The Political Economy of Climate Policies

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Abstract

This paper analyzes the distributional and generational implications of a carbon tax versus a green subsidy. We find that the policies have substantially different consequences across the different groups, giving rise to a fundamental political economy problem. In a heterogeneous agent New Keynesian (HANK) model with brown and green energy production and endogenous green innovation, we show that poorer households prefer the tax over the subsidy in the short run. A carbon tax causes a mild contraction in output and consumption, partially offset by the redistribution of tax revenues to households. Conversely, a green subsidy leads to a significant drop in consumption due to higher tax payments needed to finance the subsidy and crowding-out effects from substantially larger green R&D investment. The top 10% wealthiest households benefit from the subsidy, primarily through higher returns from dividends. However, a generational conflict arises ("tragedy of the horizon"): in the long run, the larger green R&D investment under the subsidy leads to higher productivity in the green sector, higher overall output, consumption, and welfare for all households–regardless of their wealth.

Keywords: Climate policy, Heterogeneous agents, Carbon tax, Green subsidies
JEL: C63, C32, E52, E47

1 Introduction

It is now widely accepted that ambitious policies are necessary to reduce carbon emissions and mitigate the risks of climate change. But how will these policies affect different wealth and income groups? Who will lose, and who might benefit? Likewise, how will climate measures impact economies in the short run and future generations in the long run? Different groups may have varying, and sometimes conflicting, interests. Understanding these interests is crucial for the political process of implementing effective policies. In this paper, we explore the distributional and generational consequences of climate policy instruments and shed light on the political economy of this debate.

To achieve this, we develop a medium-scale model with heterogeneous agents and an energy sector based on the heterogeneous agent New Keynesian (HANK) framework. In our model, households face borrowing

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constraints and uninsurable labor income risk. This setup breaks Ricardian equivalence, making the fiscal tax and transfer system a key determinant of households' consumption and savings decisions. This allows us to examine the distributional consequences of different climate policies. To our best knowledge, this paper is the first to study climate policies in a framework featuring full-scale household heterogeneity.

Additionally, our model incorporates both green ("clean", carbon-free) and brown ("dirty", carbon-intensive) energy as production factors, each produced in distinct energy sectors. In the green energy sector, we introduce endogenous research and development (R&D) in green energy production technology, enabling the model to capture innovation dynamics within this sector. Different policies create varying incentives for investment in new green technologies, which take time to develop and implement. This time lag makes it essential to analyze the medium- and long-term implications of climate policies.

Empirically, innovation in green technologies is a key driver of the green energy transition. Over the past decades, there has been significant technological progress in this field. Patents in green technologies have steadily increased since 2000 (left panel of Figure 1). Among these, enabling technologies – such as batteries, hydrogen, and smart grids – account for the largest share of patents.[1] These innovations have been instrumental in driving down green-energy production costs over time (right panel).

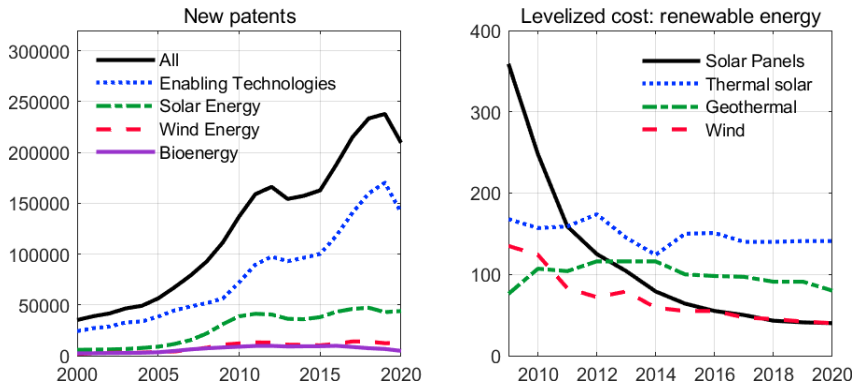

Figure 1: Innovation and production costs. The left panel shows the total number of patents worldwide. The right panel shows costs in USD/MWh. Sources: International Renewable Energy Agency, Lazard

Based on our model framework, we focus on two specific policies: a carbon tax and a green subsidy. The carbon tax is applied to the price of brown energy, increasing the costs for firms that use it as a production input. Similarly, a green subsidy reduces the effective price of green energy inputs for firms. In both cases, the policy distorts the relative prices of brown and green energy. In our model, this price distortion induces a shift in energy production from the brown sector to the green sector, driving a gradual transition to a new steady state with a lower share of brown energy.[2]

However, the two policies generate significantly different aggregate transition dynamics. A carbon tax leads to higher energy prices in the short run, which raises production costs for consumption goods and

[1] LCE technology patents are categorized into energy supply technologies, energy efficiency or fuel-switching technologies in end-use sectors (e.g., transport, buildings, industry), and enabling technologies that enhance infrastructure to support clean energy adoption (IRENA (2020)).

[2] The tax and subsidy levels are calibrated to achieve the same reduction in brown energy, ultimately resulting in a specific reduction in carbon emissions.

causes a contraction in output. The resulting decline in labor demand and wages reduces household income and, consequently, consumption. Despite this, the overall contraction from the carbon tax remains relatively moderate for two reasons. First, the relative increase in brown energy prices makes green energy more attractive. The higher demand for green energy boosts profits in the green sector, stimulating additional R&D investment in green technologies. This, in turn, increases production in the R&D sector, partially offsetting the overall decline in output. Second, the carbon tax generates additional government revenue. Assuming the government maintains a balanced budget, these revenues are redistributed to households, particularly benefiting poorer households, which helps cushion the negative impact on consumption.

In contrast, implementing a green subsidy causes energy prices to fall on impact. This temporarily lowers production costs, leading to a boom in output. Increased demand for green energy, driven by its relatively lower price and higher overall production, significantly boosts profits for green energy producers. Consequently, green R&D investments are scaled up substantially, further enhancing aggregate production. At the same time, however, household consumption declines significantly for two main reasons. First, higher aggregate production increases factor demand, driving up factor prices and inflation. In response, the central bank raises nominal interest rates, which increases real interest rates and reduces consumption incentives for non-borrowing-constrained households. Second, the government raises taxes to finance the green subsidy, disproportionately impacting poorer households.

How do the policies affect households across the wealth distribution? To assess this, we compute consumption equivalents, which allow us to quantify which scenario individual households would prefer. In the short run, all households – except the very wealthy – experience losses under both policies. However, for asset-poor households, these losses are significantly greater under the green subsidy than under the carbon tax. This is primarily due to the larger decline in consumption and higher labor demand under the subsidy, which increases the disutility from work. Conversely, the wealthiest 10% benefit from the green subsidy relative to a no-policy scenario, as they typically hold shares in firms, including green energy producers, which see a more substantial increase in profits under the subsidy. In sum, while a large share of households prefers the carbon tax in the short run, the richest households favor the green subsidy.

These results are particularly important for the practical implementation of climate policies. Dechezleprêtre et al. (2025) find in a large-scale survey that three factors are key for public support of a given climate policy: its perceived ability to reduce carbon emissions (effectiveness), its perceived distributional impact on lower-income households (inequality concerns), and its perceived economic impact on one's own household (self-interest). Our findings show that, while both policies are effective, inequality concerns may conflict with self-interest, particularly for the wealthiest households, making the adoption of either policy a non-trivial political economy problem.

Furthermore, the long-term implications of the two policies differ fundamentally from their short-run effects. As green subsidy prompts a larger surge in R&D investment early in the transition compared to the carbon tax, over time, this innovation significantly enhances productivity in the green energy sector, driving energy prices down and leading to a persistent boom in output. Additionally, higher labor demand and wages increase labor income, ultimately outweighing the higher tax payments required to finance the green subsidy. In the new steady state, consumption, output, labor, and capital levels are substantially higher under the green subsidy, driven by greater efficiency gains in green energy production. As a result, all households benefit in the long run, regardless of their wealth.

