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The Green and Equitable Challenge of Fiscal Consolidation

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Keywords

fiscal consolidation, environmental policies, inequality, DSGE

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The Green and Equitable Challenge of Fiscal Consolidation

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Abstract

Fiscal consolidation and decarbonization are two of the European Union's most pressing—and typically separately analyzed—policy challenges. This paper asks whether they can be pursued jointly, and at what distributional cost. We develop a Two-Agent New Keynesian model augmented with an environmental sector and compare a standard expenditure-based consolidation with an environmental–fiscal policy mix in which the carbon tax responds systematically to the debt gap, becoming an active consolidation instrument. The policy mix reaches the debt target faster under a pure announcement of future tax cuts (22 rather than 35 quarters), delivers a substantially larger reduction in emissions at a comparable output cost, generates a smaller transitional rise in consumption inequality, and lowers inequality in the long run. Automatic stabilizers cushion financially constrained households, roughly halving the transitional rise in inequality, while countercyclical monetary policy contains welfare costs for both household types. Debt reduction and decarbonization thus emerge as complementary, rather than competing, objectives under a coordinated policy design.

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1 Introduction

The European Union currently faces two policy imperatives that are typically analyzed in isolation. On the fiscal side, the global financial crisis, the sovereign debt crisis, and the COVID-19 pandemic have produced a structural upward shift in public debt ratios across the Euro Area. High debt exposes governments to interest rate risk, constrains discretionary policy, and may raise sovereign risk premia. Under the revised Stability and Growth Pact, Member States are now required to bring public debt back towards 60% of GDP while keeping deficits below 3%, along country-specific adjustment paths defined in Medium-Term Fiscal Structural Plans (MTFSPs).[1] On the environmental side, under the European Climate Law and the Fit for 55 package, the EU has committed to cutting greenhouse gas (GHG hereafter) emissions by at least 55% by 2030 relative to 1990 levels and to reaching climate neutrality by 2050.

These two objectives are tightly interconnected. Climate policies affect public debt dynamics through several channels, including the short-run output cost of carbon taxation and shifts in the level and composition of government revenues and expenditure. Conversely, fiscal consolidation shapes aggregate demand and output, thereby affecting firms' production decisions and optimal abatement effort and, ultimately, emissions. As shown in Figure 1, while the EU debt-to-GDP ratio has remained persistently above its 2010 level and rose sharply during the pandemic, GHG emissions have followed a downward trajectory. Fiscal consolidation, therefore, should not be designed within an environmentally neutral macroeconomic framework, but rather in the context of an economy undergoing a costly green transition.

This paper asks whether public debt can be reduced without sacrificing—or, indeed, while advancing—environmental objectives, and at what distributional cost. To address this question, we develop a Two-Agent New Keynesian (TANK) model augmented with an environmental sector featuring emissions, abatement effort, and carbon taxation. The economy is populated by optimizing Ricardian households and financially constrained rule-of-thumb consumers, so that the distributional consequences of consolidation are an integral part of the analysis rather than an afterthought. Within this framework, we compare two expenditure-based consolidation strategies that permanently reduce the debt-to-GDP ratio from 70% to 60%: a standard fiscal strategy, in which government spending responds to the debt gap and distortionary taxation adjusts residually, and an environmental–fiscal policy mix, in which the carbon tax also responds systematically to deviations of debt from its target. The distinguishing feature of the latter is that environmental taxation becomes an *active consolidation*

[1] The new legislative package (EU 2024/1263, 2024/1264 and Directive 2024/1265) emphasizes gradual but credible debt reduction strategies anchored in expenditure rules and debt sustainability analysis.

