

Road to Net Zero: Carbon Policy and Redistributive Dynamics in the Green Transition

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Abstract

This paper explores the macroeconomic and distributional effects of the European Union's transition to Net Zero emissions through a gradually increasing carbon tax. The analysis is conducted within an Environmental DSGE model featuring two household types and distinct energy and non-energy sectors. Five alternative uses of carbon tax revenues are considered: equal transfers to households, targeted transfers to hand-to-mouth households, subsidies to green energy firms, and reductions in labor and capital income taxes. The results indicate that, absent technological progress, the carbon tax induces a recession, reduces investment and consumption, and results in permanently higher energy prices. However, aggregate inflation turns deflationary after the initial adjustment. Different recycling schemes reveal a clear trade-off between efficiency and equity. Targeted transfers are the most progressive, but they entail the largest macroeconomic costs. Subsidies and tax cuts, on the other hand, mitigate output and investment, but they are more regressive. When agents revise expectations at intermediate policy targets, adjustment paths become more volatile, and inflation temporarily rises around announcements. These findings underscore the importance of designing policies that balance efficiency and equity during the Net Zero transition.

JEL Codes: E32, H23, Q43, Q52, P28

Keywords: Net Zero, green transition, inequality, macroeconomic effects, fiscal redistribution, TANK, DSGE.

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1 Introduction

The European Commission (EC) has launched a comprehensive set of measures, which go by the name of European Green Deal, to reduce national greenhouse gas (GHG) emissions in the Union to “Net Zero”¹ by 2050 in the European Union (EU), in accordance with the terms of the United Nations Conference of the Parties (COP). This ambitious transformation raises important questions about the long run macroeconomic and distributional effects of climate policy in the EU, which this paper addresses through a structural theoretical framework.

According to experts, the most effective strategy for reducing greenhouse gas emissions is to impose economic disincentives that discourage their production. Such disincentives can be implemented through price-based instruments, such as carbon taxes or emission allowances, like the cap-and-trade system currently used in the EU. Results from the empirical literature on the macroeconomic impact of these measures in the EU remain mixed. Bettarelli et al. (2025) show that a carbon tax shock can exert significant inflationary pressure, with a certain degree of heterogeneity across countries, depending on their initial inflation level and emission intensity. Metcalf and Stock (2023) analyze the impact of national carbon taxes across European countries, finding negligible, if not positive in some cases, effects on GDP and employment. On the contrary, Känzig and Konradt (2023) find that the EU-wide emission trading scheme (ETS) can have adverse effects for the economy. Additionally, some studies show that costs are not equally distributed, and that the danger of negative distributional effects is real either across countries (Berthold et al., 2023) and within society (Ascari et al., 2025; Cantore et al., 2025; Eydam & Diluiso, 2022; Känzig, 2023).

Building on empirical evidence and current European policy, this paper aims to provide a theoretical analysis of the macroeconomic and distributional implications of the EU’s transition to an economy with Net Zero emissions. Using an Environmental Dynamic Stochastic General Equilibrium (E-DSGE) model incorporating household heterogeneity² and distinguishing between energy and non-energy sectors, this study examines the long-term effects of a gradually increasing carbon tax driving the economy toward zero emissions, as well as

¹The term Net Zero refers to a state in which the anthropogenic GHG emissions going into the atmosphere are balanced by removal out of the atmosphere, either via natural sinks (land or oceans) or technical removal (air or biomass capture and geological storage). This corresponds to an average reduction of emissions between 95% and 97% from the 1990 level.

²For simplicity, unlike in the fully heterogeneous agents literature, in this model households’ groups are static.

the role of alternative revenue recycling schemes in shaping the trade-off between efficiency and equity.

While E-DSGE models are traditionally used to study short-term fluctuations, they can also be extended to capture long run transition dynamics. Solving the model under perfect foresight ensures that agents form expectations and make intertemporal decisions consistent with the entire transition path, preserving the general equilibrium structure and allowing for a rigorous analysis of the macroeconomic and distributional effects of long-term climate policy.

In this model, the carbon tax revenues are redistributed as direct household transfers, subsidies to green energy firms or employed to cut other income taxes. By increasing production costs for the polluting sectors, resources are reallocated towards green energy producers, which become relatively bigger in the new steady state at the expense of polluting firms. Along the transition, dirty-energy and non-energy firms are incentivized to abate their polluting emissions. Over time, energy prices permanently rise. However, as rational agents anticipate future income reductions, they adjust their demand, which dampens the supply-side impact. This makes the policy deflationary and recessionary. In this context, direct transfers to households effectively reduce income inequality, whereas other redistributive policies, while offering broader macroeconomic stabilization, tend to increase inequality, highlighting a clear trade-off between efficiency and equity. In the presence of expectation errors, the depression worsens and inequality increases. In the baseline scenario, carbon taxation is the sole driver of the transition. No technological growth is assumed. The aim is to isolate the effect of fiscal policy alone.³ Income and consumption inequality gradually improve in the long run. The analysis extends to scenarios with flexible prices and different non-energy sector abatement calibrations.

Literature Review

The synthesis in the literature between climate dynamics and economic models has evolved along two main pathways. The first finds expression in the integrated assessment models (IAMs). Nordhaus's dynamic integrated model of climate and the economy (DICE) (Nord-

³Additional scenarios with exogenous green TFP growth is reported in the appendix. When considering exogenous growth in green technology, the transition leads to medium-term inflation and recession, with GDP recovering to its pretax level only after the Net Zero target has been achieved.

haus, 1977, 2010; Nordhaus & Sztorc, 2013) is a pioneering example, weaving climate dynamics into the global macroeconomic system. This approach has been expanded to address inequality issues associated with environmental policies and the green transition, as described in the studies by Dennig et al. (2015), Emmerling and Tavoni (2021), and Zhao et al. (2022).⁴ These kinds of models have a general equilibrium structure at their core, and are frequently used for studying long-term climate policy impacts, especially on a global scale. However, they often tend to oversimplify the economy’s microfoundations and ignore household heterogeneity. The second path focuses on the impact of climate change and environmental policies on the short-term business cycle through E-DSGE. Initial models, such as those by Fischer and Springborn (2011) and Heutel (2012), have been expanded to include Neo-Keynesian (NK) nominal rigidities (Annicchiarico & Di Dio, 2015, 2017; Holtemöller & Sardone, 2024), financial frictions (Carattini et al., 2023), and labor market frictions (Gibson & Heutel, 2023). This paper builds on these extensions by incorporating both energy and non-energy sectors into the E-DSGE framework, within a context of nominal rigidities and other frictions. More recently, Känzig (2023) and Benmir and Roman (2022) have explored the impact of carbon pricing on emissions, economic aggregates, and inequality (in the EU and the US respectively), focusing on short-term implications. Benmir and Roman (2022) also extends to scenarios involving sticky prices, inflationary pressure and abatement learning. Finally, this paper draws on the literature on two-agent (TA) models, in the spirit of Bilbie (2008), which introduces a distinction between credit-constrained households and Savers in dynamic general equilibrium models. The choice of a TANK-EDSGE⁵ model is due to the fact that the microfoundations underlying DSGE models allow for a more detailed examination of distributional dynamics, including how income groups are affected differently by taxation and redistribution mechanisms, in a general equilibrium framework. In addition, the DSGE framework allows for the study of different expectation formations, including both standard perfect foresight and expectation error scenarios. This allows for a detailed examination of how agents’ forecast inaccuracies affect the transition and distributional dynamics under carbon pricing.

A closely related study is Coenen et al. (2024). Their work focuses on medium-term effects, leveraging constrained and unconstrained households and simulating various redistri-

⁴Related strands of literature include computable general equilibrium (CGE) models, which explore revenue recycling and the efficiency–equity trade-off of carbon taxation (e.g. Caron et al. (2018)).

⁵In full, it reads Two Agents New Keynesian Environmental Dynamic Stochastic General Equilibrium.

bution schemes and green subsidies. While similar in its use of carbon taxation as a policy lever, this paper departs from Coenen et al. (2024) in several ways. First, it extends the analysis to long-term scenarios, until the 2050 Net Zero target, capturing the enduring dynamics of carbon taxation. Second, it introduces richer heterogeneity among households, incorporating differences in energy consumption shares and elasticities of substitution. Third, it considers the effects of applying a carbon tax to both energy and non-energy sectors, highlighting interactions often overlooked in models focused solely on energy emissions. Finally, this paper systematically compares a wide variety of redistribution schemes, offering new insights into their relative effectiveness in mitigating consumption and income inequality.

In summary, my paper contributes to this second strand of literature by integrating the short-term insights on distributional impacts from Känzig (2023) and the long-term perspectives on transition effects from Ferrari and Nispi Landi (2023)⁶ into a single framework. This integration sheds light on the dynamics of carbon pricing and the equity-efficiency trade-off of redistribution mechanisms. This broadens the scope of traditional DSGE models and offers a methodological contribution to the analysis of inequality in the Net Zero transition.

The remainder of the paper is structured as follows. Section 2 describes the current situation in the EU regarding environmental policies and the goal of reducing emissions by 2050. Section 3 presents the model equations and the various redistribution policies, while in Section 4 the outcome of the long run simulations is described. In the Appendix, I present some empirical insights on the macro and distributional effects of a carbon price shock in the EU (Section B) and simulate the effects of stochastic carbon tax shocks in the E-DSGE framework (Section C). Finally, Section 6 concludes.

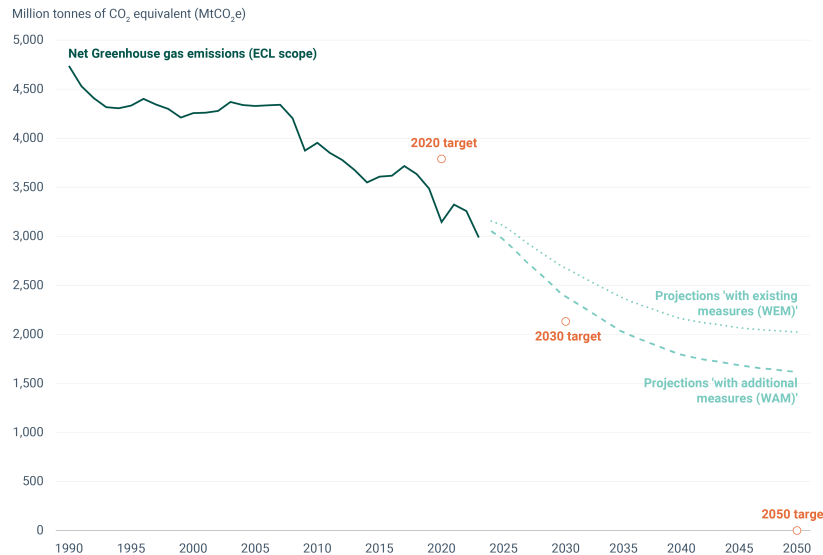
2 Emissions and Environmental Policy Framework in the EU

To get an idea of the current situation of GHG emissions in the EU, let's look at the graph 1. Total emissions projections for the EU-27 show a general downward trend over the past decades. Despite this positive trajectory, the current projections, as reported by the European Environment Agency, fall short of the reductions needed to meet the mid-term climate goals set for 2030. They are also not aligned with the more ambitious long-term goal of achieving

⁶The authors provide valuable insights into the long-term effects of central banks' Green QE policies during the transition to a carbon-free economy in the EU, though their focus is mainly macroeconomic rather than distributional.

Net Zero emissions by 2050. The gap between projected emissions and targets highlights a significant challenge: existing environmental policies are still not sufficient to deliver the required level of emissions reductions. This underscores the urgent need for stronger climate actions to close this gap and ensure that the EU can meet its climate goals in both the short- and long-term. The main instrument for reducing polluting emissions cost-effectively

Figure 1: Total emissions projections, EU-27



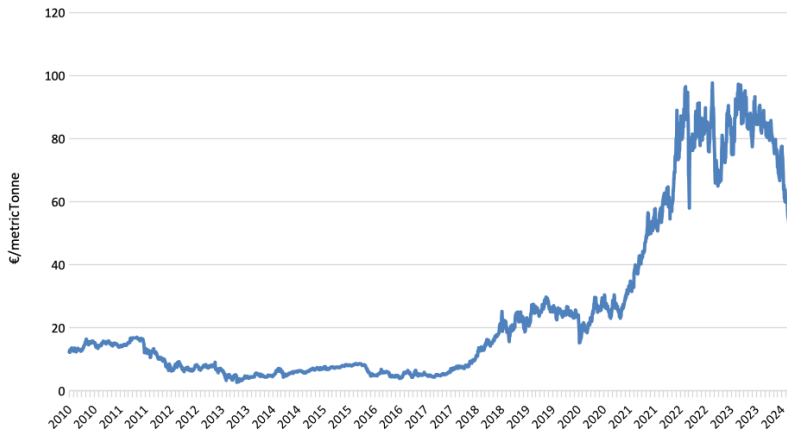
Source: Member States' greenhouse gas (GHG) emission projections, 2024, European Environment Agency (EEA); National emissions reported to the UNFCCC and to the EU Greenhouse Gas Monitoring Mechanism, April 2024; Approximated estimates for greenhouse gas emissions, 2023

is that of emission allowances, traded within the EU Emission Trading System (EU-ETS), a carbon trading scheme introduced in 2005. The EU-ETS it covers about 45% of EU GHG emissions.⁷ Companies trade emission rights on the carbon market or through the EU-ETS auctions (European Energy Exchange- EEX). The up-to-date path of ETS spot prices is shown in Figure 2.

Negative distributional effects may arise from changes in the returns to factors of production (income effect), or from increases in the prices of certain goods (price effect), as consumption baskets differ significantly across income levels, with goods from carbon-intensive sectors – such as electricity, gas and other fuels – constituting a larger share of spending for low-income households. Panel A in Figure 3 shows how households in the lowest quintile of

⁷By 2027, the European Commission will introduce the EU-ETS2, a new emissions trading system that will complement the existing one. This system will cover emissions from buildings, road transport, and additional sectors, and is expected to replace the national carbon taxes currently implemented in many EU countries.

Figure 2: ETS Spot Price, €/metric Tonne, 2010-2025



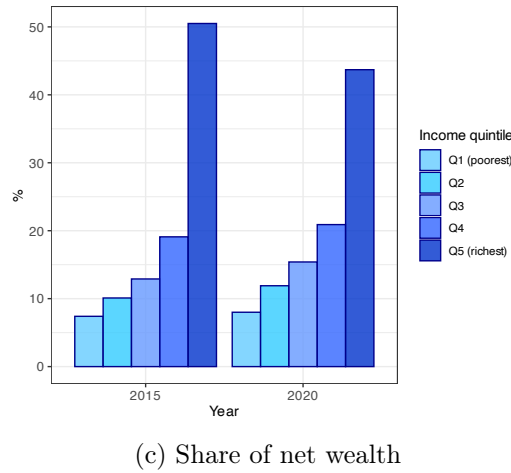
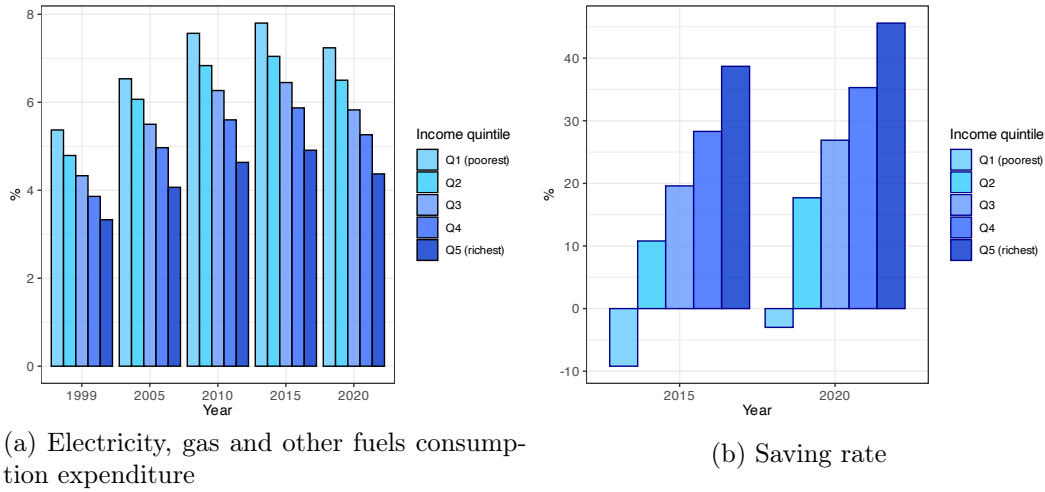
Source: Datastream. Available: LSEG Workspace.

the income distribution consume about twice the amount of energy and fuels consumed by households in the highest quintile, as a percentage of their total income. In addition, these households often lack savings (Figure 3, panel B) and access to capital markets, which limits their ability to smooth consumption over time and increases their exposure to economic shocks. Data also reveal that the top two income quintiles hold 65–70% of total wealth, underscoring the disparity between low- and high-income households (see Figure 3, panel C).

Consequently, low-income households are more likely to bear a disproportionate share of the welfare costs associated with current carbon tax policies. European institutions acknowledge that achieving a socially fair transition is essential for making the transition politically feasible (European Commission, 2018a). Indeed, one of the key goals of the Green Deal is to ensure that the transition is “just”, ensuring that “no person and no place is left behind”. To address this, the EC has designed several compensation mechanisms⁸ aimed at supporting the most vulnerable and exposed households, including programs such as the *Social Climate Fund* (SCF) and the *Just Transition Fund* (JTF). In details, the SCF provides funding to EU Member States to support vulnerable groups affected by the green transition, such as those in energy or transport poverty, ensuring they are not left behind. Member States can use the SCF for structural measures and investments in energy efficiency and renewable energy integration. It can also allocate resources for temporary direct income support. The JTF also supports the green transition by facilitating employment opportunities in emerging sec-

⁸An example of how the carbon tax revenues are employed to offset the adverse effects of the green transition outside EU, is the revenue-neutral carbon tax in British Columbia (Canada): here it is found that tax redistribution could stimulate demand for products and hence workers (Yamazaki, 2017).

Figure 3: Households' Consumption, Saving and Wealth by Income quintile, EU



Source: Eurostat. Data for European Union-27 countries; for panel a, values are computed as an average across different geographical areas – EU-27, EU-25 and EU-15 countries – from 1995 to 2010, due to the absence of complete values for a single area. Values for the period from 2015 to 2020 are computed as a weighted average of available EU country-level data (aggregate EU data are only available up to 2010). The number of households by country is used as the weight. For panel b and c, datasets are provided by the “Income, consumption and wealth” (ICW) experimental statistics, available only since 2015. For panel a, data come from the EU Statistics on Income and Living Conditions (EU-SILC).

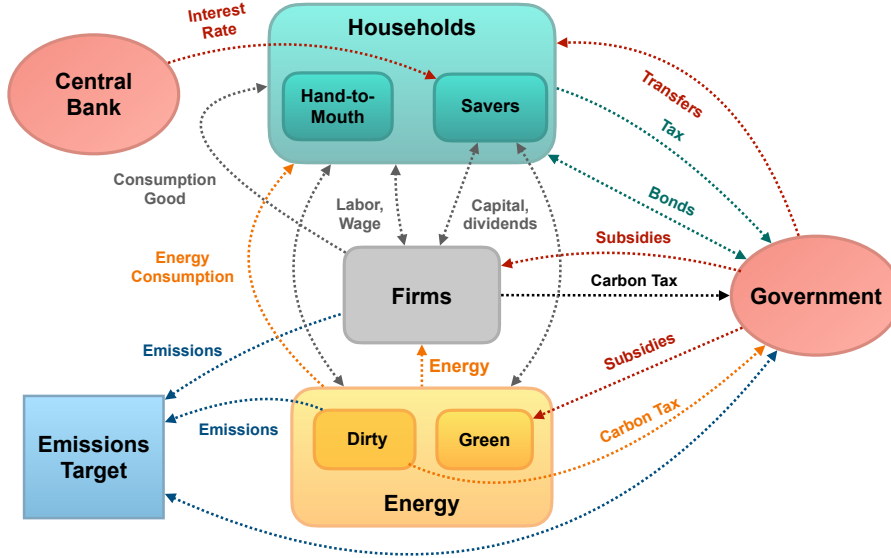
tors, promoting low-carbon technologies, and encouraging economic diversification through climate-resilient investments and jobs.

3 Model

The design of the model builds upon the foundations laid out by existing literature on environmental macroeconomics (Annicchiarico & Di Dio, 2015, 2017; Ferrari & Nispi Landi, 2024a; Hassler et al., 2021, 2022; Heutel, 2012) and two-agents DSGE models (Bilbiie, 2008; Galí et al., 2007). However, this paper extends and adapts these frameworks to incorporate

additional features tailored to the analysis of the EU's Net Zero transition, such as a disaggregated energy sector, energy use for consumption goods production, heterogeneous energy consumption, dual-sector taxation, and long-term dynamics. A sketch of the model is shown in Figure 4.

Figure 4: Scheme of the Two-Agents E-DSGE model.



3.1 Households

There is a continuum of infinitely lived households $[0, 1]$ with the same utility function. Households gain utility from consumption x and disutility from labor ℓ . As in Bilbiie (2008), a fixed share of families $(1 - \Delta)$ has access to capital and bond markets, owns final-goods firms and supplies labor, maximizing the standard intertemporal problem $\max \mathbb{E}_t \sum_{i=0}^{\infty} \beta^i U(x_{S,t+i}, \ell_{S,t+i})$, where β is the intertemporal discount factor. I call this group Savers (S). The rest of the households Δ has no assets and consume the entire budget each period. I call these households Hand-to-mouth (HM). The utility function takes the additively separable CRRA form as follows:

$$U(x_{j,t}, \ell_{j,t}) = \frac{x_{j,t}^{1-\varphi_c} - 1}{1 - \varphi_c} - \psi_j \frac{\ell_{j,t}^{1+\varphi_\ell}}{1 + \varphi_\ell}, \text{ where } j = \{\text{HM}, \text{S}\} \quad (1)$$

φ_c is the inverse elasticity of intertemporal substitution; ψ_j weights the disutility of working and φ_ℓ is the inverse of the Frisch elasticity.