Ultimately, the desirability of different carbon policies hinges on balancing the short- and long-term benefits and costs; in other words, it is a generational conflict. While about half of the current generation, prefers the carbon tax over the green subsidy, future generations gain more from the subsidy's long-term outcomes. To evaluate the desirability of these policies over time, we examine alternative welfare measures at each point in time. On impact, welfare is significantly lower under the subsidy than under the tax. However, after

approximately 10 years, welfare under the subsidy surpasses that of the carbon tax and remains permanently higher. These findings add a new dimension to the political economy of climate change policies: When faced with policy choices, governments may prioritize short-term benefits, even if they are less beneficial for society in the long run–a classic example of the "tragedy of the horizon." (Carney, 2015).

We find these results to be highly robust. Specifically, our robustness analysis examines alternative parameter specifications for the energy and R&D sectors. In all cases, the key mechanisms driving the short- and long-run dynamics under the two policies remain consistent. In summary, a carbon tax consistently raises energy prices, prompting only a modest increase in green R&D. In contrast, a green subsidy lowers energy prices, resulting in a substantially larger increase in green R&D. Over the long run, this drives greater gains in green energy production, as well as higher output and consumption.

Although significant progress has been made in empirical and model-based research on the macroeconomic impact of climate change policies, their distributional consequences remain less explored. Känzig (2023) estimates the heterogeneous effects of climate policies across household income groups. Using household-level data, they highlight substantial disparities in how carbon pricing policies affect different households: while high-income households experience only marginal declines in consumption expenditure, low-income households face significant and persistent reductions.

Furthermore, Coenen et al. (2024), using a large-scale macroeconomic model, examine the implications of climate policies in economies with both Ricardian and non-Ricardian households. Their findings show that such policies can exacerbate consumption inequality, disproportionately affecting Ricardian households. A key advantage of our approach, which employs a HANK model rather than assuming a time-invariant form of heterogeneity, is that it allows for a more precise analysis of policy implications and redistribution effects. By incorporating incomplete insurance for all households, our framework captures the fiscal implications of different climate policies as a central driver of aggregate dynamics.

Our paper also contributes to the long-standing literature on endogenous growth in DSGE models, including Comin and Gertler (2006), Bilbiie et al. (2008), Comin and Mulani (2009), Bambi et al. (2014), Bianchi et al. (2019), Anzoategui et al. (2019), and Okada (2022). These studies typically model endogenous technological change as an expansion in the variety of goods, following Romer (1990), combined with a "time-to-build" framework, as in Kydland and Prescott (1982), to capture the delayed effects of technology investment and adoption.[3]

Relatively few papers incorporate endogenous technological change for energy. One exception is Airaudo et al. (2022), who assume that technological change reduces the intensity with which the final energy product is used in the production of consumption goods. In their framework, firms allocate resources to R&D to lower energy intensity in aggregate production, with stronger incentives to do so when energy prices rise relative to the other production inputs labor and capital – such as in response to a carbon tax. Our focus differs in an important way. In our model, firms invest in R&D specifically within the green sector, which determines the level of innovation in green energy relative to brown energy. As a result, the relative price of green and brown energy in our framework is influenced not only by policy interventions, such as a carbon tax or a green subsidy, but also by the current stage of technological development in each sector. This effect plays a crucial role in determining the desirability of different policies, particularly in the long run.

Recent studies on transition policies have primarily focused on their aggregate effects.[4] For instance,

[3]This literature highlights the role of R&D spillovers in linking business cycle fluctuations to long-term growth. For instance, Bianchi et al. (2019) show that equity financing shocks during the 2001 recession led to a more persistent and severe growth slowdown compared to the 2008 financial crisis, as these shocks are more influential in driving R&D investment. In contrast, debt financing shocks, which played a larger role during the 2008 crisis, had a smaller effect on long-term growth through R&D channels.

[4]Another strand of literature includes studies on optimal carbon policies, such as Fischer and Springborn (2011), Angelopoulos et

Bartocci et al. (2024) find that a gradual carbon tax has recessionary and disinflationary effects in a large-scale DSGE model of the Euro Area. However, these recessionary effects are mitigated when green energy subsidies are combined with labor tax reductions. Similarly, Ferrari and Landi Nispi (2024) emphasize the role of expectations in shaping the economic impact of carbon taxes. Under rational expectations, carbon taxes are deflationary as agents anticipate future income losses, whereas under bounded rationality, they initially lead to inflation. Empirical studies on the macroeconomic implications of climate policies, including Moessner (2022), Metcalf and Stock (2023), Konradt and Weder di Mauro (2023), and Känzig (2023), show mixed findings. Some suggest that carbon taxes are mildly inflationary and reduce industrial production, while others argue that their effects on prices and inflation are negligible–except when monetary policy is constrained.

Finally, our paper highlights the political economy aspects of the climate change debate. Van der Straten et al. (2024) examine voter support for public adaptation measures against climate risk in an overlapping generations model. They find that the equilibrium suffers from a "tragedy of the horizon": each cohort internalizes only part of the long-term benefits of public adaptation for future generations, resulting in public investment levels that fall below the social optimum. Additionally, Fried (2021) shows that moral hazard can weaken climate risk prevention efforts in a model where climate catastrophes occur as idiosyncratic shocks. Our findings generally align with these results, emphasizing that conflicts over adaptation efforts extend to the implementation of specific climate policy measures, making their application more challenging in practice. More generally, this paper also relates to a growing empirical literature exploring the drivers of support for climate policies. This literature highlights that distributional impacts matter significantly for individuals' support (Dechezleprêtre et al., 2025; Bergquist et al., 2020; D'Acunto et al., 2022). Moreover, our macroeconomic approach provides deeper insights into the redistribution effects of these policies and the long-term impact of endogenous innovation dynamics on both the economy and individual households.

The remainder of this paper is structured as follows. Section 2 presents our economic model and Section 3 presents our central findings. Finally, Section 4 concludes.

2 Model

Our model framework is a medium-scale heterogeneous agent New Keynesian (HANK) DSGE model. Building on Boehl (2023), we incorporate household heterogeneity in productivity and asset holdings, with households facing uninsurable income risk. On the real side, we extend the model with the following features: (i) Energy is an additional production factor, alongside labor and capital. It is a mix of fossil (brown) and renewable (green) energy, produced in separate energy sectors. (ii) The green energy sector features endogenous technological progress, which enhances production possibilities and raises the aggregate efficiency of green energy over time.

2.1 The energy sector

The energy product is composed of brown and green energy, governed by the CES production function

$$E_t = \left(BR_t^{\frac{\sigma_E}{\sigma_E - 1}} + GR_t^{\frac{\sigma_E}{\sigma_E - 1}} \right)^{\frac{\sigma_E - 1}{\sigma_E}}, \tag{1}$$

al. (2010), Heutel (2012), Annicchiarico and Di Dio (2015), Hillebrand and Hillebrand (2019), Kotlikoff et al. (2021), and Hillebrand and Hillebrand (2023). These studies primarily evaluate the effectiveness of climate policies in achieving emission reduction targets. For instance, Hillebrand and Hillebrand (2023) employs a dynamic multi-country general equilibrium model to show that the optimal tax fully internalizes externalities across regions.

where E_t represents the energy product, BR_t is brown energy and GR_t is green energy. A brown (green) energy producer combines brown (green) energy inputs from intermediate firms to produce brown (green) energy, which is then sold as the final energy product to goods-producing firms. Prices in the energy sectors are assumed to be perfectly flexible. Let q_t^E denote the price paid by the goods-producing sector for E_t, and q_t^{BR} and q_t^{GR} represent the prices received by brown and green energy producers for their respective energy inputs, all expressed in real terms (i.e., divided by the aggregate price index P_t). From above, it follows that

$$\left(\left(1+\tau_t^{BR}\right)\frac{q_t^{BR}}{q_t^E}\right)^{-\sigma_E} = \frac{BR_t}{E_t}, \tag{2}$$

$$\left(\left(1+\tau_t^{GR}\right)\frac{q_t^{GR}}{q_t^E}\right)^{-\sigma_E} = \frac{GR_t}{E_t}, \tag{3}$$

where τ_t^{BR} and τ_t^{GR} are taxes (if positive) or subsidies (if negative) paid (or received) by the energy producers on top of the brown energy price, q_t^{BR}, and green energy price, q_t^{GR}, respectively.