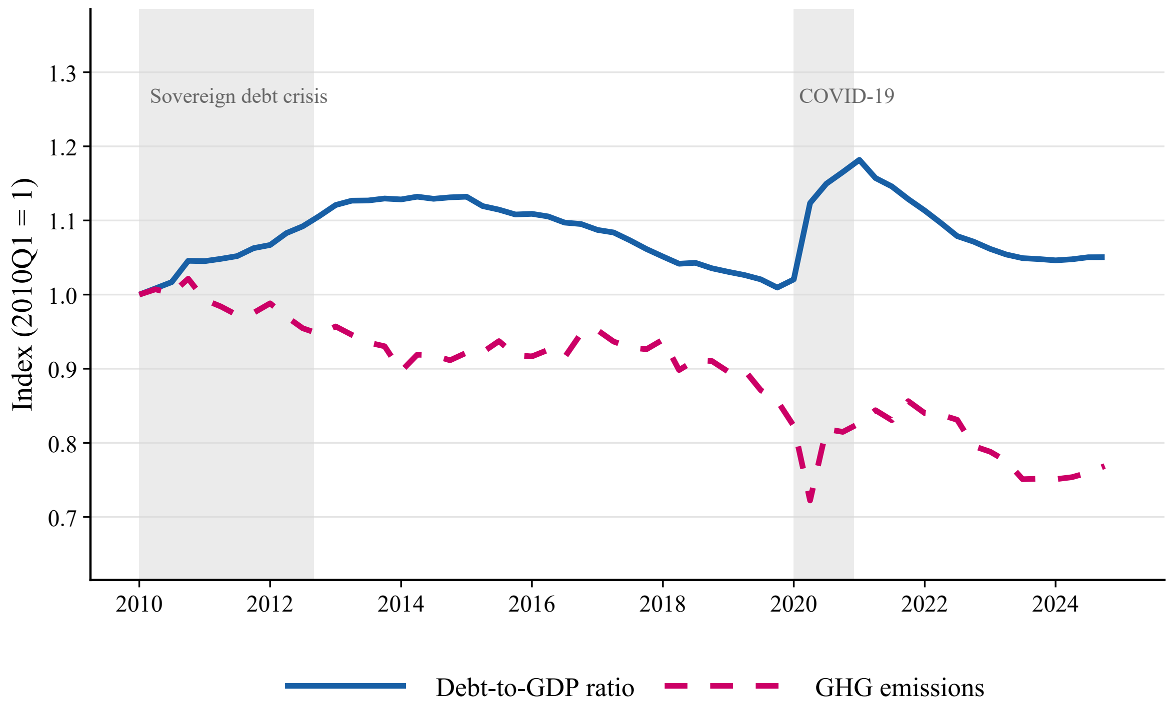

Figure 1: Debt-to-GDP ratio and greenhouse gas emissions, European Union, 2010Q1–2024Q4. Both series are normalised to 1 in 2010Q1. Debt data: Eurostat (`gov_10dd_edpt1`), seasonally adjusted using X-13ARIMA-SEATS. GHG emissions: Eurostat/EEA (`env_ac_aigg_q`), seasonally adjusted.

instrument: when debt exceeds its target, the carbon tax rises, generating fiscal revenues while simultaneously strengthening abatement incentives. We further examine how the implementation regime for tax reductions (a pure announcement of future cuts versus automatic stabilizers) and the monetary policy stance shape the macroeconomic, distributional, and environmental outcomes of the adjustment.

Our results show that the environmental–fiscal policy mix dominates the purely fiscal strategy along all three dimensions we consider. It achieves the debt target more quickly (in 22 rather than 35 quarters under a pure-announcement regime), delivers a substantially larger reduction in emissions for a comparable output cost, and generates a smaller increase in consumption inequality along the transition. When the policy mix is combined with automatic stabilizers, which cushion the disposable income of financially constrained households, the transitional rise in inequality is roughly halved. Monetary policy plays a complementary role: a countercyclical interest-rate rule mitigates output losses and supports rule-of-thumb consumption, delivering lower welfare costs for both household types than pure inflation targeting or a hawkish regime. In the long run, the policy mix reduces both emissions and inequality at the cost of only a limited recessionary effect, and these conclusions are robust to the initial debt level, to the calibration of the carbon-tax instrument, and to extending household welfare to include environmental awareness.

Our paper relates to two strands of literature. The first investigates the effects of climate policies on public debt dynamics, highlighting how climate shocks and the green transition can erode fiscal revenues and increase pressure on public expenditure. Using a computable general equilibrium (CGE) model calibrated to the Austrian economy, Bachner and Bednar-Friedl (2019) show that climate shocks and mitigation policies can negatively influence fiscal balances through both revenue and expenditure channels. Rausch (2013) shows, using an OLG model, that carbon pricing policies combined with a fiscal consolidation program may receive a more favorable social evaluation than climate policy alone. Gao (2024) adopts a Dynamic Stochastic General Equilibrium (DSGE) framework to study the impact of climate risk on government finances and finds that dedicated public funds and investments in climate resilience are needed to manage the damage without disrupting public finances. Similarly, Seghini and Dees (2025) analyze the macroeconomic consequences of the green transition in a DSGE model and its implications for public debt sustainability, showing that expenditure-based measures may worsen debt dynamics, especially in high-debt economies, but that an optimal policy mix can mitigate the adverse macroeconomic effects of carbon pricing while stabilizing the debt-to-GDP ratio. Closest to our setting, Garcia-Macia et al. (2024) find, in a TANK model, that a combination of carbon pricing and expenditure-based measures can support decarbonization while limiting the increase in public debt. More broadly, several recent policy contributions (e.g., Aphecetche, 2024; Avgousti et al., 2023) examine the fiscal implications of the green transition, arguing that climate policies may put public finances under significant strain and that continuous assessment, international coordination, tax reforms, and stronger public action are needed.