3.1.1 Hand-to-mouth

Hand-to-mouth households maximize their utility with respect to consumption and labor, subject to their budget balance:

$$p_{HM,t}x_{HM,t} = (1 - \tau_{\ell,t})w_{HM,t}\ell_{HM,t} + \mathcal{T}_{HM,t} \quad (2)$$

where $p_{HM,t}$ is the HM price index, $w_{HM,t}$ is wage, τ_{ℓ} is tax on labor income and $\mathcal{T}_{HM,t}$ represents fiscal transfers from the government. From the first-order conditions (FOCs), I get HM labor supply

$$\frac{x_{HM,t}^{-\varphi_c}}{p_{HM,t}} w_t = \psi_{HM} \frac{\ell_{HM,t}^{\varphi_l}}{(1 - \tau_{\ell})} \quad (3)$$

3.1.2 Savers

Savers' budget reads:

$$b_t + p_{S,t}x_{S,t} + i_{S,t} = b_{t-1} \frac{r_{t-1}}{\pi_t} + (1 - \tau_{k,t})r_{k,t}k_{S,t-1} + (1 - \tau_{\ell,t})w_{S,t}\ell_{S,t} + \mathcal{T}_{S,t} \quad (4)$$

where b_t represents bond holdings, $i_{S,t}$ represents investment, $b_{t-1}r_{t-1}$ denotes revenues from holding bonds, $k_{S,t-1}r_{k,t}^k$ is the income from capital service, $w_{S,t}\ell_{S,t}$ is the income from labor, τ_k is tax on capital income and $\mathcal{T}_{S,t}$ represents fiscal transfers from the government. All variables are expressed in real terms. The law of motion of capital with quadratic adjustment costs is

$$k_{S,t}(i) = (1 - \delta)k_{S,t-1}(i) + i_{S,t}(i) \left[1 - \frac{\phi_i}{2} \left(\frac{i_{S,t}(i)}{i_{S,t-1}(i)} - 1 \right)^2 \right], \quad (5)$$

where $\phi_i > 0$ denotes the investment cost parameter. S' intertemporal utility maximization yields the following FOCs with respect to x_t , $\ell_{S,t}$, k_t and $i_{S,t}$:

$$p_{S,t} \lambda_{S,t} = x_{S,t}^{-\varphi_c} \quad (6)$$

$$w_{S,t} \lambda_{S,t} = \psi_S \frac{\ell_{S,t}^{\varphi_l}}{(1 - \tau_{\ell})} \quad (7)$$

$$q_t = \beta \mathbb{E}_t \frac{\lambda_{S,t+1}}{\lambda_{S,t}} \left(r_{k,t+1}(1 - \tau_k) + q_{t+1} (1 - \delta) \right) \quad (8)$$

$$1 = q_t \left[1 - \frac{\phi_i}{2} \left(\frac{i_{S,t}}{i_{S,t-1}} - 1 \right)^2 - \phi_i \left(\frac{i_{S,t}}{i_{S,t-1}} - 1 \right) \frac{i_{S,t}}{i_{S,t-1}} \right]$$

$$+\beta\mathbb{E}_t q_{t+1} \left[\frac{\lambda_{S,t+1}}{\lambda_{S,t}} \phi_i \left(\frac{i_{S,t+1}}{i_{S,t}} - 1 \right) \left(\frac{i_{S,t+1}}{i_{S,t}} \right)^2 \right], \quad (9)$$

where λ_S is the marginal utility of consumption. From the FOC for b_t , I obtain the Euler equation:

$$\lambda_{S,t} = \beta\mathbb{E}_t \left(\lambda_{S,t+1} \frac{r_t}{\pi_{t+1}} \right) \quad (10)$$

Households differ also in labor productivity, with Savers being more productive than Hand-to-mouth and thus earning a higher wage. Therefore, their wage is defined as

$$w_{HM,t} = \psi_{l_{HM}} w_t \quad (11)$$

$$w_{S,t} = \psi_{l_s} w_t \quad (12)$$

where $\psi_{l_{HM}}$ and ψ_{l_s} determine the respective labor productivity and w_t is the baseline wage paid by firms.

3.1.3 Consumption basket

Households consume energy and non-energy goods. The consumption basket x_t takes a constant elasticity of substitution (CES) form as follows:

$$x_{j,t} = \left[\gamma_j^{\frac{1}{\epsilon_j}} c_{j,t}^{\frac{\epsilon_j-1}{\epsilon_j}} + (1-\gamma_j)^{\frac{1}{\epsilon_j}} E_{j,t}^c \frac{\epsilon_j-1}{\epsilon_j} \right]^{\frac{\epsilon_j}{\epsilon_j-1}} \quad (13)$$

where γ_j is a distribution parameter derived from the share of energy goods in the consumption basket and ϵ_j is the elasticity of substitution between energy $E_{j,t}^c$ and non-energy $c_{j,t}$ goods.

Both parameters differ across households groups. The price index reads

$$p_{j,t} = \left(1 - \gamma_j + \gamma_j p_{E,t}^{1-\epsilon_j} \right)^{\frac{1}{1-\epsilon_j}} \quad (14)$$

I define $p_{j,t} \equiv \frac{P_{j,t}}{P_{y,t}}$, $1 \equiv \frac{P_{y,t}}{P_{y,t}}$ and $p_{E,t} \equiv \frac{P_{E,t}}{P_{y,t}}$ as the price of consumption bundle, non-energy and energy goods in terms of non-energy goods price (numeraire). The demand for the two consumption goods is as follows:

$$c_{j,t} = \gamma_j \left(\frac{1}{p_{j,t}} \right)^{-\epsilon} x_{j,t} \quad (15)$$

$$E_{c,j,t} = (1 - \gamma_j) \left(\frac{p_{E,t}}{p_{j,t}} \right)^{-\epsilon} x_{j,t} \quad (16)$$

3.2 Firms

From the production side, the model features two perfectly competitive sectors, producing consumption goods and energy, respectively. The non-energy firms employ energy and value added (bundle of labor and capital) as input. Polluting emissions are a byproduct of industrial production. The energy sector consists of two kinds of firms, “green” and “dirty”, characterized by sector specific technology, labor and capital. The energy output is a composite of these two energy sources, which are intended to be good substitutes. Only dirty energy firms produce GHG emissions. Technologies adopted in all sectors do not grow over time, but are fixed at the steady-state level. This assumption allows us to isolate the potential of carbon tax alone in reducing emissions and its effect on the economy.

3.2.1 Non-energy goods producers

Each firm (i) produces a non-energy consumption good $y_t(i)$ according to the following CES function:

$$y_t(i) = TFP_{y,t} \left[v^{\frac{1}{\xi_y}} (VA_t(i))^{\frac{\xi_y-1}{\xi_y}} + (1-v)^{\frac{1}{\xi_y}} (A_{E,t} E_{y,t}(i))^{\frac{\xi_y-1}{\xi_y}} \right]^{\frac{\xi_y}{\xi_y-1}}, \quad (17)$$

$$\text{where } VA_t(i) = A_{y,t}(i) (k_{y,t-1}(i))^\alpha (\ell_{y,t}(i))^{1-\alpha} \quad \text{with } \alpha \leq 1 \quad (18)$$

$$\text{and } TFP_{y,t}(i) = (1 - D_t(e_{s,t})) \quad (19)$$

$A_{E,t}$ is energy technology and $A_{y,t}$ is the value added technology and $TFP_{y,t}$ is the total factor productivity net of the damage function D_t ; $k_{y,t-1}$ and $\ell_{y,t}$ are sector specific capital and labor and $E_{y,t}$ is the energy input. α represents capital input share in the value added. $1 - v$ defines the share of energy in the production function, and ξ_y is the elasticity of substitution between value added and energy component. Polluting emissions are a function of firms' production and abatement

$$e_{y,t}(i) = y_t(i) \gamma_y (1 - \mu_{y,t}(i)) \quad (20)$$

where $\mu_{y,t}$ is the fraction of sectoral emissions abated. Polluting is a costly activity for firms: carbon taxation incentivizes investment in abatement technologies, which can be interpreted

as improvements in production processes, gains in emission efficiency, or the installation of CO₂ capture systems. The resulting abatement function is defined as follows:

$$g(\mu_{y,t}(i)) = \theta_1(\mu_{y,t}(i))^{\theta_2} \quad (21)$$

Firms' profit function is expressed in terms of the non-energy goods price as follows:

$$\begin{aligned} \Pi_{y,t}(i) &= y_t(i) - w_t \ell_{y,t}(i) - r_{k,t} k_{y,t-1}(i) - \tau_{y,t}(i) e_{y,t}(i) \\ &- g(\mu_{y,t}(i)) y_t(i) - p_{E,t} E_{y,t}(i) \end{aligned} \quad (22)$$

where $\tau_{y,t}$ is the sectoral emissions tax. Given all firms are equal, I can drop the index (i). From firm's profit maximization problem, the FOC with respect to $k_{y,t}$ yields the demand for capital:

$$r_{k,t} = VA_t^{\frac{\xi_y - 1}{\xi_y}} v^{\frac{1}{\xi_y}} \alpha \frac{mc_{y,t}}{k_{y,t}} y_t^{\frac{1}{\xi_y}}, \quad (23)$$

where $mc_{y,t}$ is the Lagrangian multiplier related to marginal costs. From the FOC with respect to $\ell_{y,t}$, I obtain the sectoral labor demand:

$$w_t = VA_t^{\frac{\xi_y - 1}{\xi_y}} v^{\frac{1}{\xi_y}} y_t^{\frac{1}{\xi_y}} (1 - \alpha) \frac{mc_{y,t}}{\ell_{y,t}}, \quad (24)$$

FOC with respect to $E_{y,t}$ yields the energy demand for production:

$$p_{E,t} = (1 - v)^{\frac{1}{\xi_y}} mc_{y,t} y_t^{\frac{1}{\xi_y}} E_{y,t}^{\frac{(-1)}{\xi_y}} \quad (25)$$

From the FOC with respect to $\mu_{y,t}$, I get the opportunity cost of abatement with respect to the emissions tax:

$$\tau_{y,t} \gamma_y = \theta_1 \theta_2 (\mu_{y,t})^{\theta_2 - 1} \quad (26)$$

Finally, the real marginal cost of non-energy producers reads:

$$mc_{y,t} = 1 - \left(\theta_1 (\mu_{y,t})^{\theta_2} + \tau_{y,t} \gamma_y (1 - \mu_{y,t}) \right) \quad (27)$$

3.2.2 Energy sector

Energy producers aggregate renewable (green) $E_{G,t}$ and non-renewable (dirty) $E_{D,t}$ energy intermediates, according to a CES technology, to produce the energy goods E_t used for consumption by households and as a production factor by non-energy producers:

$$E_t = \left[\nu^{\frac{1}{\chi}} (E_{G,t})^{\frac{\chi-1}{\chi}} + (1-\nu)^{\frac{1}{\chi}} (E_{D,t})^{\frac{\chi-1}{\chi}} \right]^{\frac{\chi}{\chi-1}} \quad (28)$$

where ν represents the share of green energy and χ is the elasticity of substitution between the two intermediate energy inputs. The aggregate energy price is

$$p_{E,t} = \left[\nu p_{G,t}^{1-\chi} + (1-\nu) p_{D,t}^{1-\chi} \right]^{\frac{1}{1-\chi}} \quad (29)$$

The demand for green and dirty energy intermediates is respectively:

$$E_{G,t} = \nu \left(\frac{p_{G,t}}{p_{E,t}} \right)^{-\chi} E_t, \quad (30)$$

$$E_{D,t} = (1-\nu) \left(\frac{p_{D,t}}{p_{E,t}} \right)^{-\chi} E_t \quad (31)$$

The two intermediate energy producers employ a Cobb-Douglas technology, with sector specific capital and labor supplied by households. The maximization problem of dirty energy producers reads:

$$\max_{\ell_{D,t}, k_{D,t-1}, \mu_{D,t}} p_{D,t} E_{D,t} - \tau_{D,t} e_{D,t} - \theta_1 (\mu_{D,t})^{\theta_2} E_{D,t} - w_t \ell_{D,t} - r_{k,t} k_{D,t-1} \quad (32)$$

$$s.t. \quad E_{D,t} = A_{D,t} (k_{D,t-1})^{\alpha_E} (\ell_{D,t})^{1-\alpha_E}. \quad (33)$$

Non-renewable energy firms face a trade-off between paying the environmental tax $\tau_{D,t}$ on their polluting emissions $e_{D,t}$ or sacrificing a share of their output to abate emissions. The fraction of emissions from energy production that are abated is $\mu_{D,t}$. GHG emissions are again a function of dirty energy production and abatement

$$e_{D,t}(i) = E_{D,t}(i) \gamma_D (1 - \mu_{D,t}(i)) \quad (34)$$

where $\mu_{D,t}$ is the fraction of dirty energy emissions abated. The abatement function reads

$$g(\mu_{D,t}(i)) = \theta_1(\mu_{D,t}(i))^{\theta_2} \quad (35)$$

From FOC with respect to $k_{D,t}$, $\ell_{D,t}$ and $\mu_{D,t}$ I obtain:

$$r_{k,t} = \alpha_e \frac{E_{D,t}}{k_{D,t}} mc_{D,t} \quad (36)$$

$$w_t = (1 - \alpha_e) \frac{E_{D,t}}{\ell_{D,t}} mc_{D,t} \quad (37)$$

$$\tau_{D,t} \gamma_D = \theta_1 \theta_2 \mu_{D,t}^{\theta_2-1} \quad (38)$$

The real marginal cost of dirty energy producers reads:

$$mc_{D,t} = p_{D,t} - \tau_{D,t} \gamma_D (1 - \mu_{D,t}) - \theta_1 \mu_{D,t}^{\theta_2} \quad (39)$$

The maximization problem of green energy producers reads:

$$\max_{\ell_{G,t}, k_{G,t-1}} p_{G,t} E_{G,t} - w_t \ell_{G,t} - r_{k,t} k_{G,t-1} \quad (40)$$

$$s.t. \quad E_{G,t} = A_{G,t} (k_{G,t-1})^{\alpha_E} (\ell_{G,t})^{1-\alpha_E}, \quad (41)$$

The FOC of green energy firms problem are:

$$r_{k,t} = \alpha_e \frac{E_{G,t}}{k_{G,t}} mc_{G,t} \quad (42)$$

$$w_t = (1 - \alpha_e) \frac{E_{G,t}}{\ell_{G,t}} mc_{G,t} \quad (43)$$

In the green energy sector, we introduce a production subsidy $\mathcal{T}_{p_G,t}$ that reduces the effective marginal cost of firms. Under flexible prices, the first-order condition implies that the marginal cost satisfies

$$mc_{G,t} = (1 - \mathcal{T}_{p_G,t}) p_{G,t}, \quad (44)$$

where p_G denotes the price of green energy. In the presence of price rigidities, as we will see later, the production subsidy enters the Phillips curve by lowering the effective marginal cost relative to prices, appearing as $\frac{mc_{G,t}(1-\mathcal{T}_{p_G,t})}{p_{G,t}}$ inside the New Keynesian markup distor-

tion. The subsidy effectively stimulates green energy production either by directly lowering marginal costs (under flexible prices) or by reducing price distortions (under sticky prices).

3.3 Environment, Redistribution Policy and Inequality Measures

To complete the environmental module of our model, I proceed by defining the dynamics of emission accumulation, the damage function and total abatement expenditure. This paper adopts the standard E-DSGE approach to environmental externalities and does not attempt to deviate from it.⁹

$$e_{s,t} = \eta e_{s,t-1} + e_t + e_t^{ROW}, \text{ where } e_t = e_{y,t} + e_{D,t}, \quad (45)$$

$$D_t = d_0 + d_1 e_{s,t} + d_2 e_{s,t}^2, \quad (46)$$

$$z_t = g(\mu_{y,t})y_t(i) + g(\mu_{D,t})E_{D,t}(i). \quad (47)$$

The pollution stock is a function of domestic emissions e_t and emissions from the rest of the world e_t^{ROW} ; η is a parameter describing the decay rate of atmospheric pollution. Domestic emissions equal the sum of non-energy and dirty energy firms' GHG emissions; the damage D_t is a quadratic function of the pollution stock $e_{s,t}$; and z_t represents the total abatement spending from the two polluting sectors.

The government is the central fiscal authority and collects different kinds of taxes: labor and capital income taxes from households; carbon taxes from polluting firms. To evaluate the role of fiscal policy in shaping the distributional effects of carbon taxation, the model incorporates a flexible scheme for reallocating the carbon tax revenues ($\tau_Y e_Y + \tau_D e_D$) across different channels. The reallocation across agents is regulated by specific policy parameters (see table 1).

⁹More complex and specific formulations of the environmental externality are well established in the IAM literature and could be meaningfully applied to the structure of this model. Exploring these extensions is left for future research.

Table 1: Revenue recycling policy parameters

| Parameter | Description |
|---------------|---|
| σ | = 0: revenues are used to reduce distortionary taxes. = 1: revenues are redistributed to households or firms. |
| σ_{HH} | = 0: redistribution targets firms. = 1: redistribution targets households. |
| σ_{HM} | = Δ : revenues are distributed proportionally across all households. = 1: revenues are directed only to Hand-to-mouth households. |
| ξ_L | Share of revenues used to reduce the labor income tax (when $\sigma = 0$). |
| ξ_K | Share of revenues used to reduce the capital income tax (when $\sigma = 0$). |

This structure allows for a direct comparison of various policy scenarios:

1. $\mathcal{T}_{HM,t}$: lump-sum (targeted) transfers to HM households ($\sigma = 1, \sigma_{HH} = 1, \sigma_{HM} = 1$);
2. $\mathcal{T}_{HH,t}$: lump-sum (weighted) transfers to all households ($\sigma = 1, \sigma_{HH} = 1, \sigma_{HM} = \Delta$);
3. $\mathcal{T}_{pG,t}$: production subsidies to green firms ($\sigma = 1, \sigma_{HH} = 0$);
4. $\mathcal{T}_{\tau_L,t}$: reduction in labor income tax ($\sigma = 0, \xi_L = 1$);
5. $\mathcal{T}_{\tau_K,t}$: reduction in capital income tax ($\sigma = 0, \xi_K = 1$).

Using the proceeds from carbon taxes to reduce other distortionary taxes makes both labor and capital income taxes endogenous and time-varying, as follows:

$$\tau_{L,t} = \bar{\tau}_L - \mathcal{T}_{\tau_L,t}, \quad \text{where} \quad (48)$$

$$\mathcal{T}_{\tau_L,t} = \xi_L(1 - \sigma) \frac{\tau_{Y,t} e_{Y,t} + \tau_{D,t} e_{D,t}}{w_{HM,t} l_{HM,t} \Delta_{HM} + w_{S,t} l_{S,t} (1 - \Delta_{HM})};$$

$$\tau_{K,t} = \bar{\tau}_K - \mathcal{T}_{\tau_K,t}, \quad \text{where} \quad (49)$$

$$\mathcal{T}_{\tau_K,t} = \xi_K(1 - \sigma) \frac{\tau_{Y,t} e_{Y,t} + \tau_{D,t} e_{D,t}}{r_{k,t} k_{S,t}}.$$

In all other scenarios, the labor (capital) income tax rate is fixed at its baseline value $\bar{\tau}_L$ ($\bar{\tau}_K$). When $\sigma = 0$ and $\xi_L = 1$ ($\xi_K = 1$), the corresponding tax rate is reduced below the baseline level in proportion to the carbon tax revenues collected, relative to the aggregate wage (capital) income. The denominator serves to normalize the adjustment by the total wage (capital return) bill.

A popular measure to quantify income inequality among individuals is the Gini coefficient. Gini is equal to zero in case of perfect equality, 1 in case of perfect inequality. In addition to income inequality, I measure the consumption gap x_S/x_{HM} , so that the effectiveness of

redistribution policies can be quantified. Given the presence of two representative households in our model, the income Gini takes the following form:

$$G_t = \frac{1}{n} \left(n + 1 - 2 \left(\frac{n y_{HM,t} + (n-1)y_{S,t}}{y_{HM,t} + y_{S,t}} \right) \right) \quad (50)$$

where G is the Gini coefficient, n the number of households groups, $y_{HM,t}$ and $y_{S,t}$ represent HM and S income, respectively.

3.4 Market Clearing

Labor demand has to match total labor supply, equal to the weighted sum of households' supply, where Δ is the share of HM families.

$$\ell_t = \ell_{y,t} + \ell_{D,t} + \ell_{G,t} = \Delta \ell_{HM,t} + (1 - \Delta) \ell_{S,t} \quad (51)$$

Capital market clears as follows:

$$k_t = k_{y,t} + k_{D,t} + k_{G,t}. \quad (52)$$

Aggregate capital and investment are adjusted for the share of Savers, as they are the only ones with access to the capital market, as follows:

$$k_t = (1 - \Delta) k_{S,t} \quad (53)$$

$$i_t = (1 - \Delta) i_{S,t} \quad (54)$$

Energy total production must equal energy demand for consumption and production purposes:

$$E_t = E_{c,t} + E_{y,t} \quad (55)$$

Both energy and non-energy goods' total consumption is given by:

$$E_{c,t} = \Delta E_{c,HM,t} + (1 - \Delta) E_{c,S,t} \quad (56)$$

$$c_t = \Delta c_{HM,t} + (1 - \Delta) c_{S,t} \quad (57)$$

Hence, aggregate consumption reads:

$$x_t = \Delta x_{HM,t} + (1 - \Delta)x_{S,t} \quad (58)$$

Goods market clearing implies

$$y_t = c_t + i_t + g_t + z_t. \quad (59)$$

3.5 Nominal Frictions and Monetary Policy

In the baseline model, firms in all sectors operate in monopolistically competitive markets, with sticky prices and sticky wages. Nominal price rigidities are modeled by introducing quadratic adjustment costs $AC_t(i)$ à la Rotemberg (1983), which intermediate firms pay when adjusting their price with respect to the inflation target. Similarly, households pay a quadratic wage-adjustment cost $AC_{j,t}^W(i)$ which penalizes deviations of wage inflation from the inflation target. In the next section, I will show simulation results of a model inclusive of all the nominal rigidities described so far. A comparison between the baseline and the flexible prices model is provided in section 5.3.

The presence of price rigidities requires modeling the policy function adopted by the central bank in order to choose the value of the instrument (interest rate) to contrast inflation. In this case, the central bank follows a simple feedback rule of the Taylor (1993) rule class, as follows:

$$\frac{r_t}{\bar{r}} = \left(\frac{r_{t-1}}{\bar{r}} \right)^{\rho_m} \left[\left(\frac{\pi_t}{\bar{\pi}} \right)^{\phi_\pi} \right]^{1-\rho_m}, \quad (60)$$

where \bar{r} and $\bar{\pi}$ represent the corresponding Ramsey steady state of the nominal interest rate and inflation; ρ_m denotes the degree of monetary policy inertia; ϕ_π denotes the response of the interest rate to the inflation gap.¹⁰

3.6 Abatement and Carbon Tax path

I follow the approach adopted by Ferrari and Nispi Landi (2023) to define the abatement and carbon tax path. I set ex ante the initial abatement level μ_D and μ_y at zero (year 2020), and the final level at 1 (year 2050), corresponding to a 95% reduction in total emissions.

¹⁰For simplicity, I abstract from policy reaction to output gap variations.

Additionally, I define the intermediate targets for the year 2030 (55%) and 2040 (90%), in line with the GHG emission abatement policy adopted by the EC. I then calculate carbon taxes τ_y and τ_D ex post. Carbon taxes grow linearly between targets for a total of 120 quarters (30 years) until the Net Zero target is reached. After that, the abatement level and the carbon tax remain constant.