2.2 The green and brown energy sub-sectors

Green energy is produced by green intermediate firms represented by the measure A_t^m. Each intermediate firm produces a single input used in the production of the final green energy product. The measure A_t^m can vary over time and is determined by the R&D sector, which is described in the next section. The general idea is that each green input corresponds to a specific technology that contributes to green energy production. Consequently, an increase in A_t^m reflects an expansion in the technological possibilities for producing green energy.

The representative final green producer combines green inputs of measure A_t^m

$$GR_t = \left(\int_0^{A_t^m} GR_{jt}^{\frac{\varepsilon-1}{\varepsilon}}\, dj\right)^{\frac{\varepsilon}{\varepsilon-1}} \tag{4}$$

with $\varepsilon > 1$. The demand function for GR_{jt} is given by

$$GR_{jt} = \left(\frac{q_{jt}^{GR}}{q_t^{GR}}\right)^{-\varepsilon} GR_t, \tag{5}$$

where q_{jt}^{GR} is the price of green input j. The aggregate price of green energy is

$$q_t^{GR} = \left(\int_0^{A_t^m} \left(q_{jt}^{GR}\right)^{1-\varepsilon} dj\right)^{\frac{1}{1-\varepsilon}}. \tag{6}$$

Each green input is produced by an intermediate firm j who rents capital at real rate r_t^k to produce its variety according to a Cobb-Douglas technology

$$GR_{jt} = A_t^{GR}\left(K_{jt}^{GR}\right)^{\alpha_{GR}} \tag{7}$$

with $\alpha_{GR} < 1$ and A_t^{GR} the aggregate technology level in the green sector. Firm j's profit in period t is

$$\Pi_{jt}^{GR} = q_{jt}^{GR} GR_{jt} - r_t^k K_{jt}^{GR} \tag{8}$$

Assuming perfect competition, the profit-maximizing price q_{jt}^{GR} (divided by the aggregate price index) is

$$q_{jt}^{GR} = \frac{\varepsilon}{\varepsilon - 1} \frac{r_t^k}{\alpha_{GR} A_t^{GR} \left(K_{jt}^{GR}\right)^{\alpha_{GR}-1}}. \tag{9}$$

Symmetry across green input firms implies that $K_t^{GR} = \int_0^{A_t^m} K_{jt}^{GR} dj = A_t^m K_{jt}^{GR}$. Substituting this into Eq. (4), the aggregate production function becomes

$$GR_t = A_t^{GR} \left(A_t^m\right)^{\frac{\varepsilon}{\varepsilon-1} - \alpha_{GR}} \left(K_t^{GR}\right)^{\alpha_{GR}}, \tag{10}$$

with $\frac{\varepsilon}{\varepsilon-1} - \alpha_{GR} > 0$.[5] This production function highlights that A_t^m acts as a scaling factor for aggregate production: Since each firm operates under a technology with diminishing marginal productivity, an increase in A_t^m–or a greater variety of green inputs–improves aggregate productivity by enabling a more efficient distribution of resources. Consequently, a higher A_t^m enhances overall productivity in the green energy sector.

Finally, the price for green energy is given by

$$q_t^{GR} = \frac{\varepsilon}{\varepsilon - 1} \frac{r_t^{GR}}{\alpha_{GR} A_t^{GR} \left(A_t^m\right)^{\frac{\varepsilon}{\varepsilon-1} - \alpha_{GR}} \left(K_t^{GR}\right)^{\alpha_{GR}-1}}. \tag{11}$$

The brown energy sub-sector is similar to the green one, except that we assume that the number of brown intermediate goods is fixed and normalized to unity. A representative brown energy producer aggregates the continuum of brown intermediates according to

$$BR_t = \left(\int_0^1 BR_{jt}^{\frac{\varepsilon-1}{\varepsilon}} dj\right)^{\frac{\varepsilon}{\varepsilon-1}}, \tag{12}$$

with $\varepsilon > 1$. The production function of each brown intermediate firm j is given by

$$BR_{jt} = A_t^{BR} \left(K_{it}^{BR}\right)^{\alpha_{BR}} \tag{13}$$

with $\alpha_{BR} < 1$. Profit maximization of firm j yields the optimal price

$$q_{jt}^{BR} = \frac{\varepsilon}{\varepsilon - 1} \frac{r_t^k}{\alpha_{BR} A_t^{BR} \left(K_{jt}^{BR}\right)^{\alpha_{BR}-1}}. \tag{14}$$

Given symmetry across firms, $K_t^{BR} = \int_0^1 K_{jt}^{BR} dj$, the aggregate production function and the final brown energy price are

$$BR_t = A_t^{BR} \left(K_t^{BR}\right)^{\alpha_{BR}}. \tag{15}$$

[5] This is given with standard parameterization for the substitution elasticity $\epsilon > 1$ and capital return in the production function $\alpha_{GR} < 1$.

$$q_t^{BR} = \frac{\varepsilon}{\varepsilon - 1} \frac{r_t^k}{\alpha_{BR} A_t^{BR} (K_t^{BR})^{\alpha_{BR}-1}}. \tag{16}$$

2.3 The green R&D sector

The green innovation process follows the frameworks of Comin and Gertler (2006) and Anzoategui et al. (2019). Innovation expands the number of green intermediate firms in the green sector, A_t^m. The process operates as follows: innovators allocate resources to research and development (R&D) to create new technologies for green energy production. With a certain probability, these R&D investments successfully result in a new technology in the following period. Upon success, innovators sell the production rights for the new technology to a firm, which then begins producing green energy. Thus, an increase in the number of firms in the green sector reflects an expansion in the set of technologies available for green energy production.

Innovators conduct R&D by using a final goods composite, S_t, as input to develop new products. They operate under a linear production function, $\xi_t S_t$, with marginal productivity ξ_t. The investment is converted into a new technology with a constant probability ϕ^m in the subsequent period. If successful, the innovation is sold to a firm at price J_{t+1}. The probability ϕ^m also represents the survival rate of the technology, indicating the likelihood that the technology remains active in subsequent periods. The green R&D sector operates under perfect competition. Accordingly, the representative innovator's profits are given by

$$\Pi_t^I = -S_t + \beta \phi^m E_t \left\{ \frac{\pi_{t+1}}{R_t} J_{t+1} \right\} \xi_t S_t, \tag{17}$$

where $\beta E_t \frac{\pi_{t+1}}{R_t}$ represents the households' discount factor. Given perfect competition and free entry, the innovator's zero profit condition is

$$\frac{1}{\xi_t} = \beta \phi^m E_t \left\{ \frac{\pi_{t+1}}{R_t} J_{t+1} \right\}. \tag{18}$$

The price of the new product, J_t, equals the value of successfully introducing the new green intermediate. Thus, it represents the present value of profits earned by the producing green firm j

$$J_t = \Pi_{jt}^{GR} + \beta \phi^m E_t \left\{ \frac{\pi_{t+1}}{R_t} J_{t+1} \right\}, \tag{19}$$

where $\beta \phi^m E_t \left\{ \frac{\pi_{t+1}}{R_t} J_{t+1} \right\}$ represents the discounted future stream of profits, provided that the technology has not become obsolete with probability ϕ^m.

