Carbon Policy, the Green Transition, and Inflation Dynamics*

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Abstract

We study the effects of carbon taxes on inflation dynamics with a focus on a margin at the core of the green transition: green technology adoption. We build a New Keynesian model with environmental externalities and an energy sector that incorporates endogenous green technology adoption in both the goods and the energy sectors. Calibrating the model to European Union data, we show that for the same carbon tax increase in the goods and energy sectors and the same sectoral emissions shares, raising the tax on emissions from the goods sector leads to a smaller reduction in emissions, a larger increase in output, and a smaller increase in headline inflation compared to raising the tax on emissions from the energy sector. Further model analysis reveals that the ability of goods-producing firms to adopt green technologies plays a key role in explaining the positive output and inflation effects of carbon taxes in the non-energy sector in the data, while green technology adoption in the energy sector plays an out-sized role in reducing emissions. More broadly, our work highlights the importance of green technology adoption across sectors for understanding the quantitative impact of carbon taxes on both inflation and output along the transition to a lower-carbon environment.

JEL Classifications: E30, E52, E60, H23, O44, Q54, Q55
Keywords: Environmental and fiscal policy, carbon taxes and ETS, green energy and energy efficiency, endogenous green technology adoption, European Union

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1 Introduction

Policies to reduce carbon dioxide emissions are becoming increasingly important. While the potential adverse effects of carbon taxation on aggregate employment and GDP have been a concern among policymakers, recent empirical studies for the select set of economies with long-standing carbon pricing mechanisms suggest that increasing carbon taxes has no meaningful adverse effects on aggregate economic activity Metcalf and Stock (2023). Another concern among policymakers is the potential impact of carbon taxation on inflation along the green transition. Recent research exploiting carbon pricing data for the European Union (EU) documents that carbon taxes may have limited inflationary effects (Konradt and Weder di Mauro, 2023; Känzig and Konradt, 2024; Bettarelli *et al.*, 2025; Konradt *et al.*, 2024), with carbon-tax revenue recycling being one factor that may shape the effects of carbon taxation on inflation. However, much less is known about other factors associated with the green transition that can shape the response of inflation to carbon taxes as economies strive towards a lower-carbon environment.

In this paper, we focus on green technology adoption as one such factor. There are two main rationales driving this choice. First, the steady increase in national carbon taxes and the expansion of the emissions trading system (ETS) in the EU since 2000 has been accompanied by a consistent increase in the share of green energy, a trend that partly reflects increasing rates of green technology adoption as both carbon taxes and the ETS make the use of polluting technologies more costly and technological advancements reduce the cost barriers to green technology adoption[1] Second, green technology adoption can play an important role in rationalizing the non-negative effects of carbon taxes on employment and GDP documented in the empirical literature Finkelstein Shapiro and Metcalf (2023). Given that technology adoption can change the cost structure of firms, it is natural to analyze how green technology adoption may also affect the response of inflation when carbon taxes are used to foster the transition to a lower-carbon economy. To do so, we extend a standard New Keynesian model to include energy production, a choice over the adoption of regular (polluting) or green (pollution-free) technologies in both the goods-producing and energy sectors, and pollution externalities in these two sectors. Harmful, TFP-reducing emissions

[1] See Gerarden *et al.* (2025) for more on the deployment and increasing adoption of solar and wind technologies starting in the early 2000s.

generated by the use of polluting technologies in each sector are subject to separate carbon taxes. Goods-producing firms and energy producers facing these taxes can lower their burden by incurring abatement expenditures or effectively eliminate the costs of carbon taxation by adopting green technologies. The adoption and use of green technologies does not generate emissions but their adoption requires incurring fixed costs. The choice over green technology adoption in the two sectors delivers endogenous sub-measures of polluting goods firms and energy producers. In our model, the carbon tax on emissions emanating from the goods sector can be interpreted as the set of national carbon taxes currently in place in several EU economies, while the carbon tax on emissions emanating from the energy sector can be broadly interpreted as embodying the core role of the ETS: an increase in the energy-sector carbon tax in our framework is akin to a reduction in emission allowances in that sector as both lower carbon allowances and a higher carbon tax ultimately increase the price of generating emissions associated with the energy sector. Having two carbon taxes targeting two different sectors, as opposed to one tax and one cap-and-trade system, allows us to characterize, in a transparent way, the similarities and differences in the effects of these two taxes on inflation and aggregate economic activity along the green transition.

Calibrating the model to EU data, we analyze an increase in the carbon tax of roughly $40 per unit of emissions in each sector separately. This change in carbon pricing is broadly in line with similar changes analyzed in the empirical literature (Metcalf and Stock, 2023; Konradt and Weder di Mauro, 2023; Konradt *et al.*, 2024) In order to highlight the key features of our framework—specifically, endogenous green technology adoption in the goods and energy sectors—our quantitative analysis focuses exclusively on the implications of an increase in carbon taxes similar to those discussed in policy circles and abstracts from formally characterizing *optimal* carbon-tax and green-subsidy policies.

Focusing first on the year-to-year response of the economy to each of these taxes, we find that for the same quantitative increase in the carbon tax, taxing emissions from the goods sector generates a smaller reduction in emissions, a larger increase in real GDP and in core inflation, and a smaller increase in headline inflation compared to an identical carbon-tax increase in the energy sector. This result takes place even if the baseline share of emissions from each sector in total emissions is assumed to be evenly split between sectors.

Further analysis using our benchmark model delivers two additional findings. First,

the frequency at which we analyze the effects of the carbon taxes on inflation and total output along the transition path matters: focusing on annual changes in emissions, inflation, and output in response to carbon taxes—as is often done in the empirical literature—masks important qualitative differences in the short-term effects of the two carbon taxes. These differences become apparent only when we analyze the economy's transition to a lower-emissions equilibrium at a higher (quarterly) frequency. In particular, while total output increases after raising the carbon tax in the goods sector, raising the carbon tax on emissions from the energy sector by the same amount generates a non-trivial contraction in total output in the first two quarters after the tax increase, followed by a rebound within a year. Along similar lines, the response of headline inflation in the first two quarters after the implementation of the carbon-tax increase is larger under the carbon tax on emissions in the goods sector compared to the same increase in the carbon tax on emissions in the energy sector—this is the opposite result when we consider the response of headline inflation at an annual frequency. This finding is subtle but may have relevant implications for monetary policymakers and policymakers concerned about the short-term costs associated with the green transition.

Second, the ability of goods-producing firms and energy producers to adopt green technologies in response to greater carbon taxes plays an important role in shaping the quantitative reduction in emissions for a given change in these taxes. When we abstract from endogenous green technology adoption in our framework, the carbon tax generates only a fraction of the reduction in emissions obtained in the benchmark model—this result is consistent with existing studies on directed technical change and the green transition. Importantly for our purposes, though, the relevance of green technology adoption extends beyond emissions and represents a relevant force that shapes the impact of carbon taxes on both total output and inflation as the economy transitions to a lower-emissions equilibrium. Indeed, in the absence of green technology adoption in the goods sector, an increase in the carbon tax on emissions from that sector has no meaningful impact on total output or inflation—in contrast with existing empirical evidence for the EU—while an increase in the carbon tax on emissions from the energy sector generates both a larger initial contraction in output as well as a larger increase in headline inflation.

To shed more light on the role of green technology adoption in shaping inflation dynamics in response to carbon taxation, we show that each carbon tax has a differential

impact on both the effective marginal cost of goods-producing firms as well as on the polluting-green technological composition of these firms. Specifically, while an increase in the carbon tax on the emissions in the goods sector leads to an initial increase in the economy's weighted (or average) marginal cost of goods production—a key component of price dynamics—the opposite is true when we consider an increase in the carbon tax on emissions in the energy sector.

While the differential dynamics in the economy's average marginal cost are temporary and short-lived, they are powerful enough to shape the response of total output and headline inflation, both in the short term and medium term as the transition to a lower-carbon environment takes place. Green technology adoption is key in shaping this average marginal cost because adoption (1) changes the influence of polluting goods-producing firms' cost structure on the average marginal cost in the economy, and (2) makes goods-producing firms more resilient to changes in carbon taxes by giving firms an additional margin of adjustment on the extensive side. This added resilience limits the economic cost of the carbon tax and shapes the response of core and headline inflation to the tax.

All told, our findings highlight the relevance of green technology adoption for understanding the quantitative impact of carbon taxes on inflation along the transition path to a lower-emissions environment. They also illustrate the potential differential effects that sectoral carbon taxes can have on inflation and output dynamics, even as they both result in a reduction in carbon emissions.

Related Literature Recent work by Metcalf and Stock (2023) uses data for Canada and the EU and finds that carbon taxes have no significant adverse effects on employment or real GDP. Moessner (2025), Konradt and Weder di Mauro (2023), Känzig (2023), Bettarelli *et al.* (2025), Konradt *et al.* (2024) are the select few papers that analyze the effects of an increase in carbon taxes on inflation by exploiting the availability of EU data, with Känzig (2023) focusing on ETS carbon prices, Konradt and Weder di Mauro (2023) focusing on national carbon taxes, and Moessner (2025) focusing on both carbon pricing schemes. In particular, Känzig (2023) uses high-frequency movements in ETS prices and documents positive albeit quantitatively small effects on inflation from of changes in the ETS. Moessner (2025) provides similar findings

even when the ETS and national carbon taxes are analyzed together.[2] Konradt and Weder di Mauro (2023) find that national carbon taxes do not have meaningful effects on headline inflation even as the taxes generate upward pressure on energy prices and therefore energy-price inflation. Bettarelli *et al.* (2025) use sectoral, regional, and national data for both advanced and developing economies and find that carbon-tax shocks can have non-trivial inflationary effects. Existing macro models with environmental externalities are generally unable to reproduce the muted macroeconomic costs alongside the dynamics of inflation in response to carbon pricing in the data. Our model offers a way to rationalize the absence of output costs and the limited effects of carbon pricing on inflation, with green technology adoption playing a quantitatively relevant role in explaining these results jointly.

Our work is closest to existing model-based work that introduces environmental externalities into standard New Keynesian models.[3] These include Annicchiarico and Dio (2015), Annicchiarico and Diluiso (2019), Diluiso *et al.* (2021), Annicchiarico *et al.* (2024), and most recently Olovsson and Vestin (2023) and Del Negro *et al.* (2023). Annicchiarico and Dio (2015) use a one-sector New Keynesian model with a polluting production structure to analyze the response of the economy to shocks under different carbon pricing policies. Using a two-country one-sector macro-environmental model with nominal rigidities, Annicchiarico and Diluiso (2019) characterize how the international transmission of shocks is affected by cap-and-trade and carbon-tax policies. Diluiso *et al.* (2021) analyze the macro-financial stability implications of the green transition using a New Keynesian model with banking frictions and representative low-carbon energy and a fossil energy sectors, and study the role of financial regulation and monetary policy in shaping the transition. Annicchiarico *et al.* (2024) focus instead on how expectations can affect the transition by considering deviations from full rationality in a one-sector behavioral New Keynesian model with environmental externalities. Del Negro *et al.* (2023) use a two-sector New Keynesian model with representative high-emissions and low-emissions sectors and study how differing degrees of nominal rigidities between sectors matter for the inflationary consequences of the green transition. In their model, firms are un-

[2] For recent work on carbon pricing and inflation volatility that obtains similar findings to Moessner (2025), see Santabárbara and Suárez-Varela (2022). For work on carbon pricing and inflation expectations, see Hensel *et al.* (2024).

[3] For early work on environmental policies and real business cycle models, see Fischer and Springborn (2011) Heutel (2012), and Dissou and Karnizova (2016), among others. For a recent example of larger integrated assessment models with a detailed energy structure and green energy adoption, see Adão *et al.* (2024).

able to switch between low-emissions and high-emissions technologies. Finally, Olovsson and Vestin (2023) use a New Keynesian model with a goods and an energy sector that produces polluting and green energy to study the role of monetary policy during the green transition. We contribute to the growing macro-climate literature that studies the potential effects of carbon pricing on inflation dynamics by incorporating green technology adoption choices in both the goods and energy sectors—margins that are absent in existing macro-climate New Keynesian models. We then use the model to characterize the role of these margins in shaping the effect of carbon taxes on inflation along the transition path to a lower-carbon economy.

The rest of the paper is structured as follows. Section 2 briefly revisits existing evidence on the effects of carbon taxes on GDP and inflation with a focus on the EU, and considers how accounting for the share of green energy modifies the response of inflation to an increase in carbon taxes. Section 3 describes the model. Section 4 outlines our calibration strategy and presents the main quantitative analysis. Section 5 concludes.

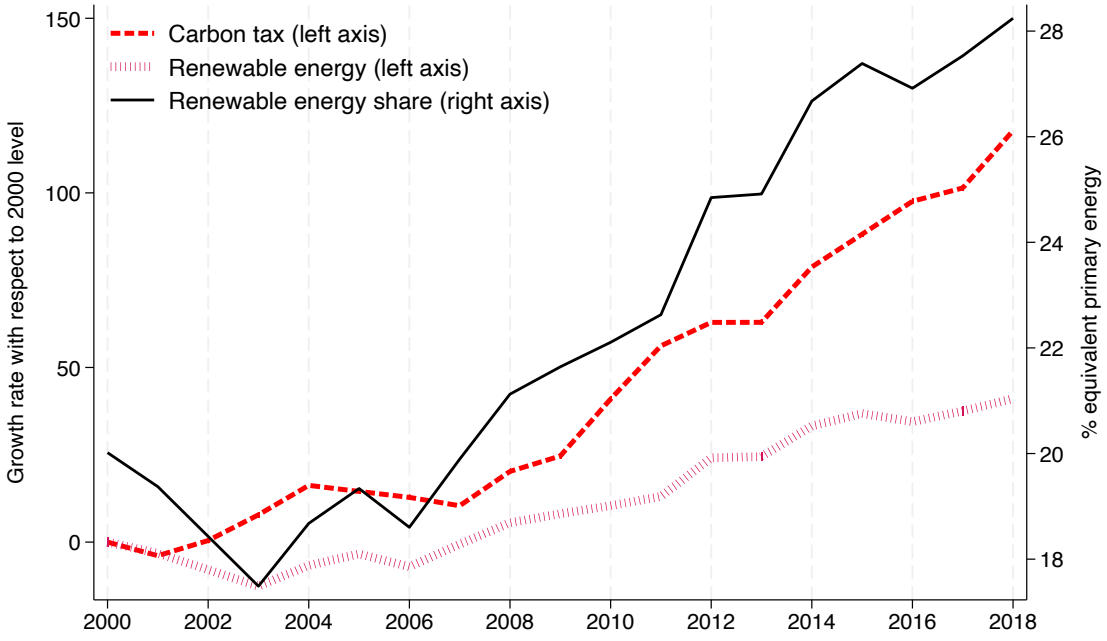
2 The Impact of EU National Carbon Taxes on Emissions, GDP, and Inflation

The EU Emissions Trading System (ETS), the world's largest cap-and-trade program, was launched in 2005 and has since expanded to include Liechtenstein, Iceland, and Norway (collectively referred to as EU+). The EU+ ETS covers approximately 38 percent of greenhouse gas (GHG) emissions, with only about 4 percent of these emissions overlapping with other carbon pricing initiatives in select EU+ economies (Finland, Ireland, the Netherlands, and Norway; World Bank Carbon Pricing Dashboard). Prior to the introduction of the ETS, many EU+ countries had already implemented national carbon taxes. Figure A1 in the Appendix presents the roll-out of these national carbon taxes over the years. As of 2018, 16 EU+ economies had adopted national carbon taxes, with 11 of these imposing a tax above \$20 per ton of CO_2. In what follows, we document that the steady increase in national carbon taxes since 2000 has coincided with a gradual but steady rise in the share of renewable (or green) energy in these economies' energy mix. While direct measures of green technology adoption are not readily available, the increase in the share of green energy partly reflects increased adoption rates of low-carbon technologies which are often needed for energy producers to shift their energy mix away from polluting sources. Gerarden *et al.* (2025) provide an excellent

summary of the introduction and trends in adoption of the most common green technologies in the EU, China, and the US.

Figure 1 uses EU+ data and plots the growth rates of the average real national carbon tax and the level of primary energy consumption from low-carbon sources—renewable or green energy for short—relative to their respective levels in 2000 (left axis). We also plot the share of green energy (right axis) to highlight the change in the energy mix since 2000. Between 2000 and 2018, the average national carbon tax increased by nearly 125 percent and the level of green energy grew by almost 50 percent. In turn, the share of green energy rose from 18 percent in 2000 to 28 percent in 2018.

Fig. 1 Growth in National Carbon Taxes and Green Energy Shares in EU Economies, 2000-2018



Source: Konradt and Weder di Mauro (2023) (national carbon tax) and Our World in Data (share of renewable energy).
Notes: The carbon tax is expressed in real terms and refers specifically to the average national carbon tax in the subset of EU economies that have such taxes. The emissions coverage of these taxes has virtually no overlap with the emissions covered by the EU+ ETS. Renewable energy corresponds to the share of primary energy consumption from low-carbon sources and is expressed as a share of total equivalent primary energy.

Motivated by the positive correlation between national carbon taxes and the share of green energy, we expand on the select set of empirical studies that have examined the effects of different EU+ climate-related policies on GDP, employment (Metcalf and Stock, 2023),

and inflation (Konradt and Weder di Mauro, 2023; Känzig and Konradt, 2024; Känzig, 2023) by incorporating the share of renewable energy as an additional factor that could influence the response of GDP and inflation to an increase in carbon taxes. Building on Konradt and Weder di Mauro (2023) and Metcalf and Stock (2023), we identify the dynamic responses of CO_2 emissions growth, GDP growth, and inflation to carbon taxation using local projections (Jordà, 2005). The main specification reads:

$$\Delta \mathbf{X}_{i,t+h} = \alpha_i + \Theta_h \tau_{i,t} + \beta(L)\tau_{i,t-1} + \delta(L)\Delta \mathbf{X}_{i,t-1} + \mu(L)\Delta \mathbf{Z}_{i,t-1} + \gamma_t + \varepsilon_{i,t+h}, \qquad (1)$$

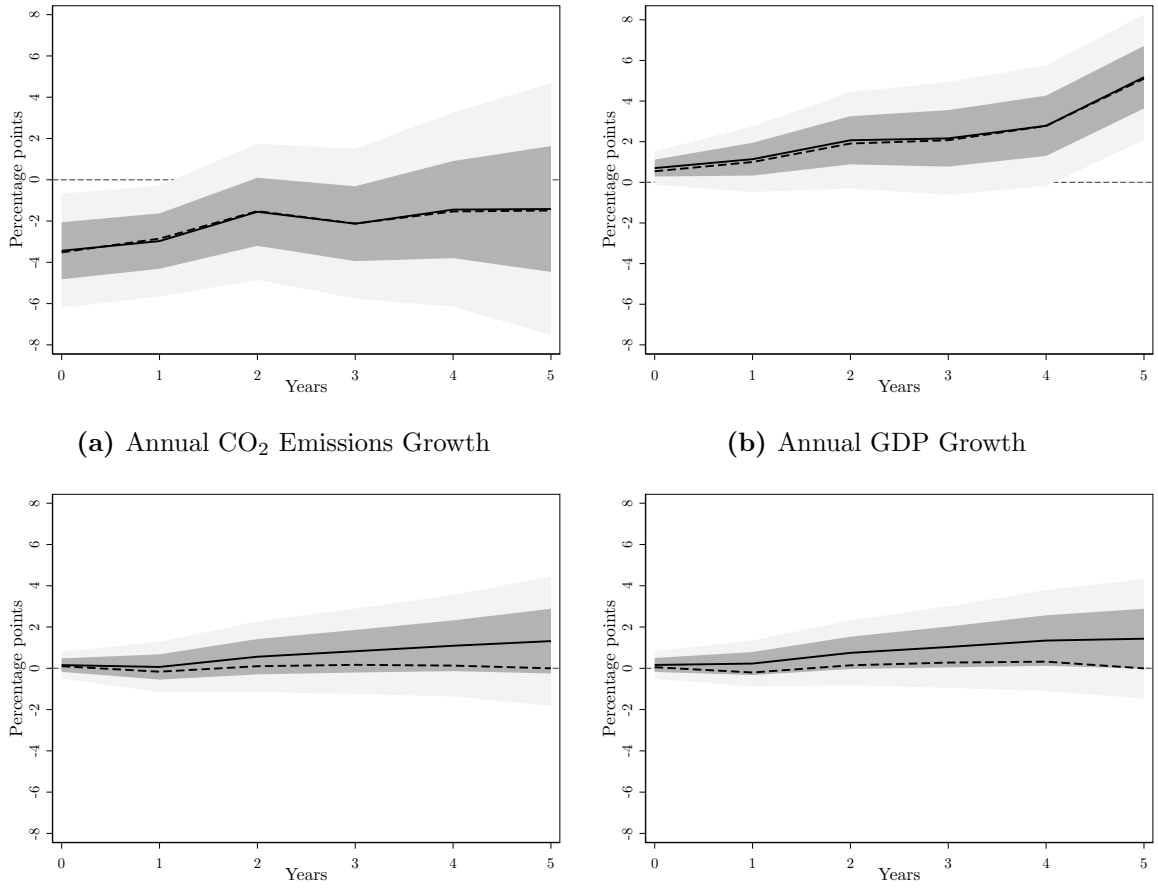
where $\mathbf{X}_{i,t+h}$ is the vector of outcome variables for country i at time $t+h$, including the log of CO_2 emissions, the log of real GDP, the log of the core consumer price index, and the log of the headline consumer price index, and Δ represents the change in these variables between consecutive periods. The coefficient Θ_h captures the effect of an unexpected change in the carbon tax rate at time t for up to h periods ahead, with $\tau_{i,t}$ denoting the coverage-weighted real carbon tax rate for country i. The vector of control variables, $\mathbf{Z}_{i,t-1}$, includes the policy interest rate and the share of primary energy consumption from renewable sources. We also include country fixed effects, α_i, and year fixed effects, γ_t. Standard errors are robust to heteroscedasticity and clustered at the country level. Additional details on the data are presented in Appendix A.1. As a robustness check, we re-estimate the regressions without including the share of primary energy consumption from renewable sources as a control variable. This alternative specification closely aligns with the benchmark specification in Konradt and Weder di Mauro (2023). Our main analysis follows previous work and considers on a $40 USD increase in the national carbon tax.