3.7 Calibration

The model is calibrated to EU data at a quarterly frequency. Data on households' income/wealth distribution and consumption habits are taken from the EU Statistics on Income and Living Conditions (EU-SILC) for the aggregate EU-27. The share of HM households corresponds to the bottom two income quintiles of the population, who hold almost zero net wealth and is equal to 40% of the population (see Figure 3). From the Household Final Consumption Expenditure database¹¹ I estimate the parameters that determine the composition of the consumption baskets for the two household groups. The calibration focuses on the category "Electricity, gas, and other fuels", both because it absorbs a sizable share of total expenditure and because it is one of the key channels through which higher carbon taxes feed into consumer prices. On average, HM consume 7.8% of their total income on energy, while this share decreases to 4.9% for S families. Note that the distribution parameter γ_j is derived from the energy share value ω_j , following the re-parametrization approach proposed by Cantore and Levine (2012). The different elasticity of substitution parameters between energy and non-energy goods consumption are borrowed from Känzig (2023), assuming HM are more constrained in their consumption behavior. Other households' parameters are borrowed from Drygalla et al. (2018) who estimate a DSGE model using German and EU data. Firms parameters are derived from Eurostat data on energy, labor and capital share of production of energy and non-energy sectors. The energy sector is relatively more capital intensive ($\alpha = 0.37$ while $\alpha_E = 0.73$).¹² Standard elasticity of substitution between dirty and green energy in the energy CES aggregator is assumed to be between 1 and 2. The long

¹¹Eurostat's annual data on Household Final Consumption Expenditure, categorized by COICOP (Classification of Individual Consumption by Purpose), provides a comprehensive analysis of household spending across the EU. COICOP categorizes expenditures into various divisions, allowing for detailed insights into how households allocate their financial resources among different goods and services.

¹²Capital intensity is calculated from labor intensity in the energy sector and the rest of the economy (here non-energy sector). Labor intensity is the ratio of compensation per employee to gross value added (GVA), corrected for the employed-to-employee ratio to account for the self-employed.

run elasticity of substitution between the capital/labor bundle and energy in the non-energy production function is provided by van der Werf (2008).¹³ The share of renewable energy consumption in the EU is around 25%, has provided by Eurostat. From this, I calculate the weighting parameter of renewable energy ν . In order to derive the emission intensity of the non-energy and dirty energy sectors, I first fix the steady state of the total pollution stock to 877.56 (GtG in 2020) and the volume of emissions from the rest of the world to be equal to 10 times the emissions from the EU. I set the share of emissions from the energy sector Q_E to 80%, reflecting emissions from energy consumption rather than production alone. This calibration aligns with Eurostat data, where emissions directly attributable to energy production account for 30%, but emissions from energy combustion – dependent on energy consumption – constitute 80% of total emissions. Thus, this approach better captures the broader impact of energy use on emissions. The amount of energy consumed by households Q_{Ec} is equal to 28% of total energy production. The resulting emission intensities from non-energy and dirty energy production are 0.050 and 1.158, respectively. In order to get the same carbon tax for both polluting sectors, for non-energy firms I scale the abatement cost function coefficient by the relative share of emission intensity. For other environmental related parameters, I use the parametrization adopted in Gibson and Heutel (2023).

¹³For the business cycle, short run analysis in the Appendix, this elasticity is reduced to a value close to zero (0.02), as estimated by Hassler et al. (2021), indicating a much stronger dependence of production on the energy input which, although plausible in the short run, is too restrictive for the long run analysis.

Table 2: 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 | 2.0 | – |
| ξ_w | CES parameter of labor supply | 6 | Standard value |
| ϕ_w | Wage adjustment cost | 59.113 | Implied from θ_c (Ascari & Rossi, 2012) |
| ϵ_{HM} | Elasticity of subs energy/non-energy goods, HM | 0.05 | Känzig (2023) |
| ϵ_S | Elasticity of subs energy/non-energy goods, S | 0.275 | – |
| γ_{HM} | Distribution parameter HM | 0.118 | Energy share $\omega_{HM} = 7.8\%$, EU-SILC |
| γ_S | Distribution parameter S | 0.069 | Energy share $\omega_S = 4.9\%$, EU-SILC |
| ϕ_i | Investment adjustment cost | 10 | Standard value |
| $\bar{\tau}_L$ | Labor income tax rate | 20% | Eurostat |
| $\bar{\tau}_K$ | Capital income tax rate | 25% | – |
| Δ | Share of HM households | 40% | – |
| Firms | | | |
| ξ_y | Elasticity of sub. between VA and energy | 0.38 – 0.02 | van der Werf (2008) – Hassler et al. (2021) |
| ξ | Elasticity of sub. between intermediate goods | 6 | Standard value |
| α | Share of capital in value added | 0.37 | Eurostat |
| $1 - v$ | Share of energy in non-energy production | 0.13 | – |
| θ_c | Calvo price parameter | 0.75 | Standard value |
| ϕ_p | Price adjustment cost | 59.113 | Implied from θ_c (Ascari & Rossi, 2012) |
| χ | Elasticity of sub. between energy sources | 1.8 | Standard value |
| ι | Share of renewable energy | 0.25 | Eurostat |
| ν | Weighting parameter of renewable energy | 0.3156 | Implied from ι |
| α_E | Share of capital in energy production | 0.73 | – |
| Q_{Ec} | Share of energy used for consumption by HH | 28% | – |
| Q_E | Energy sector share of total emissions | 80% | – |
| Environment | | | |
| γ_D | Energy sector emissions intensity | 1.158 | Implied from Q_E |
| γ_y | Non-energy sector emissions intensity | 0.050 | 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 | – |
| $\theta_{y,1}$ | Abatement cost function coefficient Non-energy firm | 0.003 | – |
| 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 |
| ρ_m | Monetary policy inertia | 0.8 | – |
| ρ_τ | Carbon tax shock inertia | 0.95 | – |

4 The Net-Zero Policy

In this section, I simulate the long-term transition to an emission-free economy, where the government sets ambitious abatement targets, and the carbon tax – the shadow price of abatement – rises gradually over time. By the end of the transition, both non-energy and dirty energy firms fully abate their emissions. The policy is announced at the beginning of the simulation. Perfectly rational agents anticipate the full trajectory of the carbon tax, designed to achieve a 95% emissions reduction by 2050. The gradual increase in the carbon tax incentivizes firms to invest in abatement technologies as emissions become increasingly costly. This raises production costs permanently, leading to necessary cuts in wages and returns on capital. In the baseline simulation, it is assumed that the technology is constant at

the steady state level.¹⁴ A key contribution of this paper is the comparison of five alternative uses of carbon tax revenues – ranging from household transfers to firm subsidies and income tax reductions – along the transition path toward the EU’s 2050 Net Zero target. Each redistribution policy entails distinct macroeconomic and distributional effects, revealing a potential trade-off between efficiency and equity.

4.1 Macroeconomics and Distributional Effects

In all scenarios, production declines in the long run, following the implementation of the Net-Zero policy. The decline in GDP is less pronounced when carbon tax revenues are allocated to reduce household labor and capital income taxes, and in the medium term, GDP variation is even positive. By the end of the transition, GDP is approximately 1.7-2.2% below its pre-policy level, in line with the literature and EC’s policy reports.¹⁵ The contraction in energy production is even more pronounced. Investment exhibits a rapid initial contraction but fluctuates around intermediate targets before stabilizing. In the capital tax reduction scenario only, the investment component reacts (temporarily) positively to the implementation of the carbon tax (see Figure 5).

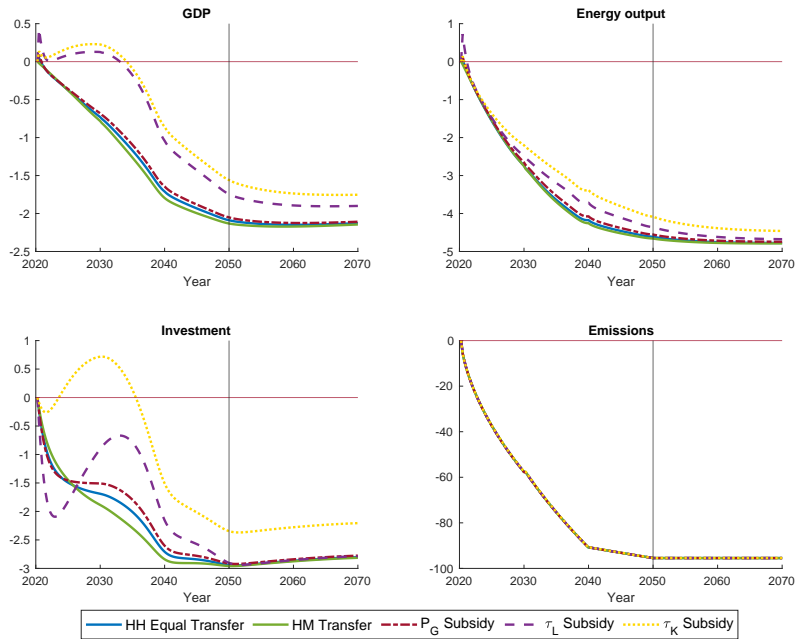
Price dynamics are also influenced by the redistributive policy in place. The energy component of inflation peaks immediately following the announcement of the Net-Zero policy. Price increases are particularly significant in scenarios involving labor and capital tax reductions. Year-on-year energy inflation remains positive throughout the transition period. However, the situation is different for headline inflation. In the case of transfers to households, inflation turns immediately negative and does not recover until the end of the simulation period (see Figure 6).

In the very short run, households increase their consumption under every redistribution scenario. Savers benefit the most from firm subsidies or a reduction in the income tax rate, enabling them to increase their consumption above the level prior to the carbon policy. By

¹⁴I acknowledge the importance of green technological development, which will become even more crucial in the future to ensure the transition to a zero-emission economy. Indeed, a significant body of literature focuses on the interaction between climate policies and green innovation (e.g. Fried (2018), Kruse-Andersen (2025)). However, the objective here is to isolate the macro and distributional effects of fiscal policy alone. Appendix E presents an additional scenario in which green energy technology increases at a linear rate of 2% per year until 2050, consistent with empirical literature.

¹⁵Comparable long run output costs are reported in Ferrari and Nispi Landi (2024b) and Coenen et al. (2024) for the euro area, as well as in the *Clean Planet for All* report by the European Commission (2018b) and in the Network for Greening the Financial System (2025) climate scenarios, which all project GDP reductions of around 2% in low-innovation transitions.

Figure 5: Macro Dynamics, Transition to Net Zero

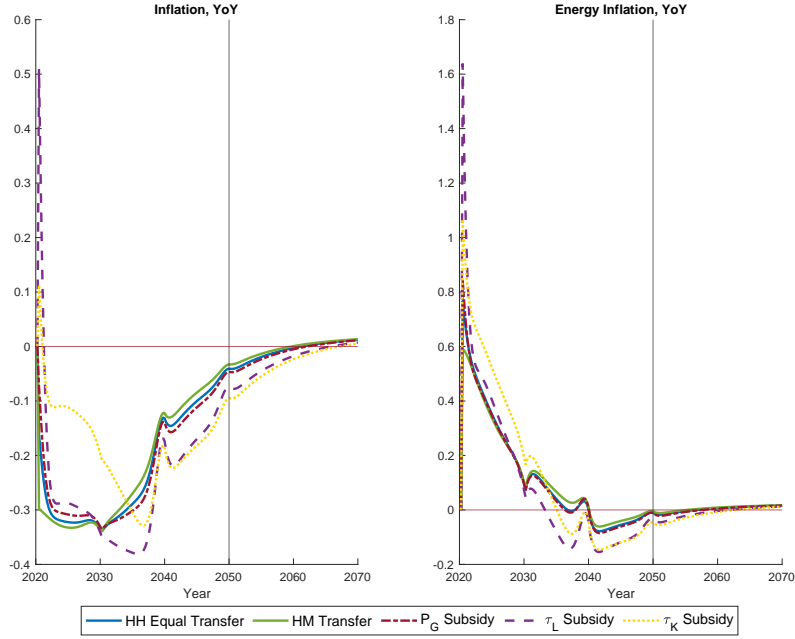


Note: variables expressed as percentage deviation from the initial steady state.

the end of the simulation period, overall consumption (x_S) settles between -1.5% and -2%. Hand-to-mouth households only significantly raise consumption when targeted transfers or labor tax cuts are implemented. In this case as well, the increase in consumption is short-lived. In the long run, x_{HM} falls between -2.3% and -2.7%. The consumer price index for the two households shows an upward concave trend, with a slowdown near the intermediate target of 2040. Notably, the price of the HM basket increases by nearly 1%, while the price for Savers increases by only about 0.5% (see Figure 7).

Households adjust their labor supply differently in response to an increase in the emissions tax, as reported in Figure 8. In the long run, HM households – who rely entirely on labor income – permanently increase their labor supply. In the short run, however, they reduce their labor effort, but only when they receive direct government transfers that substantially offset their income loss. In contrast, Savers reduce their labor supply over the medium term. This adjustment is delayed, as they initially work more in anticipation of future wage cuts, especially when the labor income tax is reduced. As the economy approaches the net-zero target, labor supply gradually returns to its steady-state level. The reduction is more pronounced under redistribution schemes targeting Savers or green firms, reflecting a positive wealth effect. In response to the carbon tax increase, both wages and the return on capital decline as firms face higher production costs. However, while wages remain permanently

Figure 6: Inflation, Transition to Net Zero



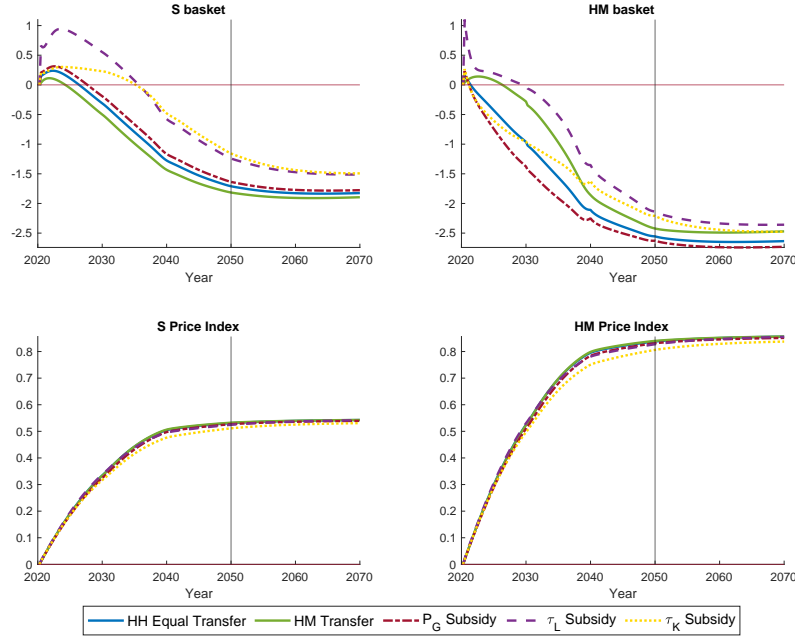
Note: variables expressed in annualized net level deviation.

below their initial level (between -2% and -2.5%), the return on capital gradually recovers in the long run. In scenarios where carbon tax revenues are used to reduce income taxes, both wages and the interest rate exhibit a short-lived positive response. One redistributive policy in particular – $\mathcal{T}_{\tau_K,t}$ – has opposing effects on labor and capital costs. It mitigates the negative impact on wages while amplifying the decline in the return on capital.

In terms of income inequality, all policies that redistribute carbon tax revenues exhibit some degree of progressivity. As shown in the left panel of Figure 9, each redistribution scheme reduces the Gini coefficient, with the largest decline observed under transfers targeted at HM households. This reduction occurs shortly after the policy is introduced and reaches its lowest point between 2030 and 2040, when carbon tax revenues peak. Turning to consumption inequality (right panel of Figure 9), only targeted transfers and cuts to the labor income tax produce a temporary reduction in the consumption gap. But in the long run, all policies become regressive, as the consumption gap rises above its initial, pre-tax level. Once again, HM targeted transfers yield the smallest long run increase in inequality. By contrast, green energy production subsidies and capital income tax cuts are the most regressive instruments according to this metric.

These results reveal a clear trade-off between efficiency and equity. Firm subsidies and reductions in capital and labor income taxes yield smaller declines in consumption, invest-

Figure 7: Households Dynamics, Transition to Net Zero



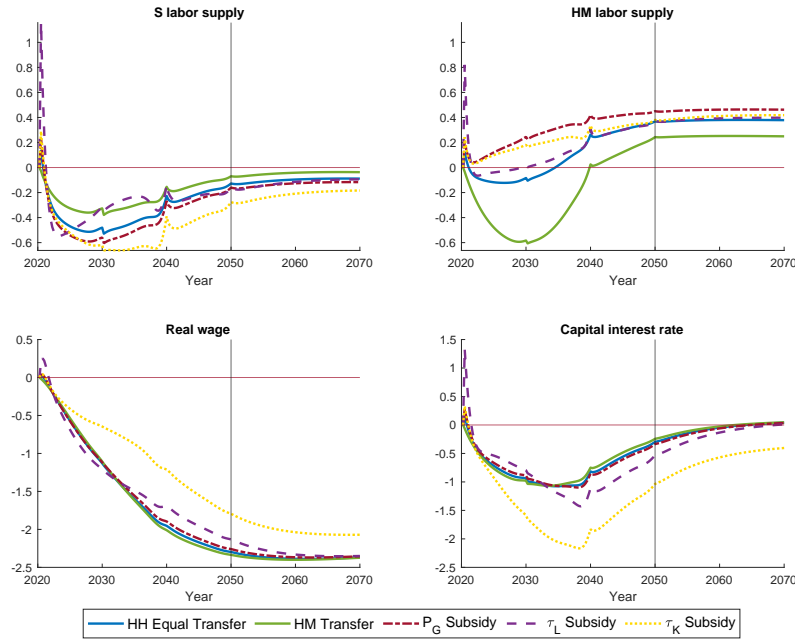
Note: variables expressed as percentage deviation from the initial steady state. Inflation expressed in annualized net level deviation.

ment, and output – implying higher efficiency – but exacerbate the consumption gap. Direct transfers to households, particularly those targeted at HM agents, are the most progressive but also the least efficient.

4.2 Discussion

After accounting for the structural differences introduced by various redistribution policies, the following overall dynamic emerges. The implementation of a gradually increasing carbon tax that leads to net-zero emissions is recessionary: it depresses energy production, consumption, and investment; it is inflationary, though only for the energy component; it induces a reallocation of resources (labor and capital) from the dirty to the green energy sector (see Figure 39 in the Appendix); it reduces real wages and has mixed effects on inequality. These outcomes are embedded in the structure of the model and the nature of the simulation, which abstracts from green technological progress to isolate the pure effects of the policy. Since the analysis is conducted under perfect foresight, agents are assumed to internalize the full trajectory of the carbon tax and the dynamic adjustment path of the economy from the moment of its announcement. The introduction of the policy increases firms' production costs, leading them to reduce wages and the rental rate of capital.

Figure 8: Labor and Capital Markets, Transition to Net Zero

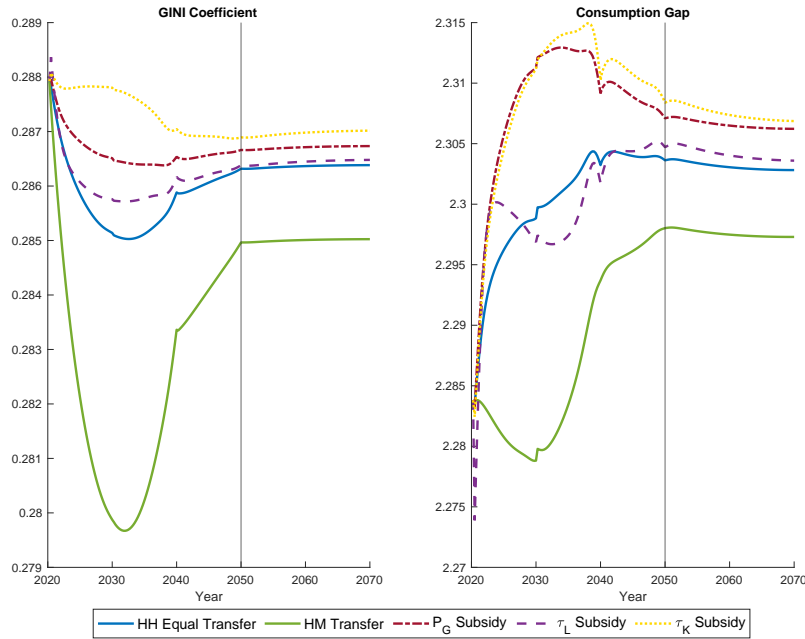


Note: variables expressed as percentage deviation from the initial steady state.

Households' labor supply responses are heterogeneous and depend on the revenue recycling scheme. By definition, HM households are myopic: they consume their entire income each period. When they receive direct transfers, they reduce their labor supply, as the subsidy compensates for their lost income and working yields disutility. In contrast, Savers primarily reduce their labor supply in two scenarios: (i) when green energy production is subsidized and (ii) when the capital income tax is reduced. In the first case, Savers benefit from the higher profits of green firms, of which they are the sole owners, due to the subsidy. This wealth effect enables them to maintain their consumption despite working less. This is reflected in the larger consumption gap observed under this policy. In the second case, the capital tax cut increases the net return on savings. This enables firms to offer a lower gross return without discouraging investment. Moreover, the initial increase in capital accumulation reduces the need to raise returns to attract further funds. Higher capital per worker increases the marginal product of labor, consequently raising the real wage received by Savers relative to other scenarios. This enables Savers to reduce their labor supply while maintaining relatively high consumption. However, this scenario is associated with the highest Gini coefficient and the largest consumption gap.

When revenues are used to reduce labor income taxes, both types of households initially

Figure 9: Inequality Measures, Transition to Net Zero



Note: inequality measures expressed in levels.

increase their labor supply. This response peaks immediately and then gradually fades. This behavior stems from the interplay of perfect foresight and intertemporal substitution. Households anticipate a higher net wage in the future due to the tax cut but also foresee a persistent decline in gross wages driven by the rising carbon tax. The initial reduction in the capital-to-labor ratio (K/L) lowers the marginal product of labor and leads to a decline in gross wages over time. Although the tax rate decreases gradually, gross wages fall more rapidly and by a greater amount. Once wages start to decline, both types of households, especially Savers, have less incentive to work and reduce their labor supply. The negative substitution effect (working fewer hours as net wages fall) and the negative wealth effect (Savers anticipating lower future income due to persistently low labor productivity) outweigh any additional benefit from marginal reductions in the labor tax rate.