In aggregate, the total stock of innovations, or the total number of producing green firms, is given by

$$A_{t+1}^m = \xi_t S_t + \phi^m A_t^m, \tag{20}$$

where the marginal productivity ξ_t can be interpreted as the conversion probability. It is endogenous and defined as

$$\xi_t = z^m \left(\frac{A_t^m}{S_t} \right)^{\nu^m}. \tag{21}$$

This formulation shows that the conversion probability ξ_t depends on the ratio of A_t^m to S_t. As in Comin and Gertler (2006), this captures the positive spillover effects from the existing stock of technologies, A_t^m. However, these spillovers may be offset by congestion effects–such as overhead costs–associated with the level of R&D investment, S_t.

2.4 Firms and households

The production of consumer goods takes place in two stages. First, a continuum of intermediate goods firms indexed by k produce heterogeneous output goods using capital, labor and energy. Then, a final good firm bundles the heterogeneous products of intermediate firms into a final output good using the following technology

$$Y_t = \left(\int_0^1 Y_{kt}^{\frac{\varepsilon_y}{\varepsilon_y - 1}} dk \right)^{\frac{\varepsilon_y - 1}{\varepsilon_y}} \tag{22}$$

where ε_y pins down the elasticity of substitution between product varieties Y_{kt}.

Intermediate goods firms face a Cobb-Douglas production technology using labor, capital and the final energy product as inputs

$$Y_{kt} = A_t \left(K_{kt}^Y \right)^{\alpha_y} N_{kt}^{1-\alpha_y-\alpha_E} E_{kt}^{\alpha_E} \tag{23}$$

where A_t is productivity in the goods sector. Firms own the capital stock, which evolves as follows:

$$K_{t+1} = I_t + (1 - \delta) K_t. \tag{24}$$

They rent capital to the production sector and the brown and green energy sectors

$$K_t = K_t^Y + K_t^{BR} + K_t^{GR} \tag{25}$$

Intermediate firms are subject to the standard Calvo (1983) price-setting frictions. In each period, each firm k faces a probability $1 - \theta$ of being able to choose its profit maximizing price.

Households, indexed by i, hold liquid bonds b_{it}, face idiosyncratic labor income risk e_{it} and a borrowing constraint on bond holdings. They accumulate net worth for the purpose of consumption smoothing and to insure against the associated idiosyncratic income risk. They have Greenwood et al. (1988, GHH) preferences over the composite good x_{it}, and their Bellman equation is given by

$$V_t(e_{it}, b_{it-1}) = \max_{c_{it}, n_{it}, b_{it}} \left\{ \frac{x_{it}^{1-\sigma_c}}{1 - \sigma_c} + \beta \mathbb{E}_t \left[V_{t+1}(e_{i,t+1}, b_{it}) | e \right] \right\}, \tag{26}$$

$$x_{it} = c_{it} - e_{it} \frac{n_{it}^{1+\sigma_l}}{1 + \sigma_l}, \tag{27}$$

$$c_{it} + b_{it} = \frac{R_{t-1}}{\pi_t} b_{i,t-1} + w_t e_{it} n_{it} + \Pi_t \bar{\Pi}(e_{it}) - \tau_t \bar{\tau}(e_{it}), \tag{28}$$

$$b_{it} \geq \bar{b}, \tag{29}$$

where n_{it} denotes household i's supplied labor, c_{it} their consumption and w_t the wage rate. e_{it} is i's household-specific productivity, which follows an AR(1) process in logs,

$$\log e_{it} = \rho_e \log e_{i,t-1} + \epsilon_{it}^e. \tag{30}$$

τ_t are total taxes and Π_t is the sum of total dividends and bank profits. $\bar{\tau}(e)$ and $\bar{\Pi}(e)$ are time-invariant skill-specific shares with $\int_0^1 \bar{\tau}(e_{it}) di = \int_0^1 \bar{\Pi}(e_{it}) di = 1$. Finally, for simplicity we assume a borrowing limit of $\bar{b} = 0$ where households cannot accumulate any debt.

Due to GHH preferences, labor supply simplifies to

$$n_t^{\sigma_l} = w_t, \tag{31}$$

and markets clear with

$$\int_0^1 c_{it} di = C_t, \tag{32}$$

$$\int_0^1 b_{it} di = B. \tag{33}$$

2.5 Government, monetary policy and market clearing

We assume that government consumption is financed by raising debt and taxes and that the government is running a balanced budget with

$$\tau_t + \tau_t^{BR} BR_t + \tau_t^{GR} GR_t = \left(\frac{R_{t-1}}{\pi_t} - 1 \right) B + g_t. \tag{34}$$

where g_t is government spending. The brown tax and the green subsidy follow AR(1) processes with persistence ρ_τ,

$$\tau_t^{BR} = \rho_\tau \tau_{t-1}^{BR} + (1 - \rho_\tau) \hat{\tau}^{BR}, \tag{35}$$

$$\tau_t^{GR} = \rho_\tau \tau_{t-1}^{GR} + (1 - \rho_\tau) \hat{\tau}^{GR}, \tag{36}$$

where $\hat{\tau}^{BR}$ and $\hat{\tau}^{GR}$ are the target values that will be studied in detail below. Monetary policy follows a Taylor-type interest rate rule

$$\ln R_t = \ln \bar{R} + \phi_\pi (\ln \pi_t - \ln \bar{\pi}) \tag{37}$$

$\bar{R}$ and $\bar{\pi}$ are the steady state nominal interest rate and inflation rate, respectively.

For bond market-clearing, we require that households hold the government bonds. This gives the aggregate accounting identity

$$Y_t = C_t + S_t + I_t + G_t \tag{38}$$

where aggregate output is given by

$$v_t Y_t = A_t \left(K_t^Y \right)^{\alpha_y} N_t^{1-\alpha_y-\alpha_E} E_t^{\alpha_E} \tag{39}$$

where $v_t \equiv \int_0^1 \left(\frac{P_{kt}}{P_t} \right)^{-\varepsilon} dk$ is a measure of price dispersion arising due to Calvo price rigidities.

2.6 Calibration and model solution

Table 1 presents our baseline calibration. On the real side, we use parameter values that are either standard in the literature or based on recent estimates from the literature. For instance, the Calvo probability ζ and the elasticity of substitution ε are commonly adopted values. The parameter α_y is taken from Boehl and Strobel (2024), while α_E reflects an average of values reported in Kotlikoff et al. (2024). The elasticity of substitution between green and brown energy, $\sigma_E = 6$, is a compromise between the various values found in the theoretical and empirical literature. For example, Acemoglu et al. (2012) suggest values ranging from $\sigma_E = 3$ to $\sigma_E = 10$.

Parameter		Value/Target
	Real side	
ζ	Calvo probability	2/3
ε	elasticity of substitution	6
π	inflation target	2% p.a.
ϕ_π	policy rule inflation sensitivity	1.5
δ	capital depreciation rate	0.025
z	level of technology	normalize $y = 1$
α_y	capital share of final goods	0.2
α_E	energy share of final goods	0.1
	Energy subsectors	
σ_E	elast. of substitution for energy inputs	6
ϕ^m	innovation survival probability	0.98
ρ_τ	persistence of energy taxes	0.8
A_{BR}	productivity of brown energy production	1
A_{GR}	productivity of green energy production	match $\frac{BR}{E} = 2/3$
z^m	R&D conversion productivity	normalize $A_t^m = 1$
ν^m	R&D spillovers	0.2
α_{GR}	capital returns to scale *GR* production	0.5
α_{BR}	capital returns to scale *BR* production	0.5
	HANK	
σ_c	intertemporal elasticity of substitution	1.5
σ_l	Frisch elasticity	3
β	discount factor	0.985
$\bar{a}$	borrowing constraint	0
σ_e	standard error of earnings	0.6
ρ_e	autocorrelation of earnings	0.966
b	bond supply	15
n_e	points for Markov chain of e	5
n_d	points for asset grid	200

Table 1: Model parameters.