The second strand, which investigates how public debt dynamics and fiscal consolidation strategies affect environmental outcomes, remains limited and its findings are mixed. On the one hand, several contributions suggest a tension between debt accumulation and environmental quality: Carnazza et al. (2023) provide empirical evidence for European countries showing that rising public debt is not always compatible with environmentally sustainable outcomes, and a similar result emerges from Boly et al. (2022). On the other hand, Baret and Menuet (2024) show, within an overlapping-generations framework, that fiscal and environmental sustainability may coexist below a critical debt-to-GDP threshold, while Kellner and Runkel (2024) demonstrate that the relationship between climate policy and optimal public debt is theoretically ambiguous, as emission taxation may justify either lower or higher public borrowing depending on the evolution of environmental damages and tax revenues over time. From a policy-design perspective, Darvas and Wolff (2023) warn that fiscal consolidation may compress green public investment and slow down decarbonization, stressing the importance of a green fiscal rule, and Caselli et al. (2024) argue that green medium-term fiscal frameworks would allow climate considerations to be incorporated more comprehensively into fiscal policy design.

Our contribution sits at the intersection of these two strands and of the empirical and theoretical literature on fiscal consolidation. A large body of empirical evidence documents that expenditure-based adjustment plans are less contractionary and more effective in stabilizing the debt-to-GDP ratio than revenue-based consolidations (Alesina and Ardagna, 2010; Alesina et al., 2015; Alesina et al., 2019; Semik and Zimmermann, 2022). On the theoretical side, Ferrara and Tirelli (2017) demonstrate within a TANK framework that an equitable spending-based consolidation can simultaneously reduce public debt and support aggregate demand by stimulating the consumption of liquidity-constrained households. Existing consolidation models, however, abstract from environmental considerations and therefore cannot assess whether debt reduction strategies are compatible with emissions mitigation targets; conversely, the environmental DSGE literature has not examined fiscal consolidation, and distributional effects are largely absent from both. We fill this gap by embedding an environmental sector and an active environmental policy instrument in a TANK model of fiscal consolidation (Debortoli and Galí, 2025).

Specifically, we contribute to the literature along three dimensions. First, we analyze the joint role of fiscal and environmental policy in shaping debt and emissions dynamics along the transition path, evaluating whether an active environmental policy can offset the potential adverse effects of fiscal consolidation on emissions—and showing that, when the carbon tax serves as a consolidation instrument, debt reduction and decarbonization become complementary rather than competing objectives. Second, we examine whether the combination of fiscal consolidation and environmental policy amplifies or mitigates inequality across household types, and how the implementation regime for tax reductions shapes this outcome. Third, we explore how alternative monetary policy regimes interact with the fiscal–environmental strategy in delivering debt reduction, emissions mitigation, and welfare outcomes for heterogeneous households.
To evaluate these interactions over the adjustment path, we use the calibrated model as a laboratory for a policy experiment involving a permanent reduction in the debt target, tracing the full nonlinear transition toward the new steady state and identifying the structural mechanisms driving it.

The rest of the paper is organized as follows. Section 2 presents the model and the implementation of the fiscal consolidation plans. Section 3 describes the calibration. Section

4 presents the results and Section 5 provides a set of robustness checks. Section 6 concludes.

2 The Model

We develop a TANK model augmented with an environmental sector. The economy is populated by Ricardian (optimizing) households, who have access to financial markets, and non-Ricardian (rule-of-thumb, RT) consumers, who are financially constrained and consume only their labor income. Building on the framework of Ferrara and Tirelli (2017), we augment the TANK structure with an environmental sector featuring emissions, abatement effort, and a carbon tax. The model features both real rigidities and nominal rigidities in the form of Calvo-type price and wage stickiness. Government consumption G_t enters household utility directly, allowing fiscal policy to have direct welfare effects.