In both scenarios in which carbon tax revenues are used to reduce income taxes – on labor or capital – the respective labor supply or investment is stimulated. As a result, these policies lead to relatively higher output. The decline in GDP is the smallest under these scenarios and turns positive within the first 10 to 15 years of the transition. However, this comes at the cost of higher inflation. Not only is energy inflation stronger, but headline inflation also rises, making these the only cases in which the carbon policy is inflationary in the first few

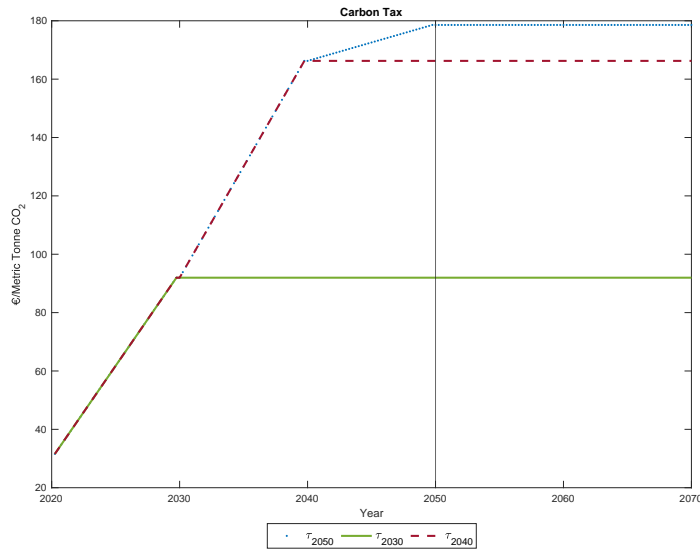
years.

5 Alternative Scenarios

5.1 Net-Zero Simulation with Expectation Errors

In the standard perfect foresight scenario, agents are initially surprised by the announcement of emission reduction targets at $t = 1$. From that point onward, they rationally anticipate all future emission cuts and the associated costs, which are captured in the carbon tax. In contrast, in a scenario with forecast errors, agents only receive updates on intermediate targets periodically. At $t = 1$, they are informed of a 55% emission reduction by 2030, and they believe that once this target is achieved, the tax will not increase further. However, at $t = 41$ (2030-Q1), a new target (90% reduction by 2040) is announced, resulting in an additional increase in the carbon tax. This same surprise effect occurs when reaching the 2040 target ($t = 81$), when the final goal of 95% reduction by 2050 is announced. The evolution of carbon tax in euros $\tau_t^\text{€}$ for different time horizons is depicted in Figure 10.¹⁶

Figure 10: Carbon Tax at Different Time Horizons Targets



Note: Energy and Non-Energy Carbon tax expressed in real terms.

In this scenario, agents are initially misinformed about future shocks and revise their

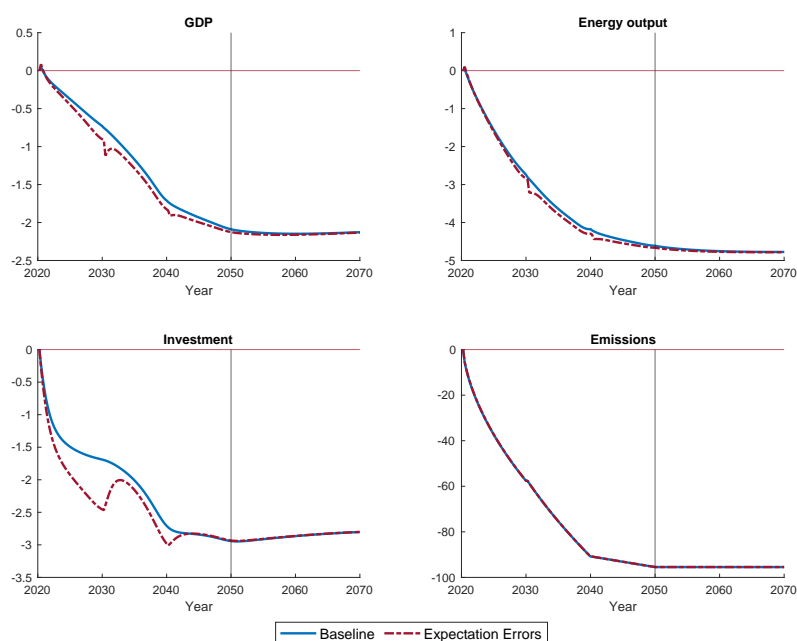
¹⁶The carbon tax τ_t is expressed in model units. By multiplying it by the ratio of nominal GDP (in euro) to GDP in model units, and converting from carbon to CO₂ units, the implied euro price of CO₂ per metric tonne can be recovered.

expectations only after the shock materializes.¹⁷ This generates staggered and more volatile adjustment paths, as agents underreact or overreact to the new information. A comparison between the baseline case and the model with expectation errors is presented in Figures 11–15. For both models, the recycling policy considered is that of equal redistribution of carbon tax revenues to households. Additional dynamics under this new scenario are displayed in detail in the Appendix F.1.

Output and investment are more volatile, as Savers are forced to adjust their consumption/investment behavior to the new targets in response to the announcements (Figure 11). The higher uncertainty leads to a sharper decline in investment, which has fallen to 1.5 times the level observed in the baseline scenario by 2030 . The rapid deterioration in investment contributes to the faster decline in production. Energy and headline inflation show a similar behavior in the two scenarios in the short term (Figure 12). Volatility rises around the time of intermediate targets. As the end of the carbon tax growth approaches, relative household demand increases, leading to a rise in inflation just before the announcement of new targets. The announcement itself triggers a sharp – though temporary – drop in prices. Similar dynamics are observed in other macroeconomic variables, including investment, consumption, labor supply and input prices.

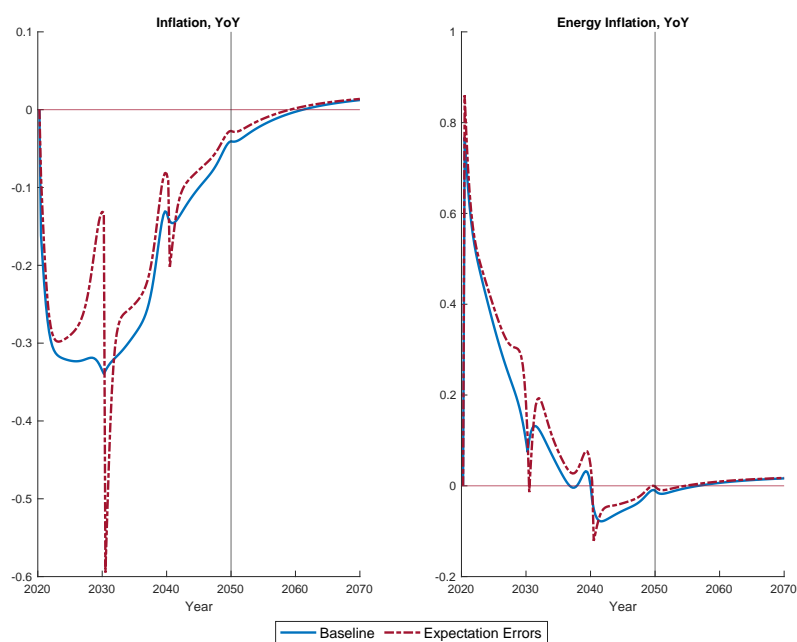
¹⁷The exact timing of when agents correct their expectations (before or during the shock) influences how sharply the economy reacts to the tax changes (τ_Y and τ_D) and how quickly it transitions to the new equilibrium.

Figure 11: Macro Dynamics, Baseline vs Expectation Errors



Note: variables expressed as percentage deviation from the initial steady state.

Figure 12: Inflation, Baseline vs Expectation Errors

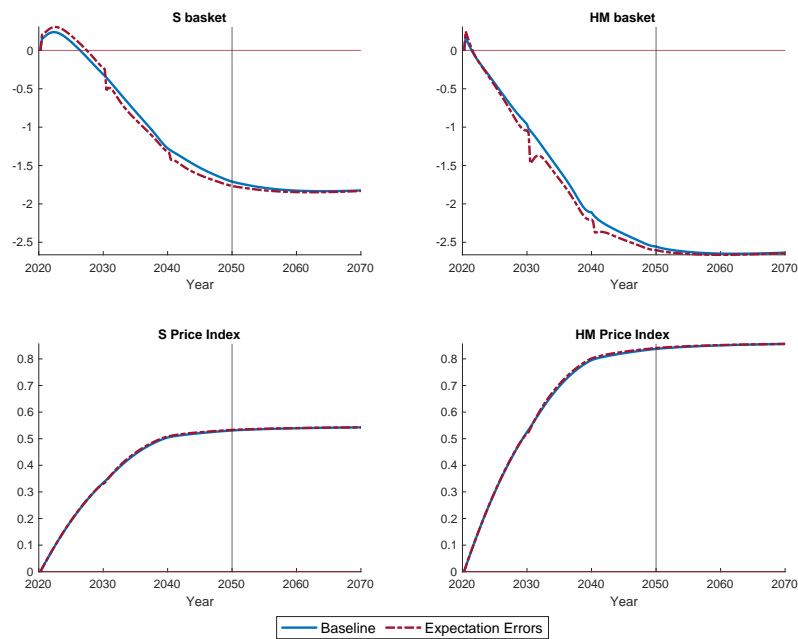


Note: variables expressed in annualized net level deviation.

The effects of expectation errors on household behavior are more evident when examining disaggregated dynamics. During the first phase of the transition (up to the 2030 target), the labor supply (Figure 14) and consumption (Figure 13) of Savers both lie above the baseline.

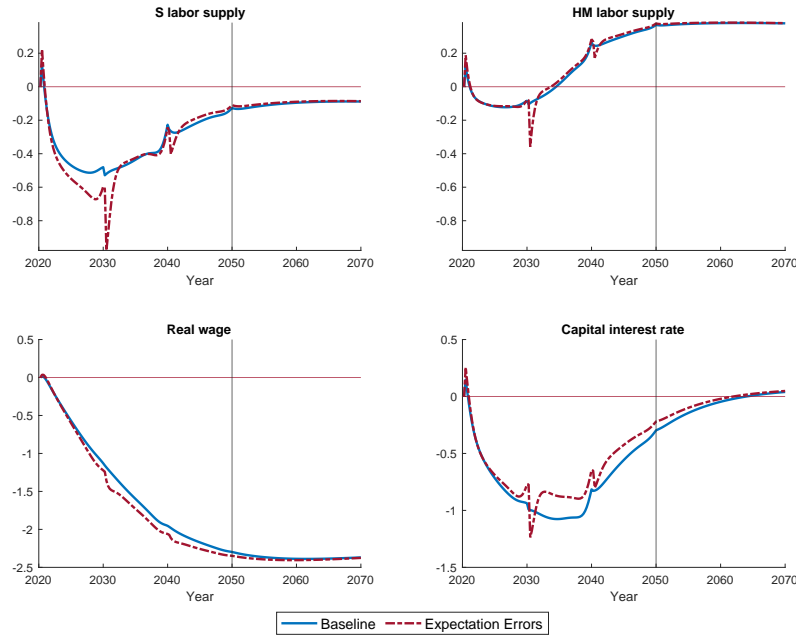
The return on capital is also slightly higher. Assuming the carbon tax will stop increasing after 2030, Savers view the redistribution scheme as permanent. Since substantial emissions remain in 2030, tax revenues are collected and subsidies continue. As a result, Savers sustain consumption by slightly reducing investment. When the 2040 target is announced, Savers are surprised by the extension of the policy path. Consumption drops sharply and remains below the baseline from that point onward. Investment fluctuates and labor supply, already relatively low, declines further but quickly rebounds.

Figure 13: Households Dynamics, Baseline vs Expectation Errors



Note: variables expressed as percentage deviation from the initial steady state. Inflation expressed in annualized net level deviation.

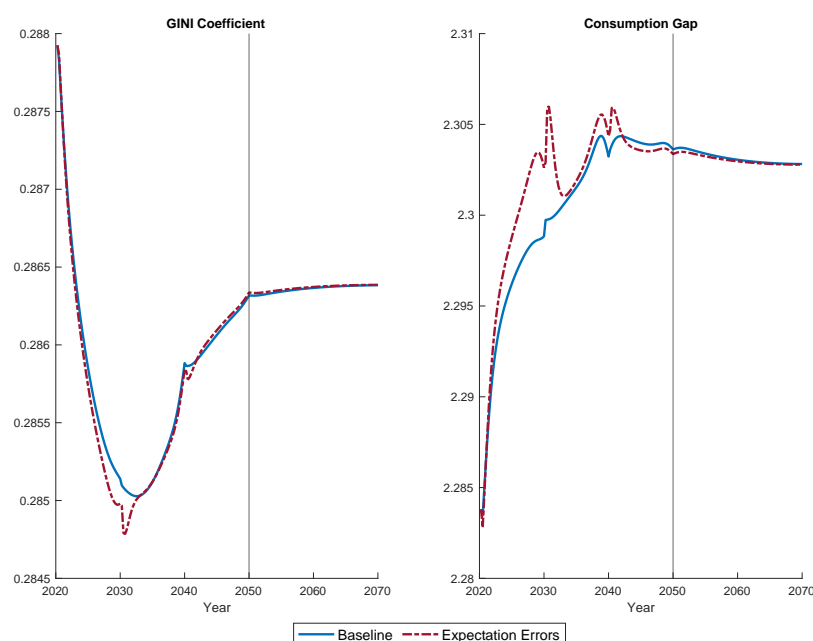
Figure 14: Labor and Capital Markets, Baseline vs Expectation Errors



Note: labor variables expressed as percentage deviation from the initial steady state.

Hand-to-mouth households also reduce consumption after the 2030 announcement. Their labor supply remains broadly aligned with the baseline except during the announcement period when it becomes more volatile, mirroring other macroeconomic variables. Prices temporarily increase, especially in the energy sector. Despite weaker aggregate demand, firms benefit from higher prices and lower production costs (in wages and capital). As a result, while the Gini coefficient remains below the baseline, the combination of a wealth effect driven by rising firm profits and a price effect due to heterogeneous consumption baskets that make inflation more severe for HM households leads to a substantial widening of the consumption gap (see Figure 15).

Figure 15: Inequality Measures, Baseline vs Expectation Errors



Note: inequality measures expressed in levels.

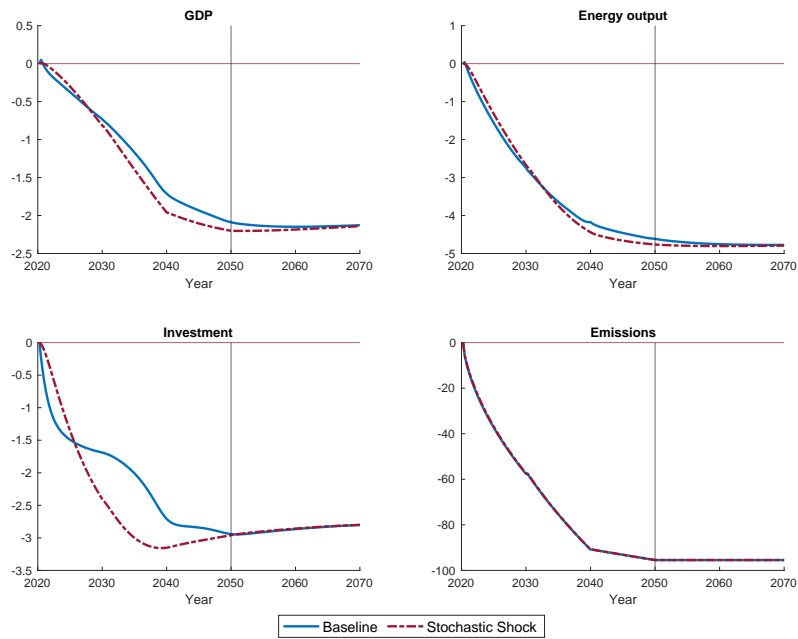
5.2 Net-Zero Simulation with Stochastic Error

What if agents ignore the Net Zero policy and view the tax increase as a new, permanent shock each period? Unlike the scenario with few and limited expectation errors, there are no sudden, sharp changes in prices and other macroeconomic variables in this scenario. Instead, changes are smooth. For example, investments show a steady, almost linear decline, leading to a 3% total reduction in 2040 and a consequent reduction in GDP (see Figure 16).

Energy inflation, on the other hand, remains more sustained because agents do not expect changes to the emissions tax over time. The policy remains deflationary (see headline inflation in the left panel of Figure 17), as the demand effect still dominates, but to a lesser extent.

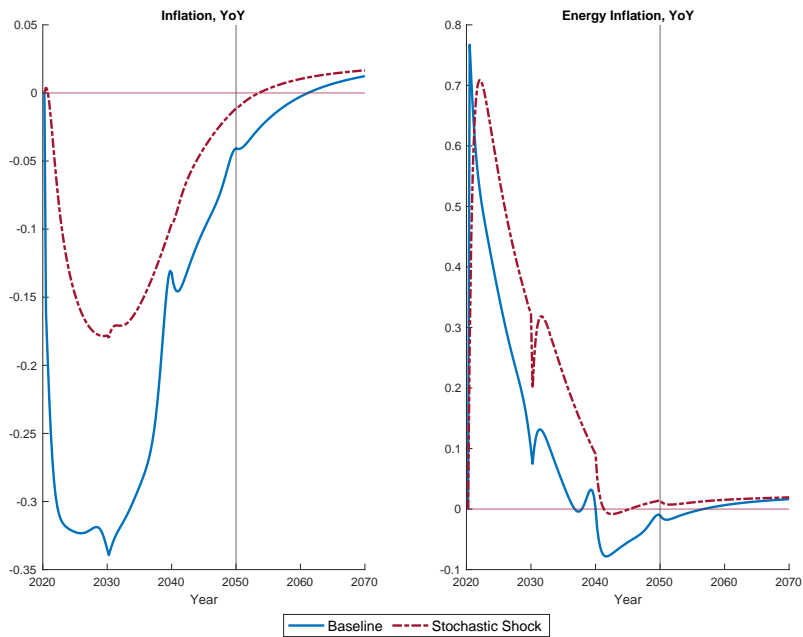
Consumption by households remains relatively high in the short and medium terms due to unexpected (increasing) government subsidies (see Figure 18). Consumption gap is smaller in the first decade but worsens after 2030 as tax growth accelerates (Figure 20).

Figure 16: Macro Dynamics, Baseline vs Stochastic Transition



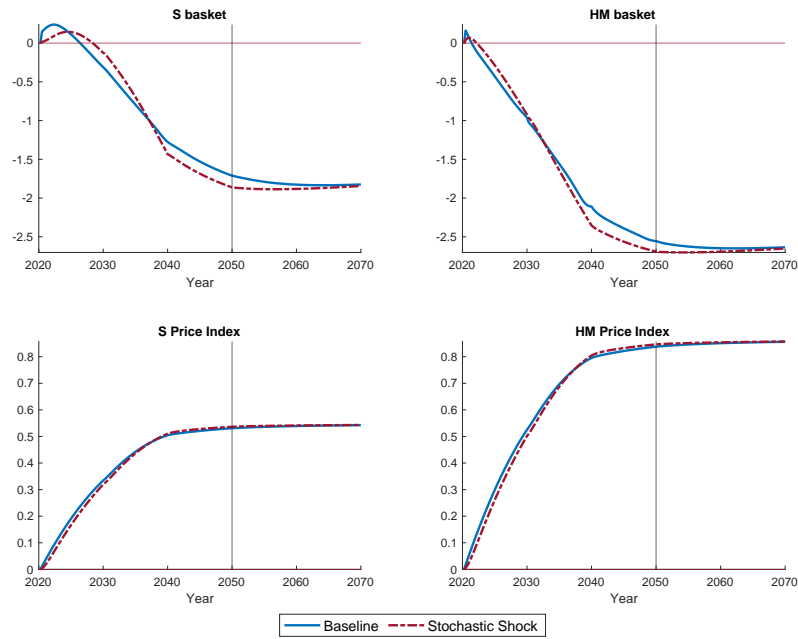
Note: variables expressed as percentage deviation from the initial steady state.

Figure 17: Inflation, Baseline vs Stochastic Transition



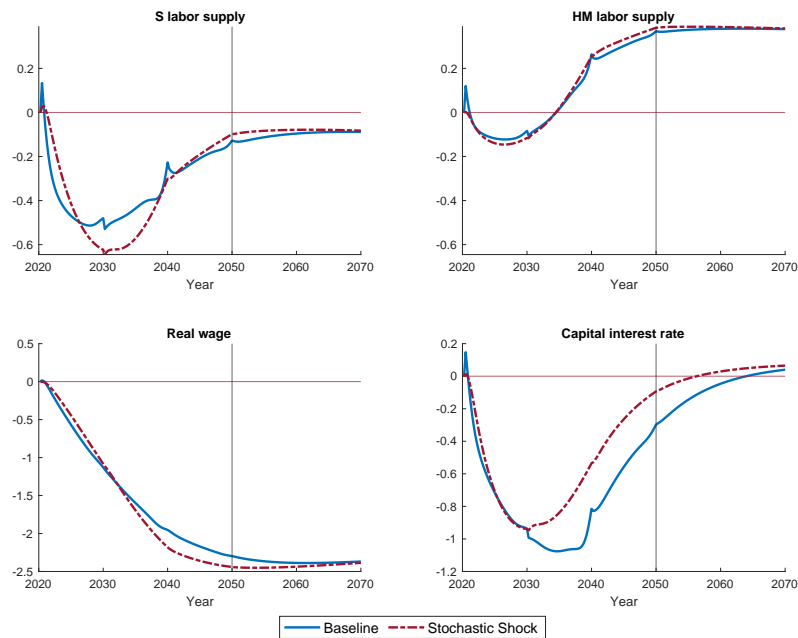
Note: variables expressed in annualized net level deviation.

Figure 18: Households Dynamics, Baseline vs Stochastic Transition



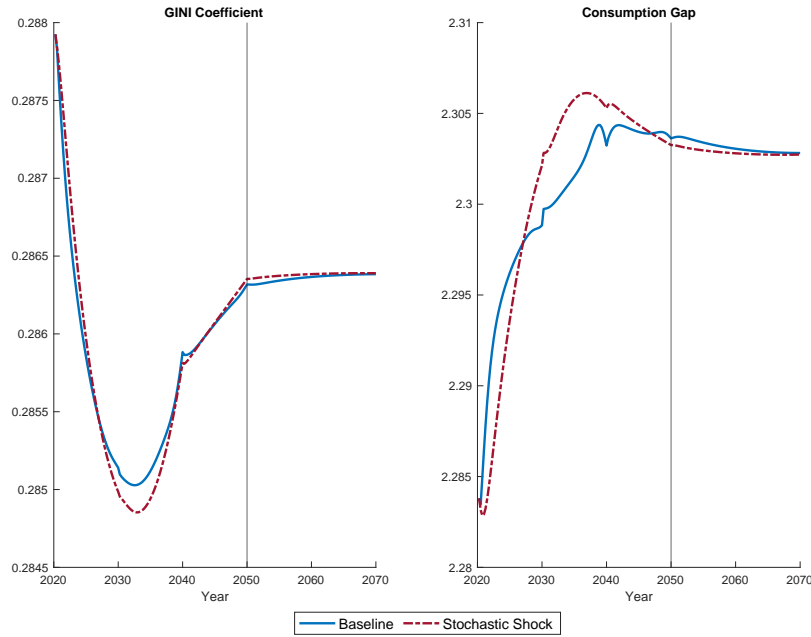
Note: variables expressed as percentage deviation from the initial steady state. Inflation expressed in annualized net level deviation.