For the energy subsectors, the parameters ϕ^m and ν^m follow Anzoategui et al. (2019) and Comin and Gertler (2006), respectively. Moreover, the value of ρ_τ is chosen to ensure a smooth but relatively quick transition to the new tax level.

The parameters for the HANK framework are taken from Boehl (2023). These are standard values, including an intertemporal elasticity of substitution of 1.5 (consistent with DSGE literature) and an inverse Frisch elasticity $1/\sigma_l$ of 1/3. Additionally, the income risk parameters, σ_e and ρ_e, are calibrated based on empirical estimates from Auclert et al. (2021) and Boehl (2023), while bond supply is set to match a realistic real rate.

The nonlinear simulations of our medium-scale heterogeneous agent model are conducted using the

EP toolbox, which implements the solution method developed by Boehl (2023).[6] This method finds the sequence of endogenous variables that solves the two-point boundary value problem associated with the transition between steady states. To minimize approximation errors from the slow-moving asset distribution, we use a terminal period of 400, equivalent to a 100-year horizon.

To capture the nonlinear transition dynamics between two steady states, particularly for the computationally challenging green subsidy case, we extend the solution method with a relaxation scheme for Newton's method. This ensures accurate and efficient computation of the transition path.

3 Results: Carbon Tax vs. Green Subsidy

This section presents our main results. The first part discusses the macroeconomic dynamics of a green transition initiated by either a carbon tax or a green subsidy, both aimed at reducing *the share of brown energy in overall energy use* by a specific percentage. The second part provides a detailed welfare analysis, focusing on the distributional and generational implications of these policies.

3.1 Transition dynamics

For our baseline analysis, we target a 50% reduction in relative brown energy use compared to the initial steady state, i.e. the share of brown energy relative to total energy inputs $\frac{BR_t}{BR_t+GR_t}$. Achieving this reduction requires a significant carbon tax rate of $\widehat{\tau}^{BR} = 148\%$, whereas a green subsidy of only $\widehat{\tau}^{GR} = -25.1\%$ is needed to reach the same target. We assume that the government implements either policy starting in period $t = 0$. Following implementation, the economy transitions to a new steady state with a lower share of brown energy. Both the initial and new steady states lie on the balanced growth path, where $\frac{A^m_{t+1}}{A^m_t} = 1$.

Figure 2 illustrates transition dynamics (solid lines) and the new steady states (dashed lines) under each policy. Under the carbon tax (blue), the transition unfolds as follows: the tax increases energy prices immediately, making the production of consumption goods more expensive. Consequently, output and the use of production factors decline, while inflation decreases. This contraction reduces labor income, leading to lower household consumption. However, the recession remains relatively modest for two reasons. First, the tax generates additional government revenue. With a balanced government budget, these revenues are redistributed to households through a lower lump sum tax (τ_t), providing additional income that particularly benefits poorer households who have a relatively higher marginal propensity to consume. Note, however, that long-run lump sum taxes return close to its initial value. Second, the tax incentivizes a shift toward green energy and green R&D. As brown energy –after tax– becomes more expensive, firms substitute toward green energy. The increased demand for green energy raises profits in the green sector, encouraging innovators to expand R&D investment. Higher production in the R&D sector helps mitigate the decline in aggregate output.

The transition dynamics under a green subsidy are distinctly different. The subsidy lowers energy prices immediately, reducing production costs for final goods. As a result, the economy experiences a boom in output, increased labor demand, and rising factor costs, leading to higher inflation. This expansion generates additional labor income for households. However, household consumption contracts more sharply than under the carbon tax for two main reasons. First, the subsidy is financed through higher income taxes to maintain a balanced government budget, offsetting the increase in labor income from working more hours. Second, the subsidy drives a significantly larger shift toward green energy and R&D. As green energy becomes relatively cheaper, consumption goods producers increasingly substitute toward it. However, under

[6] The toolbox is available at https://econpizza.readthedocs.io.

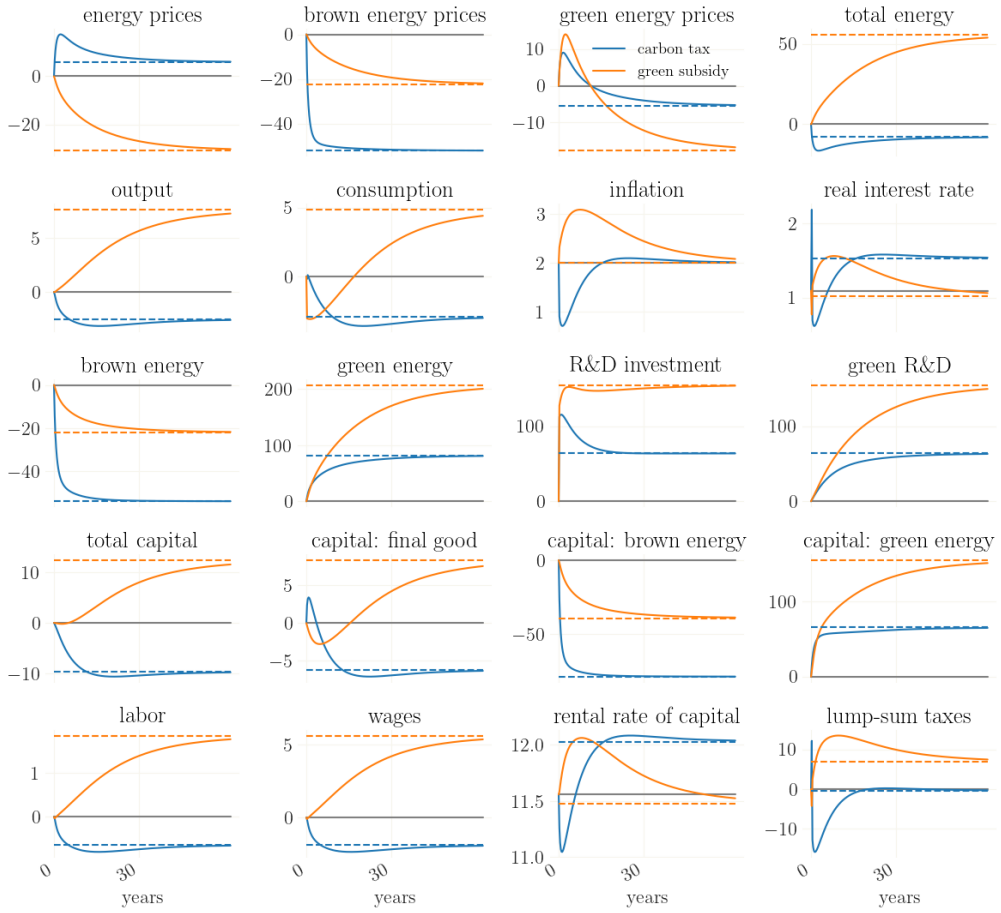

Figure 2: Transition dynamics towards a 50% reduction in relative brown energy use via a carbon tax (blue) or green subsidy (orange). All values are in percentage deviation from the pre-policy steady state. Interest rates and inflation are annualized. The dashed lines indicate the new steady states for each policy.

the subsidy, green energy demand rises substantially more because overall production expands. As a result, the total price for green energy (excluding the subsidy) that green producers receive increases significantly. Higher demand and higher total prices substantially boost profits in the green sector, intensifying green R&D investment. Ultimately, the surge in R&D production crowds out household consumption, amplifying the short-term contraction. In general equilibrium, the inflationary pressures from the boom prompt the central bank to raise nominal interest rates, which increases the real interest rate and discourages consumption for non-borrowing-constrained households.

What are the long-run implications of the two policies? In both cases, innovation dynamics in the green sector play a key role. R&D investments gradually drive technological progress, improving the efficiency of green energy production. Over time, this lowers the cost of producing green energy and, consequently, its price.

