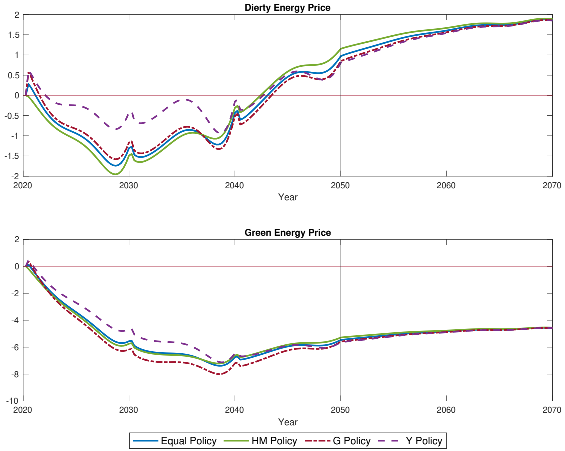
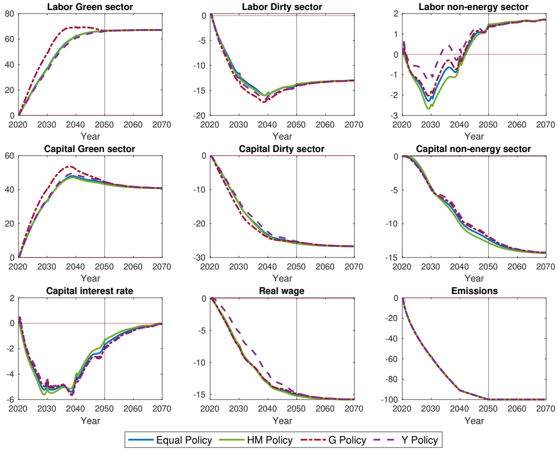
Labor Supply and Inequality Measures, Transition Dynamics with Expectation Errors



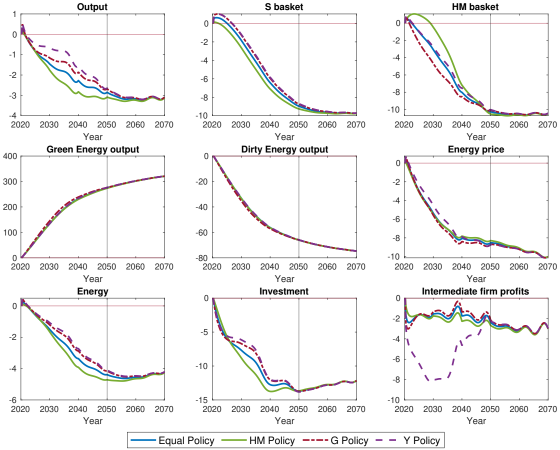
Energy Prices, Transition Dynamics with Expectation Errors



Labor, Capital and Emissions, Transition Dynamics with Expectation Errors



Transition Dynamics with Exogenous Green Growth



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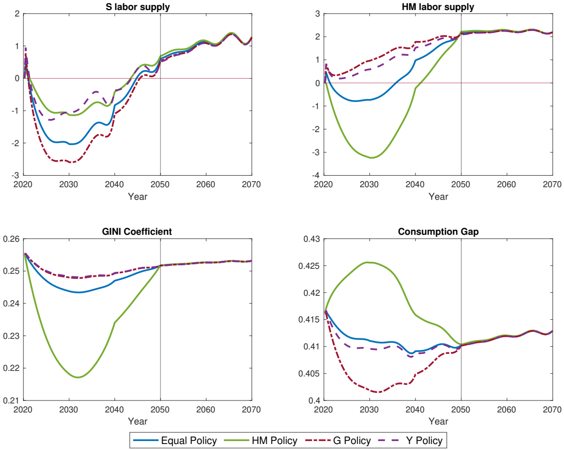
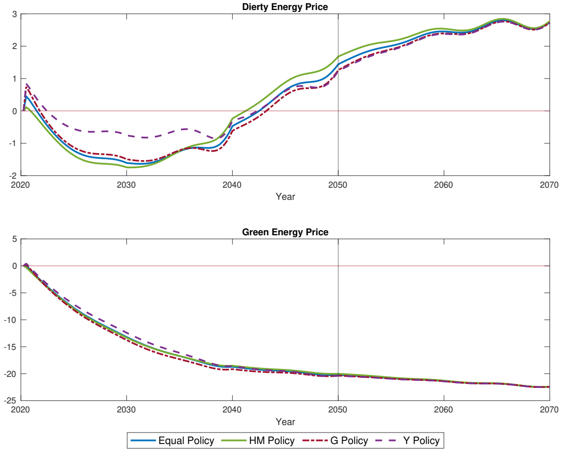
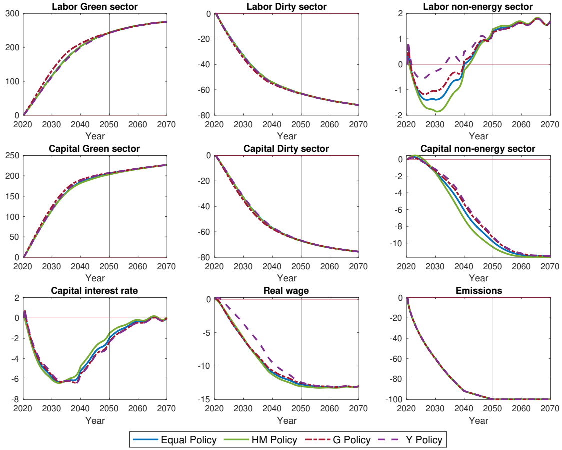
Labor Supply and Inequality Measures, Transition Dynamics with Exogenous Green Growth