Figure 19: Labor and Capital Markets, Baseline vs Stochastic Transition



Note: labor variables expressed as percentage deviation from the initial steady state.

Figure 20: Inequality Measures, Baseline vs Stochastic Transition



Note: inequality measures expressed in levels.

5.3 Net-Zero Simulation with Flexible Prices and Wages

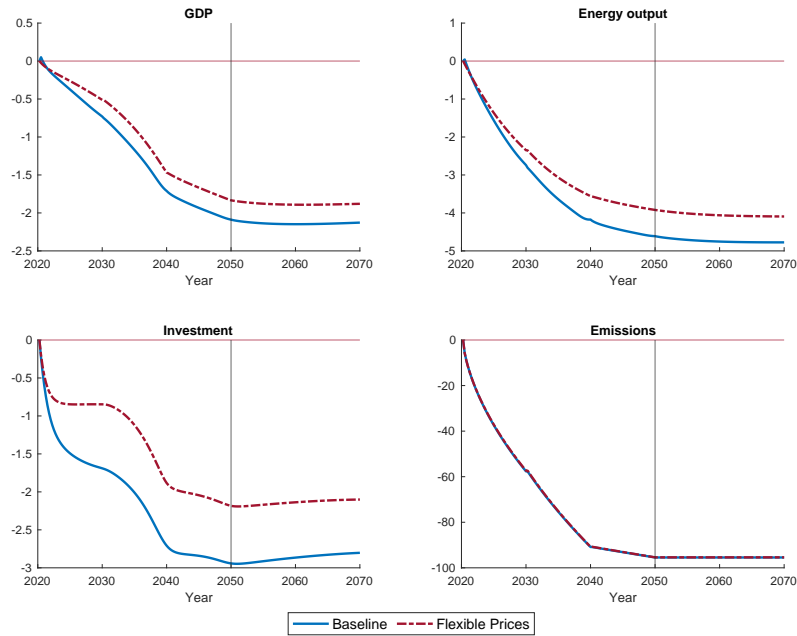
In the absence of nominal frictions (flexible prices and wages), there is a faster price adjustment and a consequent beneficial effect in terms of output. A comparison between the baseline case and the model with flexible prices and wages is presented in Figures 21–25.

The difference with the baseline scenario in GDP and energy production is 0.5% and 1% respectively (see figure 21). In this scenario, the policy turns out to be fully inflationary, but only in the short term. Year on year energy inflation reaches 1.3%, and remains above the baseline inflation until the end of the first phase (see Figure 22). Consumption for HM households is relatively higher, while Savers prefer to increase investment, which is reduced by (only) 2% (1% less than in the baseline scenario). Labor supply also recovers faster for Savers (see Figure 24). By the end of the Net-zero transition, both household groups supply 0.2% more labor compared to the initial steady state. Income inequality turns out to be substantially higher in a flexible economy (see Figure 25).

Overall, the presence of nominal frictions dampens inflation volatility but imposes adjustment costs on both producers (through price rigidities) and workers (through wage rigidities). In a fully flexible environment, wages are higher, total labor supply increases, and both investment and consumption rise. As a result, the reduction in income inequality is more

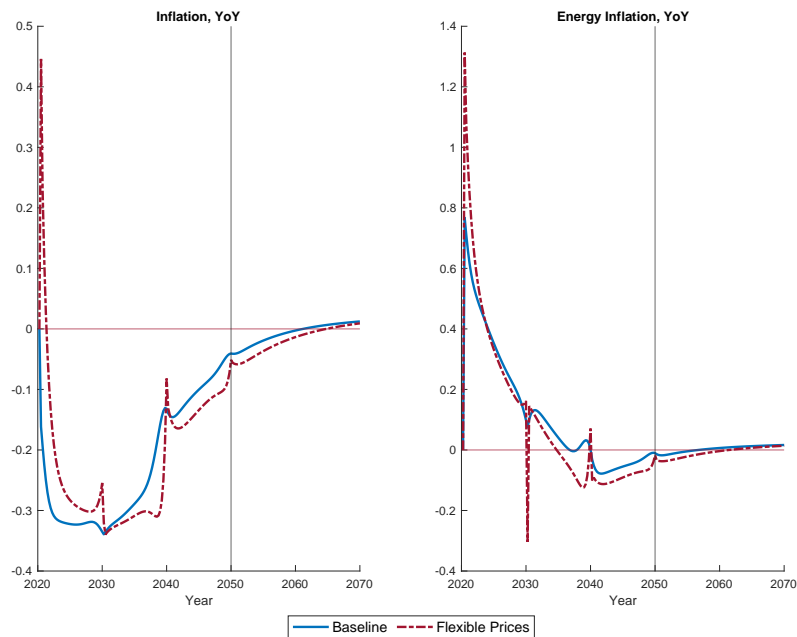
limited (also because only the equal redistribution policy is considered in this comparison), although the initial consumption gap is smaller. The detailed dynamics under this additional scenario are also displayed in the Appendix F.3.

Figure 21: Macro Dynamics, Baseline vs Flexible Prices



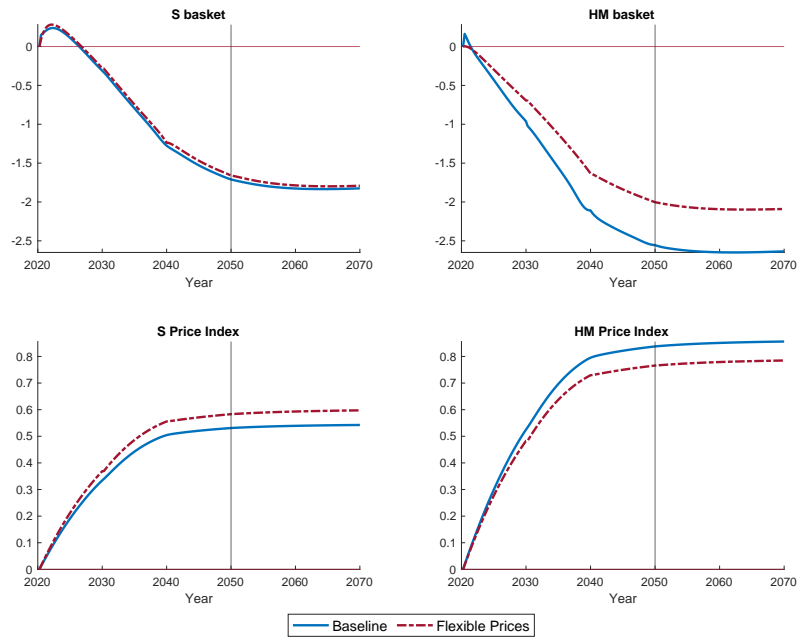
Note: variables expressed as percentage deviation from the initial steady state.

Figure 22: Inflation, Baseline vs Flexible Prices



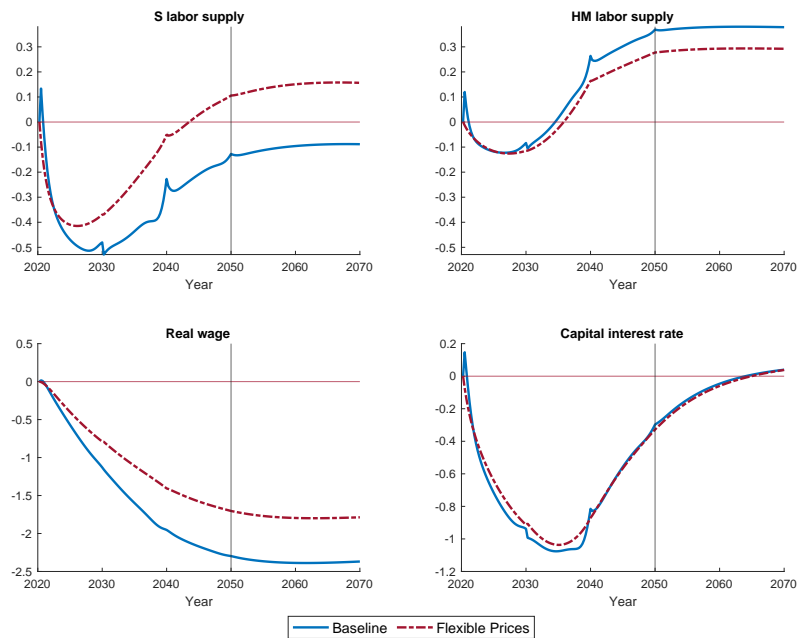
Note: variables expressed in annualized net level deviation.

Figure 23: Households Dynamics, Baseline vs Flexible Prices



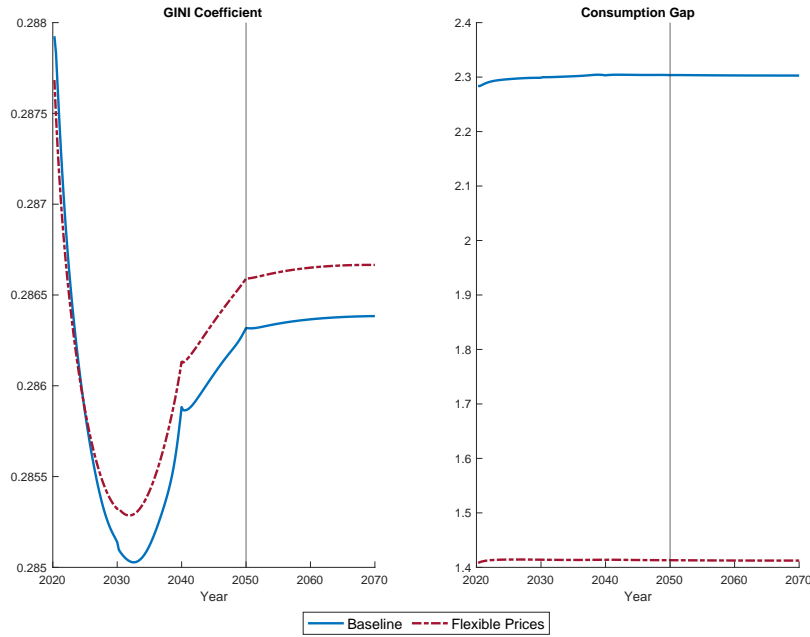
Note: variables expressed as percentage deviation from the initial steady state. Inflation expressed in annualized net level deviation.

Figure 24: Labor and Capital Markets, Baseline vs Flexible Prices



Note: labor variables expressed as percentage deviation from the initial steady state.

Figure 25: Inequality Measures, Baseline vs Flexible Prices



Note: inequality measures expressed in levels.

5.4 Net-Zero Simulation with Equal Abatement Cost for Dirty Energy and Non-energy sectors

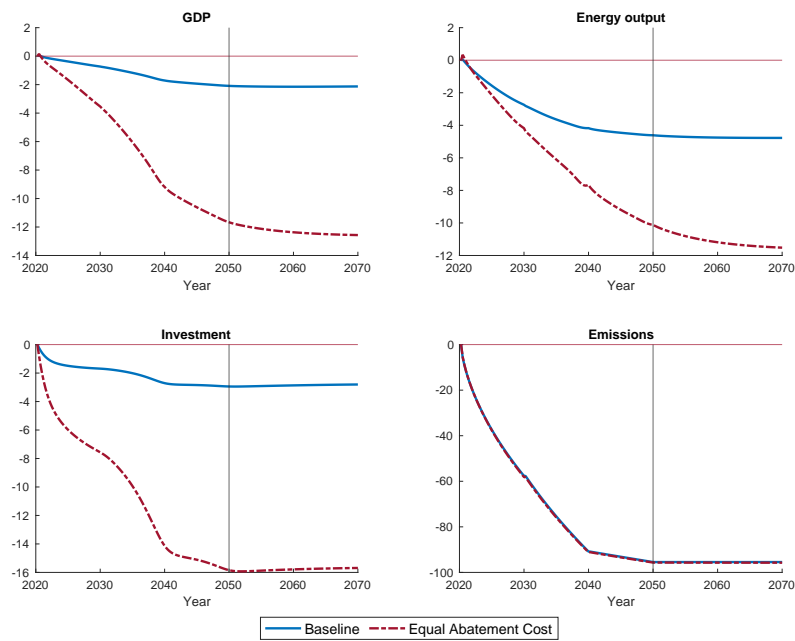
Assuming that reducing emissions entails the same cost in both sectors – that is, $\theta_1 = \theta_{y,1}$ – the transition becomes substantially more costly than in the baseline scenario. A comparison between the baseline case and the model high abatement costs for the non-energy sector is presented in Figures 26–31. As shown in Figure 26, the decline in GDP increases from 2% in the baseline to 12%. Energy production and investment also fall sharply, with investment experiencing the largest drop.

The demand-side response is particularly pronounced: agents anticipate a steep decline in wages and return on capital, which leads to reduced demand for energy and non-energy goods. This results in a sharp decline in the energy component of inflation, leading to a highly deflationary transition. Headline inflation falls as low as -1.6% around the first intermediate target (see Figure 28). Consumption also contracts significantly by 10% for Hand-to-mouth households and 13% for Savers. Firms respond to the rising cost of emissions abatement by cutting wages, which fall permanently to a level 15% below the initial steady state. The return on capital gradually recovers only at the end of the transition period. Given the persistent decline in both wages and production, Savers prefer to allocate income toward

consumption rather than investment.

In terms of distributional effects, the reduction in income inequality is more pronounced than in the baseline. However, the opposing wealth effect, driven by relatively higher firm profits due to lower input costs, leads to a substantial increase in the consumption gap (see Figure 31). Additional plots for this scenario are provided in Appendix F.4.

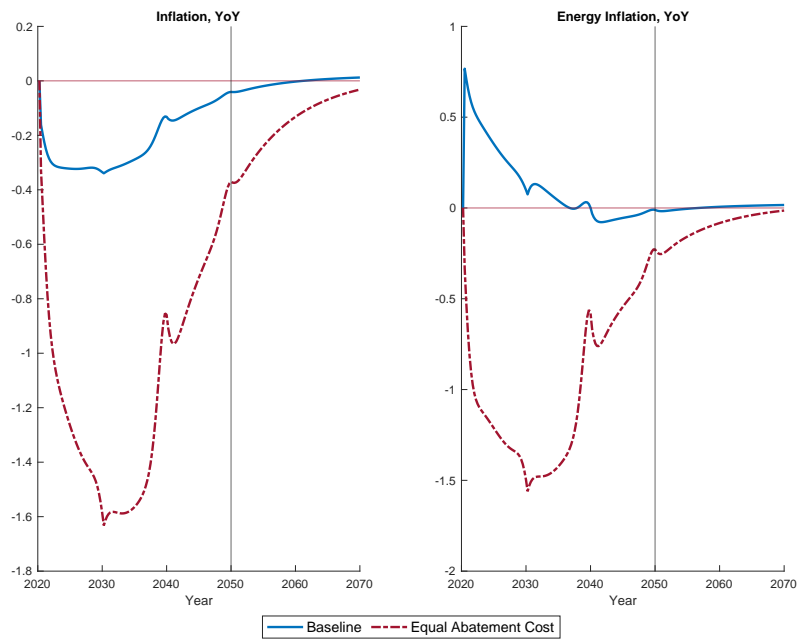
Figure 26: Macro Dynamics, Baseline vs Equal Abatement Cost



Note: variables expressed as percentage deviation from the initial steady state.

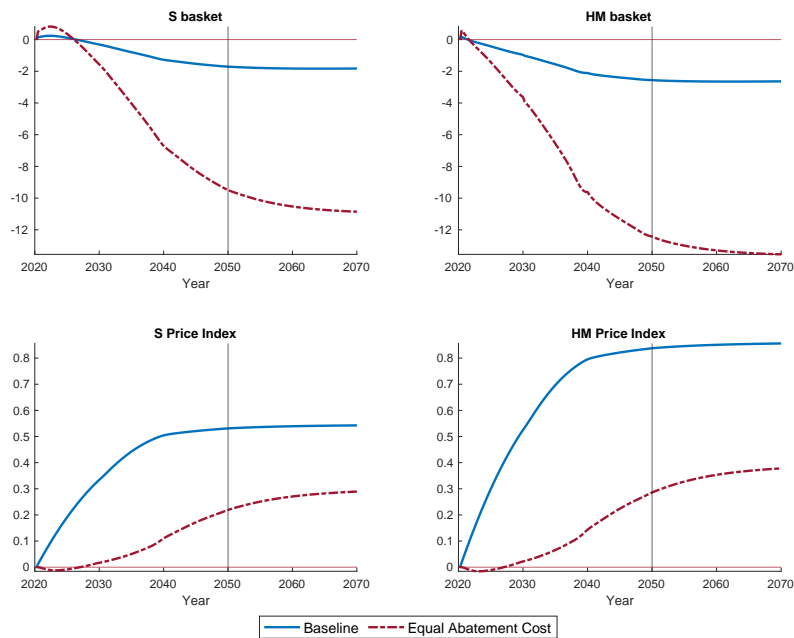
Figure 27: Macro Dynamics, Baseline vs Equal Abatement Cost

Figure 28: Inflation, Baseline vs



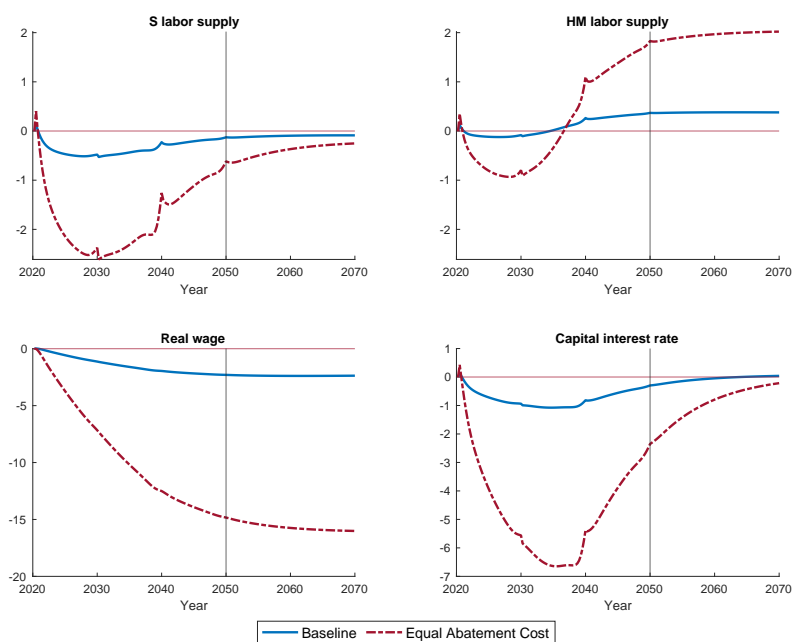
Note: variables expressed in annualized net level deviation.

Figure 29: Households Dynamics, Baseline vs Equal Abatement Cost



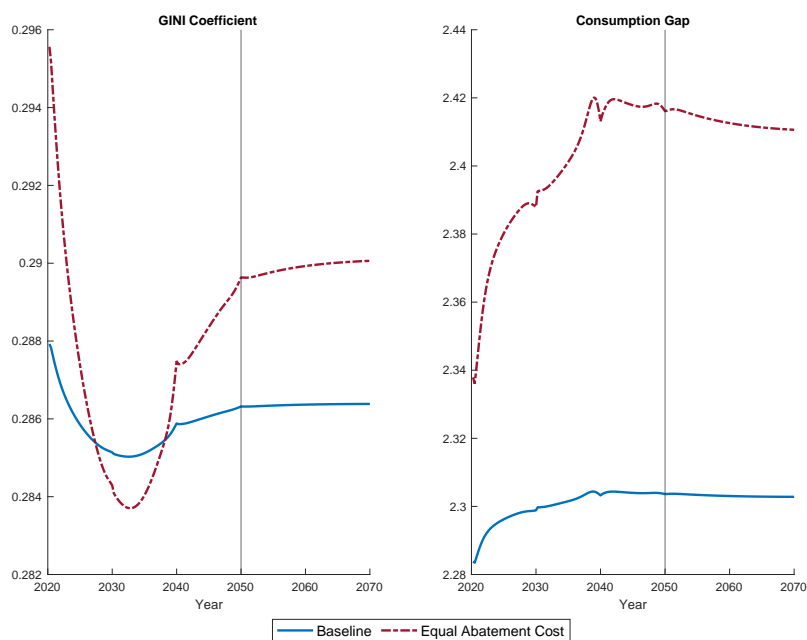
Note: variables expressed as percentage deviation from the initial steady state. Inflation expressed in annualized net level deviation.

Figure 30: Labor and Capital Markets, Baseline vs Equal Abatement Cost



Note: labor variables expressed as percentage deviation from the initial steady state.

Figure 31: Inequality Measures, Baseline vs Equal Abatement Cost



Note: inequality measures expressed in levels.

6 Conclusion

This paper develops a Two-agents Environmental DSGE model, with disaggregated energy and non-energy sectors, to analyze the EU's transition to Net Zero under a gradually rising carbon tax. Five revenue recycling schemes are compared: household transfers (equal or targeted), subsidies to green firms, and cuts to labor and capital income taxes. Three main conclusions emerge.

First, the carbon tax is recessionary in the long run in the absence of technological progress. Output, investment, and real wages decline while resources reallocate toward green energy. Energy prices permanently rise and stabilize around 2040, implying positive energy inflation until then and zero inflation once the Net Zero target is reached. Aggregate inflation, on the other hand, becomes deflationary after the initial adjustment. Income tax reductions mitigate the impact on economic activity and lead to a short-lived expansion in output. However, they also generate the only cases of higher headline inflation in the early phase.

Second, while all schemes are progressive to some extent, the distributional outcomes differ sharply. Targeted transfers to hand-to-mouth households are the most effective at reducing income inequality and the consumption gap, though this comes at the cost of weaker macroeconomic performance. Subsidies for firms and capital tax cuts mitigate output losses, but they are comparatively regressive, as they raise firm profits and capital income accruing to Savers.

Third, transition paths become more volatile when agents are only gradually informed of intermediate targets. Investment, output, and inflation fluctuate more, with temporary surges in inflation around announcements. This highlights the importance of managing expectations in climate policy.