However, the extent of early R&D investment differs significantly between the two policies. Under the

carbon tax, the economy temporarily experiences a recession, and incentives for R&D investment remain relatively modest. This leads to relatively lower profits for green energy innovators and, thereby, lower investment in green R&D. As a result, long-term technological progress in green energy production is limited under the tax, leading to only a moderate decline in green energy prices. In contrast, the green subsidy triggers a boom in aggregate production which fosters profits from green energy production and drives a substantial increase in green R&D investment. This leads to significant technological progress, sharply reducing green energy prices in the long run. Consequently, the new steady state under the subsidy features significantly higher levels of output, labor, and capital. Additionally, consumption in the new steady state is notably higher. Over time, the crowding-out effect of R&D production diminishes, and the additional income from higher productivity and increased labor hours outweighs the income loss from higher taxes used to fund the subsidy.

The transition results for both policies are highly robust. In Appendix A, we examine alternative parameter specifications for the energy and R&D sectors. The results remain qualitatively consistent in both the short and long run: across all cases, the carbon tax increases energy prices, leading to a contraction in output and only a modest rise in green R&D investment. In contrast, the green subsidy lowers energy prices, boosts production and factor demand, and results in a significantly higher increase in green R&D investment. In the long run, greater R&D investment translates into larger gains in green energy production, as well as higher output and consumption. Importantly, this key mechanism holds across all realistic parameter values that influence the R&D process, including those that determine how effectively R&D spending is converted into actual innovation or other key model parameters such as the elasticity of substitution between green and brown energy. For example, with a higher ν^m, implying stronger congestion effects from R&D spending (S_t), the relative differences between the tax and the subsidy shrink but never fully disappear.

3.2 Welfare: distributional and generational conflicts

Next, we examine the welfare implications of the energy transition. Figure 3 presents the consumption equivalent variations (CEVs) for both policies. CEVs measure how much consumption a household would be willing to forgo or require to remain indifferent between a given policy and an economy without that policy. This amount is measured relative to consumption in the initial, non-policy steady state. Negative CEVs indicate that a household would willingly forgo (or *pay*) part of its steady-state consumption to avoid the policy, while positive CEVs imply that a household would require additional consumption in the non-policy steady state to maintain the same level of welfare. Simply put, negative CEVs reflect a preference for the non-policy equilibrium, whereas positive CEVs indicate a preference for the given policy.

The CEV $\mathfrak{v}(e_{it}, b_{it})$ of a household with skill e_{it} and wealth b_{it} is obtained by solving

$$E_0 \sum_{t=0}^{\infty} \beta^t u([1 + \mathfrak{v}(e_{it}, b_{it})]c^*_{it}, n^*_{it}) = E_0 \sum_{t=0}^{\infty} \beta^t u(c_{it}, n_{it}), \tag{40}$$

where $\{c^*_{it}, n^*_{it}\}$ is their consumption and labor supply in the non-policy steady state. We compute CEVs for both the "current generation" and the "next generation". CEVs for the current generation measure welfare starting from period $t = 0$, while CEVs for the next generation correspond to welfare computations starting from period $t = 120$, the latter being equivalent to 30 years after the policy's implementation.

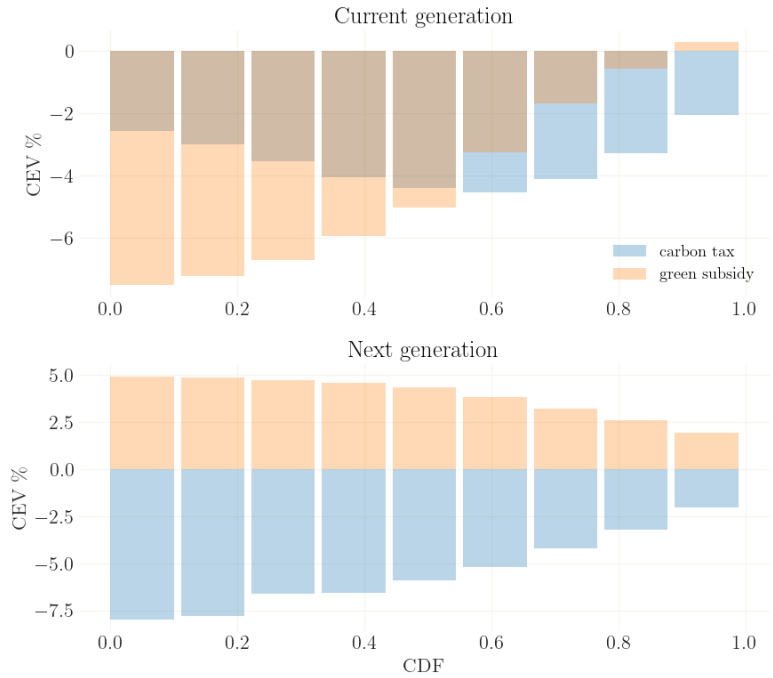

Figure 3: Consumption equivalent variations (CEVs) across the wealth distribution for the current generation (top panel) and the next generation in 30 years (bottom panel). The bottom panel assumes that agents compare CEVs with the counterfactual from the same wealth level without adjusting for transition dynamics.

The top panel of Figure 3 displays the CEVs for the current generation across the wealth distribution. All households, except for the top 10% of wealth holders, prefer the non-policy equilibrium over both the carbon tax and the green subsidy. Among the two policies, most households – particularly poorer households – favor the carbon tax over the subsidy. As discussed in the previous section, the subsidy leads to a substantial initial decline in consumption, coupled with higher tax payments to finance the subsidy and greater disutility from working more hours due to the output boom. Only the richest 10% prefer the green subsidy over the carbon tax. They benefit from the boom because they hold firm shares, including those of green energy firms, which experience a significant increase in profits under the subsidy, resulting in higher dividend payouts.

The bottom panel displays CEVs for the next generation.[7] The results contrast sharply with those for the current generation. While carbon taxes remain less favorable than the non-policy equilibrium – even less so than for the current generation –, households' CEVs under the green subsidy are positive and large in absolute terms.

The CEVs are particularly high for poorer households and gradually decline across the wealth distribution. The greater efficiency gains in green energy production achieved through the subsidy result in significant increases in output, consumption, and labor income. This disproportionately benefits poorer households.[8]

[7]Note that we still assume the policy was implemented in period $t = 0$.

[8]Figure 3 shows CEVs computed from period $t = 0$ or $t = 120$ onward for different wealth groups, but it does not track the same

In sum, our analysis reveals distributional conflicts in the short run and a generational conflict in the long run between the two policy measures. In the short run, poor and middle-wealth households strongly prefer the carbon tax over the green subsidy, whereas the top 10% of the wealth distribution favors the subsidy. However, in the long run, households across all wealth groups benefit more from the green subsidy. This finding strongly aligns with the "tragedy of the horizon" problem (Van der Straten et al., 2024): when selecting a policy today, the current generation may not fully internalize its long-term benefits or costs for future generations.

For a comprehensive welfare analysis *across* generations, we consider two measures of aggregate social welfare: the utilitarian welfare measure and the max-min measure. The utilitarian welfare measure is the simple average of all households' utilities in a given period. It can also be interpreted as unconditional welfare under the *veil of ignorance*, representing the expected welfare of an unborn individual whose skill or wealth group will only be revealed at birth. The max-min measure, by contrast, captures the utility of the least well-off household.