Figure 2 presents the dynamic responses of the growth in CO_2 emissions, real GDP growth, core inflation, and headline inflation to this shock. The solid lines correspond to the specification in equation 1, while the dashed lines represent the specification that does not include the share of green energy. The results for CO_2 emissions (Panel 2a) and real GDP growth (Panel 2b) from our specification are virtually identical to those in Konradt and Weder di Mauro (2023), where emissions decline by about 4 percent while GDP increases by 1 percent in the year following the increase in the national carbon tax. However, incorporating the share of green energy generates differences in the response of core and headline inflation

relative to a specification where the share of green energy is not included, even if the national carbon tax does not lead to a marked and significant increase inflation. For completeness, Figures A2 and Figure A3 in the Appendix present results where we separate the economies in our sample into two groups based on their average share of green energy between 1995 and 1999: one group has a high share of green energy relative to the whole-country-sample mean, and the other group has a low share of green energy relative to the same mean. A large part of the effect that we see in Figure 2 seems to come from the economies with a low average share of green energy trying to catch up in terms of their usage of green energy.

To better understand how the share of green energy may influence inflation dynamics after an increase in carbon taxes, the next section presents a model that allows us to characterize the role of changes in the green energy mix—rooted in endogenous green technology adoption—in response to an increase in carbon taxes.

Fig. 2 Impulse Responses to an Increase in USD $40 in the National Carbon Tax for EU+28



(a) Annual CO_2 Emissions Growth

(b) Annual GDP Growth

(c) Annual Core Inflation

(d) Annual Headline Inflation

Source: Own calculation using data from Konradt and Weder di Mauro (2023) and Our World in Data.
Notes: The dashed lines correspond to the baseline specification in Konradt and Weder di Mauro (2023), which includes country and year fixed effects, real GDP growth, and the domestic monetary policy rate. The solid lines correspond to our specification (that is, Konradt and Weder di Mauro (2023) expanded to include the share of green energy). Shaded gray areas denote one standard deviation (light gray) and two standard deviations (dark gray) around the estimated response using our specification.

3 The Model

We assume a closed economy to focus on the relevance of domestic green technology adoption and energy efficiency. The economy is comprised of a fixed measure (normalized to one) of goods-producing firms that face nominal price rigidities, a fixed measure of electrical energy producers, a representative household who owns both goods-producing firms and electrical energy producers, and a central bank that sets nominal interest rates according to a standard

Taylor Rule. For expositional brevity, in the rest of the paper we refer to electrical energy producers as energy producers and to goods-producing firms as firms.[4]

Households consume, supply labor to firms, and accumulate physical capital. Firms use labor, physical capital, and energy as inputs, and their prices are subject to nominal rigidities. Energy producers use only physical capital as an input and their prices are fully flexible.

In contrast with most existing models that analyze the impact of carbon taxes on inflation dynamics, energy producers and firms each face a choice between two available production technologies. The first technology is polluting: it generates harmful emissions as a by-product of the production process. These emissions are subject to a carbon tax, but those using this technology can spend resources on abatement to reduce their carbon-tax burden (this represents an intensive margin of emissions reductions). The second technology is less intensive in energy and is green—that is, it does not generate emissions as a by-product of the production process and is therefore not subject to the carbon tax. However, its adoption is subject to a fixed cost. Technology adoption choices are determined by the respective realized idiosyncratic productivities of energy producers and firms. In particular, only those energy producers and firms with an idiosyncratic productivity level that is high enough adopt the green technology. As such, the polluting-green structure of both goods and energy production is endogenous. Effectively, our framework merges the endogenous polluting-green goods-production structure in Finkelstein Shapiro and Metcalf (2023) with the endogenous polluting-green energy-production structure in Finkelstein Shapiro and Nuguer (2025), and introduce nominal rigidities in the goods sector to this environment by following Bilbiie *et al.* (2007).[5]

[4] Energy can be chemical, electrical, light, and mechanical, among other categories. Electricity use is one of the major three contributors to carbon emissions alongside transport and heating. Importantly, electricity can be produced using non-renewable energy sources (coal, gas, oil) or renewable energy sources (hydro, solar, wind). In contrast, transport and heating rely primarily on non-renewable energy sources unless the sectors are electrified and the electricity used is generated by using renewables.

[5] As shown in Finkelstein Shapiro and Metcalf (2023), endogenous firm entry can play a role in shaping the macroeconomic effects of carbon taxes amid green technology adoption in the goods sector by limiting the output gains that otherwise occur when firms adopt green technologies. We abstract from modeling endogenous firm entry since we find no evidence for the EU that carbon taxes affect measures of new firm entry. For earlier work on carbon pricing and endogenous firm entry in a one-sector macro model with pollution externalities and no green production, see Annicchiarico *et al.* (2018). Two key differences between our work and Annicchiarico *et al.* (2018) are the inclusion of (1) an energy sector alongside a goods-producing sector and (2) endogenous green technology adoption in both goods production and energy production.

Consistent with evidence on the use of carbon-tax revenue in EU economies, a fraction of the revenue from carbon taxation is used to subsidize green technology adoption in the production of energy and goods. The remaining portion is transferred back to the household in a lump-sum fashion.

To the extent that green technology adoption entails a fixed resource cost that ultimately appears in the economy's resource constraint, expenditures on green technology adoption can be interpreted as green investment and subsidies to these fixed costs as subsidies to green investment. For tractability, we abstract from modeling research and development of green technologies and instead focus on the adoption of existing green technologies that are able to reduce emissions.[6].

3.1 Goods Production Structure

For expositional clarity and following the New Keynesian literature, we separate goods-producing firms into two categories: monopolistically competitive final goods firms and who face nominal rigidities, and perfectly competitive intermediate goods producers who sell their output to final-goods firms.

3.1.1 Intermediate Goods Production

A measure one of perfectly competitive intermediate goods producers use capital, labor, and energy to produce two categories of intermediate goods—regular (polluting) r and green (pollution-free) g. More specifically, intermediate goods producers choose labor $n_{j,t}$, physical capital $k_{j,t}$, and energy $\mathbf{e}_{j,t}$ for each intermediate goods category $j \in \{r, g\}$ to maximize $\mathbb{E}_0 \sum_{t=0}^{\infty} \Xi_{t|0} \Pi_t$ where

$$\begin{aligned}\Pi_t = &\left[mc_{r,t} D(x_t) z_{r,t} H(n_{r,t}, k_{r,t}, \mathbf{e}_{r,t}) - w_{r,t} n_{r,t} - r_{k,t} k_{r,t} - \rho_{e,t} \mathbf{e}_{r,t} - \tau_{f,t} em_{f,t} - \Gamma_{r,t}\right] \\ &+ \left[mc_{g,t} D(x_t) z_{g,t} F(n_{g,t}, k_{g,t}, \mathbf{e}_{g,t}) - w_{g,t} n_{g,t} - r_{k,t} k_{g,t} - \rho_{e,t} \mathbf{e}_{g,t}\right],\end{aligned}$$

[6] A very reduced-form way of analyzing the implications of research and development in green technologies in our framework would be to assume that goods firms and energy producers that use green technologies incur resource costs that improve their technology's productivity relative to their polluting counterparts—a way to capture green-innovation expenditures that are productivity enhancing. For seminal research that explicitly models the research and development of clean technologies in a macro framework, see Acemoglu *et al.* (2012)

and $\Xi_{t|0}$ denotes the stochastic discount factor of the household (defined in Section 3.2). $D(x_t)$ is a pollution damages function and x_t is the total pollution stock, where $D'(x_t) < 0$ and $D(0) = 1$ and $D(x_t)$ is taken as given by the intermediate goods producer (Nordhaus, 2008). Following the macro-climate literature, we assume that $D(x_t) = exp\left[-D_0(x_t - \overline{x})\right]$, where parameter $D_0 > 0$ dictates the impact of changes in pollution on damages and $\overline{x}$ is a parameter that represents the pre-industrial atmospheric concentration of carbon dioxide. $z_{j,t}$, $mc_{j,t}$, and $w_{j,t}$ denote exogenous productivity, the real price of intermediate goods, and the real wage, respectively, in category j. $r_{k,t}$ is the real price of capital and $\rho_{e,t}$ is the real price of energy, both of which are common across intermediate goods. $H(n_{r,t}, k_{r,t}, \mathbf{e}_{r,t})$ and $F(n_{g,t}, k_{g,t}, \mathbf{e}_{g,t})$ are both constant-returns-to-scale production functions. Production of intermediate goods in category r generates emissions $em_{f,t} = (1 - \mu_{r,t})D(x_t)z_{r,t}H(n_{r,t}, k_{r,t}, \mathbf{e}_{r,t})$, $\mu_{r,t}$ is the endogenous abatement rate, and $\tau_{f,t} \geq 0$ is a carbon tax on emissions associated with the production of r intermediate goods (Heutel, 2012; Annicchiarico and Dio, 2015; Finkelstein Shapiro and Metcalf, 2023). These emissions can be abated by incurring abatement expenditures $\Gamma_{r,t} = \gamma\mu_{r,t}^{\eta} D(x_t)z_{r,t}H(n_{r,t}, k_{r,t}, \mathbf{e}_{r,t})$, where $\gamma > 0$ and $\eta > 1$.

Profit maximization yields standard optimal demand expressions for labor, capital, and energy for each category of intermediate goods j that can be expressed as:

$$mc_{r,t}D(x_t)z_{r,t}H_{n_r,t} = w_{r,t} + \left[\gamma\mu_{r,t}^{\eta} + \tau_{f,t}\frac{em_{f,t}}{D(x_t)z_{r,t}H(n_{r,t}, k_{r,t}, \mathbf{e}_{r,t})}\right] D(x_t)z_{r,t}H_{n_r,t}, \tag{2}$$

$$mc_{r,t}D(x_t)z_{r,t}H_{k_r,t} = r_{k,t} + \left[\gamma\mu_{r,t}^{\eta} + \tau_{f,t}\frac{em_{f,t}}{D(x_t)z_{r,t}H(n_{r,t}, k_{r,t}, \mathbf{e}_{r,t})}\right] D(x_t)z_{r,t}H_{k_r,t}, \tag{3}$$

$$mc_{r,t}D(x_t)z_{r,t}H_{\mathbf{e}_r,t} = \rho_{e,t} + \left[\gamma\mu_{r,t}^{\eta} + \tau_{f,t}\frac{em_{f,t}}{D(x_t)z_{r,t}H(n_{r,t}, k_{r,t}, \mathbf{e}_{r,t})}\right] D(x_t)z_{r,t}H_{\mathbf{e}_r,t}, \tag{4}$$

$$mc_{g,t}D(x_t)z_{g,t}F_{n_g,t} = w_{g,t}, \tag{5}$$

$$mc_{g,t}D(x_t)z_{g,t}F_{k_g,t} = r_{k,t}, \tag{6}$$

and

$$mc_{g,t}D(x_t)z_{g,t}F_{\mathbf{e}_g,t} = \rho_{e,t}, \tag{7}$$

where the optimal demand conditions for inputs used to produce intermediate goods in category r are affected by the presence of the carbon tax and abatement expenditures. Specifically,

all else equal, both the carbon tax and abatement expenditures increase the marginal cost of using these inputs in the production process. Finally, we also obtain a standard optimal abatement rate, where the intermediate goods producer equates the marginal benefit of abating emissions stemming from the production of r intermediate goods (given by the resource savings from not having to pay the carbon tax due to the abatement-related reduction in emissions) to the marginal cost of doing so:

$$\tau_{f,t} = \gamma \mu_{r,t}^{\eta}. \tag{8}$$

In what follows, we assume that the production functions of intermediate goods producers are Cobb-Douglas: $H(n_{r,t}, k_{r,t}, \mathbf{e}_{r,t}) = (n_{r,t})^{1-\alpha_r}(k_{r,t})^{\alpha_r-\alpha_{e_r}}(\mathbf{e}_{r,t})^{\alpha_{e_r}}$ and $F(n_{g,t}, k_{g,t}, \mathbf{e}_{g,t}) = (n_{g,t})^{1-\alpha_g}(k_{g,t})^{\alpha_g-\alpha_{e_g}}(\mathbf{e}_{g,t})^{\alpha_{e_g}}$, where $0 < \alpha_r, \alpha_g, \alpha_{e_r}, \alpha_{e_g} < 1$.

3.1.2 Final Goods Production

Total Output Total output is given by $Y_t = \left(\int_{\zeta \in Z} y_t(\zeta)^{\frac{\varepsilon-1}{\varepsilon}} d\zeta\right)^{\frac{\varepsilon}{\varepsilon-1}}$, where $y_t(\zeta)$ denotes final-goods firm ζ's output, Z is normalized to 1, and $\varepsilon > 1$ is the elasticity of substitution. The aggregate price index is $P_t = \left(\int_{\zeta \in Z} \varrho_t(\zeta)^{1-\varepsilon} d\zeta\right)^{\frac{1}{1-\varepsilon}}$, where $\varrho_t(\zeta)$ is the nominal price of final-goods firm ζ's output.

Final Goods Firm Profits Final goods firms draw their idiosyncratic productivity a from a common distribution $G(a)$ with support $[a_{\min}, \infty)$. The realized level of a of each firm remains unchanged once it is drawn. Following the literature and to minimize notation, we refer to a given firm ζ by its idiosyncratic productivity a instead. The presence of a endogenizes the choice over the intermediate goods category that a given final-goods firm a decides to use in production, and therefore the firm's choice over which technology to adopt, r or g (see, for example, Finkelstein Shapiro and Metcalf, 2023).

The real profits of a final goods firm a that uses r intermediate goods (and therefore adopts the r technology) are

$$d_{r,t}(a) = \left[\left(\frac{\varrho_{r,t}(a)}{P_t} - \frac{mc_{r,t}}{a}\right) y_{r,t}(a) - \frac{\nu_r}{2}\left(\frac{\varrho_{r,t}(a)}{\varrho_{r,t-1}(a)} - 1\right)^2 \frac{\varrho_{r,t}(a)}{P_t} y_{r,t}(a)\right],$$

where $\varrho_{r,t}(a)$ is the firm's nominal price and the last term in $d_{r,t}(a)$ is a quadratic price adjustment cost with $\nu_r > 0$ (Bilbiie *et al.*, 2007). In turn, the real profits of a final goods firm a that uses g intermediate goods (and therefore adopts the g technology) are

$$d_{g,t}(a) = \left[\left(\frac{\varrho_{g,t}(a)}{P_t} - \frac{mc_{g,t}}{a}\right) y_{g,t}(a) - \frac{\nu_g}{2}\left(\frac{\varrho_{g,t}(a)}{\varrho_{g,t-1}(a)} - 1\right)^2 \frac{\varrho_{g,t}(a)}{P_t} y_{g,t}(a)\right] - (1-\zeta_{g,t})\,\varphi_f mc_{g,t},$$

where $\varrho_{g,t}(a)$ is the firm's nominal price, $\nu_g > 0$ dictates the cost of changing prices, $\varphi_f mc_{g,t}$ is the real fixed cost of using the g technology with $\varphi_f > 0$, and $0 \leq \zeta_{g,t} < 1$ is the subsidy rate on green technology adoption in the production of final goods.

Optimal Pricing Similar to Bilbiie *et al.* (2007), it is straightforward to show that the demand function for firm a is $y_{j,t}(a) = \left(\varrho_{j,t}(a)/P_t\right)^{-\varepsilon}(Y_t + \Phi_t)$ for $j \in \{r, g\}$, where Φ_t denotes total average expenditures on price adjustments (defined explicitly in Section 3.4). Then, the optimal price for firm a using technology $j \in \{r, g\}$ is a time-varying markup $\Psi_{j,t}$ over marginal cost:

$$\rho_{j,t}(a) = \Psi_{j,t}\frac{mc_{j,t}}{a}, \tag{9}$$

where $\rho_{j,t}(a) \equiv \varrho_{j,t}(a)/P_t$ and $\Psi_{j,t}$ is

$$\Psi_{j,t} = \frac{\varepsilon}{\left[\begin{array}{c}(\varepsilon-1)\left(1 - \frac{\nu_j}{2}\left(\frac{\rho_{j,t}(a)}{\rho_{j,t-1}(a)}\frac{P_t}{P_{t-1}} - 1\right)^2\right) \\ +\nu_j\left(\frac{\rho_{j,t}(a)}{\rho_{j,t-1}(a)}\frac{P_t}{P_{t-1}}\right)\left(\frac{\rho_{j,t}(a)}{\rho_{j,t-1}(a)}\frac{P_t}{P_{t-1}} - 1\right)\frac{\rho_{j,t+1}(a)}{\rho_{j,t}(a)}\frac{y_{j,t+1}(a)}{y_{j,t}(a)} \\ -\nu_j \mathbb{E}_t \Xi_{t+1|t}\left(\frac{\rho_{j,t+1}(a)}{\rho_{j,t}(a)}\frac{P_{t+1}}{P_t}\right)\left(\frac{\rho_{j,t+1}(a)}{\rho_{j,t}(a)}\frac{P_{t+1}}{P_t} - 1\right)\frac{\rho_{j,t+1}(a)}{\rho_{j,t}(a)}\frac{y_{j,t+1}(a)}{y_{j,t}(a)}\end{array}\right]}.$$

In the absence of costly price adjustments and under Dixit-Stiglitz aggregation, the term $\Psi_{j,t}$ collapses to the standard constant markup under flexible prices, $\Psi_{j,t} = \varepsilon/(\varepsilon - 1)$.

Technology Adoption Choices Only firms that have an idiosyncratic productivity level that is high enough incur the fixed cost and adopt the g technology while the remaining firms adopt the r technology. Then, the endogenous threshold productivity level $\overline{a}_t$ above which a firm adopts the g technology is implicitly pinned down by condition $d_{r,t}(\overline{a}_t) = d_{g,t}(\overline{a}_t)$. That is, at the endogenous $\overline{a}_t$, firm a is indifferent between the two technologies.

Endogenous Firm Shares Recalling that the endogenous threshold productivity level is $\overline{a}_t$, $N_{r,t} = G(\overline{a}_t)$ and $N_{g,t} = [1 - G(\overline{a}_t)]$ are the measures of final goods firms that use the r and g technologies, respectively.

Firm Averages Following the literature, we focus on firm averages. Then, the average idiosyncratic productivity of r firms is $\widetilde{a}_{r,t} = \left[\frac{1}{G(\overline{a}_t)} \int_{a_{min}}^{\overline{a}_t} a^{\varepsilon-1} dG(a)\right]^{\frac{1}{\varepsilon-1}}$ while the average idiosyncratic productivity of g firms is $\widetilde{a}_{g,t} = \left[\frac{1}{1-G(\overline{a}_t)} \int_{\overline{a}_t}^{\infty} a^{\varepsilon-1} dG(a)\right]^{\frac{1}{\varepsilon-1}}$. With these average productivity levels in mind, we can define the average quantities, real prices, and markups associated with final goods firms as follows: $\widetilde{y}_{r,t} = y_{r,t}(\widetilde{a}_{r,t})$, $\widetilde{y}_{g,t} = y_{g,t}(\widetilde{a}_{g,t})$, $\widetilde{\rho}_{r,t} = \rho_{r,t}(\widetilde{a}_{r,t})$, $\widetilde{\rho}_{g,t} = \rho_{g,t}(\widetilde{a}_{g,t})$, $\widetilde{\Psi}_{r,t} = \Psi_{r,t}(\widetilde{a}_{r,t})$, and $\widetilde{\Psi}_{g,t} = \Psi_{g,t}(\widetilde{a}_{g,t})$. Along similar lines, average firm profits are $\widetilde{d}_{r,t} = d_{r,t}(\widetilde{a}_{r,t})$ and $\widetilde{d}_{g,t} = d_{g,t}(\widetilde{a}_{g,t})$. Finally, following the literature, $G(a)$ follows a Pareto distribution $G(a) = \left[1 - (a_{min}/a)^{k_p}\right]$ where $k_p > \varepsilon - 1$. This functional form implies that we can write $\widetilde{a}_{r,t} = \widetilde{a}_{g,t} \left[\frac{\overline{a}_t^{k_p-(\varepsilon-1)} - (a_{min})^{k_p-(\varepsilon-1)}}{\overline{a}_t^{k_p} - (a_{min})^{k_p}}\right]^{\frac{1}{\varepsilon-1}} a_{min}$ and $\widetilde{a}_{g,t} = \left(\frac{k_p}{k_p-(\varepsilon-1)}\right)^{\frac{1}{\varepsilon-1}} \overline{a}_t$.

3.1.3 Energy Production

To introduce green technology adoption in the energy sector, we adopt the endogenous energy production structure and notation in Finkelstein Shapiro and Nuguer (2025). Following their description, we separate energy producers into two categories: a measure one of perfectly competitive intermediate-energy-input producers and a measure one of monopolistically competitive energy producers that use these energy inputs.

Energy producers have idiosyncratic productivity a_e, which they draw from a common distribution $G(a_e)$ with support $[a_{e,min}, \infty)$. The idiosyncratic productivity draw determines which intermediate energy inputs these energy producers adopt: those produced with a regular (r) energy technology that uses regular physical capital and generates harmful emissions as a byproduct, or those produced with a green (g) energy technology that uses green physical capital and does not generate emissions. Similar to the goods-production structure, emissions generated by the production of r intermediate energy inputs are taxed, but the burden stemming from this tax can be lowered by incurring emissions-abatement expenditures. In contrast, emissions-free g intermediate energy inputs do not face carbon taxes but their adoption by energy producers requires incurring a fixed cost. As was the case with goods-producing

firms, energy producers' choice over which category of intermediate energy inputs to use is equivalent to a choice between adopting a polluting or green energy technology. Prices in the energy sector are fully flexible.

Total Energy Production and Energy Categories Let $E_t = \left(\int_{a^e_{min}}^{\infty} e_t(a_e)^{\frac{\varepsilon_e-1}{\varepsilon_e}} da_e\right)^{\frac{\varepsilon_e}{\varepsilon_e-1}}$ be the total amount of energy production, where $e_t(a_e)$ is the energy produced by energy producer a_e and $\varepsilon_e > 1$, and let $P_{e,t} = \left(\int_{a^e_{min}}^{\infty} p_{e,t}(a_e)^{1-\varepsilon_e} da_e\right)^{\frac{1}{1-\varepsilon_e}}$ be the nominal price of that energy, where $p_{e,t}(a_e)$ denotes the nominal price of energy producer a_e's output. Define $\rho^r_{e,t}(a_e) = p^r_{e,t}(a_e)/P_t$ as the relative price of energy associated with the r energy technology, $\rho^g_{e,t}(a_e) = p^g_{e,t}(a_e)/P_t$ as the relative price of energy associated with the g energy technology, and $\rho_{e,t} \equiv P_{e,t}/P_t$ as the relative price of total energy. Then, we can express the relative price of total energy as $\rho_{e,t} = \left(\int_{a^e_{min}}^{\overline{a}_{e,t}} \rho^r_{e,t}(a_e)^{1-\varepsilon_e} da_e + \int_{\overline{a}_{e,t}}^{\infty} \rho^g_{e,t}(a_e)^{1-\varepsilon_e} da_e\right)^{\frac{1}{1-\varepsilon_e}}$, where $\overline{a}_{e,t}$ is the endogenous idiosyncratic productivity threshold above which energy producer a_e adopts the g technology. Denoting by $e^j_t(a_e)$ the energy produced by energy producer a_e with energy technology $j \in \{r, g\}$, the demand for energy produced with energy technology j is $e^j_t(a_e) = \left(\rho^j_{e,t}(a_e)/\rho_{e,t}\right)^{-\varepsilon_e} E_t$.