Taken together, the results reveal a fundamental trade-off between efficiency and equity in designing carbon tax revenue recycling policies. Policymakers must decide whether to prioritize macroeconomic stabilization or distributional fairness, or attempt to balance both using combinations of instruments. Although additional simulations with exogenous green productivity growth indicate that technology can mitigate long run output losses (reported in the appendix E), they do not eliminate the trade-off between equity and efficiency. Future work should integrate endogenous technological change, border adjustments, and monetary–fiscal interactions to provide a more comprehensive assessment of the transition to Net Zero. A

balanced approach to environmental sustainability and social justice will be crucial for the success of EU in transitioning to a Net-Zero economy.

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Appendix

A Nominal Frictions: Price and Wage Rigidities

The baseline model features monopolistic competition, sticky prices, and sticky wages. For brevity, I show only the equations for the non-energy sector, as the equations for the energy intermediate producers follow the same logic.

I define the non-energy goods y as an aggregation of intermediate inputs $y(i)$ produced by a continuum of monopolistically competitive firms indexed with i , with constant elasticity of substitution:

$$y_t = \left(\int_0^1 (y_t(i))^{\frac{\xi_t-1}{\xi_t}} di \right)^{\frac{\xi_t}{\xi_t-1}}. \quad (\text{A.1})$$

where ξ_t is the elasticity of substitution parameter and y_t is the Dixit-Stiglitz aggregator (Dixit & Stiglitz, 1977). Nominal price rigidities are modeled by introducing quadratic adjustment costs $AC_t(i)$ à la Rotemberg (1983), which intermediate non-energy firms pay when adjusting their price with respect to the inflation target:

$$AC_t(i) = \frac{\phi_p}{2} \left(\frac{P_{y,t}(i)}{P_{y,t-1}(i)} - \bar{\pi} \right)^2 y_t P_{y,t}. \quad (\text{A.2})$$

where ϕ_p is an adjustment cost parameter.

From the FOC with respect to price $P_{y,t}(i)$, I obtain the non-energy goods Phillips curve¹⁸:

$$\begin{aligned} \pi_{y,t} (\pi_{y,t} - \bar{\pi}) = & \beta \mathbb{E}_t \left[\frac{\lambda_{t+1}}{\lambda_t} \frac{y_{t+1}}{y_t} \pi_{y,t+1} (\pi_{y,t+1} - \bar{\pi}) \right] \\ & + \frac{\xi_t}{\phi_p} \left[mc_{y,t} - \frac{\xi_t - 1}{\xi_t} + \tau_{y,t} (1 - \mu_{y,t}) \gamma_y + \theta_1 \mu_{y,t}^{\theta_2} \right], \end{aligned} \quad (\text{A.3})$$

The inflation level for HM and S price index and the headline inflation π_t are as follows

$$\pi_{HM,t} = \pi_{y,t} \frac{p_{HM,t}}{p_{HM,t-1}} \quad (\text{A.4})$$

$$\pi_{S,t} = \pi_{y,t} \frac{p_{S,t}}{p_{S,t-1}} \quad (\text{A.5})$$

$$\pi_t = \pi_{HM,t}^{\Delta} \pi_{S,t}^{1-\Delta}. \quad (\text{A.6})$$

¹⁸In the green energy Phillips curve, the marginal cost variable is reduced by the variable $\mathcal{T}_{p_G,t}$ to account for the subsidy to green energy production.

Individual labor supply varieties are aggregated using the Dixit-Stiglitz function.

$$\ell_{j,t} = \left(\int_0^1 (\ell_{j,t}(i))^{\frac{\xi_W-1}{\xi_W}} di \right)^{\frac{\xi_W}{\xi_W-1}}, \quad \text{and } j \in \{HM, S\}. \quad (\text{A.7})$$

where ξ_W is the elasticity of substitution between individual labor supply. The latter is defined as a function of individual to aggregate wage share

$$\ell_{j,t}(i) = \left(\frac{W_{j,t}(i)}{W_{j,t}} \right)^{-\xi_W} \ell_{j,t}, \quad (\text{A.8})$$

such that the aggregate intermediate wage reads

$$W_{j,t} = \left(\int_0^1 W_{j,t}(i)^{1-\xi_W} di \right)^{\frac{1}{1-\xi_W}}. \quad (\text{A.9})$$

Again we introduce sectoral nominal wage rigidity in the form of quadratic adjustment costs à la Rotemberg:

$$AC_{j,t}^W(i) = \frac{\phi_W}{2} \left(\frac{W_{j,t}(i)}{W_{j,t-1}(i)} - \bar{\pi} \right)^2 \ell_{j,t} W_{j,t}, \quad (\text{A.10})$$

which is added to the left-hand side of the budget constraint of both households (2 and 4). Here ϕ_W represents the nominal wage adjustment cost parameter. Households' utility maximization problem yields the following new FOC with respect to $w_t^j(i)$:

$$mrs_{j,t} = \frac{\psi_j \ell_{j,t}^{\varphi_1}}{\lambda_{j,t}(1 - \tau_L)} \quad (\text{A.11})$$

$$\begin{aligned} \pi_{j,t}^W (\pi_{j,t}^W - \bar{\pi}) &= \beta \frac{\lambda_{j,t+1}}{\lambda_{j,t}} \frac{\ell_{j,t+1}}{\ell_{j,t}} \frac{w_{j,t+1}}{w_{j,t}} \pi_{j,t+1}^W (\pi_{j,t+1}^W - \bar{\pi}) \\ &+ \frac{\xi_W}{\phi_W} (1 - \tau_L) \left(\frac{mrs_{j,t}}{w_{j,t}} - \frac{\xi_W - 1}{\xi_W} \right), \end{aligned} \quad (\text{A.12})$$

where:

$$\begin{aligned} \pi_{j,t}^W &= \frac{W_{j,t}}{W_{j,t-1}} \\ &= \frac{W_{j,t}}{p_t} \frac{p_t}{p_{t-1}} \frac{p_{t-1}}{W_{j,t-1}} \\ &= \frac{w_{j,t}}{w_{j,t-1}} \pi_{y,t}. \end{aligned} \quad (\text{A.13})$$

and $mrs_{j,t}$ is the inverse of the marginal rate of substitution between consumption and leisure; $\pi_{j,t}^W$ is the household j wage inflation.

B Macroeconomic and Distributional Effects of a Carbon Policy Shock

This section provides supporting empirical evidence on the macroeconomic and distributional consequences of carbon policy. The analysis is inspired by the methodology of Känzig (2023), who identifies exogenous carbon policy shocks by exploiting high-frequency changes in the price of EU ETS futures around the announcement of specific regulatory events. The advantage of this identification strategy is that, by using a sufficiently tight window, one can be confident that the variation in ETS futures prices captures the exogenous component of the policy and is not contaminated by endogeneity.¹⁹ These surprises are then mapped into structural shocks using an external instrument approach.

In this work, I do not replicate the identification procedure but instead rely directly on the baseline structural carbon policy shock series made publicly available by the author.²⁰ The daily surprise series has already been aggregated by the author to monthly frequency. For consistency with my macroeconomic data, I further convert it to quarterly frequency and include it as the first variable in a standard VAR estimated on Euro Area and Italian macroeconomic data. While this approach allows for a tractable analysis, it does not replicate the full two-stage proxy-VAR methodology of the original study. The results should therefore be interpreted as conditional responses to an already-identified carbon policy shock.

B.1 Data Sources

All macroeconomic and financial series – including real GDP, energy and headline inflation, industrial production, unemployment, bond yields, stock-market index, and crude oil prices – are obtained from Datastream at quarterly frequency. With the exception of the unemployment rate, all series are transformed into natural logarithms to stabilize variance and ensure that impulse responses can be interpreted as percentage deviations.

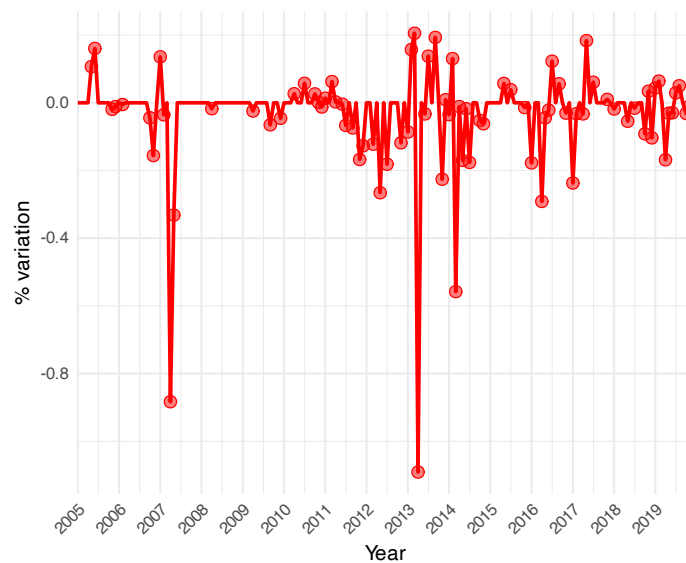
The carbon policy shock series is constructed from daily changes in EUA futures prices (sourced from Datastream); these prices react to regulatory announcements issued by the European Commission and reflect market expectations about future carbon policy (see (Känzig, 2023)). I aggregate the monthly series provided by the author to quarterly frequency to match the macroeconomic data (Figure 32).

¹⁹The author provides several robustness checks to support this claim, including evidence of no correlation with other relevant macroeconomic shocks.

²⁰Replication data available at <https://www.diegokaenzig.com/research>.

Quarterly data on greenhouse gas emissions are retrieved from Eurostat. Since household consumption data by income quintile are not available at the EU level, I use annual Italian data from ISTAT as a proxy. Both series are available only at annual frequency, so I apply the Chow–Lin time-disaggregation method to convert them to quarterly frequency, following the procedure used by the UK Office for National Statistics for estimating quarterly GHG emissions. Consumption data are provided by income quintile; I group the bottom two quintiles into a “Hand-to-mouth” category and the top three into a “Savers” category, mirroring the structure assumed in the E-DSGE model.

Figure 32: Carbon Policy Surprise, Quarterly (2005Q1–2019Q4)



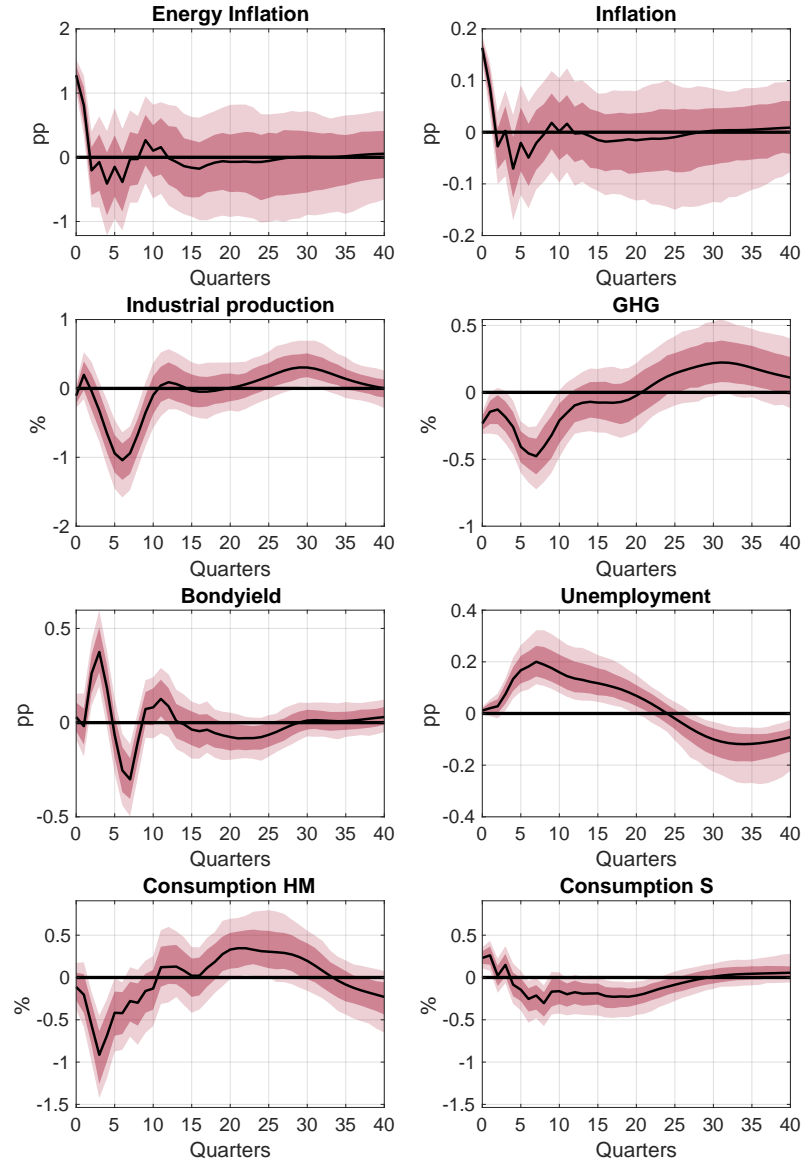
Sources: Datastream and European Commission Climate Action news.

B.2 The Effect of a Carbon Policy Shock

Figure 33 shows the impulse responses of key macroeconomic variables to a one standard deviation carbon policy shock. As expected, the shock has an immediate and pronounced impact on the energy component of inflation, which rises by approximately 1 percentage point on impact. Headline inflation also increases, though to a smaller extent, reflecting the relatively modest weight of energy in the overall consumer price index. In the quarters following the inflation spike, industrial production contracts with a lag, and greenhouse gas emissions decline in parallel. Both variables partially rebound after about ten to fifteen quarters. At the same time, unemployment rises, while bond yields increase as the central bank tightens monetary policy in response to higher inflation.

Turning to consumption, a clear heterogeneity emerges. Hand-to-mouth consumption falls by almost 1% within the first year and tracks industrial production closely thereafter. In contrast, the consumption of Savers initially rises modestly, then turns negative after five quarters, never declining by more than 0.5%. It gradually recovers to around zero after thirty quarters. Taken together, these findings reveal that the carbon-price shock not only generates the predictable macroeconomic response – higher energy and headline inflation, lower industrial output, reduced emissions, rising unemployment, and a tightening of monetary policy – but also a clear distributional effect: lower-income, hand-to-mouth households experience a substantially larger decline in consumption than higher-income Savers.

Figure 33: The Effect of a Carbon Policy Shock



Impulse responses to a one standard deviation carbon policy shock, estimated using a standard VAR. Red shaded areas represent 68 (dark) and 90 (light) percent confidence bands. All variables are expressed in percentage deviations from trend; the policy rate, unemployment, and inflation are in percentage point deviations.

C Carbon Shock and Business Cycle

In the short run business cycle analysis, the economy is hit by an exogenous carbon tax shock.

The tax evolves following an AR(1) process:

$$\ln \tau_{s,t} = \rho_{\tau} \ln \tau_{s,t-1} + (1 - \rho_{\tau}) \ln \bar{\tau}_s + e_{\tau,t}, \quad \text{where } s = [y, D] \quad (\text{C.1})$$

$\bar{\tau}_s$ is the steady state level of emission tax in sector s and e_τ is the exogenous carbon tax shock.

In this section, I analyze the business cycle effect of a temporary 25% increase in the carbon tax for both non-energy and dirty energy sectors. I consider five scenarios that differ in the way carbon tax revenues are recycled and compare the resulting model dynamics. These scenarios, described in the main text, can be grouped into three categories: (i) household transfers, (ii) green subsidies, and (iii) income tax reductions. The first category includes the *HH Equal Transfer* and *HM Transfer* schemes. In the former, revenues are redistributed across all households in proportion to their relative weight, while in the latter they are allocated entirely to hand-to-mouth households. In the *PG Subsidy* scenario, revenues are used to subsidize green energy firms as outlined in the previous sections. Finally, in the τ_L and τ_K scenarios, carbon tax revenues are employed to reducing labor and capital income taxes, respectively. Figures 34-36 show the effects of the carbon shock on the economy.

The positive carbon tax shock directly affects production costs in both sectors (y and E) and indirectly impacts non-energy firms. The direct effect arises from the higher cost of polluting emissions: all firms face the same carbon tax, but their abatement costs differ. The indirect effect stems from higher prices of energy goods, both for household consumption and as inputs in non-energy production. In most scenarios, the policy is inflationary and recessionary. This is reflected in a rise in energy inflation and in both households' consumer price indices, alongside a significant and persistent contraction in net GDP (defined as total output net of abatement, government spending, and price/wage adjustment costs), as shown in Figure 34. The largest contraction occurs under the *HM Transfer* scheme (-0.055%), affecting both the energy and non-energy sectors. The investment component of GDP exhibits the sharpest decline, particularly when tax revenues are redistributed to households. The only exceptions are the scenarios with income tax reductions. In these cases, the policy is deflationary and expansionary, with investment benefiting most when the capital income tax is reduced. Cutting distortionary taxes releases resources for Savers, enabling higher investment. At the same time, firms reduce gross wages and the rental rate of capital (see Figure 35), since households receive higher net (after-tax) income and are therefore willing to supply labor and capital at lower gross returns. This frees additional resources for firms, partially offsetting the carbon cost shock.

As a result of production cuts, emissions fall by about 11% across all scenarios. Higher

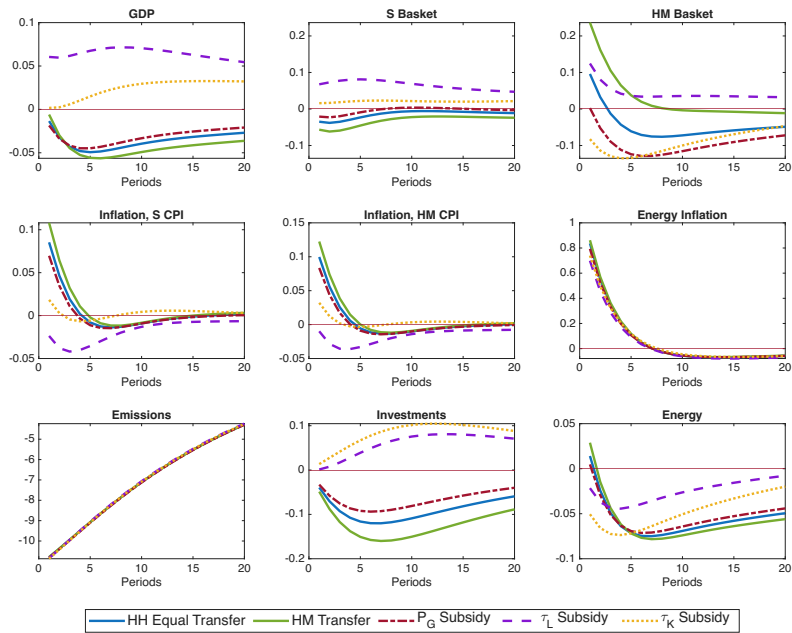
prices lead households to reduce consumption of both energy and non-energy goods, with some notable exceptions. HM households benefit most from direct transfers – especially targeted ones – and from labor income tax cuts. By contrast, Savers achieve the highest consumption levels when firms are subsidized or when either labor or capital income taxes are reduced. The labor income tax cut is the only policy under which both household groups are better off after the shock. Across all redistribution schemes, however, the consumer price index faced by HM households remains slightly higher than that of Savers.

Figure 35 clearly illustrates the redistribution of resources from the dirty to the green energy sector. Green capital and labor increase by about 1%, especially when green energy production is subsidized. Non-energy firms also experience a rise in capital when labor and capital income taxes are reduced, while at the same time employing less labor despite lower gross wages. This reflects the overall reduction in household labor supply under these two redistributive schemes (see Figure 36). The availability of higher net wages and capital returns induces both household groups to work less, as they seek to maximize utility.

Even when revenues are redistributed to households – particularly in the HM transfer scenario – HM families reduce their labor supply. By receiving the subsidy, HM agents can sustain consumption while supplying fewer hours (a strong income effect). Lacking access to savings, they therefore prefer to work less. Savers, by contrast, temporarily increase labor supply under household transfers or firm subsidies. This is linked to their wealth component: as sole owners of firms, they benefit when green firms receive subsidies, since production costs fall and profits rise. This additional income allows Savers to consume more even with reduced labor effort.

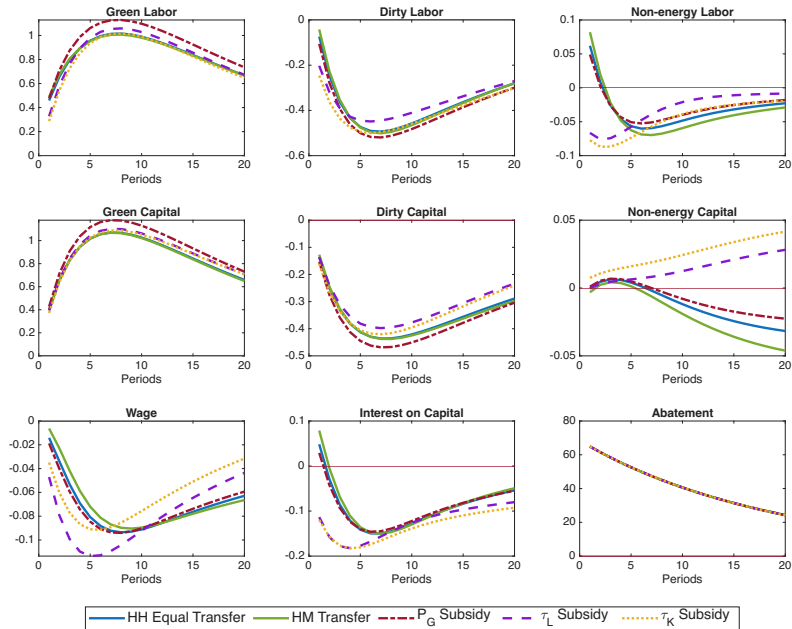
Targeted transfers to HM households achieve the largest and most persistent reduction in the Gini coefficient, which remains below its steady-state value even beyond the simulation horizon (see Figure 36). Equal redistribution is also progressive, but reduces inequality to a lesser extent. Subsidies to firms and labor income tax cuts are less effective in lowering inequality, while a reduction in capital income tax is outright regressive. Regarding the consumption gap, targeted transfers to HM households are again the most progressive in the short run. Yet this effect reverses after about a year, as the gap widens across all five scenarios. Subsidies to green firms and capital tax cuts are the most regressive: in these cases, the consumption gap increases as Savers benefit from higher profits of green energy firms (wealth effect) and higher net capital income (income effect).