2.1 Households

The households' utility depends on their private consumption choices, on labor activity and on public spending:

$$U_0^i = \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left\{ ln\left(c_t^i - bc_{t-1}^i\right) - \Phi_h \frac{\left(h_t^i\right)^{1+\psi}}{1+\psi} + \chi^g ln G_t \right\}, \tag{1}$$

where $i = o, rt$ indexes Ricardian (o) and Rule-of-thumb (rt) households. The parameter $b \in (0,1)$ captures habit formation in consumption and $\beta \in (0,1)$ is the discount factor. In addition, $\Phi_h > 0$ governs the disutility of labor supply, ψ denotes the inverse Frisch elasticity of labor supply, and χ^g measures the weight assigned to public spending in utility.

2.2 Ricardian Households

Ricardian households receive income from labor, capital rental, and holdings of state-contingent assets. Labor and capital income are taxed at rates τ^h and τ^k, respectively. Optimizing agents allocate resources across consumption c_t^o, investment i_t^o and state-contingent nominal payment X_{t+1} in period t+1 at the cost $\mathbb{E}_t[r_{t,t+1}x_{t+1}]$. Accordingly, the period-by-period budget constraint is:

$$c_t^o + i_t^o + \mathbb{E}_t[r_{t,t+1}x_{t+1}] = (1-\tau_t^h)\, w_t\, h_t^d + (1-\tau_t^k)\left[r_t^k u_t - a(u_t)\right] k_t^o + \tau_t^k \delta k_t^o + \frac{x_t}{\pi_t}, \tag{2}$$

where $\frac{x_t}{\pi_t} \equiv \frac{X_t}{P_t}$ denotes real asset payoffs received at time t.

As in Christiano et al. (2005) (CEE, hereafter), the intensity of utilizing physical capital u_t is subject to a proportional cost $a(u_t) = \gamma_1(u_t - 1) + \frac{\gamma_2}{2}(u_t - 1)^2$ which is assumed to satisfy $a(1) = 0$, $a'(1) > 0$ and $a''(1) > 0$. The stock of physical capital evolves according to:

$$k^o_{t+1} = (1-\delta)k^o_t + i^o_t \left[1 - S\left(\frac{i^o_t}{i^o_{t-1}}\right)\right] \tag{3}$$

where δ is the depreciation rate and the function $S\left(\frac{i^o_t}{i^o_{t-1}}\right) = \frac{\kappa_I}{2}\left(\frac{i^o_t}{i^o_{t-1}} - 1\right)^2$ denotes the investment adjustment costs, where κ_I represents a scale parameter for investment adjustment costs.

Ricardian households maximize the utility function by choosing c^o_t, x_{t+1}, k^o_{t+1}, i^o_t, and u_t. The first order conditions are respectively:

$$\lambda^o_t = \frac{1}{c^o_t - bc^o_{t-1}} - \frac{b\beta}{c^o_{t+1} - bc^o_t} \tag{4}$$

$$\lambda^o_t = \beta\left(\lambda^o_{t+1}\frac{r_{t,t+1}}{\pi_{t+1}}\right) \tag{5}$$

$$\lambda^o_t q_t = \beta\lambda^o_{t+1}\left\{(1-\tau^k_t)\left[r^k_{t+1}u_{t+1} - a(u_{t+1})\right] + (1-\delta)q_{t+1} + \tau^k_t\delta\right\} \tag{6}$$

$$q_t\left\{1 - \frac{\kappa_I}{2}\left(\frac{i^o_t}{i^o_{t-1}} - 1\right)^2 - \kappa_I\frac{i^o_t}{i^o_{t-1}}\left(\frac{i^o_t}{i^o_{t-1}} - 1\right)\right\} + \beta\mathbb{E}_t\left[\frac{\lambda^o_{t+1}}{\lambda^o_t}q_{t+1}\left(\frac{i^o_{t+1}}{i^o_t}\right)^2\kappa_I\left(\frac{i^o_{t+1}}{i^o_t} - 1\right)\right] = 1 \tag{7}$$

$$r^k_t = a'(u_t) = \gamma_1 + \gamma_2(u_t - 1) \tag{8}$$

where Equation (4) represents the marginal utility of consumption and Equation (5) is the standard Euler equation for consumption. Equation 6 is the asset-pricing condition for capital, where q_t denotes the shadow price of installed capital (Tobin's q): it equates the expected discounted after-tax return on capital to its current shadow value. Equation 7 is the first-order condition for investment. Equation 8 is the optimality condition for capital utilization, equating the marginal return of capital to the marginal cost of utilization.