Intermediate Energy Inputs Real profits associated with the production of intermediate energy inputs are

$$\Pi_{e,t} = \left[mc^r_{e,t} D(x_t) z^r_{e,t} k^r_{e,t} - r_{k,t} k^r_{e,t} - \tau_{e,t} em_{e,t} - \Gamma_{e,t}\right] + \left[mc^g_{e,t} D(x_t) z^g_{e,t} k^g_{e,t} - r^g_{k,t} k^g_{e,t}\right],$$

where $mc^j_{e,t}$, $z^j_{e,t}$, and $k^j_{e,t}$ denote, respectively, the real price of intermediate energy inputs, exogenous sectoral productivity, and physical capital in intermediate-energy-input category $j \in \{r, g\}$. Emissions from producing intermediate energy inputs with the r technology are given by $em_{e,t} = (1 - \mu_{e,t}) D(x_t) z^r_{e,t} k^r_{e,t}$, where $\mu_{e,t}$ is the endogenous abatement rate and $\tau_{e,t} \geq 0$ is the carbon tax on energy-related emissions. The total abatement cost is $\Gamma_{e,t} = \gamma \mu^{\eta}_{e,t} D(x_t) z^r_{e,t} k^r_{e,t}$, with $\gamma > 0$ and $\eta > 1$, where $\mu_{e,t}$ is the endogenous abatement rate (Finkelstein Shapiro and Nuguer, 2025).

The optimal demand for capital used to produce intermediate energy inputs with the r technology is

$$D(x_t) mc^r_{e,t} z^r_{e,t} = r_{k,t} + \left[\tau_{e,t}(1 - \mu_{e,t}) + \mu^{\eta}_{e,t}\right] D(x_t) z^r_{e,t}. \tag{10}$$

The optimal demand for capital used to produce intermediate energy inputs with the g technology is

$$D(x_t)mc^g_{e,t}z^g_{e,t} = r^g_{k,t}. \tag{11}$$

Finally, the optimal abatement rate is given by

$$\eta\gamma\mu^{\eta-1}_{e,t} = \tau_{e,t}. \tag{12}$$

Intuitively, producers of r energy intermediate inputs equate the marginal cost of abating their emissions to the marginal benefit, where the latter is given by the resource savings from not having to pay the carbon tax due to the marginal reduction in emissions associated with abatement.

Energy Producer Profits, Optimal Pricing, and Technology Adoption Choices The real profits of an energy producer a_e that uses intermediate energy inputs produced with the r energy technology (and therefore adopts the r technology) are

$$d^r_{e,t}(a_e) = \left[\rho^r_{e,t}(a_e) - \frac{mc^r_{e,t}}{a_e}\right] e_{r,t}(a_e),$$

while the real profits of an energy producer a_e that uses intermediate energy inputs produced with the g energy technology (and therefore adopts the g technology) are

$$d^g_{e,t}(a_e) = \left[\rho^g_{e,t}(a_e) - \frac{mc^g_{e,t}}{a_e}\right] e_{g,t}(a_e) - (1-\zeta_{e,t})\,\varphi_e mc^g_{e,t},$$

where $\varphi_e mc^g_{e,t}$ is the fixed cost associated with adopting the g energy technology, with $\varphi_e > 0$, and $0 \leq \zeta_{e,t} < 1$ is the subsidy rate on green-energy technology adoption. Recalling that the demand function for an energy producer that adopts energy technology $j \in \{r, g\}$ is $e^j_t(a_e) = \left(\rho^j_{e,t}(a_e)/\rho_{e,t}\right)^{-\varepsilon_e} E_t$, the optimal relative energy prices associated with energy technologies r and g are $\rho^r_{e,t}(a_e) = [\varepsilon_e/(\varepsilon_e - 1)]\left(mc^r_{e,t}/a_e\right)$ and $\rho^g_{e,t}(a_e) = [\varepsilon_e/(\varepsilon_e - 1)]\left(mc^g_{e,t}/a_e\right)$, respectively. Finally, the endogenous threshold above which an energy producer decides to adopt the g energy technology, $\overline{a}_{e,t}$, is implicitly pinned down by condition $d^r_{e,t}(\overline{a}_{e,t}) = d^g_{e,t}(\overline{a}_{e,t})$. That is, at the endogenous threshold $\overline{a}_{e,t}$, energy producer a_e is indifferent between the two

energy technologies.

Energy Producer Averages Similar to the goods-production structure, the average idiosyncratic productivities of energy producers using the r and g energy technologies, respectively, are $\widetilde{a}^r_{e,t} = \left[\frac{1}{G(\overline{a}_{e,t})}\int_{a^e_{min}}^{\overline{a}_{e,t}} a_e^{\varepsilon_e-1}dG(a_e)\right]^{\frac{1}{\varepsilon_e-1}}$ and $\widetilde{a}^g_{e,t} = \left[\left(\frac{1}{1-G(\overline{a}_{e,t})}\right)\int_{\overline{a}_{e,t}}^{\infty} a_e^{\varepsilon_e-1}dG(a_e)\right]^{\frac{1}{\varepsilon_e-1}}$. We can also define $\widetilde{e}_{r,t} = e_{r,t}(\widetilde{a}^r_{e,t})$, $\widetilde{e}_{g,t} = e_{g,t}(\widetilde{a}^g_{e,t})$, $\widetilde{\rho}^r_{e,t} = \rho^r_{e,t}(\widetilde{a}^r_{e,t})$, $\widetilde{\rho}^g_{e,t} = \rho^g_{e,t}(\widetilde{a}^g_{e,t})$, and $\widetilde{d}^r_{e,t} = d^r_{e,t}(\widetilde{a}^r_{e,t})$ and $\widetilde{d}^g_{e,t} = d^g_{e,t}(\widetilde{a}^g_{e,t})$. Finally, we continue to assume that $G(a_e)$ follows a Pareto distribution: $G(a_e) = \left[1-\left(a^e_{min}/a_e\right)^{k^e_p}\right]$ where $k^e_p > \varepsilon_e - 1$. These functional forms imply that we can write $\widetilde{a}^r_{e,t} = \widetilde{a}^g_{e,t}\left[\frac{\overline{a}_{e,t}^{k^e_p-(\varepsilon_e-1)}-\left(a^e_{min}\right)^{k^e_p-(\varepsilon_e-1)}}{\overline{a}_{e,t}^{k^e_p}-\left(a^e_{min}\right)^{k^e_p}}\right]^{\frac{1}{\varepsilon_e-1}} a^e_{min}$ and $\widetilde{a}^g_{e,t} = \left[\frac{k^e_p}{k^e_p-(\varepsilon_e-1)}\right]^{\frac{1}{\varepsilon_e-1}}\overline{a}_{e,t}$.

3.2 Households

Households own all goods-producing firms, energy producers, and their respective intermediate-input suppliers. They choose consumption c_t, bond holdings b_{t+1}, labor supply $n_{r,t}$ and $n_{g,t}$, and regular and green capital accumulation k_{t+1} and $k^g_{e,t+1}$ to maximize expected lifetime utility $\mathbb{E}_0\sum_{t=0}^{\infty}\beta^t\left[\frac{c_t^{1-\sigma_c}}{1-\sigma_c}-\kappa\frac{(n_{r,t}+n_{g,t})^{1+\frac{1}{\chi}}}{1+\frac{1}{\chi}}\right]$ subject to

$$\begin{aligned} &c_t + b_{t+1} + \left[k_{t+1} - (1-\delta_k)\,k_t\right] + \left[k^g_{e,t+1} - (1-\delta_g)\,k^g_{e,t}\right] \\ &= \frac{R_{t-1}}{1+\pi_t}b_t + w_{r,t}n_{r,t} + w_{g,t}n_{g,t} + r_{k,t}k_t + r^g_{k,t}k^g_{e,t} + \widetilde{d}_t + \widetilde{d}_{e,t} + \Pi_t + \Pi_{e,t} + T_t, \end{aligned}$$

where $\sigma_c, \kappa, \chi > 0$, $0 < \delta_k < 1$ and $0 < \delta_g < 1$ are the exogenous physical capital depreciation rates, R_{t-1} is the gross nominal interest rate, $1+\pi_t \equiv P_t/P_{t-1}$ is the gross core CPI inflation rate, $\widetilde{d}_t \equiv N_{r,t}\widetilde{d}_{r,t} + N_{g,t}\widetilde{d}_{g,t}$ are real average firm profits, $\widetilde{d}_{e,t} \equiv G(\overline{a}_{e,t})\widetilde{d}^r_{e,t} + \left[1-G(\overline{a}_{e,t})\right]\widetilde{d}^g_{e,t}$ are real aggregate energy-producer profits, and T_t are lump-sum transfers.

The first-order conditions deliver standard labor supply conditions $\kappa\left(n_{r,t}+n_{g,t}\right)^{1/\chi} = w_{j,t}c_t^{-\sigma_c}$ for $j \in \{r, g\}$, an optimal consumption-savings condition $1 = \mathbb{E}_t\Xi_{t+1|t}\left[R_t/\left(1+\pi_{t+1}\right)\right]$, and standard capital Euler equations for regular capital and green capital

$$1 = \mathbb{E}_t\Xi_{t+1|t}\left[r_{k,t+1} + (1-\delta_k)\right] \quad \text{and} \quad 1 = \mathbb{E}_t\Xi_{t+1|t}\left[r^g_{k,t+1} + (1-\delta_g)\right], \tag{13}$$

where $\Xi_{t+1|t} \equiv \beta\mathbf{u}_{c,t+1}/\mathbf{u}_{c,t}$ is the household's stochastic discount factor.

3.3 Government Budget Constraint and Technology-Adoption Subsidy Rates

Total revenue from carbon taxation is $(\tau_{f,t} em_{f,t} + \tau_{e,t} em_{e,t})$. This revenue is used to subsidize green technology adoption in the production of energy and goods and as lump-sum transfers to the household. Then, the government budget constraint is

$$T_t + \zeta_{g,t} \varphi_f mc_{g,t} N_{g,t} + \zeta_{e,t} \varphi_e mc^g_{e,t} \left[1 - G(\overline{a}_{e,t})\right] = \tau_{f,t} em_{f,t} + \tau_{e,t} em_{e,t}. \tag{14}$$

We assume that an exogenous fraction $0 \leq \omega^e_g \leq 1$ of the revenue from the carbon tax in the energy sector is used to finance the subsidy on green technology adoption in the goods production sector and an exogenous fraction $0 \leq \omega^e_e \leq 1$ of that same revenue is used to finance the subsidy on green technology adoption in the energy sector. Similarly, we assume that an exogenous fraction $0 \leq \omega^r_g \leq 1$ of the revenue from the carbon tax on goods-producing firms is used to finance the subsidy on green technology adoption in the goods production sector and an exogenous fraction $0 \leq \omega^r_e \leq 1$ of that same revenue is used to finance the subsidy on green technology adoption in the energy sector. Then, the subsidy rates $\zeta_{g,t}$ and $\zeta_{e,t}$ are determined by

$$\zeta_{g,t} \varphi_f mc_{g,t} N_{g,t} = \omega^r_g \tau_{f,t} em_{f,t} + \omega^e_g \tau_{e,t} em_{e,t}, \tag{15}$$

and

$$\zeta_{e,t} \varphi_e mc^g_{e,t} \left[1 - G(\overline{a}_{e,t})\right] = \omega^r_e \tau_{f,t} em_{f,t} + \omega^e_e \tau_{e,t} em_{e,t}, \tag{16}$$

where ω^e_g, ω^r_g, ω^r_e, and ω^e_r are calibrated to capture particular recycling schemes for the revenue from carbon taxes.

3.4 Symmetric Equilibrium and Market Clearing

Total Stock of Pollution Emissions from the production of polluting intermediate goods and intermediate energy inputs contribute to the economy's total pollution stock $x_t = \rho_x x_{t-1} + [em_{f,t} + em_{e,t}] + em^{row}_t$, where $0 < \rho_x < 1$ is the persistence of the pollution stock and em^{row}_t are exogenous emissions from the rest of the world.

Symmetric Equilibrium and Market Clearing Focusing on a symmetric equilibrium (Ghironi and Melitz, 2005; Bilbiie *et al.*, 2012), market clearing in goods production is given by

$$D(x_t)z_{r,t}H(n_{r,t},k_{r,t},\mathbf{e}_{r,t}) = N_{r,t}\left(\frac{\widetilde{y}_{r,t}}{\widetilde{a}_{r,t}}\right) \quad \text{and} \quad D(x_t)z_{g,t}F(n_{g,t},k_{g,t},\mathbf{e}_{g,t}) = N_{g,t}\left(\frac{\widetilde{y}_{g,t}}{\widetilde{a}_{g,t}}\right). \tag{17}$$

Similarly, market clearing in energy production is given by

$$D(x_t)z^r_{e,t}k^r_{e,t} = G(\overline{a}_{e,t})\left(\frac{\widetilde{e}_{r,t}}{\widetilde{a}^r_{e,t}}\right) \quad \text{and} \quad D(x_t)z^g_{e,t}k^g_{e,t} = [1-G(\overline{a}_{e,t})]\left(\frac{\widetilde{e}_{g,t}}{\widetilde{a}^g_{e,t}}\right). \tag{18}$$

Moreover, we can express total energy production and the relative price of total energy as follows:

$$E_t = \left\{G(\overline{a}_{e,t})\widetilde{e}_{r,t}^{\frac{\varepsilon_e-1}{\varepsilon_e}} + [1-G(\overline{a}_{e,t})]\,\widetilde{e}_{g,t}^{\frac{\varepsilon_e-1}{\varepsilon_e}}\right\}^{\frac{\varepsilon_e}{\varepsilon_e-1}}, \tag{19}$$

and

$$\rho_{e,t} = \left\{G(\overline{a}_{e,t})\left(\widetilde{\rho}^r_{e,t}\right)^{1-\varepsilon_e} + [1-G(\overline{a}_{e,t})]\left(\widetilde{\rho}^g_{e,t}\right)^{1-\varepsilon_e}\right\}^{\frac{1}{1-\varepsilon_e}}, \tag{20}$$

where recall that $G(\overline{a}_{e,t})$ is an endogenous object. Market clearing in the energy and physical capital markets is such that $E_t = e_{r,t} + e_{g,t}$ and $k_t = k_{r,t} + k_{g,t} + k^r_{e,t}$. Symmetry also allows us to characterize the total cost of price adjustments in the goods-producing sector, Φ_t. Specifically, similar to Bilbiie *et al.* (2007), the total resource cost of price adjustment is

$$\Phi_t = \frac{\nu_r}{2}\left[\frac{\widetilde{\rho}_{r,t}}{\widetilde{\rho}_{r,t-1}}(1+\pi_t)-1\right]^2\widetilde{\rho}_{r,t}\widetilde{y}_{r,t}N_{r,t} + \frac{\nu_g}{2}\left[\frac{\widetilde{\rho}_{g,t}}{\widetilde{\rho}_{g,t-1}}(1+\pi_t)-1\right]^2\widetilde{\rho}_{g,t}\widetilde{y}_{g,t}N_{g,t}.$$

Resource Constraint The resource constraint of the economy is given by

$$\begin{aligned} Y_t =& c_t + [k_{t+1} - (1-\delta_k)\,k_t] + \left[k^g_{e,t+1} - (1-\delta_g)\,k^g_{e,t}\right] \\ &+ \varphi_f mc_{g,t}N_{g,t} + \varphi_e mc^g_{e,t}\,[1-G(\overline{a}_{e,t})] + \Gamma_{r,t} + \Gamma_{e,t} + \Phi_t, \end{aligned} \tag{21}$$

where the second line of expression (21) includes the costs of green technology adoption, emissions abatement of firms and energy producers, and the resource cost of price adjustments in the goods-producing sector.

3.5 Monetary Policy

We assume a standard Taylor Rule whereby the nominal interest rate responds to deviations in total output and gross headline inflation from trend:

$$\frac{R_t}{R} = \left(\frac{R_{t-1}}{R}\right)^{\rho_R} \left[\left(\frac{1+\pi_t^h}{1+\pi^h}\right)^{\phi_\pi} \left(\frac{Y_t}{Y}\right)^{\phi_y}\right]^{1-\rho_R}, \tag{22}$$

where $0 < \rho_R < 1$ dictates the degree of interest rate smoothing, $\phi_y > 0$ is the weight on total output deviations from trend, $\phi_\pi > 0$ is the weight on gross-headline-inflation deviations from trend, and variables without subscripts denote those same variables in steady state, where gross headline inflation is defined as $(1+\pi_t^h) = (1+\pi_t)^{\nu_\pi}(1+\pi_t^e)^{1-\nu_\pi}$, where $(1+\pi_t^e)$ denotes gross energy-price inflation and $0 < \nu_\pi < 1$ dictates the weight of core inflation on headline inflation.

4 Quantitative Analysis

To quantitatively analyze the effects of carbon taxation on inflation dynamics along the transition path to a lower-carbon environment, we calibrate the model to EU averages. Given our focus on dynamics and to discipline the model, we introduce capital adjustment costs associated with the accumulation of regular and green capital, and the adjustment in the demand for capital by goods-producing g firms. Specifically, we assume that the accumulation of regular capital and capital used by g energy producers entails convex adjustment costs $\frac{\varphi_k}{2}\left(\frac{k_{t+1}-k_t}{k}\right)^2$ and $\frac{\varphi_k}{2}\left(\frac{k^g_{e,t+1}-k^g_{e,t}}{k^g_e}\right)^2$, respectively. In addition, the production of intermediate goods used by goods-producing g firms entails capital adjustment costs $\frac{\varphi_k}{2}\left(\frac{k_{g,t}-k_{gt-1}}{k_g}\right)^2$, where we assume a common adjustment cost parameter $\varphi_k > 0$. One way to interpret the adjustment cost for the production of intermediate goods for goods-producing g firms is as an extra cost required to adapt regular capital for use in the less energy intensive production technology. More broadly, this adjustment cost is important for limiting the speed of reallocation of capital away from firms and energy producers that generate emissions and into firms that adopt green technologies, which shapes the quantitative response of total output along the transition path to a lower-emissions equilibrium and allows us to better discipline our quantitative analysis.

4.1 Baseline Calibration: Average EU Economy

Parameter Values from Existing Literature The time period is a quarter. The energy shares in production used in the literature typically range between 0.03 and 0.07. We set $\alpha_{e_r} = 0.07$ and $\alpha_{e_g} = 0.03$ to reflect the fact that the g technology in the model not only has zero emissions but also entails a lower energy share in production that reflects greater energy efficiency. We set $\alpha_r = \alpha_g = 0.36$, a standard assumption in the macro literature that, combined with the values for α_{e_r} and α_{e_g}, delivers a weighted average labor share of 0.58 that is in line with EU data. The subjective discount factor is $\beta = 0.99$, the physical capital depreciation rate is $\delta_k = 0.025$, the green capital depreciation rate is $\delta_g = 0.02$, the household relative risk aversion parameter is $\sigma_c = 2$, and the inverse elasticity of labor supply is $\chi = 4$. We also normalize the levels of exogenous productivity for goods-producing g firms and both r and g energy producers so that $z_g = z_e^r = z_e^g = 1$. Following related literature that studies macroeconomic dynamics in the EU, we set the Rotemberg price adjustment parameters $\nu_r = \nu_g = 80$, the interest-smoothing parameter in the Taylor rule $\rho_R = 0.80$, and the Taylor rule coefficients $\phi_\pi = 2$ and $\phi_y = 0.2$ (Cacciatore *et al.*, 2016). We set $\nu_\pi = 0.11$, which corresponds to the weight of energy in the harmonized CPI for EU economies. Following the macro literature, as a baseline we set $\varepsilon = \varepsilon_e = 3.4$. Also, without loss of generality, we set $a_{min} = a_{min}^e = 1$, a standard normalization in the literature.

Turning to the environmental parameters, we set the convexity of the abatement cost functions $\eta = 2.8$ (Nordhaus, 2008), and the weight on abatement costs $\gamma = 0.05$, all of which are consistent with macro-climate models (Heutel, 2012). Finally, based on the latest data from the European Commission, we set the shares of carbon-tax revenue from the energy sector devoted to subsidizing green technology adoption in the goods-producing and energy sectors to $\omega_g^e = \omega_e^e = 0.50$ and the shares of carbon-tax revenue from the goods-producing sector devoted to subsidizing green technology adoption in both the goods-producing and energy sectors to $\omega_g^r = \omega_e^r = 0.25$. The remaining carbon-tax revenue is rebated lump-sum back to the household.[7]

[7] Introducing exogenous government spending unrelated to green-technology subsidies and using the remaining carbon-tax revenue to finance these government expenditures does not change our main conclusions.

Calibrated Parameters As a baseline, we assume the same carbon tax in both sectors, $\tau_e = \tau_f$. Using averages for the European Union for year 2019, we calibrate the remaining parameters $D_0, \varphi_e, \varphi_f, e^{row}, \kappa, \tau_f (= \tau_e), \xi_e, z_r$, and $\bar{x}$ to match the following targets: a ratio of pollution damages to GDP of 0.0026 (Annicchiarico *et al.*, 2018), a share of polluting energy in total energy of 75 percent (Our World in Data), an effective fixed cost of adopting the green technology in the goods-producing sector of 50 percent of the price of energy (consistent with estimated avoidance costs associated with energy-savings projects from European Court of Auditors 2022 and Eurostat data), a share of domestic emissions in global emissions of 10 percent (Our World in Data), an average share of time devoted to labor of 0.33 (a standard target in the macro literature), a carbon tax on energy that represents roughly \$30 per unit of emissions (on a quarterly basis, roughly 0.25 percent of average EU GDP per capita), a share of emissions from energy in total emissions of 0.50 (Our World in Data), a share of goods-producing g firms of 40 percent (roughly consistent with the share of firms that invest in energy efficiency and other green technologies per data from the European Investment Bank), and a ratio of pre-industrial atmospheric concentration of carbon dioxide to current atmospheric concentration of carbon dioxide of 0.6983 (Annicchiarico *et al.*, 2018).

Finally, we calibrate the capital adjustment cost parameter φ_k and the Pareto distribution parameters $k_p = k_p^e$ so that the model matches the response of gross headline inflation and total output in the first year after a one-time increase in the carbon tax in the goods-producing sector of \$40 per unit of emissions relative to its baseline level. This quantitative increase in the carbon tax is consistent with facts on national carbon taxes in the EU presented in Section 2 and with related empirical analyses in both Metcalf and Stock (2023) and Konradt and Weder di Mauro (2023). The resulting parameter values are presented at the bottom of Table 1, which summarizes the parameters from the literature and the calibrated parameter values. Figure A4 in Appendix A.4 shows how the model matches the path of headline inflation and real GDP in the first year after the carbon-tax increase.