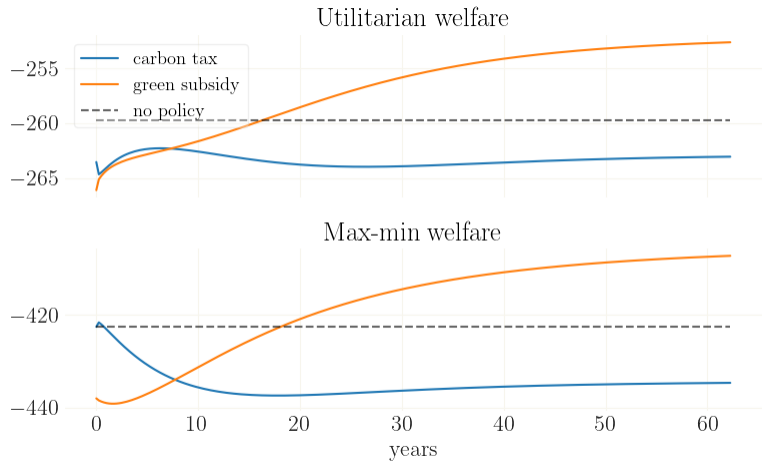

Figure 4: Utilitarian welfare (top) and max-min welfare (bottom) under the carbon tax, green subsidy and in the non-policy case, i.e., the steady state without any policy.

Figure 4 illustrates utilitarian welfare (top) and max-min welfare (bottom) under the carbon tax, the green subsidy, and in the absence of any policy. The results align with our previous findings. In the short run, both utilitarian and max-min welfare are lower under the green subsidy than under the carbon tax. However, welfare gains from the subsidy grow substantially over time. After less than 10 years, utilitarian welfare under the subsidy begins to exceed that under that the carbon tax. Similarly, around the same time, max-min welfare under the subsidy surpasses its carbon tax counterpart. In the long run, welfare under the subsidy is clearly higher than under either the carbon tax or the non-policy economy. Appendix A confirms that these results are highly robust across alternative parameter specifications.

households over time. Thus, the poorest households that bear the highest costs from the subsidy in the current generation are not necessarily the same ones that benefit the most in the future.

4 Conclusion

We show that climate change measures have fundamental distributional and generational implications. Using a medium-scale DSGE model with heterogeneous agents, energy production, and endogenous technological progress in green energy, we study the effects of a carbon tax and a green subsidy on both the aggregate economy and individual households.

In the short run, most households experience a welfare loss under either policy. However, the carbon tax leads to smaller losses because it causes only a mild contraction in output and consumption while simultaneously redistributing part of the tax revenues to households. In contrast, a green subsidy leads to a significant short-term contraction in consumption. This is primarily because households face higher tax payments necessary to finance the subsidy and substantial crowding-out effects due to the reallocation of resources toward the green sector and green R&D investment. Only the top 10% of the wealth distribution benefit from the green subsidy because they hold shares in firms, including green energy producers, whose profits increase substantially.

However, the long-run implications differ significantly. The subsidy triggers a larger increase in R&D investment in new technologies for green energy production. Lower green energy prices lead to higher demand, causing a boom in this sector. Over time, higher R&D investment results in greater overall productivity in green energy production, ultimately leading to a new steady state with higher output, consumption, and welfare for all households—regardless of their wealth.

Our findings highlight the necessity of analyzing both the distributional impacts and the short- and long-term effects of various climate policy measures. This is particularly relevant from a political economy perspective. Dechezleprêtre et al. (2025) empirically identify three key factors that influence public support for climate policies: the policy's impact on households, its distributional consequences (especially for poorer households), and its perceived effectiveness. In democratic societies, governments must consider these factors to gain voter support.

Another important aspect is how and by whom climate measures should be financed. In our model, we assume a standard case where policy costs or benefits are financed through taxes proportional to household income. Alternative approaches could involve more targeted financing mechanisms or debt financing, which could have further redistributive effects. Future research needs to explore these aspects in greater detail.

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Appendix A Robustness

This section examines the robustness of our simulation results with respect to parameter choices. Given their importance, we focus on parameters governing the energy sectors and the specification of the R&D sector.

The productivity of the brown energy sector, A_{BR}, acts as a scaling factor and does not affect the transition dynamics. Furthermore, our main results are largely invariant to the target value of A^{GR}. The productivity variable A_t^m enters the aggregate production function for green energy in Eq. 4 with an exponent $\frac{\varepsilon}{\varepsilon-1} - \alpha_{GR}$. For reasonable values of α_{GR} and ε, this exponent remains sufficiently close to 1, meaning that a higher level of A_t^m proportionally increases the aggregate productivity of green energy production.

Our results also remain qualitatively robust to variations in the innovation survival probability ϕ^m for realistic values greater than 0.8 (Comin and Gertler, 2006; Anzoategui et al., 2019), as well as to alternative values of the AR(1) coefficient for the brown tax and green subsidy shocks, ρ_τ. By construction, for very high levels of ρ_τ, the transition process becomes significantly more persistent.

Thus, two parameters remain that may be particularly pivotal for the transition process: σ_E, the elasticity of substitution between brown and green energy, and ν^m, which governs the endogenous R&D conversion probability.

Appendix A.1 Elasticity of substitution between brown and green energy σ_E

Alongside our benchmark value for σ_E, we consider two alternative specifications: $\sigma_E = 3$, as in Acemoglu et al. (2012), and $\sigma_E \to \infty$. When $\sigma_E = 3$, green and brown energy are less substitutable than in the benchmark case, whereas under $\sigma_E \to \infty$, they become perfect substitutes.

We replicate the central Figures 3 and 4 from the paper. Note that with a lower degree of substitutability, $\sigma_E = 3$, both a larger carbon tax and a larger green subsidy are required to achieve a 50% reduction in relative brown energy use, as it becomes more difficult to substitute green for brown energy. Conversely, under perfect substitutability, $\sigma_E \to \infty$, much lower tax and subsidy levels are sufficient to meet the target.

Figure A.5 shows consumption equivalent variations for $\sigma_E = 3$ (left) and $\sigma_E \to \infty$ (right). In general, the social costs of the carbon tax tend to be higher for both the current and the next generation when green and brown energy are less substitutable. In this case, energy prices remain elevated despite investment in R&D and efficiency gains in green energy production, leading to a greater contraction in output and consumption. Similarly, welfare gains under the subsidy are significantly lower for the next generation compared to the benchmark case. In this scenario, substantially larger green R&D investment is required in equilibrium to replace brown energy in the final energy mix, resulting in a stronger crowding-out effect on consumption.

In sum, a lower degree of substitutability increases the welfare costs of both the carbon tax and the green subsidy for the current generation and reduces the welfare gains from the subsidy for the next cohort. Nevertheless, the overall relative desirability of the policies across wealth groups and generations remains identical to the benchmark findings in the paper.

Appendix A.2 R&D conversion probability ν^m

Another important parameter is ν^m in the endogenous R&D conversion probability function $\xi_t = z^m \left(\frac{A_t^m}{S_t}\right)^{\nu^m}$. The parameter ν^m governs two effects: the spillover effect, $(A_t^m)^{\nu^m}$, and the congestion effect, $(S_t)^{\nu^m}$. Based on their profit maximization problem, innovators choose the optimal level of S_t, given the current level of A_t. A lower ν^m reduces the degree of congestion effects, thereby increasing the incentives for innovators to raise S_t all else equal.