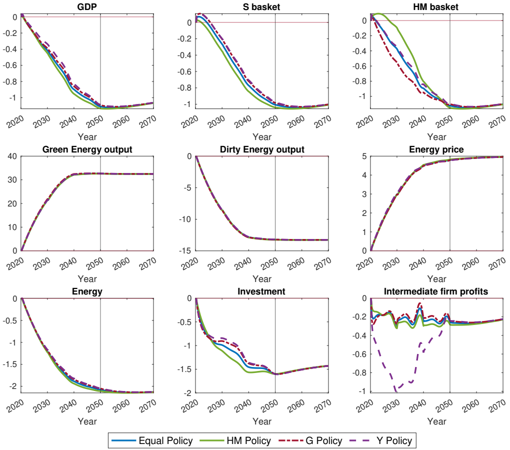
Energy Prices, Transition Dynamics with Exogenous Green Growth



Labor, Capital and Emissions, Transition Dynamics with Exogenous Green Growth



Transition Dynamics with Energy Carbon Tax only



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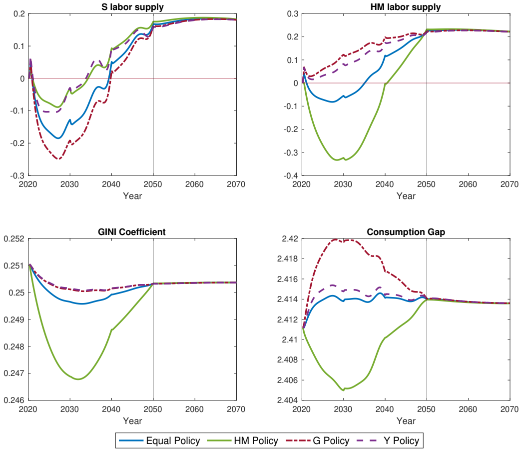
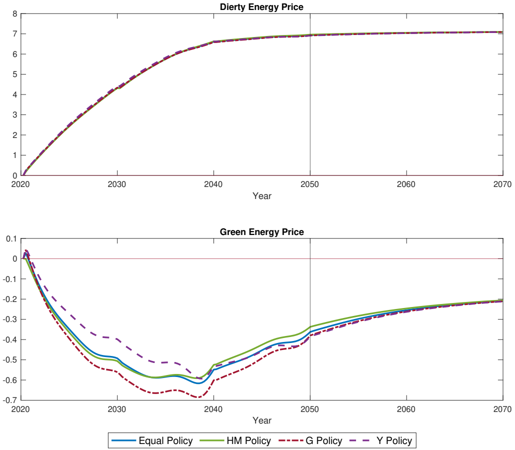
Labor Supply and Inequality Measures, Transition Dynamics with Energy Carbon Tax only



Energy Prices, Transition Dynamics with Energy Carbon Tax only



Labor, Capital and Emissions, Transition Dynamics with Energy Carbon Tax only