Tab. 1 Parameter Values—Benchmark Model

Parameter	Value	Parameter Description	Source
Parameters from Literature and Baseline Parameter Values			
α_r	0.36	Capital share, r goods-firm	Macro literature
α_g	0.36	Capital share, g goods-firm	Macro literature
α_{e_r}	0.07	Energy share, r goods-firm	Baseline assumption
α_{e_g}	0.03	Energy share, g goods-firm	Baseline assumption
a_{min}, a^e_{min}	1	Min. idiosyncratic prod., firms and energy	Normalization
β	0.99	Discount factor	Macro literature
δ_k	0.025	Reg. capital depreciation rate	Macro literature
δ_g	0.020	Green capital depreciation rate	Baseline assumption
χ	4	Inverse elasticity of labor supply	Macro literature
ε, ε_e	3.4	Elast. substit., firms and energy producers	Macro literature
η_r, η_e	2.8	Elasticity of emissions abatement	Nordhaus (2008)
ν_π	0.89	Core inflation weight in headline inflation	European Central Bank
γ	0.05	Weight abatement cost function	Heutel (2012)
ω^e_g	0.50	τ_e share of revenue used for φ_g subsidy	European Commission 2021
ω^e_e	0.50	τ_e share of revenue used for φ_e subsidy	European Commission 2021
ω^r_g	0.25	τ_r share of revenue used for φ_g subsidy	European Commission 2021
ω^r_e	0.25	τ_r share of revenue used for φ_e subsidy	European Commission 2021
ϕ_π	2	Headline inflation, Taylor Rule	Cacciatore *et al.* (2016)
ϕ_y	0.2	Output, Taylor Rule	Cacciatore *et al.* (2016)
ρ_r	0.80	Interest rate smoothing, Taylor Rule	Cacciatore *et al.* (2016)
ρ_x	0.9979	Persistence of pollution stock	Heutel (2012)
σ_c	2	CRRA parameter	Macro literature
ξ_r	1	Scaling parameter in em_r	Normalization
z_g	1	Exog. sectoral productivity, g firms	Normalization
z^r_e	1	Exog. sectoral productivity, r energy prod.	Normalization
z^g_e	1	Exog. sectoral productivity, g energy prod.	Normalization
Calibrated Baseline Parameter Values			
D_0	0.000001848	Damages function parameter	Pollution damages/GDP = 0.0026
φ_e	0.452	g tech. adoption fixed cost, energy prod.	Share of r energy prod. = 0.75
φ_f	0.162	g tech. adoption fixed cost, prod. firms	$\varphi_g mc_g = 0.50\rho_e$
e^{row}	8.799	Emissions rest of world	$em^{row}/(em + em^{row}) = 0.90$
κ	3.255	Labor disutility param.	$n_r + n_g = 0.33$
k_p, k^e_p	13.6	Pareto shape param. $k_p > \varepsilon - 1$	Year 1 inflation response to τ_f
φ_k	1	Adjustment cost parameter	Year 1 total output response to τ_f
τ_e	0.00227	Carbon tax on em_e	Carbon tax of \$30 per unit of em
τ_r	0.00227	Carbon tax on em_r	Baseline assumption: τ_e=τ_r
ξ_e	0.826	Scaling parameter in em_e	$em_e = 0.50em$
z_r	1.039	Exogenous sectoral productivity, r firms	$N_g = 0.40$
$\bar{x}$	3250.752	Pre-industrial pollution stock	$\bar{x} = 0.6983x$

4.2 Main Results: Benchmark Model

Long Run Effects from Carbon Taxation To understand the key factors that shape inflation dynamics along the transition path to a lower-carbon environment, it is useful to first consider the long run (steady-state) effects of increasing each carbon tax τ_f and τ_e separately. Following recent empirical studies on the macroeconomic effects of carbon taxes in the EU (Metcalf and Stock, 2023; Konradt and Weder di Mauro, 2023), for each scenario, we consider an increase in the carbon tax of \$40 relative to the baseline carbon-tax level.

Table 2 compares the steady-state outcomes of the two policy experiments. First consider column (1) of Table 2, which shows the impact of increasing the carbon tax τ_f on emissions generated by the subset of goods-producing firms that adopt the r technology while keeping the energy-sector carbon tax τ_e at its baseline level.

Raising τ_f by \$40 relative to its baseline level reduces emissions by 5.7 percent, increases total labor by 0.25 percent, and increases total output by almost 0.80 percent—a model outcome that is consistent with existing empirical studies showing that carbon taxes reduce emissions and have non-negative employment and output consequences (Metcalf and Stock, 2023). The carbon tax also increases real wages and leads to a shift away from polluting technologies and into green technologies. Indeed, the share of goods-producing firms and energy producers that adopt green technologies increase by 2.7 percentage points and 3.3 percentage points, respectively. The greater adoption of green technologies by energy producers increases the share of green energy by 5 percentage points, which exerts downward pressure on the price of energy and generates an equilibrium reduction in energy prices of almost 0.80 percent. The carbon tax leads to a small increase in consumption which, coupled with the increase in labor, delivers no change in household welfare. The output and welfare effects from increasing τ_f are broadly consistent with the results in Finkelstein Shapiro and Metcalf (2023) in the context of the U.S. and are explained by the same mechanism described in their framework: since goods-producing g firms are endogenously more productive than goods-producing r firms, the tax-induced endogenous increase in the share of goods-producing firms that adopt the g technology improves average firm productivity in the economy and leads to very mild though positive output and welfare effects while simultaneously reducing emissions.[8]

[8] While reducing emissions improves firms' and energy producers' productivity via reduced pollution damages—a reduction in the negative pollution externality—this mechanism is quantitatively negligible. Hold-

Turning to the effects of raising the carbon tax τ_e on emissions from the subset of energy producers that use the r technology, column (2) of Table 2 shows the impact of increasing τ_e by \$40 while keeping τ_f at its baseline level. The increase in τ_e has similar qualitative effects to those of τ_f, though the quantitative changes differ in non-trivial ways. In particular, compared to the increase in τ_f, increasing τ_e reduces emissions by almost twice as much (12 percent vs. 5.7 percent), raises the share of green energy producers and the share of green energy almost threefold and fourfold, respectively, but only increases total output by half (0.42 percent vs. 0.78 percent). The fact that total output does not increase as much is reflected in a negligible increase in consumption that, coupled with the same increase in labor, results in a slight fall in welfare.

More broadly, for the same quantitative changes in carbon taxes, a carbon tax on goods-producing firms that generate emissions as a byproduct of production delivers larger output gains but smaller reductions in emissions while the opposite is true for the carbon tax on energy producers that generate harmful emissions as a byproduct of production. The fact that carbon taxes on energy-related emissions have a smaller effect on output relative to carbon taxes on goods-related emissions is broadly consistent with the findings in Känzig and Konradt (2024) regarding the differential effects of the ETS (which primarily focuses on energy-related emissions) and national carbon taxes (which primarily focus on non-energy-related emissions) in the EU.

Anticipating our quantitative analysis of transitional dynamics and the response of inflation to carbon taxation along the transition path, we note that both carbon taxes generate an increase in the weighted effective marginal cost of goods-producing g firms and a reduction in the corresponding marginal cost for r firms, with the increase in τ_f generating quantitatively larger changes in these effective marginal costs compared to the increase in τ_e (see Table 2). This finding is important as it implies that, as the carbon tax leads to an increase in the share of goods-producing g firms, the weighted average effective marginal cost of production in the economy—a key factor that feeds into firms' prices and, in doing so, shapes inflation dynamics—becomes more heavily influenced by changes in the marginal-cost structure of g firms.

ing pollution damages fixed at their baseline level and increasing each of the carbon taxes as in Table 2 would still deliver a net increase in total output due to the policy-induced improvement in average firm productivity that stems from endogenous technology adoption in the goods sector.

Tab. 2 Long Run Effects of Increasing Each Carbon Tax by $40—Benchmark Model

	(1)	(2)
Carbon Tax Change	$\Delta\tau_f > 0$, $\Delta\tau_e = 0$	$\Delta\tau_f = 0$, $\Delta\tau_e > 0$
Variable	Percent Change Relative to Baseline	
Total Emissions	-5.695	-11.773
Total Output	0.782	0.415
Consumption	0.167	0.050
Capital Investment	1.376	0.418
Total Labor	0.250	0.253
Real Wage	0.398	0.164
Real Price of Energy	-0.795	1.567
Welfare Gain (% of Consumption)*	0.015	-0.104
Weighted Effective Marginal Cost, g Firms	7.541	3.780
Weighted Effective Marginal Cost, r Firms	-3.765	-1.922
	Percentage-Point Change Relative to Baseline	
Share of Goods-Producing g Firms	2.669	1.325
Abatement Rate μ_r	1.403	0.011
Abatement Rate μ_e	0.029	1.346
Share of Energy Producers using g Tech.	3.269	9.380
Share of Green Energy	5.022	17.081
Tax Revenue-Output Ratio	0.124	0.087

Notes: Values rounded to three decimal places. The weighted effective marginal cost for goods-producing firm $j \in \{r, g\}$ is defined as $N_j(mc_j/\widetilde{a}_j)$. *The welfare gain from the carbon tax Θ (expressed as a percent of steady-state consumption) is implicitly given by

$$\frac{\left[\left(1+\frac{\Theta}{100}\right)c^{base}\right]^{1-\sigma_c}}{1-\sigma_c} - \kappa\frac{\left(n_r^{base}+n_g^{base}\right)^{1+\frac{1}{\chi}}}{1+\frac{1}{\chi}} = \frac{(c^{\tau})^{1-\sigma_c}}{1-\sigma_c} - \kappa\frac{\left(n_r^{\tau}+n_g^{\tau}\right)^{1+\frac{1}{\chi}}}{1+\frac{1}{\chi}},$$

where we denote variables under the baseline scenario with superscript *base* and variables in the higher carbon tax equilibrium with superscript τ. Then, $\Theta > 0$ implies that the carbon tax generates a welfare gain while $\Theta < 0$ implies that the carbon tax generates a welfare loss.

Transition Path to a Lower-Emissions Equilibrium Figure 3 plots the *yearly* transition path of emissions, total output, gross core inflation, and gross headline inflation for the first five years after a one-time $40 increase in each of the carbon taxes.[9] The solid blue line shows the response to the increase τ_f while the dashed-dotted orange line shows the response to the increase in τ_e.

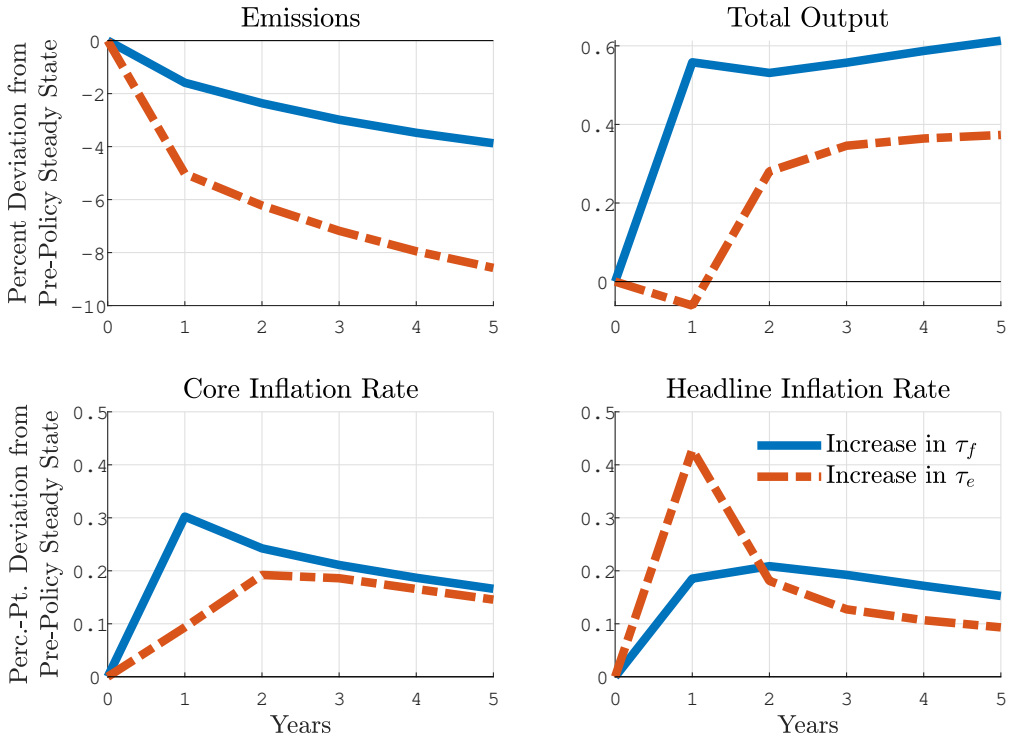
Consistent with the steady-state results in Table 2, the increase in the carbon tax on emissions from the energy sector τ_e generates a larger reduction in emissions and a smaller increase in total output compared to the increase in the carbon tax on emissions from the goods-producing sector τ_f. Turning to the response of inflation, τ_f leads to a larger increase

[9] We compute the transition path by solving the full non-linear model under perfect foresight (Juillard, 1996).

in core inflation in the first three years after the tax increase, but once we consider headline inflation, the sharp increase in the price of energy due to the increase in τ_e (not shown) dominates and leads to a larger spike in headline inflation in the first two years compared to the response under an increase in τ_f. While we do not explicitly model an emissions trading system (ETS) that primarily affects emissions in the energy sector and sectors that are more intensive in energy as is the case in the EU, τ_e in our framework can be broadly interpreted as mimicking the affects of the ETS on emissions reductions in energy-related sectors: an increase in τ_e increases the cost of generating emissions in the energy sector. In this sense, the fact that an increase in τ_f has a smaller effect on headline inflation compared to an increase in τ_e is broadly in line with empirical findings by Känzig and Konradt (2024) regarding the larger impact of the ETS relative to a national carbon tax on headline inflation in the EU.

As we illustrate in more detail below by focusing on the quarterly (as opposed to annual) transition path, the difference in the response of core inflation in the first three years stems primarily from the differential response of firms' effective marginal costs. In addition, we highlight how looking solely at the yearly change in these variables as opposed to a higher frequency masks important quantitative differences in the responses of total output and inflation in the first two years after the increase in carbon taxes.

Fig. 3 Yearly Transition Path of Emissions, Total Output, and Inflation in Response to a One-Time $40 Increase in Each Carbon Tax—Benchmark Model



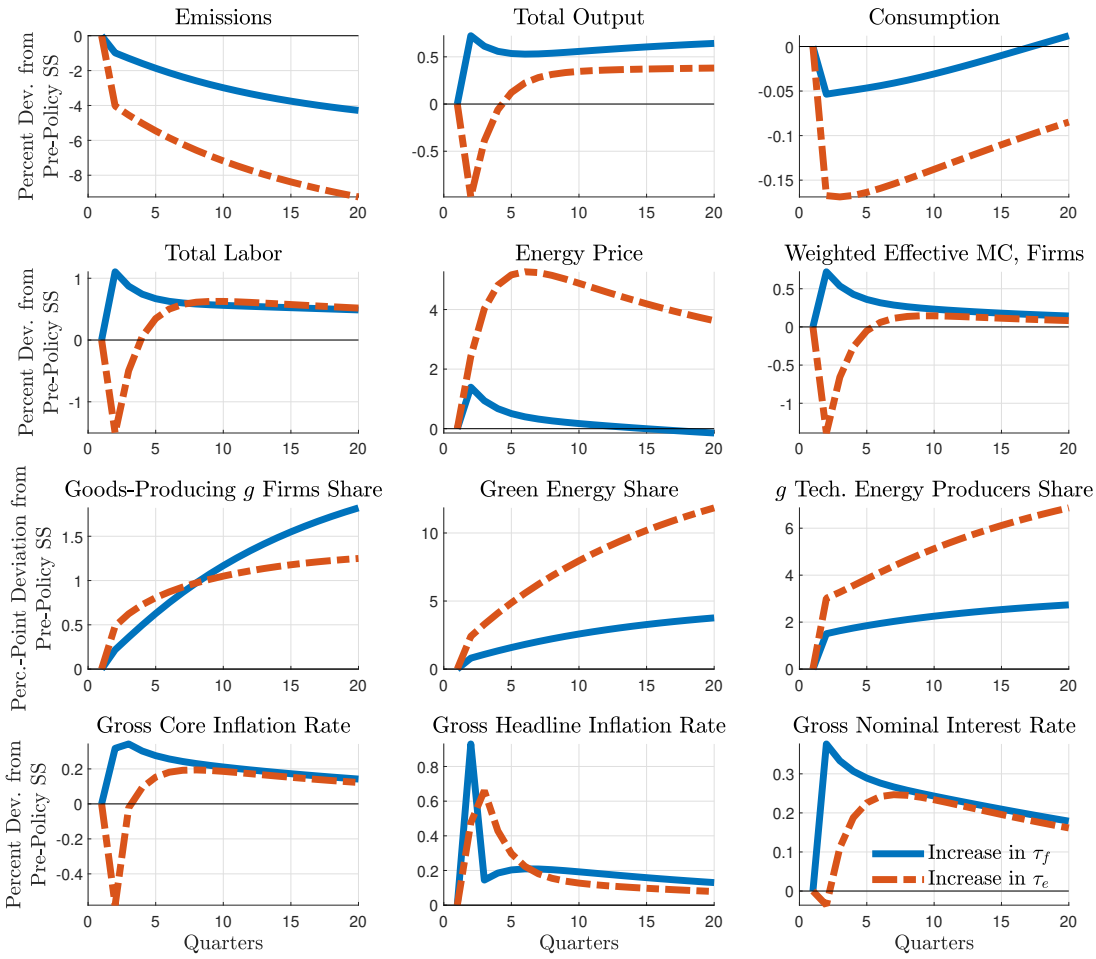
Notes: Core and headline inflation are expressed in annual terms.

Figure 4 plots the *quarterly* transition path of a wider set of variables for the two carbon-tax scenarios that includes the price of energy, the share of green energy, the shares of firms and energy producers that adopt green technologies, and a weighted measure of the economy's effective marginal cost of goods-producing firms defined as $N_{r,t}(mc_{r,t}/\widetilde{a}_{r,t}) + N_{g,t}(mc_{g,t}/\widetilde{a}_{g,t})$. Several results are worth highlighting. First, while the quarterly transition path of total output shows that an increase in τ_e generates a short-term reduction in output of almost 1 percent before rebounding and eventually surpassing its baseline steady-state level. To understand this result and its implications for inflation dynamics, note that the increase in τ_e leads to a sharp increase in the price of energy. Goods-producing firms initially respond by cutting back on labor demand, capital demand, and energy demand, which exerts downward pressure on input prices and eventually leads to an initial contraction in firms' marginal costs. The latter contributes to a drop in core inflation that, alongside the response of total output,

limits the extent to which the increase in energy prices puts upward pressure on headline inflation. The tax also incentivizes goods-producing firms to adopt the green technology (recall that adopting these technologies in the goods sector also entails adopting a technology with a lower energy share). As the share of goods-producing firms that adopt the green technology increases and input demand by these firms increases, the weighted effective marginal cost in the economy rebounds, thereby leading to a rebound in core inflation that, coupled with the sustained increase in energy prices, generates a short-term increase in headline inflation.

The response of the weighted effective marginal cost to an increase in τ_f is qualitatively different, with this measure unambiguously increasing in the first quarter after the carbon-tax increase. Both the increase in total output and the increase in the weighted marginal cost of goods-producing firms contribute to the increase in core inflation and, in turn, to the increase in headline inflation. Importantly, the differential response of both output and firms' marginal costs in the first quarter after the tax increase generates a larger increase in headline inflation compared to the corresponding change in response to an increase in τ_e. Critically, this is only apparent when we consider the quarterly transition path: as shown in Figure 3, if we consider the yearly path, the response of headline inflation to an increase in τ_e is almost twice as large as the response to an increase in τ_f in the first two years after the increase in the tax.

Fig. 4 Quarterly Transition Path in Response to $40 Increase in Each Carbon Tax—Benchmark Model



Note: Inflation and interest rates are expressed in annual terms. The weighted effective marginal cost (MC) is defined as $N_{r,t}(mc_{r,t}/\widetilde{a}_{r,t}) + N_{g,t}(mc_{g,t}/\widetilde{a}_{g,t})$.