Figure 34: Macro Dynamics, Carbon Shock



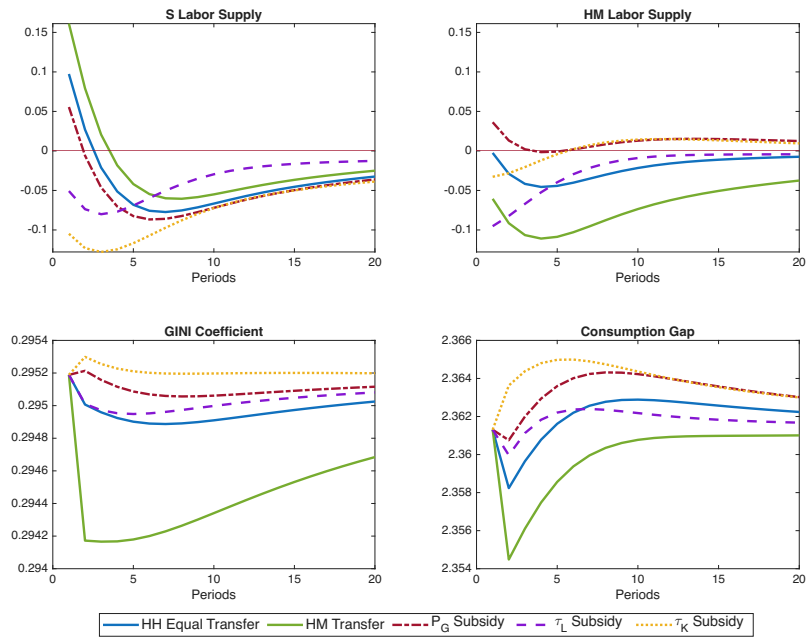
Note: IRF to a 25% increase in carbon tax. Variables expressed as percentage deviation from the initial steady state.

Figure 35: Labor and Capital Markets, Carbon Shock



Note: IRF to a 25% increase in carbon tax. Variables expressed as percentage deviation from the initial steady state.

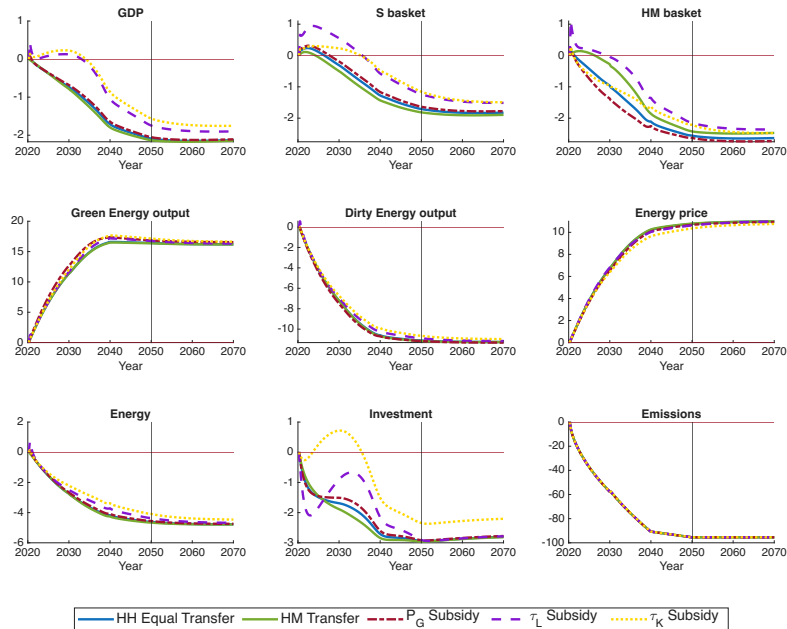
Figure 36: Inequality Measures, Carbon Shock



IRF to a 25% increase in carbon tax. Variables expressed in levels.

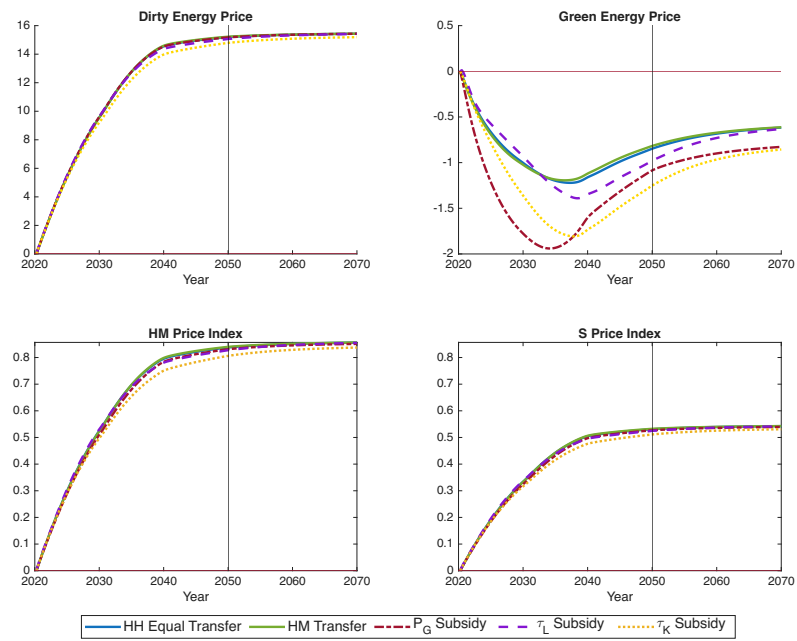
D Additional figures: Net-Zero Simulation

Figure 37: Net Zero Policy: Transition Dynamics



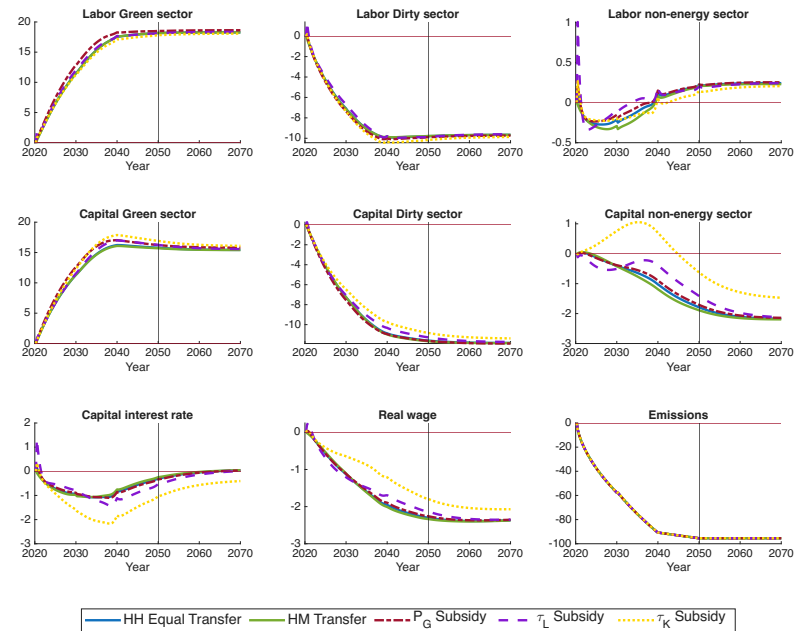
Note: variables expressed as percentage deviation from the initial steady state.

Figure 38: Energy Prices, Transition Dynamics



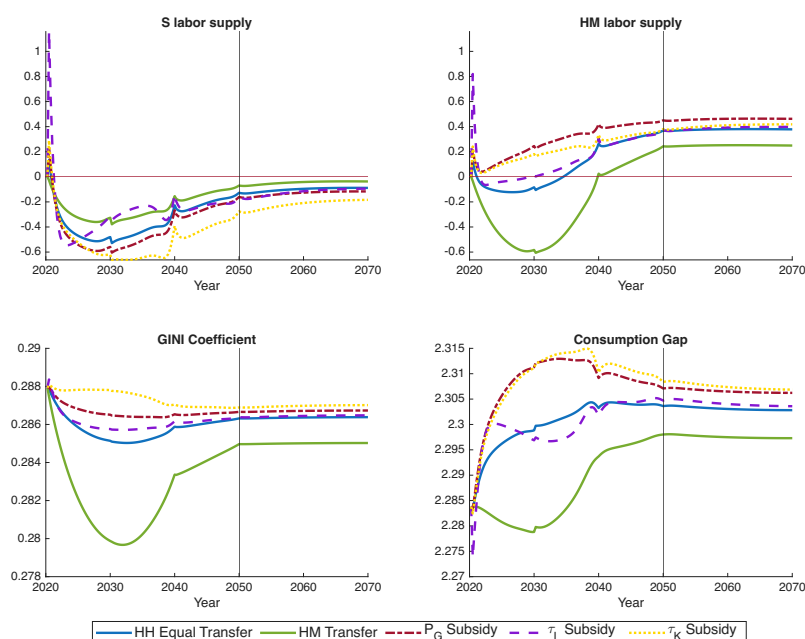
Note: variables expressed as percentage deviation from the initial steady state.

Figure 39: Labor, Capital and Emissions, Transition Dynamics



Note: variables expressed as percentage deviation from the initial steady state.

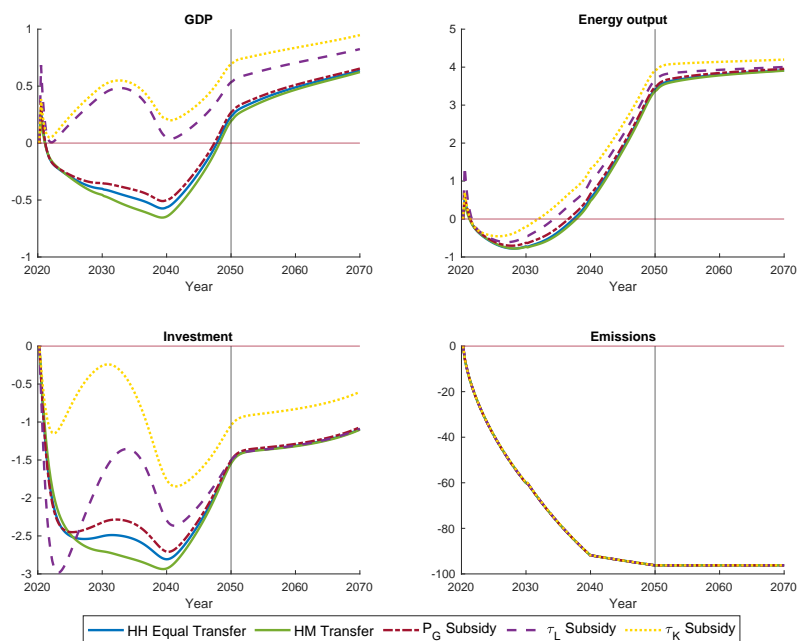
Figure 40: Labor Supply and Inequality Measures, Transition Dynamics



Note: labor variables expressed as percentage deviation from the initial steady state. Inequality measures expressed in levels.

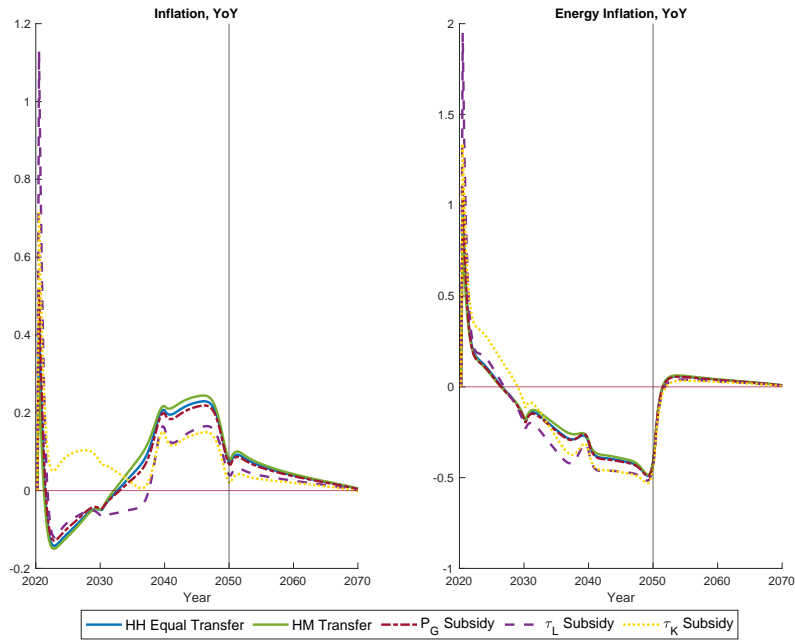
E Exogenous Green Technology Growth

Figure 41: Macro Dynamics with Green TFP Growth



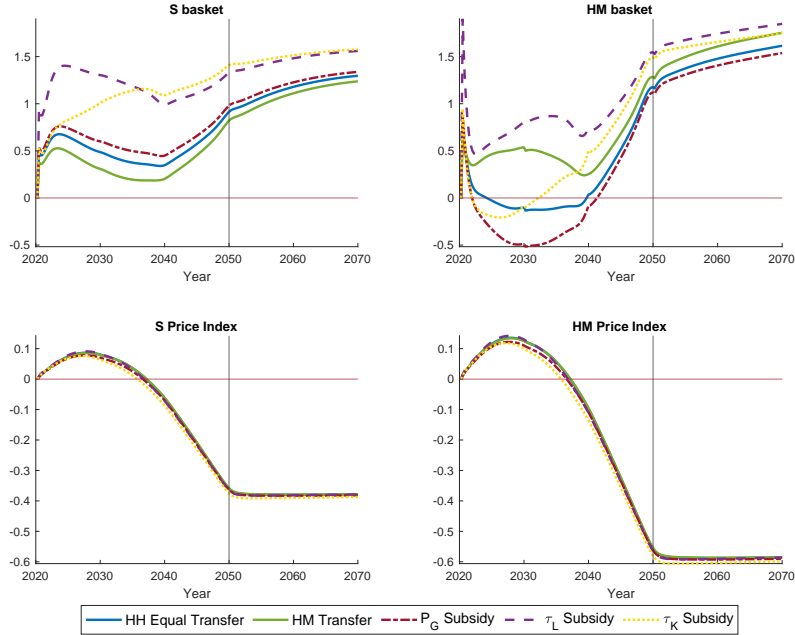
Note: variables expressed as percentage deviation from the initial steady state.

Figure 42: Energy Prices with Green TFP Growth



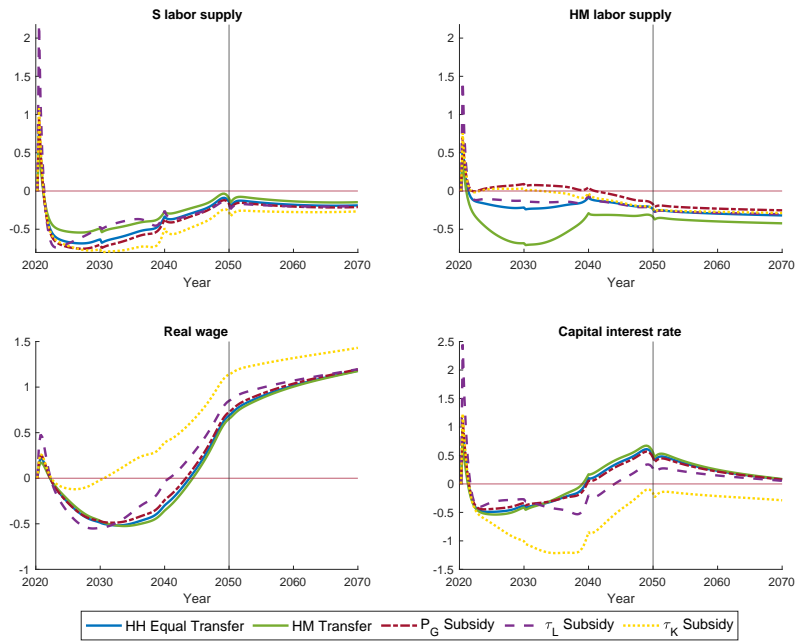
Note: variables expressed as percentage deviation from the initial steady state.

Figure 43: Households Dynamics with Green TFP Growth



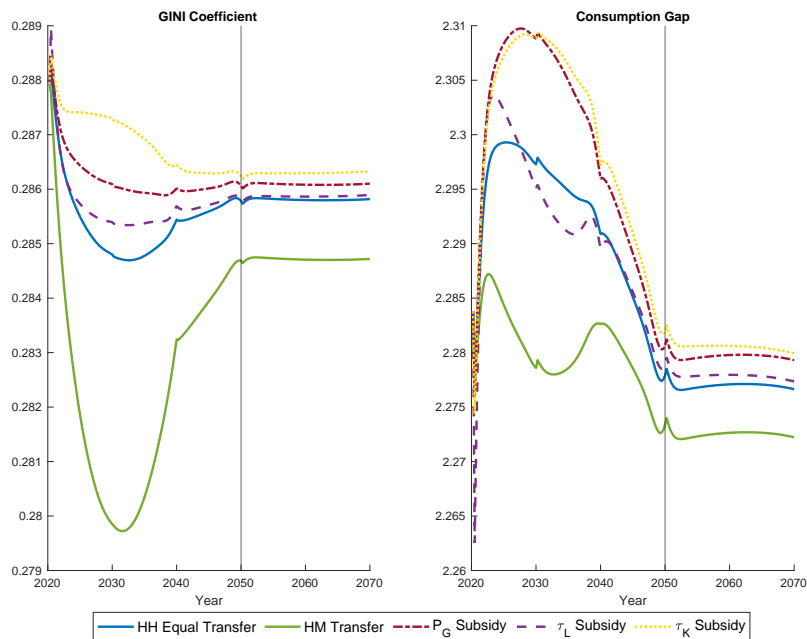
Note: variables expressed as percentage deviation from the initial steady state.

Figure 44: Labor, Capital and Emissions with Green TFP Growth



Note: variables expressed as percentage deviation from the initial steady state.

Figure 45: Labor Supply and Inequality Measures with Green TFP Growth

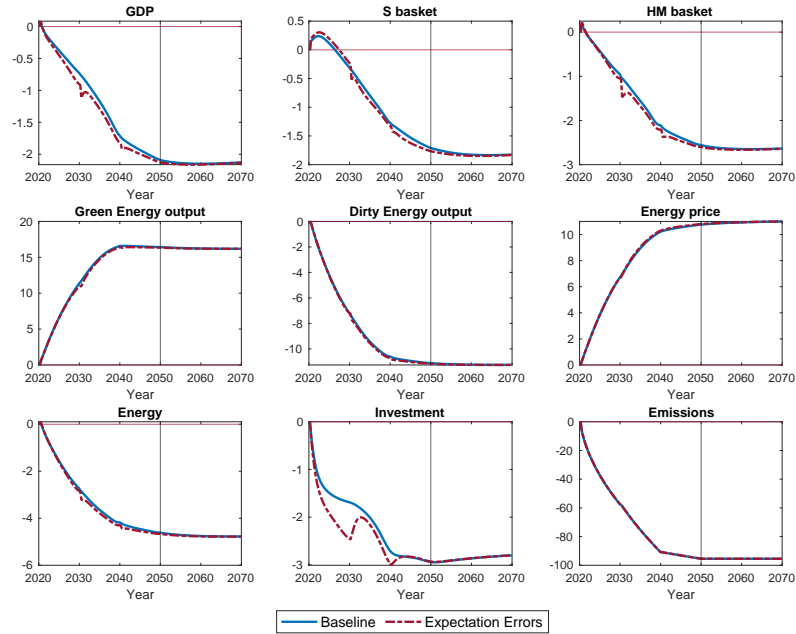


Note: labor variables expressed as percentage deviation from the initial steady state. Inequality measures expressed in levels.

F Additional figures: Model comparisons

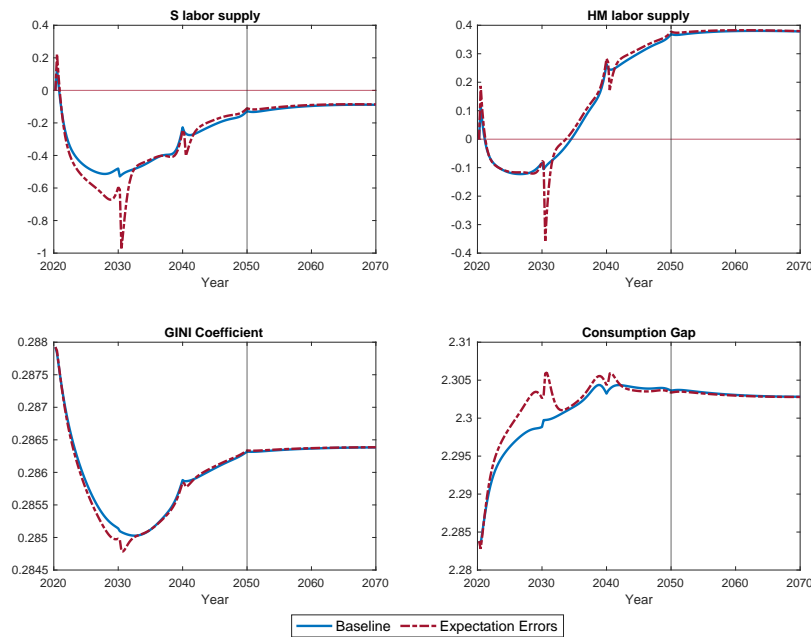
F.1 Expectation Errors

Figure 46: Net Zero Policy: Baseline vs Expectation Errors Model



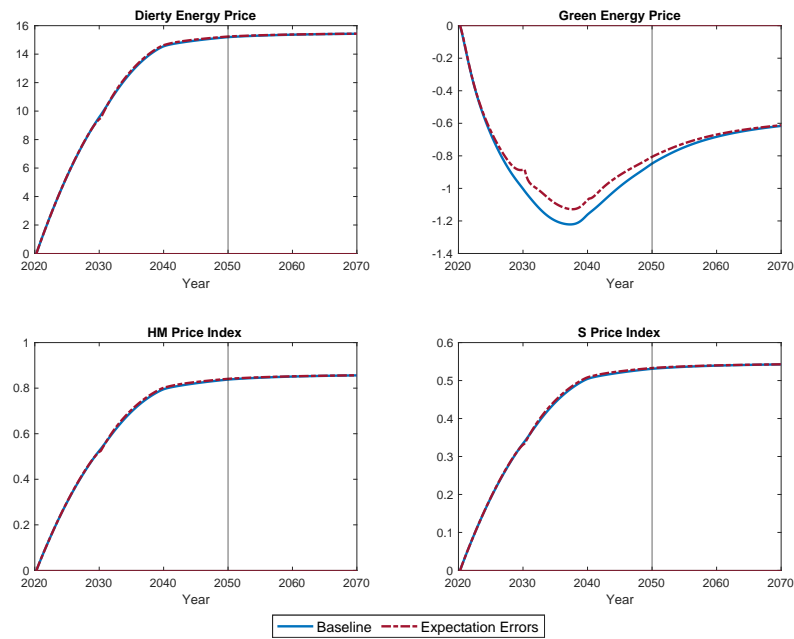
Note: variables expressed as percentage deviation from the initial steady state.