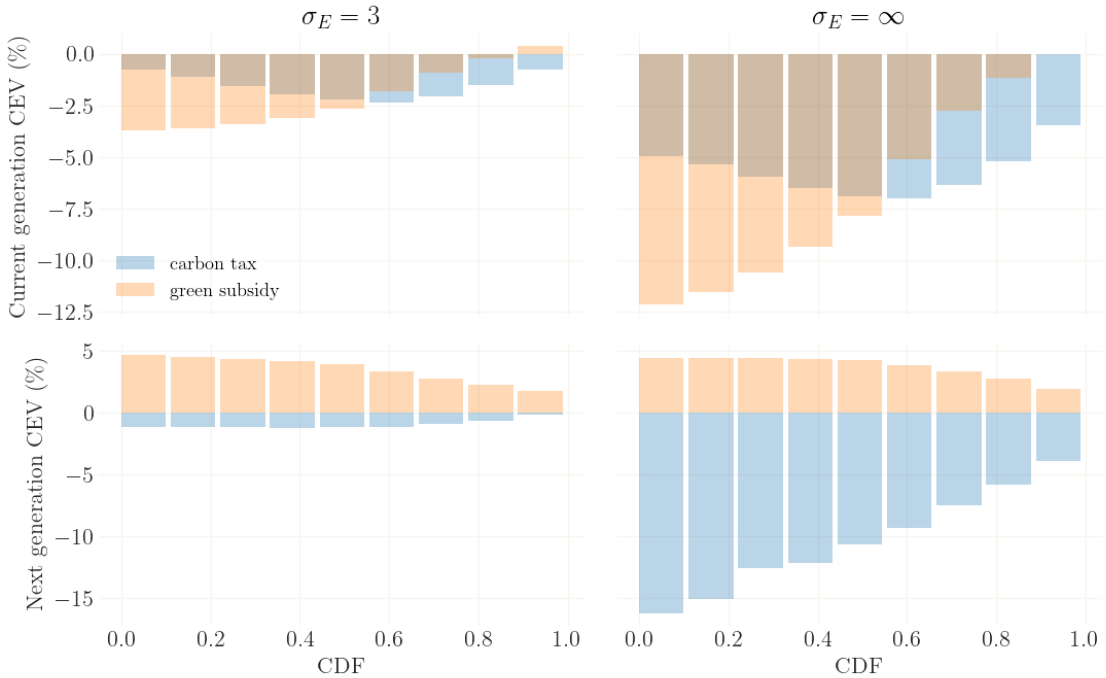

Figure A.5: Consumption equivalent variations (CEVs) across the wealth distribution for the current generation (top panels) and the next generation in 30 years (bottom panels) for $\sigma_E = 3$ (left) and $\sigma_E \to \infty$ (right). The bottom panel assumes that agents compare CEVs with the counterfactual from the same wealth level without adjusting for transition dynamics.

Figure A.7 displays Utilitarian and max-min welfare for the two policies across various values of ν^m. The figure distinguishes between welfare for the current generation and the next generation, the latter defined as households 30 years in the future.[9]

The figure reveals another generational conflict. Current generations dislike low levels of ν^m under both the green subsidy and the carbon tax. A lower ν^m, which weakens congestion effects, leads to a larger increase in R&D spending S_t. This substantial resource reallocation to the green sector drives higher output, factor prices, and inflation. In response, the central bank raises nominal interest rates, causing real interest rates to rise, which dampens consumption.

In the medium run, however, households prefer a smaller value of ν^m. Reduced congestion effects, combined with the significant initial investment in R&D, accelerate the transition process, enabling households to benefit from higher green productivity earlier in the transition.

Moreover, Figure A.7 highlights that, for a given value of ν^m, current households consistently favor the carbon tax over the green subsidy, whereas future generations prefer the subsidy over the tax. For any ν^m, the

[9]Calculating the transition dynamics for the green subsidy is computationally intensive. For this robustness exercise, we consider only a 30% reduction of carbon energy relative to the benchmark, shorten the sequence length to 300 periods, and limit the asset grid to 50 points. These adjustments significantly reduce the computational cost while keeping approximation errors negligible, thereby minimizing the environmental footprint of this paper.

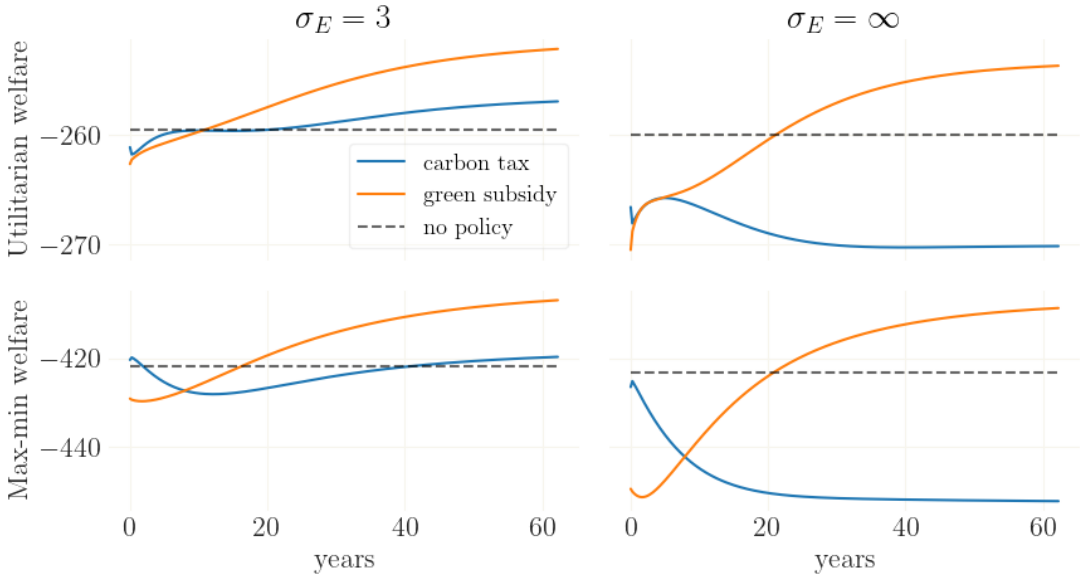

Figure A.6: Utilitarian welfare (top) and max-min welfare (bottom) under the carbon tax, green subsidy and in the non-policy case, i.e., the steady state without any policy. Simulation for a lower elasticity of substitution at the left, and for perfect subsitutability between green and brown energy at the right.

green subsidy leads to a greater reallocation of resources toward the green and R&D sectors, accompanied by a larger decline in consumption during the early stages of the transition. Households begin to reap the benefits of this larger reallocation to the green sector only in the medium run.

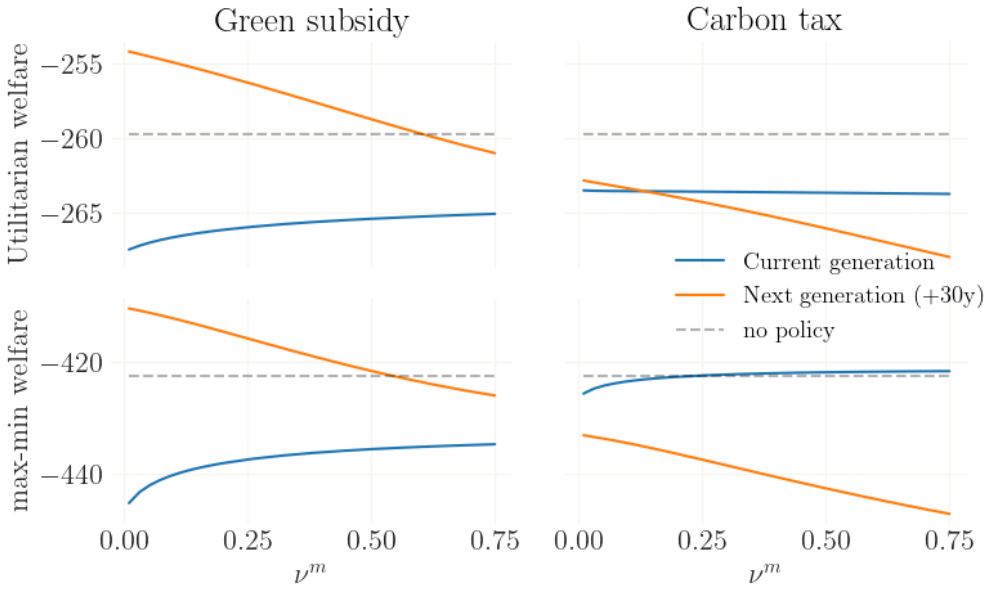

Figure A.7: Utilitarian and max-min welfare (top vs. bottom row) given policy measures over a range of values of the R&D spillover parameter ν^m. The welfare values for the current generation (blue lines) and the next generation (orange line) are taken from a transition towards a 30% reduction in brown energy via a green subsidy and a carbon tax (left vs. right column).