Long Run Outcomes and Inflation Dynamics: Robustness Analysis Appendix A.5 presents results for a set of robustness experiments where we consider relevant alternative parameterizations of the benchmark model. Specifically, we look at versions of the benchmark model where: (1) goods-producing firms have the same energy share in production ($\alpha_{e_r} = \alpha_{e_g} = 0.05$ vs. the original $\alpha_{e_r} = 0.03$ and $\alpha_{e_g} = 0.07$, see Table A3 and Figure A8); (2) firms and energy producers have a higher elasticity of substitution ($\varepsilon = \varepsilon_e = 6$ vs. the original $\varepsilon = \varepsilon_e = 3.4$, see Table A4 and Figure A9); and (3) the baseline economy has a smaller baseline share of

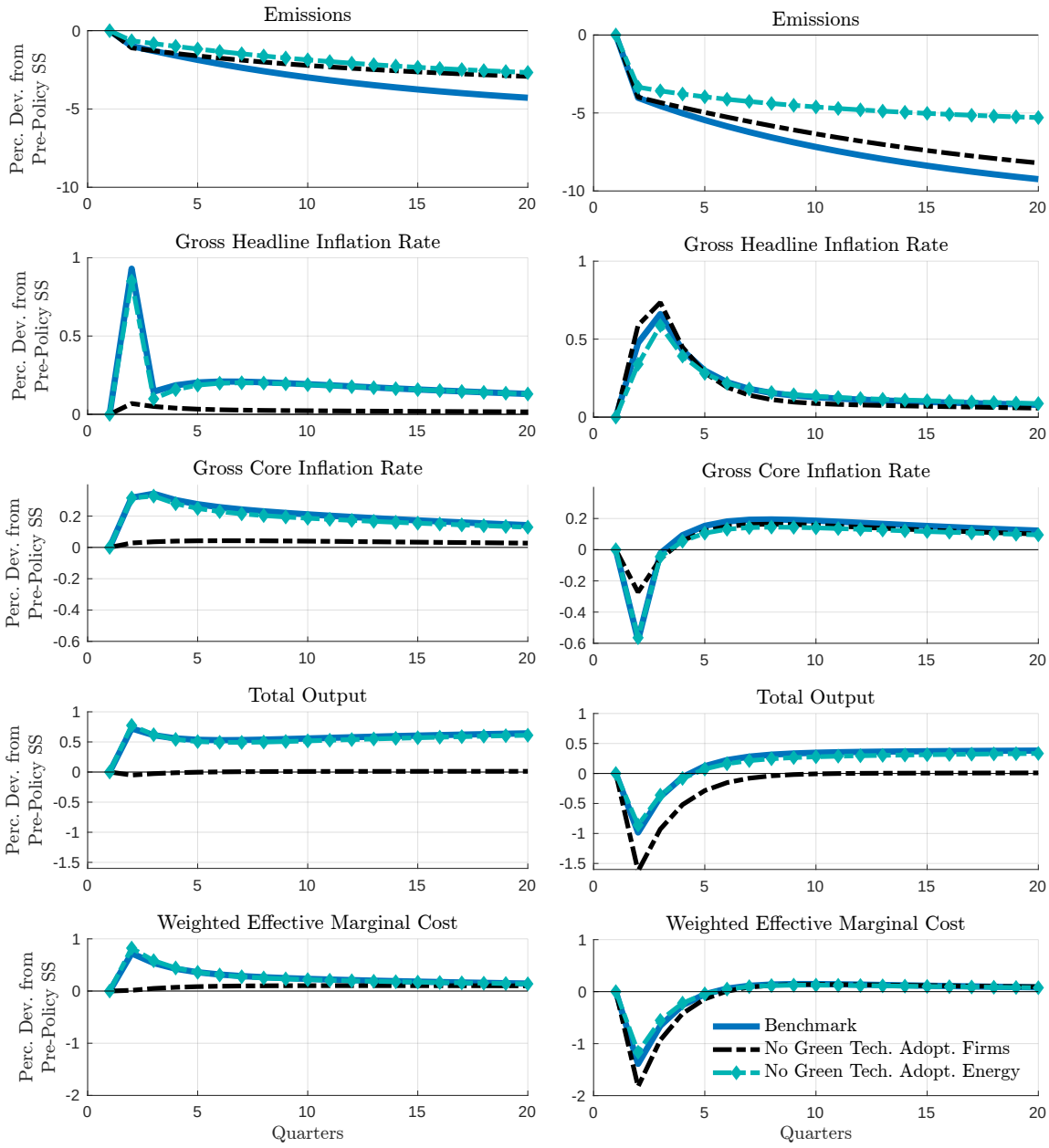
emissions from the energy sector (0.40 vs. the original 0.50, see Table A5 and Figure A10). The experiments in Appendix A.5 confirm that our main findings and conclusions are robust to alternative plausible parameterizations of the model.

Finally, recall that we calibrate the baseline model to capture broad features of carbon-tax revenue recycling in the EU, where a portion of the revenue is used to subdisize green technology adoption. For completeness, Figure A12 in the same Appendix compares the transition path in the benchmark model to the path in a version of the same model where all carbon tax revenue is rebated lump sum back to the household (that is, there are no subsidies to green technology adoption). The figure shows that devoting a portion of the revenue from carbon taxation generates smaller quantitative changes in inflation and output for the same increase in the two carbon taxes.

4.3 Inflation and Output Dynamics Amid Carbon Taxation: The Role of Green Technology Adoption

To understand the relevance of green technology adoption, we consider the same carbon-tax experiments above in separate variants of the benchmark model that abstract from endogenous green technology adoption in the goods-producing and energy sectors, respectively. That is, each of the model variants still features subsets of goods-producing firms and energy producers that either use the polluting technology or the green technology, but there is no choice over the adoption of green technologies in response to carbon taxes, only reallocation of inputs between fixed firm or energy-producer categories. For comparability, the baseline of each model variant has the exact same steady state as the benchmark model.

Fig. 5 Quarterly Transition Path in Response to $40 Increase in Each Carbon Tax—Benchmark Model vs. Model Variants without Green Technology Adoption



(a) Increase in τ_f **(b)** Increase in τ_e

Note: Perc. Dev. denotes percent deviations. Inflation and interest rates are expressed in annual terms. The weighted effective marginal cost (MC) is defined as $N_{r,t}(mc_{r,t}/\widetilde{a}_{r,t}) + N_{g,t}(mc_{g,t}/\widetilde{a}_{g,t})$.

Figure 5 plots the quarterly transition path of select variables for the benchmark model (solid blue line), a version of the benchmark model without green technology adoption in the

goods-producing sector (dashed-dotted black line), and a version of the benchmark model without green technology adoption in the energy sector (dash-dotted teal line with diamond markers). The response to an increase in τ_f is shown on the left column of the figure while the response to an increase in τ_e is shown on the right column of the same figure.[10]

Focusing on the response to an increase in τ_f first, abstracting from endogenous green technology adoption in either the goods sector or the energy sector implies that the same increase in the carbon tax generates a smaller reduction in emissions compared to the benchmark model. This result highlights the relevance of endogenous green-technology adoption in contributing to lower emissions amid carbon taxation. Comparing the response of headline inflation, core inflation, output, and the effective marginal costs of goods-producing firms illustrates the importance of green technology adoption in the goods sector: absent this margin, the increase in τ_f has virtually no effects on inflation or total output—a result that is inconsistent with the existing empirical evidence illustrated in Section 2.

Turning to the response to an increase in τ_e, similar to the increase in τ_f, abstracting from green technology adoption in either sector also significantly limits the reduction in emissions from the tax. However, green technology adoption in the energy sector appears to play a more significant role in reducing emissions when the carbon tax applies to emissions stemming from the energy sector. The stark differences in the evolution of emissions across model variants does not carry through to the paths of inflation and output: the benchmark model and its variant without green technology adoption in the energy sector deliver similar paths in response to an increase in τ_e. However, this is not the case when we abstract from green technology adoption in the goods sector. Indeed, the reduction in output and increase in headline inflation are greater in this model variant compared to the benchmark model. To understand this result, note that the absence of green technology adoption among goods-producing firms implies that, when the increase in τ_e raises energy prices, goods-producing firms are only able to adjust by reducing their demand for inputs and cannot switch technologies. As a result, the tax has a larger quantitative impact on the reduction in the weighted effective marginal cost in the economy. On its own, this larger reduction puts more downward pressure on core inflation compared to the benchmark model, but the larger output drop in the absence of green technology adoption by goods-producing firms counteracts the response of the marginal

[10] Tables A1 and A2 in Appendix A.4 show the corresponding steady-state effects of the carbon taxes.

cost, leading to a smaller equilibrium reduction in core inflation compared to the benchmark model. This smaller reduction implies that for a similar increase in energy prices, the increase in τ_e leads to a greater increase in headline inflation. More broadly, a comparison of the two columns in Figure 5 illustrates how green technology adoption in the goods sector matters significantly more for understanding the response of core and headline inflation to an increase in carbon taxes in the non-energy sector compared to green technology adoption in the energy sector, while the latter matters much more for the tax-induced reduction in emissions, even as the contribution of the goods sector and the energy sector to total emissions is evenly split.

5 Conclusion

We study the impact of carbon taxes on inflation dynamics along the transition path to an economy with lower carbon emissions with a focus on a margin that is at the core of a successful green transition that limits its economic costs: green technology adoption. First, using data for the European Union (EU), we highlight how the increase in national carbon taxes in the EU has been accompanied by an increase in the share of green energy, and how existing evidence using annual data suggests that national carbon taxes can lead to a persistent increase (albeit small) in real GDP and in inflation.

To shed light on how green technology adoption can shape these facts, we build a macro model with environmental externalities, nominal rigidities, and energy production where goods-producing firms and energy producers have a choice over green technology adoption. Calibrating the model to EU data and assuming evenly-split shares of goods-sector and energy-sector emissions in total emissions, we show that increasing the carbon tax on emissions from the goods sector leads to a smaller reduction in annual emissions, to a larger increase in annual GDP and core inflation, and to a smaller increase in annual headline inflation compared to an identical increase in the carbon tax on emissions from the energy sector. Additional analysis reveals that a focus on annual changes in key macro variables masks important short-run differences in the response of output and headline inflation within the first year of the carbon-tax changes. Moreover, using the model, we show that green technology adoption in the goods sector plays a critical role in shaping the quantitative response of inflation and output to a carbon tax on emissions in the goods sector and in rationalizing

the response of these variables to national carbon taxes in the data. More broadly, our work highlights the importance taking into account sectoral heterogeneity and green technology adoption for a better understanding of the impact of carbon taxes on emissions, output, and inflation dynamics along the transition path to a lower-carbon economy. While our quantitative analysis focused on the implications of an increase in carbon taxes without considering their optimality, a natural extension of our analysis would consider an explicit characterization of optimal carbon-tax and green-subsidy policies.

References

Acemoglu, D., Aghion, P., Bursztyn, L. and Hemous, D. (2012) The Environment and Directed Technical Change, *American Economic Review*, **102**, 131–166.

Adão, B., Narajabad, B. and Temzelides, T. (2024) Renewable technology adoption costs and economic growth, *Energy Economics*, **129**, 107255.

Annicchiarico, B., Correani, L. and Dio, F. D. (2018) Environmental Policy and Endogenous Market Structure, *Resource and Energy Economics*, **52**, 186–215.

Annicchiarico, B. and Diluiso, F. (2019) International Transmission of the Business Cycle and Environmental Policy, *Resource and Energy Economics*, **58**, 1–29.

Annicchiarico, B. and Dio, F. D. (2015) Environmental Policy and Macroeconomic Dynamics in a New Keynesian Model, *Journal of Environmental Economics and Management*, **69**, 1–21.

Annicchiarico, B., Dio, F. D. and Diluiso, F. (2024) Climate actions, Market Beliefs, and Monetary Policy, *Journal of Economic Behavior & Organization*, **218**, 176–208.

Bettarelli, L., Furceri, D., Pisano, L. and Pizzuto, P. (2025) Greenflation: Empirical Evidence Using Macro, Regional and Sectoral Data, *European Economic Review*, **174**.

Bilbiie, F. O., Ghironi, F. and Melitz, M. J. (2007) Monetary Policy and Business Cycles with Endogenous Entry and Product Variety, Working Paper 13199, National Bureau of Economic Research.

Bilbiie, F. O., Ghironi, F. and Melitz, M. J. (2012) Endogenous Entry, Product Variety, and Business Cycles, *Journal of Political Economy*, **120**, 304–345.

Cacciatore, M., Duval, R., Fiori, G. and Ghironi, F. (2016) Short-Term Pain for Long-Term Gain: Market Deregulation and Monetary Policy in Small Open Economies, *Journal of International Money and Finance*, **68**, 358–385.

Del Negro, M., di Giovanni, J. and Dogra, K. (2023) Is the Green Transition Inflationary?, Tech. rep., Federal Reserve Bank of New York Staff Reports No. 1053, February.

Diluiso, F., Annicchiarico, B., Kalkuhl, M. and Minx, J. C. (2021) Climate Actions and Macro-Financial Stability: The Role of Central Banks, *Journal of Environmental Economics and Management*, **110**, 102548.

Dissou, Y. and Karnizova, L. (2016) Emissions Cap or Emissions Tax? A Multi-Sector Business Cycle Analysis, *Journal of Environmental Economics and Management*, **79**, 169–188.

Finkelstein Shapiro, A. and Metcalf, G. E. (2023) The macroeconomic effects of a carbon tax to meet the U.S. Paris agreement target: The role of firm creation and technology adoption, *Journal of Public Economics*, **218**, 104800.

Finkelstein Shapiro, A. and Nuguer, V. (2025) Climate Policies, Labor Markets, and Macroeconomic Outcomes in Emerging Economies, Tech. rep.

Fischer, C. and Springborn, M. (2011) Emissions Targets and the Real Business Cycle: Intensity Targets Versus Caps or Taxes, *Journal of Environmental Economics and Management*, **62**, 352–366.

Gerarden, T. D., Reguant, M. and Xu, D. (2025) The Role of Industrial Policy in the Renewable Energy Sector, NBER Working Papers 34079, National Bureau of Economic Research, Inc.

Ghironi, F. and Melitz, M. J. (2005) International Trade and Macroeconomic Dynamics with Heterogeneous Firms, *The Quarterly Journal of Economics*, **120**, 865–915.

Hensel, J., Mangiante, G. and Moretti, L. (2024) Carbon Pricing and Inflation Expectations: Evidence from France, *Journal of Monetary Economics*, p. 103593.

Heutel, G. (2012) How Should Environmental Policy Respond to Business Cycles? Optimal Policy under Persistent Productivity Shocks, *Review of Economic Dynamics*, **15**, 244–264.

Jordà, O. (2005) Estimation and Inference of Impulse Responses by Local Projections, *American Economic Review*, **95**, 161–182.

Juillard, M. (1996) Dynare: A Program for the Resolution and Simulation of Dynamic Models with Forward Variables Through the Use of a Relaxation Algorithm, Tech. rep., CEPREMAP Working Papers (Couverture Orange) 9602, CEPREMAP.

Känzig, D. (2023) The Unequal Economic Consequences of Carbon Pricing, Tech. rep., National Bureau of Economic Research.

Känzig, D. and Konradt, M. (2024) Climate Policy and the Economy: Evidence from Europe's Carbon Pricing Initiatives, *IMF Economic Review*, **72**, 1081–1124.

Konradt, M., McGregor, T. and Toscani, F. (2024) Carbon Prices and Inflation in the Euro Area, Tech. rep., IMF Working Paper WP/24/31.

Konradt, M. and Weder di Mauro, B. (2023) Carbon Taxation and Greenflation: Evidence from Europe and Canada, *Journal of the European Economic Association*, p. jvad020.

Metcalf, G. E. and Stock, J. H. (2023) The Macroeconomic Impact of Europe's Carbon Taxes, *American Economic Journal: Macroeconomics*, **15**, 265–86.

Moessner, R. (2025) Effects of Carbon Pricing on Inflation, *Climate Policy*, pp. 1–14.

Nordhaus, W. (2008) *A Question of Balance: Weighing the Options on Global Warming Policies*, Yale University Press: New Haven and London.

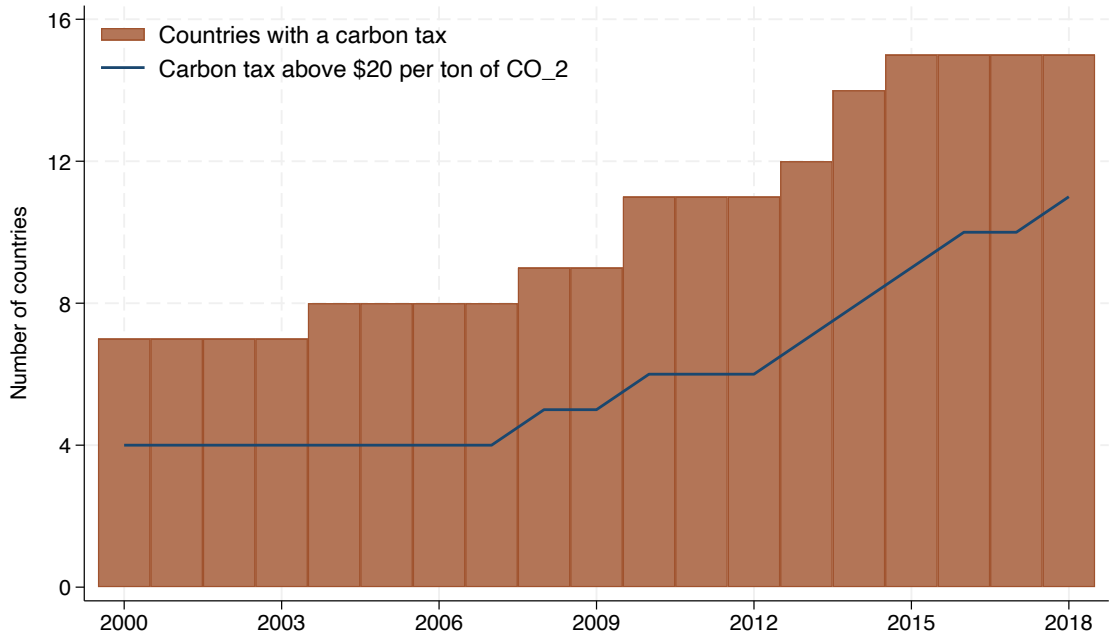
Olovsson, C. and Vestin, D. (2023) Greenflation?, Tech. rep., Sveriges Riksbank Working Paper Series 420.

Santabárbara, D. and Suárez-Varela, M. (2022) Carbon Pricing and Inflation Volatility, Tech. rep., Banco de España Documento de Trabajo No. 2231.

A Appendix – Not For Publication

A.1 Data

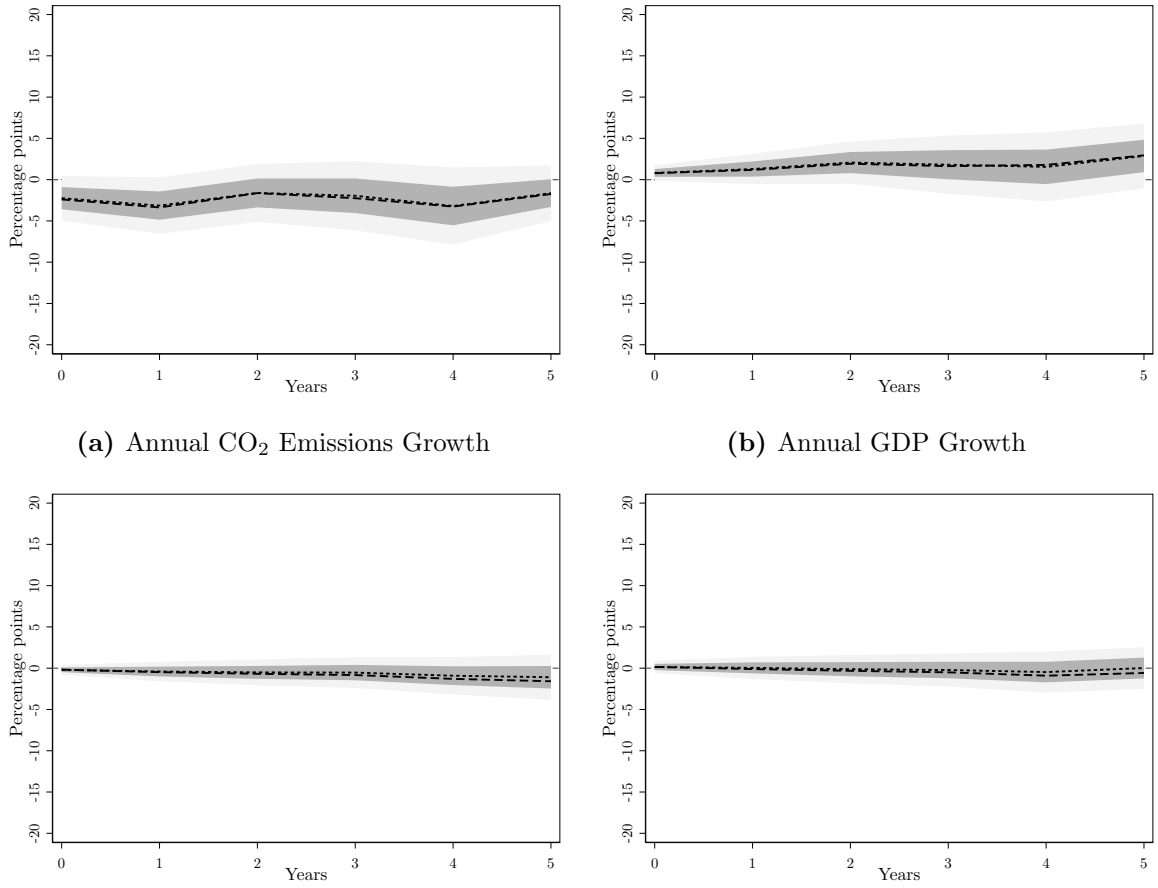
Fig. A1 Number of European Countries with a National Carbon Tax



Source: Konradt and Weder di Mauro (2023).

A.2 Local Projection Additional Exercises

Fig. A2 Impulse Responses to an Increase in USD $40 in the National Carbon Tax for EU+28: High-renewable-energy-share mean (average 1995-1999)



(a) Annual CO_2 Emissions Growth

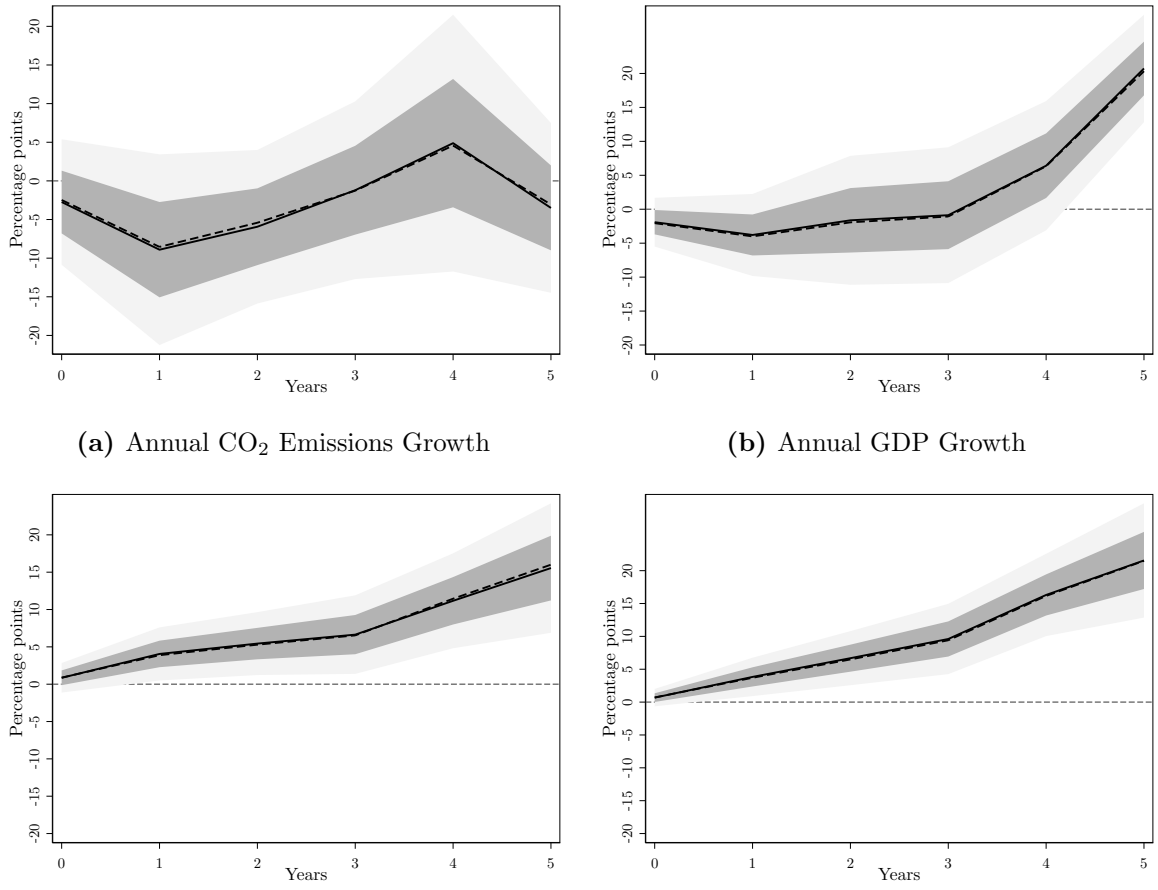
(b) Annual GDP Growth

(c) Annual Core Inflation

(d) Annual Headline Inflation

Source: Own calculation using data from Konradt and Weder di Mauro (2023) and Our World in Data.
Notes: The dashed lines correspond to the baseline specification in Konradt and Weder di Mauro (2023), which includes country and year fixed effects, real GDP growth, and the domestic monetary policy rate. The solid lines correspond to our specification (that is, Konradt and Weder di Mauro (2023) expanded to include the share of green energy). Shaded gray areas denote one standard deviation (light gray) and two standard deviations (dark gray) around the estimated response using our specification. The group of countries is the same in both specifications.