Figure 47: Labor Supply and Inequality Measures: Baseline vs Expectation Errors Model



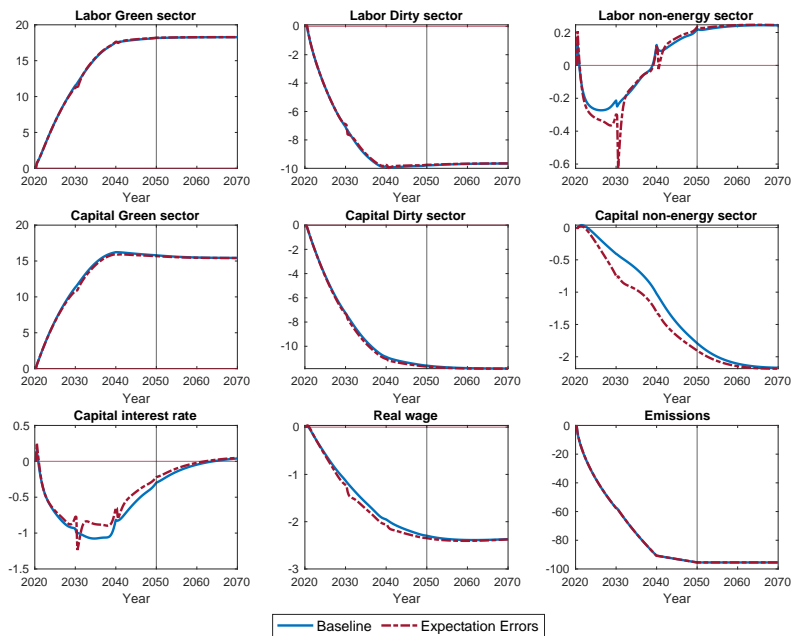
Note: labor variables expressed as percentage deviation from the initial steady state. Inequality measures expressed in levels.

Figure 48: Energy Prices, Transition with Expectation Errors



Note: variables expressed as percentage deviation from the initial steady state.

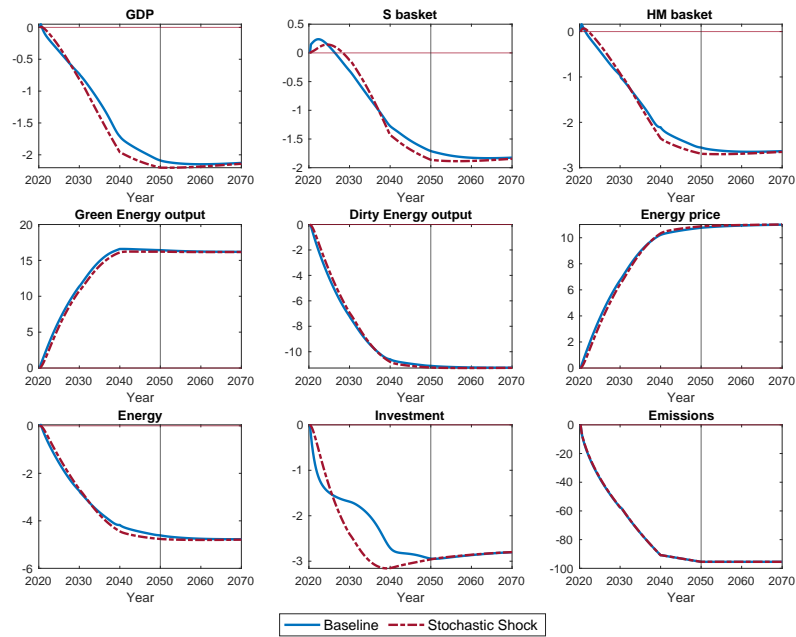
Figure 49: Labor, Capital and Emissions, Transition with Expectation Errors



Note: variables expressed as percentage deviation from the initial steady state.

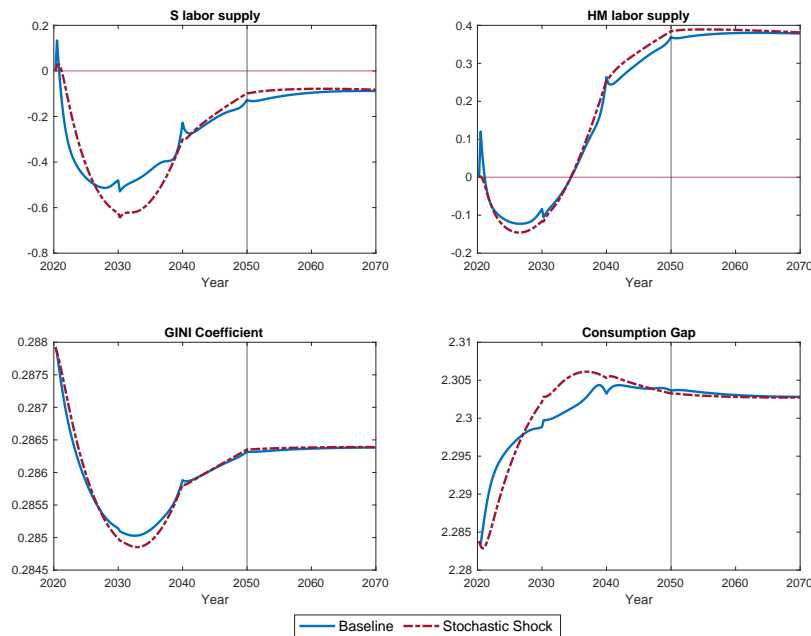
F.2 Stochastic Shock

Figure 50: Net Zero Policy: Baseline vs Expectation Errors Model



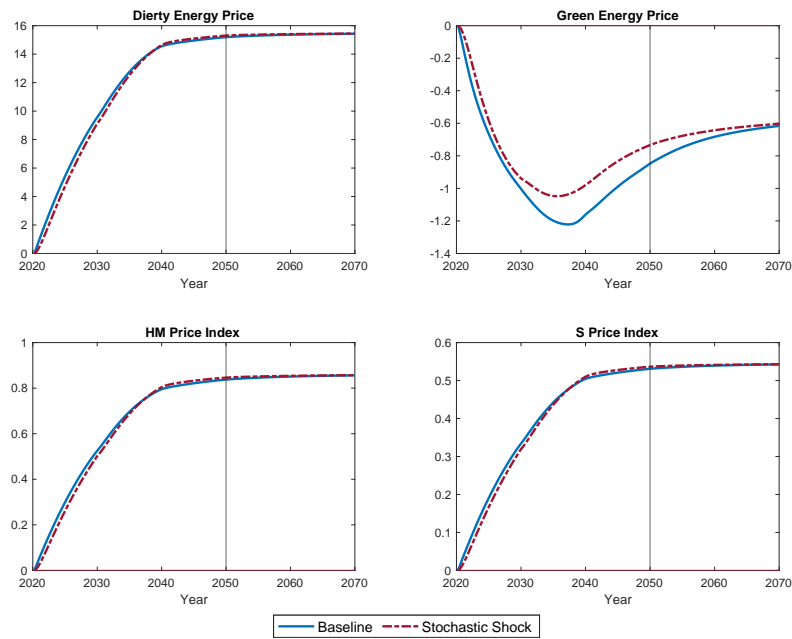
Note: variables expressed as percentage deviation from the initial steady state.

Figure 51: Labor Supply and Inequality Measures: Baseline vs Expectation Errors Model



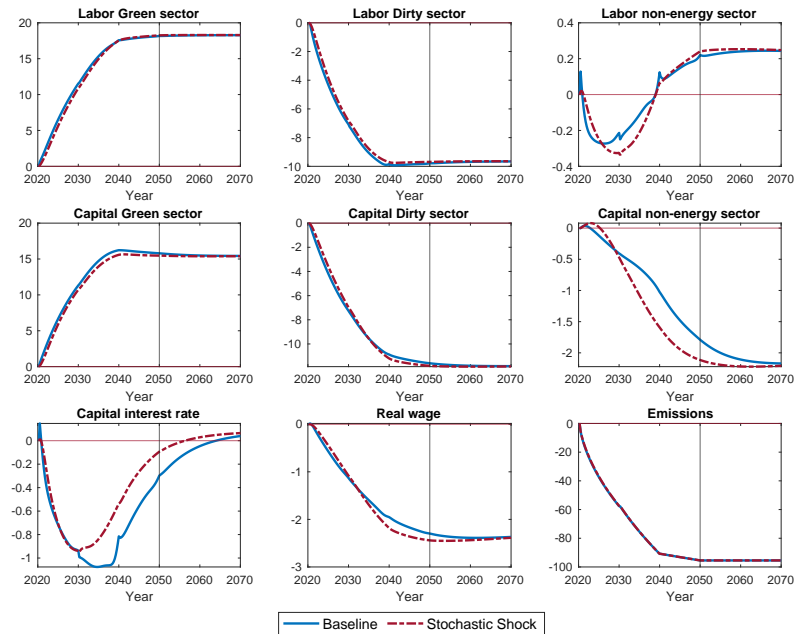
Note: labor variables expressed as percentage deviation from the initial steady state. Inequality measures expressed in levels.

Figure 52: Energy Prices, Transition with Expectation Errors



Note: variables expressed as percentage deviation from the initial steady state.

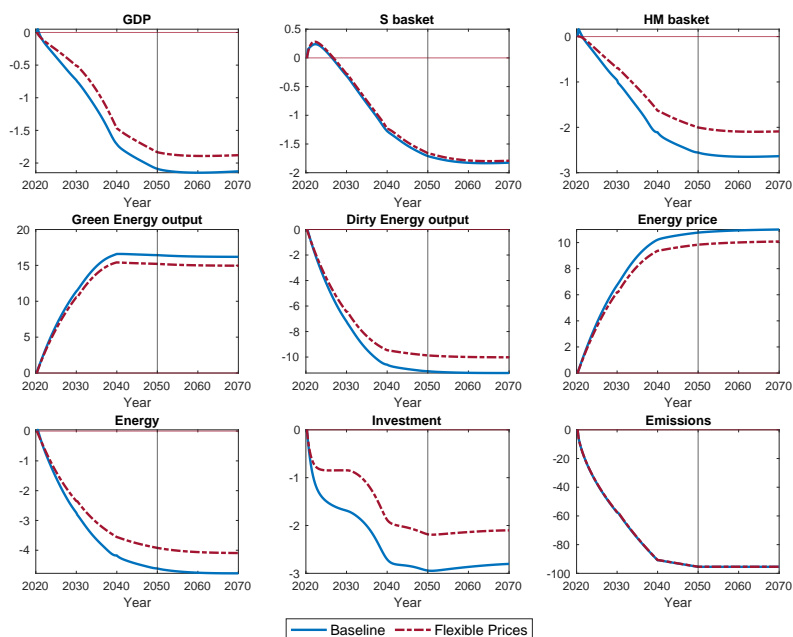
Figure 53: Labor, Capital and Emissions, Transition with Expectation Errors



Note: variables expressed as percentage deviation from the initial steady state.

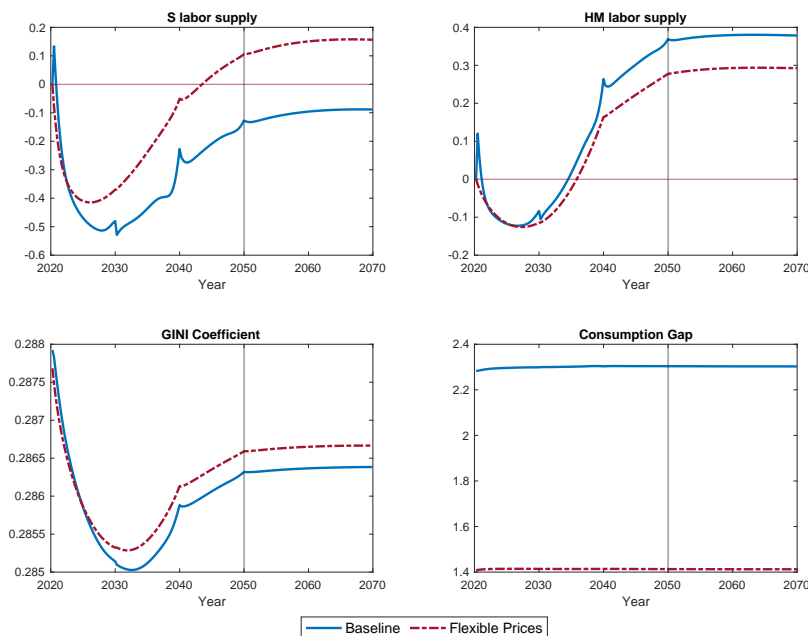
F.3 Flexible Prices

Figure 54: Net Zero Policy: Baseline vs Flexible Prices Model



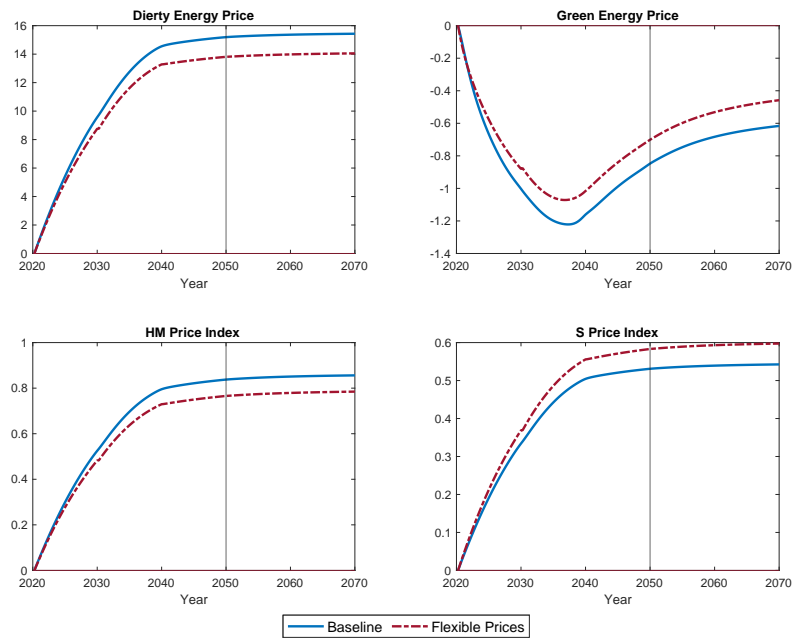
Note: variables expressed as percentage deviation from the initial steady state.

Figure 55: Labor Supply and Inequality Measures: Baseline vs Flexible Prices Model



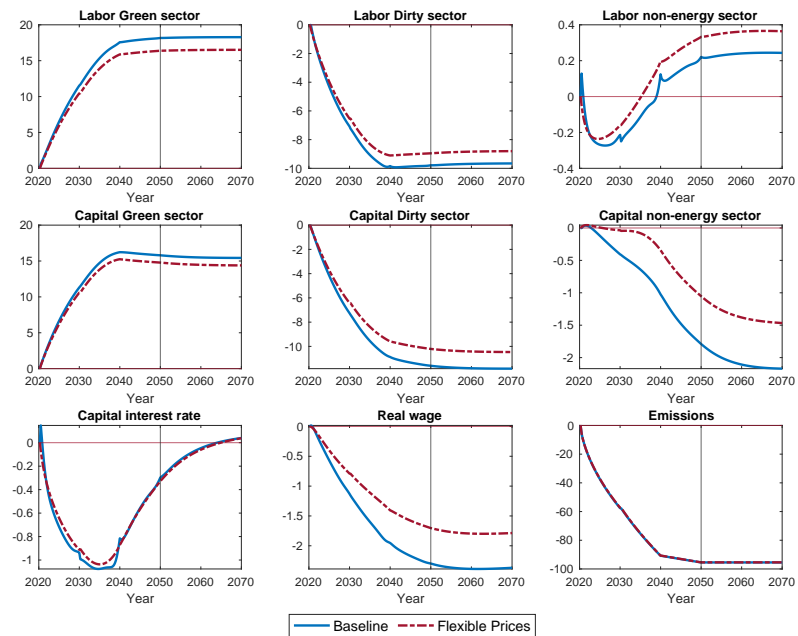
Note: labor variables expressed as percentage deviation from the initial steady state. Inequality measures expressed in levels.

Figure 56: Energy Prices, Transition Dynamics



Note: variables expressed as percentage deviation from the initial steady state.

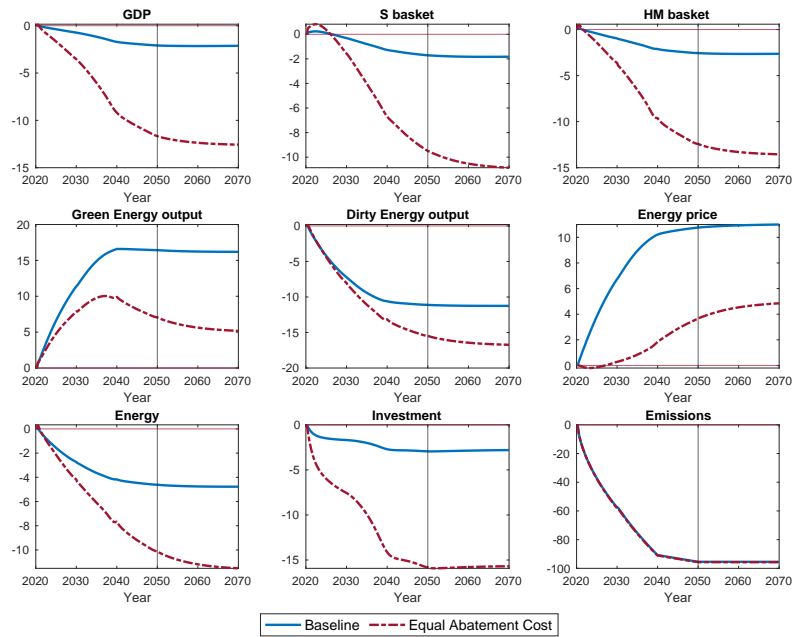
Figure 57: Labor, Capital and Emissions, Transition Dynamics



Note: variables expressed as percentage deviation from the initial steady state.

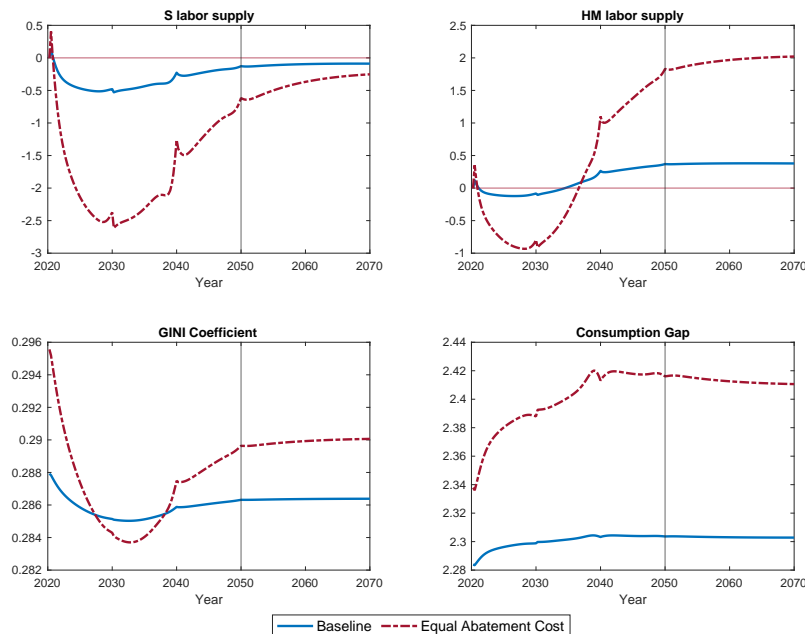
F.4 Same Abatement Cost

Figure 58: Net Zero Policy: Baseline vs Equal Abatement Cost Model



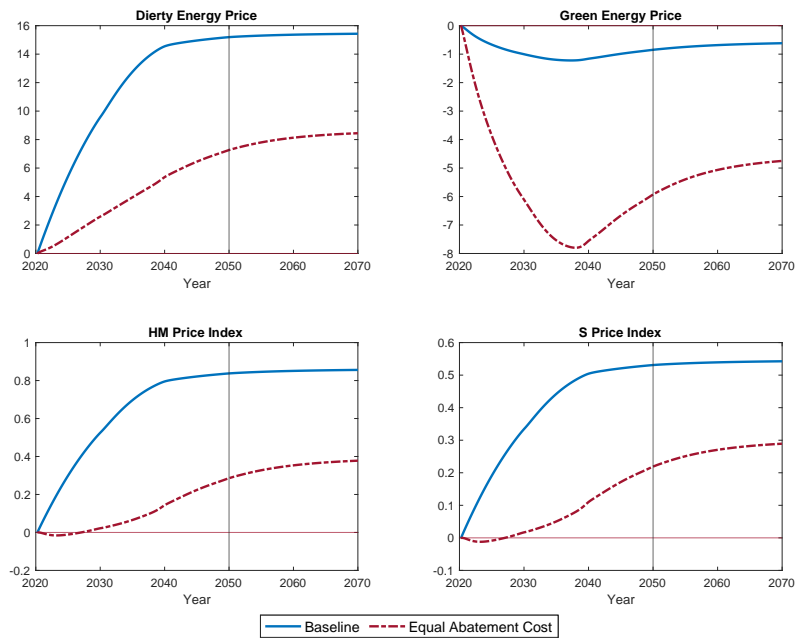
Note: variables expressed as percentage deviation from the initial steady state.

Figure 59: Labor Supply and Inequality Measures: Baseline vs Equal Abatement Cost Model



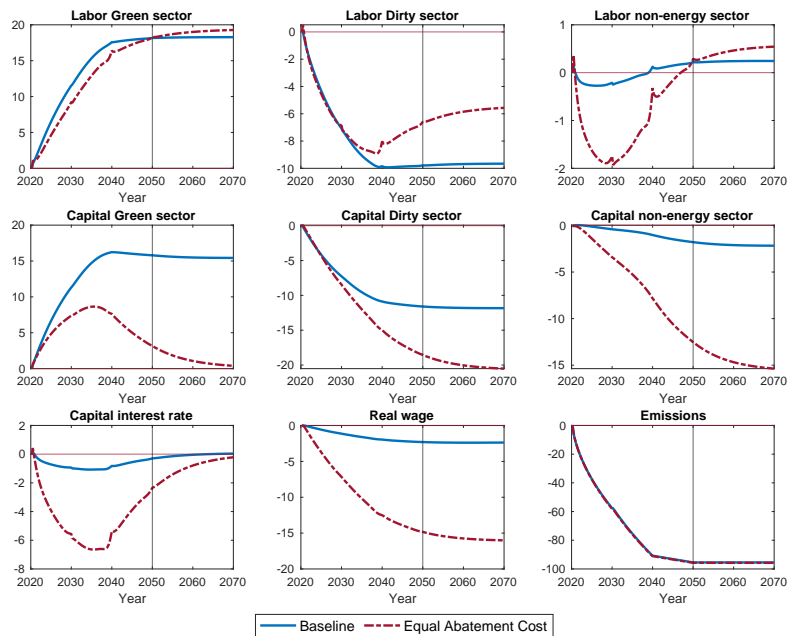
Note: labor variables expressed as percentage deviation from the initial steady state. Inequality measures expressed in levels.

Figure 60: Energy Prices, Transition Dynamics



Note: variables expressed as percentage deviation from the initial steady state.

Figure 61: Labor, Capital and Emissions, Transition Dynamics



Note: variables expressed as percentage deviation from the initial steady state.