2.3 Rule-of-thumb Households

Rule-of-thumb households do not have access to financial markets and consume their entire after-tax labor income each period. Their budget constraint is:

$$c_t^{rt} = \left(1 - \tau_t^h\right) w_t h_t^d \tag{9}$$

The marginal utility of consumption is:

$$\lambda_t^{rt} = \frac{1}{c_t^{rt} - bc_{t-1}^{rt}} - \frac{b\beta}{c_{t+1}^{rt} - bc_t^{rt}} \tag{10}$$

2.4 Intermediate good firms

There is a continuum of monopolistically competitive polluting producers indexed by z, producing an intermediate good input using the following production function:

$$y_{z,t} = (1 - D_t)k_{z,t}^{\alpha} h_{z,t}^{(1-\alpha)} \tag{11}$$

where D_t denotes the damage function which captures the negative effects of emissions on production, which is defined following Ferrari and Nispi Landi (2024):

$$D_t = D_0 + D_1 M_t + D_2 M_t^2 \tag{12}$$

The production activity produces emissions given by:

$$E_{z,t} = (1 - U_{z,t})\epsilon y_{z,t} \tag{13}$$

where $U_{z,t}$ is the abatement effort and ϵ denotes the emissions per unit of output. The cost of emissions abatement $AC_{z,t}$ depends on output and abatement effort:

$$AC_{z,t} = \phi_1 U_{z,t}^{\phi_2} y_{z,t} \tag{14}$$

where ϕ_1 and ϕ_2 are abatement cost function technological parameters.

The firms' optimality conditions for the demand of labor, capital and abatement effort are, respectively:

$$w_t = (1-\alpha)(1-D_t)mc_{z,t}k_{z,t-1}^{\alpha}h_{z,t}^{-\alpha} \tag{15}$$

$$r_t^k = \alpha(1-D_t)\ mc_{z,t}k_{z,t-1}^{\alpha-1}h_{z,t}^{1-\alpha} \tag{16}$$

$$U_{z,t} = \left(\frac{\tau_t^E \epsilon}{\phi_1\phi_2}\right)^{\frac{1}{\phi_2-1}} \tag{17}$$

where $mc_{z,t}$ denotes the marginal cost of production, while $MC_{z,t}$ is the overall marginal cost that additionally incorporates the costs associated with emissions and abatement activities, i.e.

$$MC_{z,t} = mc_{z,t} + \phi_1 U_{z,t}^{\phi_2} + \tau_t^E \epsilon(1-U_{z,t}) \tag{18}$$

Firms face price rigidity à la Calvo (1983). In each period, a firm faces a constant probability $(1-\alpha_p)$ of being able to reoptimize prices. Those firms which cannot reoptimize adjust their price according to past inflation and steady-state inflation:

$$P_{z,t} = P_{z,t-1}\left(\frac{P_{t-1}}{P_{t-2}}\right)^{\chi_p}\pi^{1-\chi_p} = P_{z,t-1}\pi_{t-1}^{\chi_p}\pi^{1-\chi_p} \tag{19}$$

where χ_p denotes the price indexation parameter.

The optimal pricing condition is obtained by equating dynamic marginal revenues to dynamic marginal costs. Accordingly, the optimal reset price satisfies:

$$p_t^* = \frac{P_t^*}{P_t} = \frac{\eta_p}{\eta_p-1}\frac{\mathbb{E}_t\sum_{s=0}^{\infty}\alpha_p^s Q_{t,t+s}^R y_{t+s}^d\left(\frac{\prod_{k=1}^s \pi_{t+k}}{\prod_{k=1}^s \pi_{t+k-1}^{\chi_p}\pi^{1-\chi_p}}\right)^{\eta_p} MC_{t+s}}{\mathbb{E}_t\sum_{s=0}^{\infty}\alpha_p^s Q_{t,t+s}^R y_{t+s}^d\left(\frac{\prod_{k=1}^s \pi_{t+k}}{\prod_{k=1}^s \pi_{t+k-1}^{\chi_p}\pi^{1-\chi_p}}\right)^{\eta_p-1}} \tag{20}$$

where $Q_{t,t+s}^R$ denotes the stochastic discount factor of Ricardian households, α_p the degree of price stickiness. In addition, $\eta_p > 1$ is the elasticity of substitution across intermediate goods, χ_p governs the degree of price indexation to past inflation. The derivation of the recursive representation is provided in the Appendix B.