Fig. A3 Impulse Responses to an Increase in USD $40 in the National Carbon Tax for EU+28: Low-renewable-energy-share mean (average 1995-1999)



(a) Annual CO_2 Emissions Growth

(b) Annual GDP Growth

(c) Annual Core Inflation

(d) Annual Headline Inflation

Source: Own calculation using data from Konradt and Weder di Mauro (2023) and Our World in Data.
Notes: The dashed lines correspond to the baseline specification in Konradt and Weder di Mauro (2023), which includes country and year fixed effects, real GDP growth, and the domestic monetary policy rate. The solid lines correspond to our specification (that is, Konradt and Weder di Mauro (2023) expanded to include the share of green energy). Shaded gray areas denote one standard deviation (light gray) and two standard deviations (dark gray) around the estimated response using our specification. The group of countries is the same in both specifications.

A.3 Equilibrium Conditions: Benchmark Model

Taking the exogenous processes $\left\{z_{r,t}, z_{g,t}, z^r_{e,t}, z^g_{e,t}, em^{row}_t\right\}$ as given, the allocations and prices $\left\{Y_t, k_{r,t}, k_{g,t}, \mathbf{e}_{r,t}, \mathbf{e}_{g,t}, N_{r,t}, N_{g,t}, \overline{a}_t, \widetilde{d}_t, \widetilde{d}_{r,t}, \widetilde{d}_{g,t}, d_{r,t}(\overline{a}_t), d_{g,t}(\overline{a}_t), \rho_{r,t}(\overline{a}_t), \rho_{g,t}(\overline{a}_t), y_{r,t}(\overline{a}_t)\right\}$, $\left\{y_{g,t}(\overline{a}_t), mc_{r,t}, mc_{g,t}, \widetilde{\rho}_{r,t}, \widetilde{\rho}_{g,t}, \rho_{e,t}, E_t, \overline{a}_{e,t}, \widetilde{\rho}^r_{e,t}, \widetilde{\rho}^g_{e,t}, d^r_{e,t}(\overline{a}_{e,t}), d^g_{e,t}(\overline{a}_{e,t}), \rho^r_{e,t}(\overline{a}_{e,t}), \rho^g_{e,t}(\overline{a}_{e,t})\right\}$, $\left\{mc^r_{e,t}, mc^g_{e,t}, e_{g,t}(\overline{a}_{e,t}), e_{r,t}(\overline{a}_{e,t}), em_t, x_t, k^r_{e,t}, \mu_{r,t}, \mu_{e,t}, k^g_{e,t}, k_t, n_{r,t}, n_{g,t}, r_{k,t}, w_{r,t}, w_{g,t}\right\}$, $\left\{\widetilde{e}_{r,t}, \widetilde{e}_{g,t}, \widetilde{y}_{r,t}, \widetilde{y}_{g,t}, c_t, \widetilde{a}_{r,t}, \widetilde{a}_{g,t}, \widetilde{a}^r_{e,t}, \widetilde{a}^g_{e,t}, \Gamma_{r,t}, \Gamma_{e,t}, \widetilde{\Psi}_{r,t}, \widetilde{\Psi}_{g,t}, \overline{\Psi}_{r,t}, \overline{\Psi}_{g,t}, R_t, \pi_t, T_t, \zeta_{g,t}, \zeta_{e,t}\right\}$ satisfy:

$$1 = \left[N_{g,t}\left(\widetilde{\rho}_{g,t}\right)^{1-\varepsilon} + N_{r,t}\left(\widetilde{\rho}_{r,t}\right)^{1-\varepsilon}\right]^{\frac{1}{1-\varepsilon}}, \tag{23}$$

$$mc_{r,t}D(x_t)z_{r,t}H_{n_r,t} = w_{r,t} + \left(\gamma\mu^{\eta}_{r,t} + \tau_{f,t}\frac{em_{f,t}}{D(x_t)z_{r,t}H(n_{r,t}, k_{r,t}, \mathbf{e}_{r,t})}\right)D(x_t)z_{r,t}H_{n_r,t}, \tag{24}$$

$$mc_{r,t}D(x_t)z_{r,t}H_{k_r,t} = r_{k,t} + \left(\gamma\mu^{\eta}_{r,t} + \tau_{f,t}\frac{em_{f,t}}{D(x_t)z_{r,t}H(n_{r,t}, k_{r,t}, \mathbf{e}_{r,t})}\right)D(x_t)z_{r,t}H_{k_r,t}, \tag{25}$$

$$mc_{r,t}D(x_t)z_{r,t}H_{\mathbf{e}_r,t} = \rho_{e,t} + \left(\gamma\mu^{\eta}_{r,t} + \tau_{f,t}\frac{em_{f,t}}{D(x_t)z_{r,t}H(n_{r,t}, k_{r,t}, \mathbf{e}_{r,t})}\right)D(x_t)z_{r,t}H_{\mathbf{e}_r,t}, \tag{26}$$

$$mc_{g,t}D(x_t)z_{g,t}H_{k_g,t} = r_{k,t}, \tag{27}$$

$$mc_{g,t}D(x_t)z_{g,t}H_{n_g,t} = w_{g,t}, \tag{28}$$

$$mc_{g,t}D(x_t)z_{g,t}H_{\mathbf{e}_g,t} = \rho_{e,t}, \tag{29}$$

$$N_{g,t} = \left[1 - G(\overline{a}_t)\right], \tag{30}$$

$$N_{r,t} = G(\overline{a}_t), \tag{31}$$

$$d_{r,t}(\overline{a}_t) = d_{g,t}(\overline{a}_t), \tag{32}$$

$$\widetilde{d}_t = N_{g,t}\widetilde{d}_{g,t} + N_{r,t}\widetilde{d}_{r,t}, \tag{33}$$

$$\widetilde{d}_{g,t} = \left(\widetilde{\rho}_{g,t} - \frac{mc_{g,t}}{\widetilde{a}_{g,t}} - \frac{\nu_g}{2}\left(\frac{\widetilde{\rho}_{g,t}}{\widetilde{\rho}_{g,t-1}}\left(1+\pi_t\right) - 1\right)^2\widetilde{\rho}_{g,t}\right)\widetilde{y}_{g,t} - (1-\zeta_{g,t})\varphi_f mc_{g,t}, \tag{34}$$

$$\widetilde{d}_{r,t} = \left(\widetilde{\rho}_{r,t} - \frac{mc_{r,t}}{\widetilde{a}_{r,t}} - \frac{\nu_r}{2}\left(\frac{\widetilde{\rho}_{r,t}}{\widetilde{\rho}_{r,t-1}}\left(1+\pi_t\right) - 1\right)^2\widetilde{\rho}_{r,t}\right)\widetilde{y}_{r,t}, \tag{35}$$

$$d_{g,t}(\overline{a}_t) = \left(\rho_{g,t}(\overline{a}_t) - \frac{mc_{g,t}}{\overline{a}_t} - \frac{\nu_g}{2}\left(\frac{\overline{\rho}_{g,t}}{\overline{\rho}_{g,t-1}}\left(1+\pi_t\right) - 1\right)^2\overline{\rho}_{g,t}\right)y_{g,t}(\overline{a}_t) - (1-\zeta_{e,t})\varphi_f mc_{g,t}, \tag{36}$$

$$d_{r,t}(\overline{a}_t) = \left(\rho_{r,t}(\overline{a}_t) - \frac{mc_{r,t}}{\overline{a}_t} - \frac{\nu_r}{2} \left(\frac{\overline{\rho}_{r,t}}{\overline{\rho}_{r,t-1}} (1+\pi_t) - 1 \right)^2 \overline{\rho}_{r,t} \right) y_{r,t}(\overline{a}_t), \tag{37}$$

$$\widetilde{\rho}_{g,t} = \widetilde{\Psi}_{g,t} \frac{mc_{g,t}}{\widetilde{a}_{g,t}}, \tag{38}$$

$$\widetilde{\rho}_{r,t} = \widetilde{\Psi}_{r,t} \frac{mc_{r,t}}{\widetilde{a}_{r,t}}, \tag{39}$$

$$\widetilde{\Psi}_{g,t} = \frac{\varepsilon}{\left[\begin{array}{c} (\varepsilon - 1) \left(1 - \frac{\nu_g}{2} \left(\frac{\widetilde{\rho}_{g,t}}{\widetilde{\rho}_{g,t-1}} (1+\pi_t) - 1 \right)^2 \right) \\ + \nu_g \left(\frac{\widetilde{\rho}_{g,t}}{\widetilde{\rho}_{g,t-1}} (1+\pi_t) \right) \left(\frac{\widetilde{\rho}_{g,t}}{\widetilde{\rho}_{g,t-1}} (1+\pi_t) - 1 \right) \frac{\widetilde{\rho}_{g,t+1}}{\widetilde{\rho}_{g,t}} \frac{\widetilde{y}_{g,t+1}}{\widetilde{y}_{g,t}} \\ - \nu_g \mathbb{E}_t \Xi_{t+1|t} (1-\delta) \left(\frac{\widetilde{\rho}_{g,t+1}}{\widetilde{\rho}_{g,t}} (1+\pi_{t+1}) \right) \left(\frac{\widetilde{\rho}_{g,t+1}}{\widetilde{\rho}_{g,t}} (1+\pi_{t+1}) - 1 \right) \frac{\widetilde{\rho}_{g,t+1}}{\widetilde{\rho}_{g,t}} \frac{\widetilde{y}_{g,t+1}}{\widetilde{y}_{g,t}} \end{array} \right]}, \tag{40}$$

$$\widetilde{\Psi}_{r,t} = \frac{\varepsilon}{\left[\begin{array}{c} (\varepsilon - 1) \left(1 - \frac{\nu_r}{2} \left(\frac{\widetilde{\rho}_{r,t}}{\widetilde{\rho}_{r,t-1}} (1+\pi_t) - 1 \right)^2 \right) \\ + \nu_r \left(\frac{\widetilde{\rho}_{r,t}}{\widetilde{\rho}_{r,t-1}} (1+\pi_t) \right) \left(\frac{\widetilde{\rho}_{r,t}}{\widetilde{\rho}_{r,t-1}} (1+\pi_t) - 1 \right) \frac{\widetilde{\rho}_{r,t+1}}{\widetilde{\rho}_{r,t}} \frac{\widetilde{y}_{r,t+1}}{\widetilde{y}_{r,t}} \\ - \nu_r \mathbb{E}_t \Xi_{t+1|t} (1-\delta) \left(\frac{\widetilde{\rho}_{r,t+1}}{\widetilde{\rho}_{r,t}} (1+\pi_{t+1}) \right) \left(\frac{\widetilde{\rho}_{r,t+1}}{\widetilde{\rho}_{r,t}} (1+\pi_{t+1}) - 1 \right) \frac{\widetilde{\rho}_{r,t+1}}{\widetilde{\rho}_{r,t}} \frac{\widetilde{y}_{r,t+1}}{\widetilde{y}_{r,t}} \end{array} \right]}, \tag{41}$$

$$\widetilde{y}_{g,t} = (\widetilde{\rho}_{g,t})^{-\varepsilon} \left(\begin{array}{c} Y_t + N_{g,t} \frac{\nu_g}{2} \left(\frac{\widetilde{\rho}_{g,t}}{\widetilde{\rho}_{g,t-1}} (1+\pi_t) - 1 \right)^2 \widetilde{\rho}_{g,t} \widetilde{y}_{g,t} \\ + N_{r,t} \frac{\nu_r}{2} \left(\frac{\widetilde{\rho}_{r,t}}{\widetilde{\rho}_{r,t-1}} (1+\pi_t) - 1 \right)^2 \widetilde{\rho}_{r,t} \widetilde{y}_{r,t} \end{array} \right), \tag{42}$$

$$\widetilde{y}_{r,t} = (\widetilde{\rho}_{r,t})^{-\varepsilon} \left(\begin{array}{c} Y_t + N_{g,t} \frac{\nu_g}{2} \left(\frac{\widetilde{\rho}_{g,t}}{\widetilde{\rho}_{g,t-1}} (1+\pi_t) - 1 \right)^2 \widetilde{\rho}_{g,t} \widetilde{y}_{g,t} \\ + N_{r,t} \frac{\nu_r}{2} \left(\frac{\widetilde{\rho}_{r,t}}{\widetilde{\rho}_{r,t-1}} (1+\pi_t) - 1 \right)^2 \widetilde{\rho}_{r,t} \widetilde{y}_{r,t} \end{array} \right), \tag{43}$$

$$\rho_{g,t}(\overline{a}_t) = \overline{\rho}_{g,t} = \overline{\Psi}_{g,t} \frac{mc_{g,t}}{\overline{a}_t}, \tag{44}$$

$$\rho_{r,t}(\overline{a}_t) = \overline{\rho}_{r,t} = \overline{\Psi}_{r,t} \frac{mc_{r,t}}{\overline{a}_t}, \tag{45}$$

$$\overline{\Psi}_{g,t} = \frac{\varepsilon}{\left[\begin{array}{c} (\varepsilon - 1) \left(1 - \frac{\nu_g}{2} \left(\frac{\overline{\rho}_{g,t}}{\overline{\rho}_{g,t-1}} (1+\pi_t) - 1 \right)^2 \right) \\ + \nu_g \left(\frac{\overline{\rho}_{g,t}}{\overline{\rho}_{g,t-1}} (1+\pi_t) \right) \left(\frac{\overline{\rho}_{g,t}}{\overline{\rho}_{g,t-1}} (1+\pi_t) - 1 \right) \frac{\overline{\rho}_{g,t+1}}{\overline{\rho}_{g,t}} \frac{\overline{y}_{g,t+1}}{\overline{y}_{g,t}} \\ - \nu_g \mathbb{E}_t \Xi_{t+1|t} (1-\delta) \left(\frac{\overline{\rho}_{g,t+1}}{\overline{\rho}_{g,t}} (1+\pi_{t+1}) \right) \left(\frac{\overline{\rho}_{g,t+1}}{\overline{\rho}_{g,t}} (1+\pi_{t+1}) - 1 \right) \frac{\overline{\rho}_{g,t+1}}{\overline{\rho}_{g,t}} \frac{\overline{y}_{g,t+1}}{\overline{y}_{g,t}} \end{array} \right]}, \tag{46}$$

$$\overline{\Psi}_{r,t} = \frac{\varepsilon}{\left[\begin{array}{c}(\varepsilon-1)\left(1-\frac{\nu_r}{2}\left(\frac{\overline{\rho}_{r,t}}{\overline{\rho}_{r,t-1}}(1+\pi_t)-1\right)^2\right)\\ +\nu_s\left(\frac{\overline{\rho}_{r,t}}{\overline{\rho}_{r,t-1}}(1+\pi_t)\right)\left(\frac{\overline{\rho}_{r,t}}{\overline{\rho}_{r,t-1}}(1+\pi_t)-1\right)\frac{\overline{\rho}_{r,t+1}}{\overline{\rho}_{r,t}}\frac{\overline{y}_{r,t+1}}{\overline{y}_{r,t}}\\ -\nu_r\mathbb{E}_t\Xi_{t+1|t}(1-\delta)\left(\frac{\overline{\rho}_{r,t+1}}{\overline{\rho}_{r,t}}(1+\pi_{t+1})\right)\left(\frac{\overline{\rho}_{r,t+1}}{\overline{\rho}_{r,t}}(1+\pi_{t+1})-1\right)\frac{\overline{\rho}_{r,t+1}}{\overline{\rho}_{r,t}}\frac{\overline{y}_{r,t+1}}{\overline{y}_{r,t}}\end{array}\right]}, \quad (47)$$

$$y_{g,t}(\overline{a}_t) = \overline{y}_{g,t} = \left(\overline{\rho}_{g,t}\right)^{-\varepsilon}\left(\begin{array}{c}Y_t + N_{g,t}\frac{\nu_g}{2}\left(\frac{\overline{\rho}_{g,t}}{\overline{\rho}_{g,t-1}}(1+\pi_t)-1\right)^2\overline{\rho}_{g,t}\overline{y}_{g,t}\\ +N_{r,t}\frac{\nu_r}{2}\left(\frac{\overline{\rho}_{r,t}}{\overline{\rho}_{r,t-1}}(1+\pi_t)-1\right)^2\overline{\rho}_{r,t}\overline{y}_{r,t}\end{array}\right), \quad (48)$$

$$y_{r,t}(\overline{a}_t) = \overline{y}_{r,t} = \left(\overline{\rho}_{r,t}\right)^{-\varepsilon}\left(\begin{array}{c}Y_t + N_{g,t}\frac{\nu_g}{2}\left(\frac{\overline{\rho}_{g,t}}{\overline{\rho}_{g,t-1}}(1+\pi_t)-1\right)^2\overline{\rho}_{g,t}\overline{y}_{g,t}\\ +N_{r,t}\frac{\nu_r}{2}\left(\frac{\overline{\rho}_{r,t}}{\overline{\rho}_{r,t-1}}(1+\pi_t)-1\right)^2\overline{\rho}_{r,t}\overline{y}_{r,t}\end{array}\right), \quad (49)$$

$$\rho_{e,t} = \left(G(\overline{a}_{e,t})\left(\widetilde{\rho}^r_{e,t}\right)^{1-\varepsilon_e} + [1-G(\overline{a}_{e,t})]\left(\widetilde{\rho}^g_{e,t}\right)^{1-\varepsilon_e}\right)^{\frac{1}{1-\varepsilon_e}}, \quad (50)$$

$$E_t = \mathbf{e}_{g,t} + \mathbf{e}_{r,t}, \quad (51)$$

$$d^r_{e,t}(\overline{a}_{e,t}) = d^g_{e,t}(\overline{a}_{e,t}), \quad (52)$$

$$\widetilde{\rho}^r_{e,t} = \frac{\varepsilon_e}{\varepsilon_e - 1}\frac{mc^r_{e,t}}{\widetilde{a}^r_{e,t}}, \quad (53)$$

$$\widetilde{\rho}^g_{e,t} = \frac{\varepsilon_e}{\varepsilon_e - 1}\frac{mc^g_{e,t}}{\widetilde{a}^g_{e,t}}, \quad (54)$$

$$d^r_{e,t}(\overline{a}_{e,t}) = \left(\rho^r_{e,t}(\overline{a}_{e,t}) - \frac{mc^r_{e,t}}{\overline{a}_{e,t}}\right)e_{r,t}(\overline{a}_{e,t}), \quad (55)$$

$$d^g_{e,t}(\overline{a}_{e,t}) = \left(\rho^g_{e,t}(\overline{a}_{e,t}) - \frac{mc^g_{e,t}}{\overline{a}_{e,t}}\right)e_{g,t}(\overline{a}_{e,t}) - (1-\zeta_{e,t})\varphi_e mc^g_{e,t}, \quad (56)$$

$$\rho^r_{e,t}(\overline{a}_{e,t}) = \frac{\varepsilon_e}{\varepsilon_e - 1}\frac{mc^r_{e,t}}{\overline{a}_{e,t}}, \quad (57)$$

$$\rho^g_{e,t}(\overline{a}_{e,t}) = \frac{\varepsilon_e}{\varepsilon_e - 1}\frac{mc^g_{e,t}}{\overline{a}_{e,t}}, \quad (58)$$

$$e_{r,t}(\overline{a}_{e,t}) = \left(\frac{\rho^r_{e,t}(\overline{a}_{e,t})}{\rho_{e,t}}\right)^{-\varepsilon_e}E_t, \quad (59)$$

$$e_{g,t}(\overline{a}_{e,t}) = \left(\frac{\rho^g_{e,t}(\overline{a}_{e,t})}{\rho_{e,t}}\right)^{-\varepsilon_e}E_t, \quad (60)$$

$$\widetilde{e}_{r,t} = \left(\frac{\widetilde{\rho}^{r}_{e,t}}{\rho_{e,t}}\right)^{-\varepsilon_e} E_t, \tag{61}$$

$$\widetilde{e}_{g,t} = \left(\frac{\widetilde{\rho}^{g}_{e,t}}{\rho_{e,t}}\right)^{-\varepsilon_e} E_t, \tag{62}$$

$$em_t = (1-\mu_{e,t})\left[D(x_t) z^r_{e,t} k^r_{e,t}\right] + (1-\mu_{r,t})\left[D(x_t) z_{r,t} F(n_{r,t}, k_{r,t}, \mathbf{e}_{r,t})\right], \tag{63}$$

$$x_t = \rho_x x_{t-1} + em_t + em^{row}_t, \tag{64}$$

$$D(x_t) mc^r_{e,t} z^r_{e,t} = r_{k,t} + \left(\tau_{e,t}(1-\mu_{e,t}) + \mu^{\eta}_{e,t}\right) D(x_t) z^r_{e,t}, \tag{65}$$

$$\eta\gamma\mu^{\eta-1}_{e,t} = \tau_{e,t}, \tag{66}$$

$$D(x_t) mc^g_{e,t} z^g_{e,t} = r^g_{k,t}, \tag{67}$$

$$k_t = k_{l,t} + k_{s,t} + k^r_{e,t}, \tag{68}$$

$$1 = \mathbb{E}_t \Xi_{t+1|t}\left[r_{k,t+1} + (1-\delta_k)\right], \tag{69}$$

$$1 = \mathbb{E}_t \Xi_{t+1|t}\left[r^g_{k,t+1} + (1-\delta_g)\right], \tag{70}$$

$$\kappa\left(n_{r,t} + n_{g,t}\right)^{\frac{1}{\chi}} = w_{g,t} c_t^{-\sigma_c}, \tag{71}$$

$$\kappa\left(n_{r,t} + n_{g,t}\right)^{\frac{1}{\chi}} = w_{r,t} c_t^{-\sigma_c}, \tag{72}$$

$$D(x_t) z^r_{e,t} k^r_{e,t} = G(\overline{a}_{e,t})\left(\frac{\widetilde{e}_{r,t}}{\widetilde{a}^r_{e,t}}\right), \tag{73}$$

$$D(x_t) z^g_{e,t} k^g_{e,t} = \left[1 - G(\overline{a}_{e,t})\right]\left(\frac{\widetilde{e}_{g,t}}{\widetilde{a}^g_{e,t}}\right), \tag{74}$$

$$D(x_t) z_{g,t} H(n_{g,t}, k_{g,t}, \mathbf{e}_{g,t}) = N_{g,t}\left(\frac{\widetilde{y}_{g,t}}{\widetilde{a}_{g,t}}\right), \tag{75}$$

$$D(x_t) z_{r,t} F(n_{r,t}, k_{r,t}, \mathbf{e}_{r,t}) = N_{r,t}\left(\frac{\widetilde{y}_{r,t}}{\widetilde{a}_{r,t}}\right), \tag{76}$$

$$Y_t = c_t + (k_{t+1} - (1-\delta_k)k_t) + \left(k^g_{e,t+1} - (1-\delta_g)k^g_{e,t}\right) + \varphi_f mc_{g,t} N_{g,t} + \varphi_e mc^g_{e,t}\left[1 - G(\overline{a}_{e,t})\right] + \Gamma_{e,t} + \Gamma_{s,t} + \sum_{j\in\{g,r\}}\left[\frac{\nu_j}{2}\left(\frac{\widetilde{\rho}_{j,t}}{\widetilde{\rho}_{j,t-1}}(1+\pi_t) - 1\right)^2 \widetilde{\rho}_{j,t}\widetilde{y}_{j,t}N_{j,t}\right], \tag{77}$$

$$\widetilde{a}_{s,t} = \widetilde{a}_{l,t}\left(\frac{\overline{a}_t^{k_p-(\varepsilon-1)} - a_{min}^{k_p-(\varepsilon-1)}}{\overline{a}_t^{k_p} - a_{min}^{k_p}}\right)^{\frac{1}{\varepsilon-1}} a_{min}, \tag{78}$$

$$\widetilde{a}_{l,t} = \left(\frac{k_p}{k_p-(\varepsilon-1)}\right)^{\frac{1}{\varepsilon-1}}\overline{a}_t, \tag{79}$$

$$\widetilde{a}^r_{e,t} = \widetilde{a}^g_{e,t}\left(\frac{\overline{a}_{e,t}^{k^e_p-(\varepsilon_e-1)} - a_{e,min}^{k^e_p-(\varepsilon_e-1)}}{\overline{a}_{e,t}^{k^e_p} - a_{e,min}^{k^e_p}}\right)^{\frac{1}{\varepsilon_e-1}} a_{e,min}, \tag{80}$$

$$\widetilde{a}^g_{e,t} = \left(\frac{k^e_p}{k^e_p-(\varepsilon_e-1)}\right)^{\frac{1}{\varepsilon_e-1}}\overline{a}_{e,t}, \tag{81}$$

$$\Gamma_{e,t} = \gamma\mu^{\eta}_{e,t}D(x_t)z^r_{e,t}k^r_{e,t}, \tag{82}$$

$$\Gamma_{r,t} = \gamma\mu^{\eta}_{r,t}D(x_t)z_{r,t}F(n_{r,t},k_{r,t},\mathbf{e}_{r,t}), \tag{83}$$

$$1 = \mathbb{E}_t\Xi_{t+1|t}\left(\frac{R_t}{1+\pi_{t+1}}\right), \tag{84}$$

$$T_t + \zeta_{g,t}\varphi_f mc_{g,t}N_{g,t} + \zeta_{e,t}\varphi_e mc^g_{e,t}\left[1 - G(\overline{a}_{e,t})\right] = \tau_{f,t}em_{f,t} + \tau_{e,t}em_{e,t}, \tag{85}$$

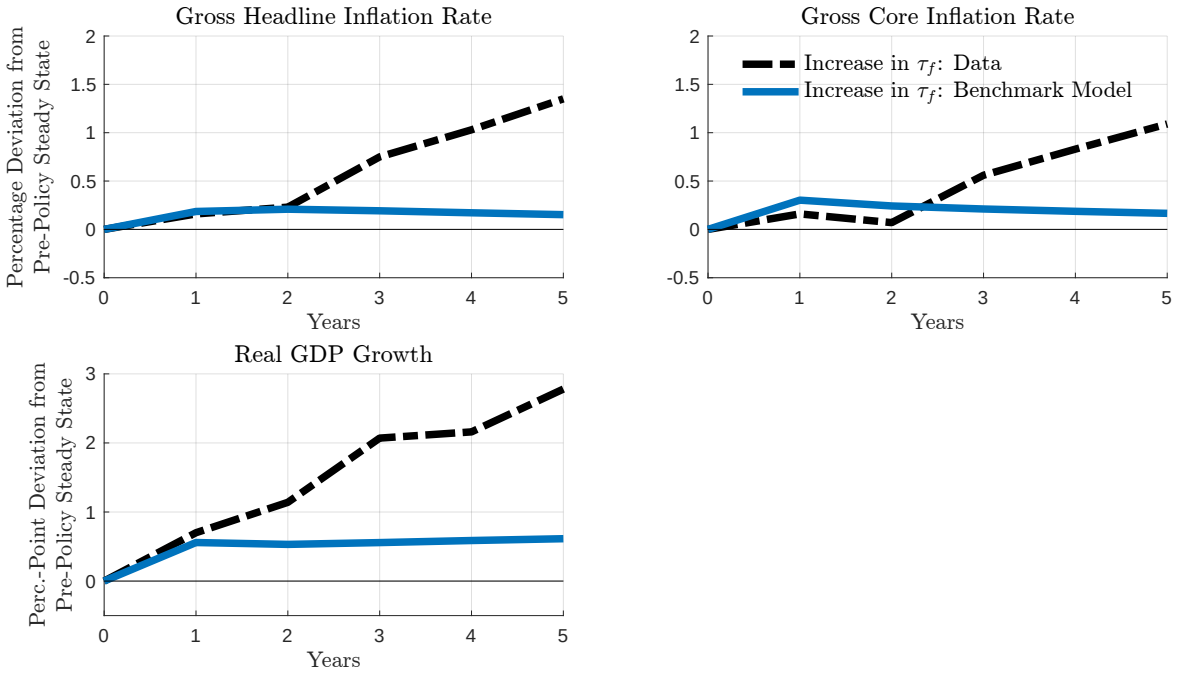
$$\zeta_{g,t}\varphi_f mc_{g,t}N_{g,t} = \omega^r_g\tau_{f,t}em_{f,t} + \omega^e_g\tau_{e,t}em_{e,t}, \tag{86}$$

$$\zeta_{e,t}\varphi_e mc^g_{e,t}\left[1 - G(\overline{a}_{e,t})\right] = \omega^r_e\tau_{f,t}em_{f,t} + \omega^e_e\tau_{e,t}em_{e,t}, \tag{87}$$

$$\frac{R_t}{R} = \left(\frac{R_{t-1}}{R}\right)^{\rho_R}\left(\left(\frac{1+\pi^h_t}{1+\pi^h}\right)^{\phi_\pi}\left(\frac{Y_t}{Y}\right)^{\phi_y}\right)^{1-\rho_R}. \tag{88}$$

A.4 Additional Model Results

Fig. A4 Annual Transition Path of Inflation and Total Output in Response to $40 Increase in the Carbon Tax in the Goods-Producing Sector τ_f—Benchmark Model vs. Data



Note: Both gross inflation and interest rates are expressed in annual terms.

Tab. A1 Long Run Effects of Carbon Taxes—Benchmark Model vs. Model without Green Technology Adoption in Goods Production Under Alternative Combinations of Carbon-Tax Changes

	(1)	(2)	(3)	(4)
	Benchmark Model		No Green Tech. Adopt. in Goods-Firm	
Carbon Tax Change	$\Delta\tau_f > 0$ $\Delta\tau_e = 0$	$\Delta\tau_f = 0$ $\Delta\tau_e > 0$	$\Delta\tau_f > 0$ $\Delta\tau_e = 0$	$\Delta\tau_f = 0$ $\Delta\tau_e > 0$
Variable	Percent Change Relative to Baseline			
Total Emissions	-5.695	-11.773	-3.681	-10.734
Total Output	0.782	0.415	0.017	0.035
Consumption	0.167	0.050	-0.053	-0.058
Capital Investment	1.376	0.418	0.054	-0.240
Total Labor	0.250	0.253	-0.016	0.121
Real Wage	0.398	0.164	-0.109	-0.086
Real Price of Energy	-0.795	1.567	-0.890	1.493
Welfare Gain* (% of Consumption)	0.015	-0.104	-0.043	-0.132
	Percentage-Point Change Relative to Baseline			
Share of Goods-Producing g Firms	2.669	1.325	–	–
Abatement Rate μ_r	1.403	0.011	1.354	0.000
Abatement Rate μ_e	0.029	1.346	0.027	1.337
Share of Energy Prod. using g Tech.	3.269	9.380	3.623	9.512
Share of Green Energy	5.022	17.081	5.532	17.222
Tax Revenue-Output Ratio	0.124	0.087	0.134	0.090

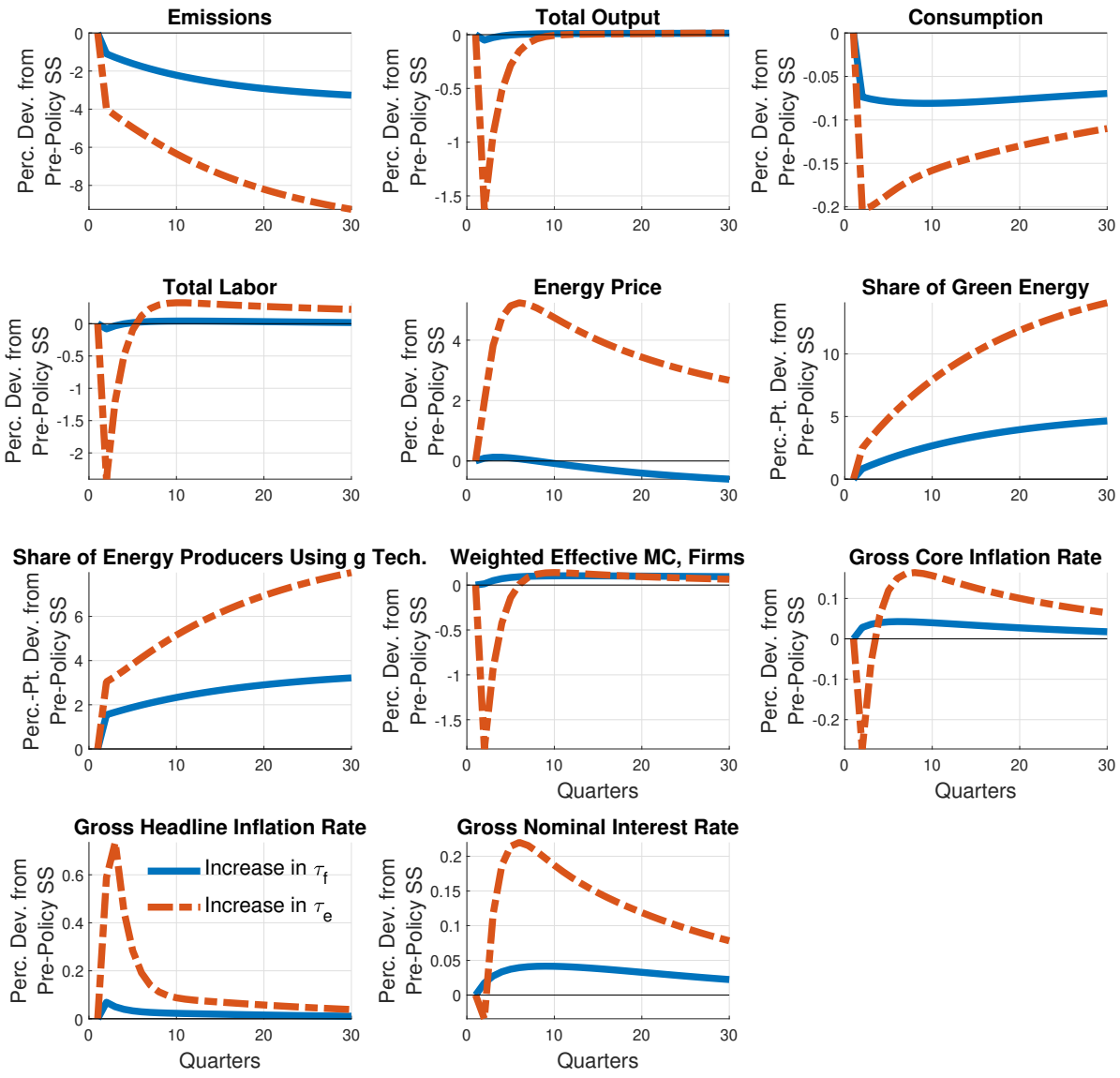
Note: Values rounded to three decimal places. The benchmark model and the model with no production-firm green technology adoption are calibrated to have the same baseline steady state.

Tab. A2 Long Run Effects of Carbon Taxes—Benchmark Model vs. Model without Green Technology Adoption in Energy Production Under Alternative Combinations of Carbon-Tax Changes

	(1)	(2)	(3)	(4)
	Benchmark Model		No Green Tech. Adopt. in Energy Sector	
Carbon Tax Change	$\Delta\tau_f > 0$ $\Delta\tau_e = 0$	$\Delta\tau_f = 0$ $\Delta\tau_e > 0$	$\Delta\tau_f > 0$ $\Delta\tau_e = 0$	$\Delta\tau_f = 0$ $\Delta\tau_e > 0$
Variable	Percent Change Relative to Baseline			
Total Emissions	-5.695	-11.773	-3.579	-5.967
Total Output	0.782	0.415	0.765	0.424
Consumption	0.167	0.050	0.157	0.028
Capital Investment	1.376	0.418	1.430	0.655
Total Labor	0.250	0.253	0.254	0.298
Real Wage	0.398	0.164	0.378	0.129
Real Price of Energy	-0.795	1.567	0.016	4.452
Welfare Gain* (% of Consumption)	0.015	-0.104	0.002	-0.154
	Percentage-Point Change Relative to Baseline			
Share of Goods-Producing g Firms	2.669	1.325	2.866	2.178
Abatement Rate μ_r	1.403	0.011	1.406	0.019
Abatement Rate μ_e	0.029	1.346	0.006	1.226
Share of Energy Producers using g Tech.	3.269	9.380	–	–
Share of Green Energy	5.022	17.081	0.011	2.758
Tax Revenue-Output Ratio	0.124	0.087	0.128	0.119

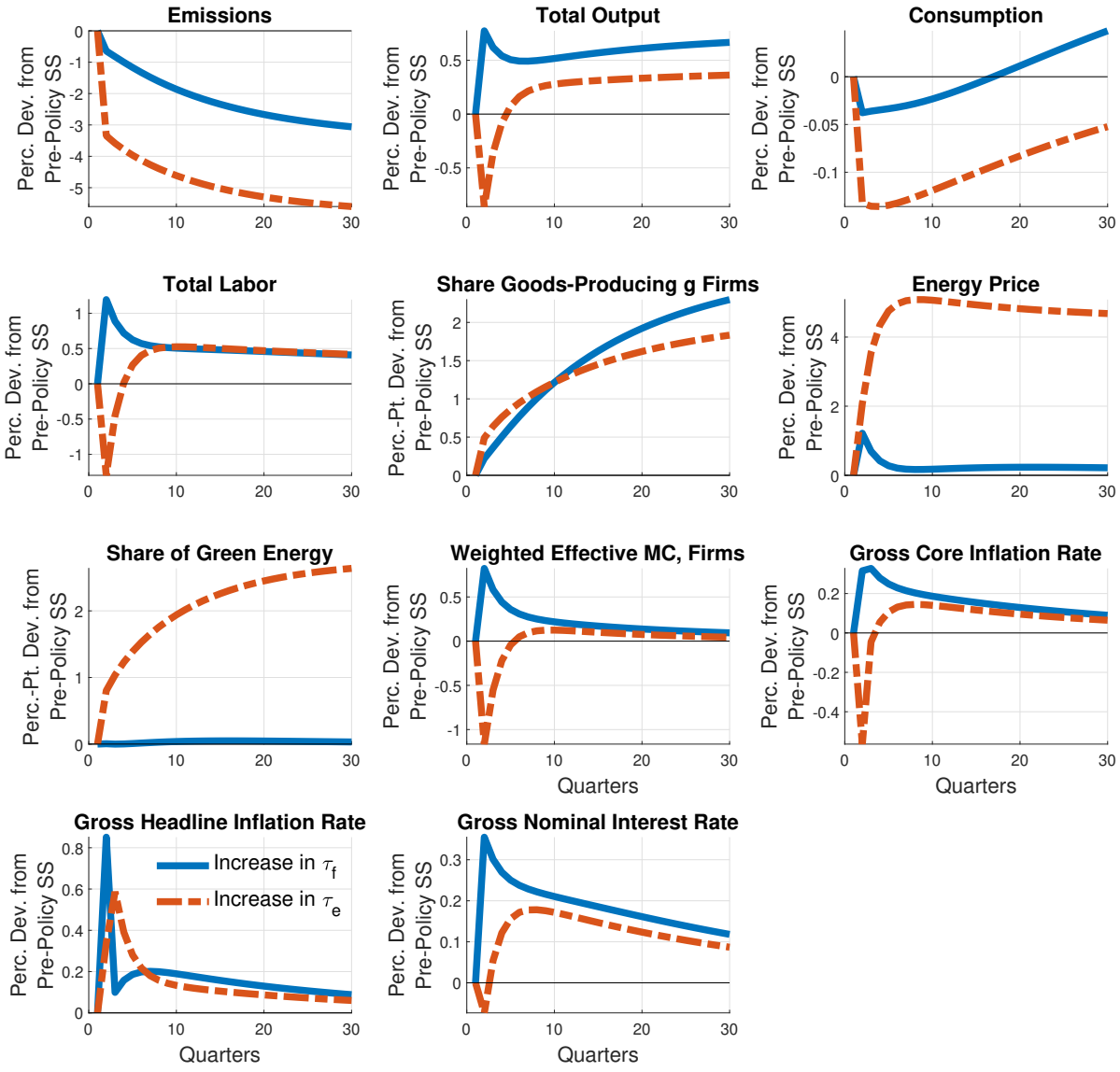
Note: Values rounded to three decimal places. The benchmark model and the model with no production-firm green technology adoption are calibrated to have the same baseline steady state.

Fig. A5 Quarterly Transition Path in Response to $40 Increase in Each Carbon Tax—Benchmark Model Variant with No Green Technology Adoption in Goods-Producing Sector



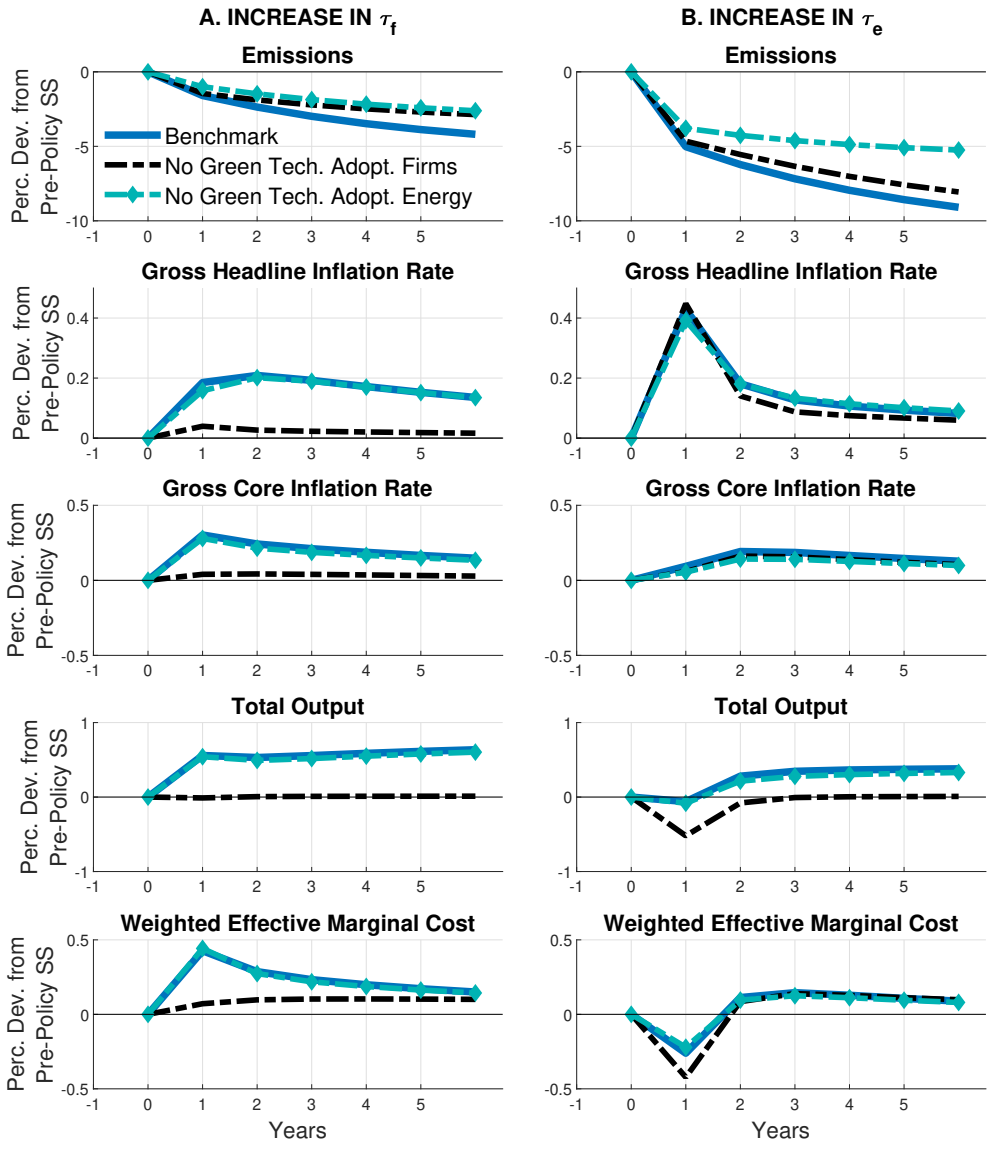
Note: Perc. Dev. denotes percent deviations and Perc.-Pt. Dev. denotes percentage-point deviations. Gross inflation and interest rates are expressed in annual terms.