2.5 Unions

Nominal wage rigidity is modeled according to the Calvo (1983) mechanism, whereby each period a union faces a constant probability $(1-\alpha_w)$ of being able to reoptimize wages. Those unions which cannot reoptimize adjust the wage according to past inflation and steady-state inflation:

$$W_t = W_{t-1}\left(\frac{P_{t-1}}{P_{t-2}}\right)^{\chi_w}\pi^{1-\chi_w} = W_{t-1}\pi_{t-1}^{\chi_w}\pi^{1-\chi_w} \tag{21}$$

where χ_w denotes the degree of wage indexation. This implies that wages which are optimally reset at period t will be at period $t+s$:

$$w_{t+s} = w_t^* \prod_{k=1}^{s} \frac{\pi_{t+k-1}^{\chi_w}\pi^{1-\chi_w}}{\pi_{t+k}} \tag{22}$$

Each household supplies a differentiated labor service through a union that sets wages in a monopolistically competitive labor market. The union chooses the optimal wage w_t^* to solve:

$$\max_{w_t^*} \mathbb{E}_t \sum_{s=0}^{\infty}(\beta\alpha_w)^s \left(\prod_{k=1}^{s}\frac{\pi_{t+k}^{\chi_w}\pi^{1-\chi_w}}{\pi_{t+k}}\right)^{-\eta_w} (1-\tau_{t+s}^h)h_{t+s}^d w_{t+s}^{\eta_w}\lambda_{t+s}\times$$
$$\left\{(w_t^*)^{1-\eta_w}\left(\prod_{k=1}^{s}\frac{\pi_{t+k}^{\chi_w}\pi^{1-\chi_w}}{\pi_{t+k}}\right) + \frac{U_{t+s}^h}{\lambda_{t+s}}(w_t^*)^{-\eta_w}\right\}$$

where $\eta_w > 1$ denotes the elasticity of substitution across differentiated labor services, $\alpha_w \in (0,1)$ the degree of wage stickiness and U_{t+s}^h denotes the marginal disutility of labor. By defining:

$$f_t^1 = \frac{(\eta_w - 1)}{\eta_w} w_t^* \mathbb{E}_t \sum_{s=0}^{\infty}(\beta\alpha_w)^s\, \lambda_{t+s}\,(1-\tau_{t+s}^h)h_{t+s}^d \left(\frac{w_{t+s}}{w_t^*}\right)^{\eta_w}\left(\prod_{k=1}^{s}\frac{\pi_{t+k}}{\pi_{t+k-1}^{\chi_w}\pi^{(1-\chi_w)}}\right)^{\eta_w - 1} \tag{23}$$

$$f_t^2 = -(w^*{}_t)^{-\eta_w}\mathbb{E}_t \sum_{s=0}^{\infty}(\beta\alpha_w)^s(1-\tau_{t+s}^h)h_{t+s}^d(w_{t+s})^{\eta_w}U_{t+s}^h\left(\prod_{k=1}^{s}\frac{\pi_{t+k}}{\pi_{t+k-1}^{\chi_w}\pi^{(1-\chi_w)}}\right)^{\eta_w} \tag{24}$$

The optimal wage satisfies:

$$f_t^1 = f_t^2$$

2.6 Equilibrium and aggregation

2.6.1 Good Market Equilibrium

The market clearing condition in the final good market is:

$$y_t = \int_0^1 \left(\frac{P_{z,t}}{P_t}\right)^{-\eta_p} y_t^d dz = s_t^p y_t^d \tag{25}$$

where s_t^p denotes the price dispersion in the Calvo framework which reads as

$$s_t^P = (1-\alpha_p)(p_t^*)^{-\eta_p} + \alpha_p \left(\frac{\pi_t}{\pi_{t-1}^{\chi_p}\pi^{1-\chi_p}}\right)^{\eta_p} s_{t-1}^P \tag{26}$$

The aggregate price index evolution is:

$$1 = \alpha_p \pi_t^{\eta_p - 1}\left(\pi_{t-1}^{\chi_p}\pi^{1-\chi_p}\right)^{1-\eta_p} + (1-\alpha_p)(p_t^*)^{1-\eta_p} \tag{27}$$

2.6.2 Labor Market Equilibrium

The labor market clearing condition reads as:

$$h_t^s = \int_0^1 h_t^j \, dj = h_t^d \int_0^1 \left(\frac{W_t^j}{W_t}\right)^{-\eta_w} dj = s_t^w h_t^d \tag{28}$$

where s_t^w denotes the wage dispersion in the Calvo framework. It evolves according to:

$$s_t^w = (1-\alpha_w)\left(\frac{w_t^*}{w_t}\right)^{-\eta_w} + \alpha_w \left(\frac{w_{t-1}}{w_t}\right)^{-\eta_w}\left(\frac{\pi_t}{\pi_{t-1}^{\chi_w}\pi^{(1-\chi_w)}}\right)^{\eta_w} s_{t-1}^w \tag{29}$$

The aggregate wage index implied by the Calvo mechanism satisfies:

$$w_t^* = \left\{\frac{w_t^{(1-\eta_w)} - \alpha_w w_{t-1}^{(1-\eta_w)}\left(\frac{\pi_{t-1}^{\chi_w}\pi^{1-\chi_w}}{\pi_t}\right)^{(1-\eta_w)}}{(1-\alpha_w)}\right\}^{\frac{1}{(1-\eta_w)}} \tag{30}$$

2.6.3 Aggregation

The aggregate consumption, investment, capital and marginal utility are given by Eqs. (31)–(34).

$$c_t = (1-\Omega)c_t^o + \Omega c_t^{rt} \tag{31}$$

$$i_t = (1-\Omega)i_t^o \tag{32}$$

$$k_t = (1-\Omega)k_t^o \tag{33}$$

$$\lambda_t = \Omega\lambda_t^{rt} + (1-\Omega)\lambda_t^o \tag{34}$$

Consumption inequality CI_t is measured as the ratio between Ricardian and rule-of-thumb consumption,

$$CI_t = \frac{c_t^o}{c_t^{rt}} \tag{35}$$

The aggregate production function and the aggregate absorption read, respectively, as:

$$y_t = (1-D_t)(u_t k_t)^\alpha h_t^{(1-\alpha)} \tag{36}$$

$$y_t^d = c_t + i_t + g_t + a(u_t)k_t + AC_t, \tag{37}$$

where $a(u_t)k_t$ denotes the aggregate cost of capital utilization. AC_t is the aggregate abatement cost which reads as:

$$AC_t = \phi_1 U_t^{\phi_2} \int_0^1 y_{z,t}dz = \phi_1 U_t^{\phi_2} s_t^p y_t^d \tag{38}$$

The aggregate emissions read as:

$$E_t = \int_0^1 E_{z,t}dz = \int_0^1 (1-U_t)\epsilon y_t(z)dz = (1-U_t)\epsilon \int_0^1 y_t(z)dz = (1-U_t)\epsilon s_t^p y_t^d \tag{39}$$

The accumulation of emissions in the economy, M_t, is related to the stock of pollution in the previous period, M_{t-1}, and to the emissions in the economy, E_t:

$$M_t = (1-\delta_M)M_{t-1} + E_t \tag{40}$$

where $\delta_M \in (0,1)$ denotes the natural decay rate of atmospheric pollution.

2.7 Fiscal authority

The government budget constraint is given by

$$P_tG_t + B_t = P_t\tau_t^k[r_t^k u_t - a(u_t) - \delta]k_t + \tau_t^E E_t + P_t\tau_t^h w_t h_t + V_t B_{t+1}$$

The government expenditures G_t are financed by revenues on emissions ($\tau_t^E E_t$), labor and capital income taxes (τ_t^k and τ_t^h) and by holding bonds. In more detail, B_t is the number of 1-period bonds issued at time $t-1$, where reimbursement at maturity is 1 dollar. V_t is the dollar price at which the bond is sold at time t, and the gross interest rate is $R_t = \frac{1}{V_t}$. Rewriting:

$$G_t + \frac{b_t}{\pi_t} = \tau_t^k[r_t^k u_t - a(u_t) - \delta]k_t + \tau_t^h w_t h_t + \tau_t^E E_t + \frac{b_{t+1}}{R_t} \tag{41}$$

where $b_t = \frac{B_t}{P_{t-1}}$ is the real reimbursement value of debt.

Implementation. We model fiscal consolidation as a permanent reduction in the debt-to-GDP ratio from 70% to 60% through a temporary reduction in the public-expenditure-to-GDP ratio. Following Coenen et al. (2008) and Ferrara and Tirelli (2017), the government spending is the key tool and it evolves according to the following rule:

$$\left(\frac{g_{y,t}}{g_y}\right) = \left(\frac{b_{y,t}}{b_y^{**}}\right)^{-\phi^g} \tag{42}$$

where b_y^{**} denotes the new target of the debt-to-GDP ratio and $g_y = \frac{G^*}{y^*} = \frac{G^{**}}{y^{**}}$ is the public-spending-to-output ratio, assumed to be constant across the two steady states, with G^* (G^{**}) denoting the pre-consolidation (post-consolidation) steady-state level of public spending. The variables $b_{y,t}$ and $g_{y,t}$ represent debt and public spending in terms of post-consolidation steady-state output. The parameter ϕ^g governs the speed of fiscal adjustment (Coenen et al., 2008).