Fig. A6 Quarterly Transition Path in Response to $40 Increase in Each Carbon Tax—Benchmark Model Variant with No Green Technology Adoption in Energy Sector



Note: Perc. Dev. denotes percent deviations and Perc.-Pt. Dev. denotes percentage-point deviations. Gross inflation and interest rates are expressed in annual terms.

Fig. A7 Annual Transition Path in Response to $40 Increase in Each Carbon Tax—Benchmark Model vs. Model Variants without Green Technology Adoption



Note: Perc. Dev. denotes percent deviations. Gross inflation and interest rates are expressed in annual terms. The weighted effective marginal cost (MC) is defined as $N_{r,t}(mc_{r,t}/\widetilde{a}_{r,t}) + N_{g,t}(mc_{g,t}/\widetilde{a}_{g,t})$.

A.5 Robustness Results: Benchmark Model

Tab. A3 Long Run Effects of Carbon Taxes—Benchmark Model vs. Model with $\alpha_{e_r} = \alpha_{e_g} = 0.05$

	(1)	(2)	(3)	(4)
	Benchmark Model		Benchmark Model with $\alpha_{e_r} = \alpha_{e_g} = 0.05$	
Carbon Tax Change	$\Delta\tau_f > 0$ $\Delta\tau_e = 0$	$\Delta\tau_f = 0$ $\Delta\tau_e > 0$	$\Delta\tau_f > 0$ $\Delta\tau_e = 0$	$\Delta\tau_f = 0$ $\Delta\tau_e > 0$
Variable	Percent Change Relative to Baseline			
Total Emissions	-5.695	-11.773	-5.140	-10.826
Total Output	0.782	0.415	0.802	0.291
Consumption	0.167	0.050	0.196	0.029
Capital Investment	1.376	0.418	1.313	0.142
Total Labor	0.250	0.253	0.226	0.188
Real Wage	0.398	0.164	0.449	0.105
Real Price of Energy	-0.795	1.567	-0.860	1.127
Welfare Gain* (% of Consumption)	0.015	-0.104	0.058	-0.085
	Percentage-Point Change Relative to Baseline			
Share of Goods-Producing g Firms	2.669	1.325	2.789	0.916
Abatement Rate μ_r	1.403	0.011	1.360	0.007
Abatement Rate μ_e	0.029	1.346	0.021	1.247
Share of Energy Producers using g Tech.	3.269	9.380	3.542	9.614
Share of Green Energy	5.022	17.081	5.353	16.838
Tax Revenue-Output Ratio	0.124	0.087	0.118	0.086

Note: Values rounded to three decimal places.

Tab. A4 Long Run Effects of Carbon Taxes—Benchmark Model vs. Benchmark with $\varepsilon = \varepsilon_e = 6$, $k_p = k_p^e = 4$

	(1)	(2)	(3)	(4)
	Benchmark Model		Benchmark Model with $\varepsilon = \varepsilon_e = 6$, $k_p = k_p^e = 4$	
Carbon Tax Change	$\Delta\tau_f > 0$ $\Delta\tau_e = 0$	$\Delta\tau_f = 0$ $\Delta\tau_e > 0$	$\Delta\tau_f > 0$ $\Delta\tau_e = 0$	$\Delta\tau_f = 0$ $\Delta\tau_e > 0$
Variable	Percent Change Relative to Baseline			
Total Emissions	-5.695	-11.773	-5.188	-10.121
Total Output	0.782	0.415	0.493	0.239
Consumption	0.167	0.050	0.092	0.021
Capital Investment	1.376	0.418	0.658	0.044
Total Labor	0.250	0.253	0.168	0.158
Real Wage	0.398	0.164	0.226	0.082
Real Price of Energy	-0.795	1.567	-0.552	1.207
Welfare Gain* (% of Consumption)	0.015	-0.104	-0.033	-0.096
	Percentage-Point Change Relative to Baseline			
Share of Goods-Producing g Firms	2.669	1.325	2.007	0.937
Abatement Rate μ_r	1.403	0.011	1.439	0.009
Abatement Rate μ_e	0.029	1.346	0.019	1.049
Share of Energy Producers using g Tech.	3.269	9.380	1.744	4.719
Share of Green Energy	5.022	17.081	4.225	15.542
Tax Revenue-Output Ratio	0.124	0.087	0.110	0.083

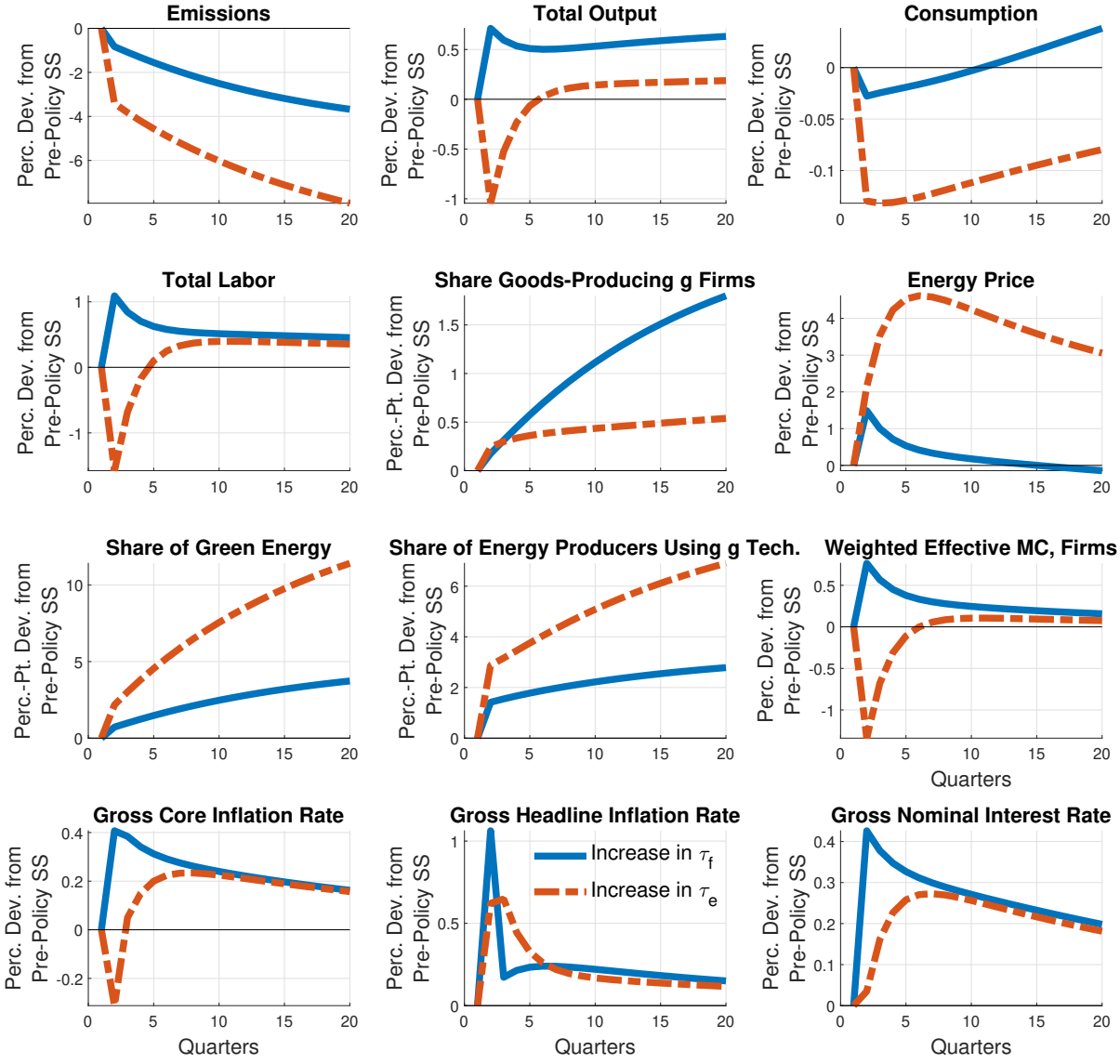
Note: Values rounded to three decimal places.

Tab. A5 Long Run Effects of Carbon Taxes—Benchmark Model vs. Benchmark with Lower Baseline Energy Emissions Share (0.40 vs. Original 0.50)

	(1)	(2)	(3)	(4)
	Benchmark Model		Benchmark Model with Lower em_e Share	
Carbon Tax Change	$\Delta\tau_f > 0$ $\Delta\tau_e = 0$	$\Delta\tau_f = 0$ $\Delta\tau_e > 0$	$\Delta\tau_f > 0$ $\Delta\tau_e = 0$	$\Delta\tau_f = 0$ $\Delta\tau_e > 0$
Variable	Percent Change Relative to Baseline			
Total Emissions	-5.695	-11.773	-6.073	-7.594
Total Output	0.782	0.415	0.783	0.289
Consumption	0.167	0.050	0.174	0.047
Capital Investment	1.376	0.418	1.353	0.251
Total Labor	0.250	0.253	0.241	0.158
Real Wage	0.398	0.164	0.408	0.133
Real Price of Energy	-0.795	1.567	-0.962	0.699
Welfare Gain* (% of Consumption)	0.015	-0.104	0.026	-0.050
	Percentage-Point Change Relative to Baseline			
Share of Goods-Producing g Firms	2.669	1.325	2.634	0.877
Abatement Rate μ_r	1.403	0.011	1.403	0.007
Abatement Rate μ_e	0.029	1.346	0.027	1.028
Share of Energy Producers using g Tech.	3.269	9.380	4.267	8.380
Share of Green Energy	5.022	17.081	6.277	14.115
Tax Revenue-Output Ratio	0.124	0.087	0.125	0.066

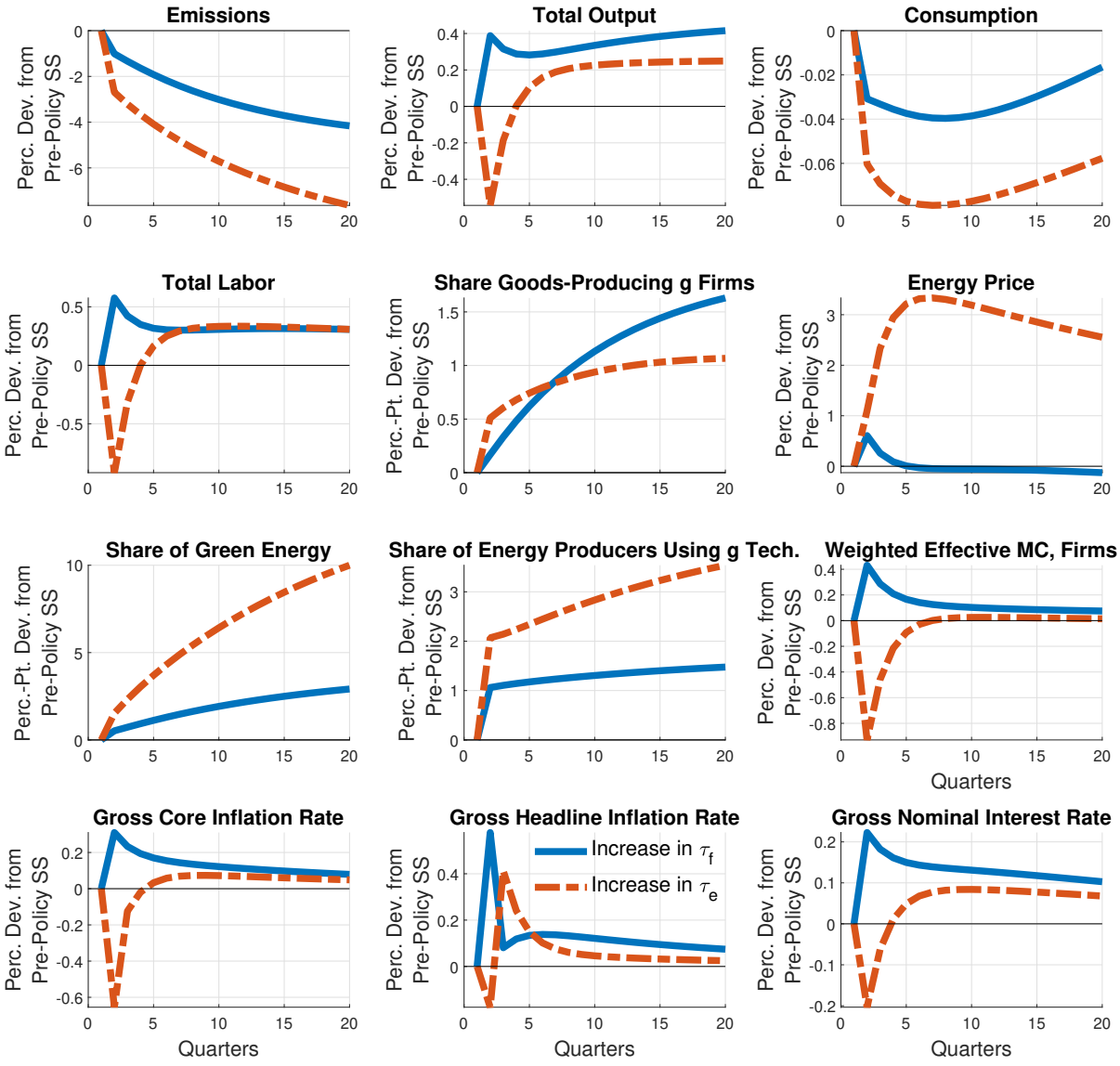
Note: Values rounded to three decimal places.

Fig. A8 Quarterly Transition Path in Response to \$40 Increase in Each Carbon Tax—Benchmark Model with $\alpha_r^e = \alpha_g^e = 0.05$



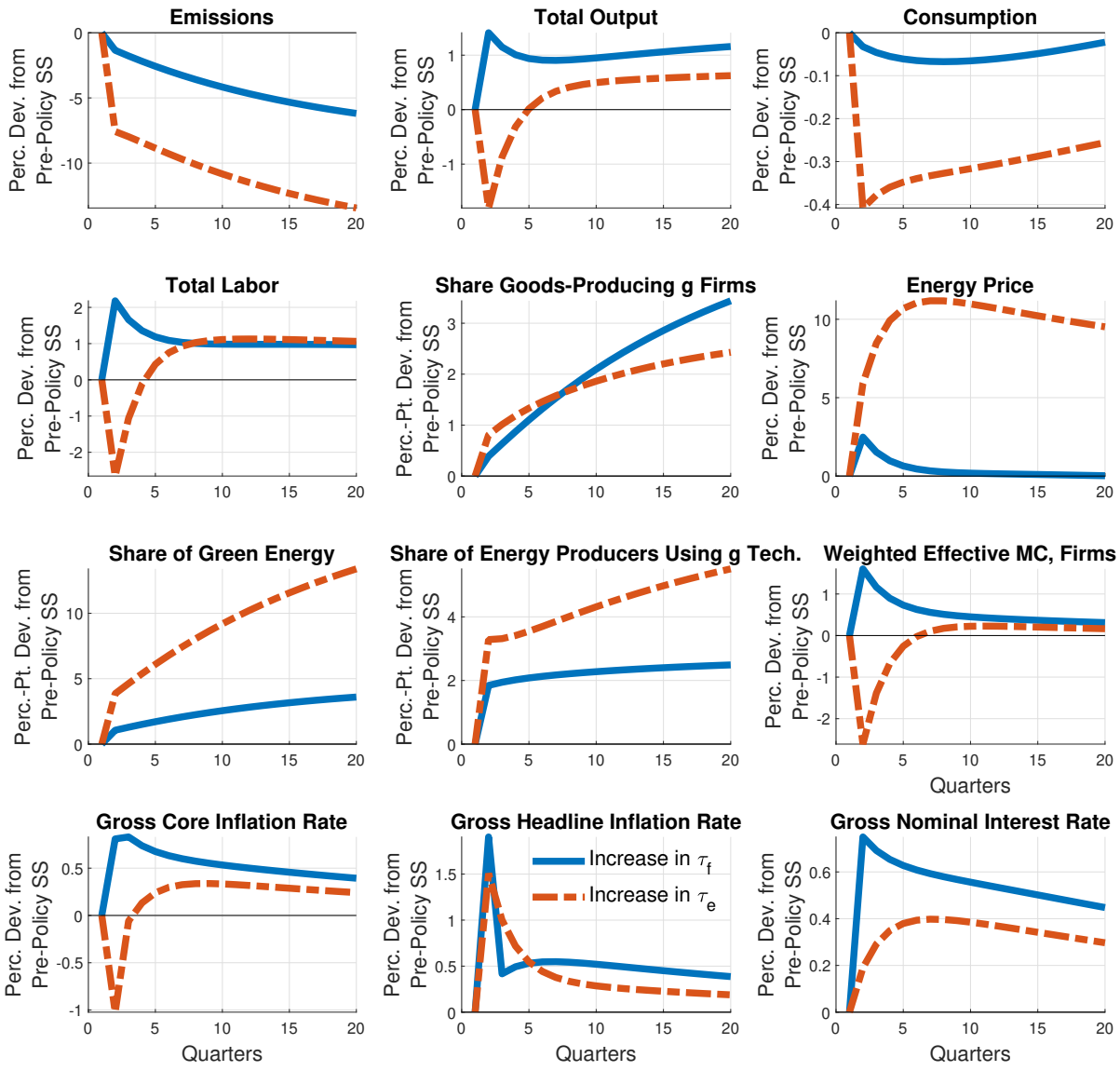
Note: Perc. Dev. denotes percent deviations and Perc.-Pt. Dev. denotes percentage-point deviations. Gross inflation and interest rates are expressed in annual terms.

Fig. A9 Quarterly Transition Path in Response to \$40 Increase in Each Carbon Tax—Benchmark Model with Higher $\varepsilon = \varepsilon_e = 6$



Note: Perc. Dev. denotes percent deviations and Perc.-Pt. Dev. denotes percentage-point deviations. Gross inflation and interest rates are expressed in annual terms. This alternative baseline calibration continues to assume that $k_p > \varepsilon - 1$, where similar to the baseline calibration, we set $k_p = 4\varepsilon$.

Fig. A10 Quarterly Transition Path in Response to $40 Increase in Each Carbon Tax—Benchmark Model with Lower Baseline Share of Emissions (40 Percent vs. 50 Percent)

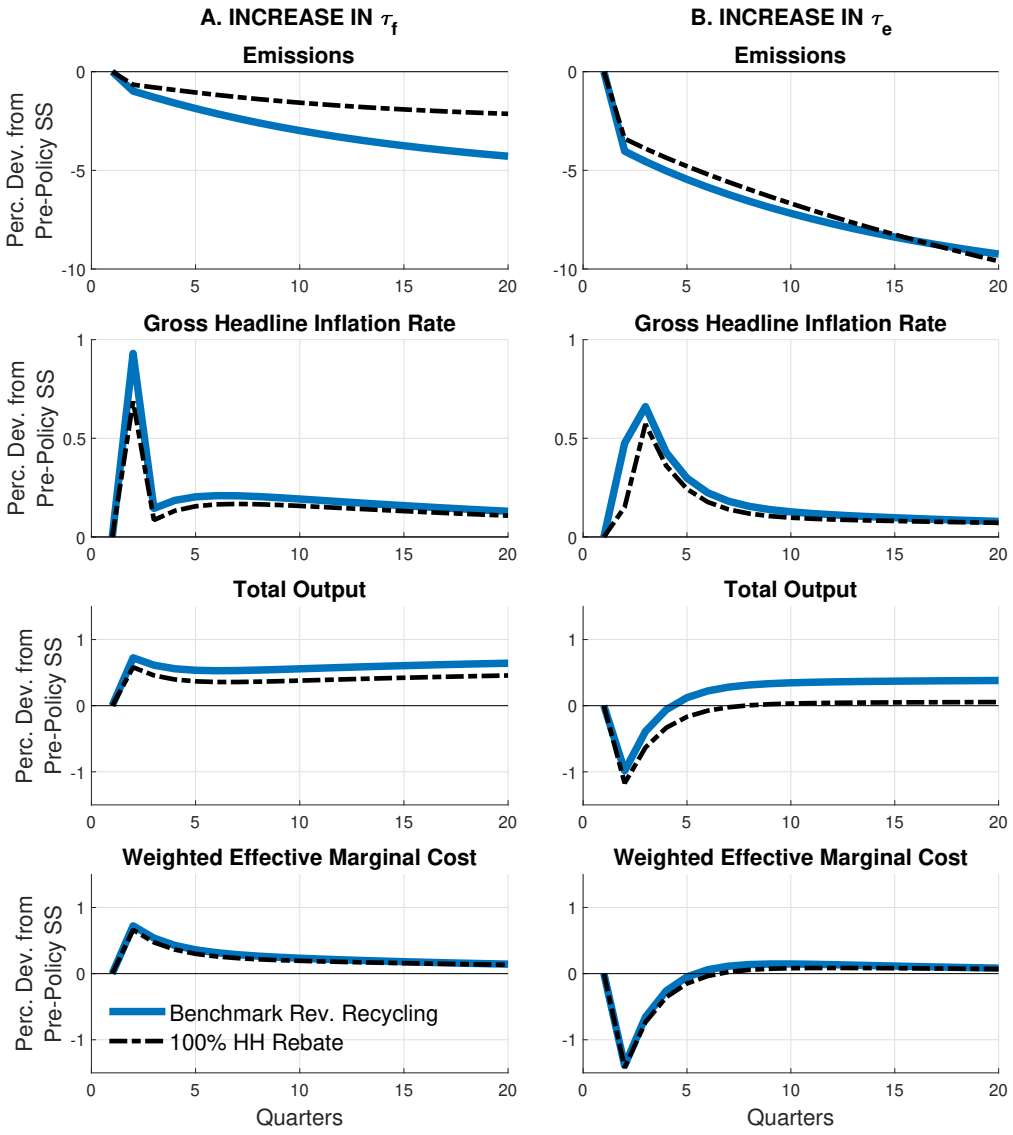


Note: Perc. Dev. denotes percent deviations and Perc.-Pt. Dev. denotes percentage-point deviations. Gross inflation and interest rates are expressed in annual terms.

Fig. A11 Quarterly Transition Path in Response to $40 Increase in Each Carbon Tax—Benchmark Model with Core Inflation in Taylor Rule

Note: Perc. Dev. denotes percent deviations and Perc.-Pt. Dev. denotes percentage-point deviations. Gross inflation and interest rates are expressed in annual terms.

Fig. A12 Quarterly Transition Path in Response to $40 Increase in Each Carbon Tax—Benchmark Model with Baseline Revenue Recycling vs. Model with 100 Percent Carbon-Tax Revenue Rebated Lump-Sum Back to Household



Note: Perc. Dev. denotes percent deviations. Gross inflation and interest rates are expressed in annual terms. The weighted effective marginal cost (MC) is defined as $N_{r,t}(mc_{r,t}/\widetilde{a}_{r,t}) + N_{g,t}(mc_{g,t}/\widetilde{a}_{g,t})$.