In an alternative policy experiment, we examine a fiscal consolidation strategy based on a policy mix that combines fiscal tools with environmental taxation. Specifically, similarly to public consumption, the carbon tax rate responds to debt dynamics according to the following rule

$$\left(\frac{\tau_t^E}{\tau^E}\right) = \left(\frac{b_{y,t}}{b_y^{**}}\right)^{\phi^E} \tag{43}$$

This specification allows us to evaluate the macroeconomic and distributional effects of a fiscal consolidation that jointly employs fiscal and environmental instruments. We examine what occurs when the fiscal authority simultaneously addresses fiscal sustainability and environmental objectives through coordinated policy action. The positive sign of ϕ^E implies that when the debt-to-GDP ratio exceeds its target, the carbon tax rate rises, generating additional fiscal revenues while simultaneously strengthening the environmental policy stance. This creates a complementarity between fiscal consolidation and emissions reduction. Section 5 assesses the sensitivity of our results to the calibration of ϕ^E and to the size of the carbon-tax adjustment.

We assume that the tax ratio remains constant throughout the consolidation, $\frac{\tau^{k,*}}{\tau^{h,*}} = \frac{\tau^{k,**}}{\tau^{h,**}}$, in order to isolate the effects of consolidation and to abstract from changes in the composition of taxation, which could affect the transition path but lies outside the scope of this paper. We refer to the labor tax rate only, since the capital tax rate is pinned down by the capital-to-labor tax rate ratio. Moreover, during the transition, the improvement in the government's budgetary position arising from lower debt service payments enables a reduction in distortionary taxation. We consider two alternative specifications for the labor income tax rate:

$$\tau_t^h = (1 - \rho_h)\tau_{t-1}^h + \rho_h \tau^h \tag{44}$$

$$\frac{\tau_t^h}{\tau^h} = \left(\frac{y_t}{y^{**}}\right)^{\delta_1} \tag{45}$$

Equation (44) denotes a pure announcement rule which captures the inertial tax adjustment over the transition path. This specification isolates the permanent income effect operating through forward-looking Ricardian households' expectations of future tax reductions. Equation (45) captures the automatic stabilizers mechanism. Under this specification, tax reductions have an immediate impact on RT households' disposable income, directly stimulating their consumption behavior.

2.8 Monetary authority

The monetary authority sets the nominal interest rate according to the following Taylor rule:

$$\left(\frac{R_t}{R^{**}}\right) = \left(\frac{R_{t-1}}{R^{**}}\right)^{\rho_r} \left[\left(\frac{\pi_t}{\pi^{**}}\right)^{\phi_\pi} \left(\frac{y_t}{y^{**}}\right)^{\phi_y}\right]^{(1-\rho_r)} \tag{46}$$

where R, y and π denote the steady state gross nominal interest rate, output and inflation rate, respectively. The coefficients ϕ_π and ϕ_y represent, respectively, the weights assigned by the central bank to deviations of inflation and output from their respective targets and ρ_r denotes the interest rate smoothing parameter.

3 Calibration and Solution Method

3.1 Calibration

The model is calibrated at a quarterly frequency for the euro area, and the analysis is framed as a calibrated policy experiment.[2] Table 1 reports the parameter values.

Following Albonico et al. (2019), we set the quarterly depreciation rate of physical capital to 0.025 and the capital share in the firms' intermediate-good production technology to 0.3. The degree of habit formation is fixed at 0.789, the inverse of the Frisch elasticity of labor supply is set to 2.734, and the capital adjustment cost parameter is set to 4.163. Following the same study, the share of rule-of-thumb households is set to 0.30.[3] We set the degree of price and wage stickiness to 0.897 and to 0.920, respectively. The price indexation parameter χ_p is fixed at 0.142 and the wage indexation is set to 0.746. Moreover, the price-elasticity of demand for a specific good variety parameter and the wage elasticity of demand for a specific labor variety are fixed at 6. Following CEE (2005), we normalize $u = 1$ and impose $a(u) = 0$. It follows that the capital-utilization cost parameter γ_1 is pinned down by the steady-state rental rate of capital. Accordingly, we set the steady-state value for γ_2 in order to match $a''(1)/a'(1) = 0.01$.

The discount factor is set to 0.9951 in order to imply a steady-state equilibrium real interest rate of 2.0% (Ferrari and Nispi Landi, 2023) and the steady-state inflation target $\bar{\pi}$ is set to 1.005, which corresponds to 2% yearly. In addition, we set the weight of government expenditures in the utility function χ^g to 0.3691 and the disutility of labor parameter Φ_h to 1.1196. The inflation and output stabilization coefficients are set following Albonico et al. (2019), with ϕ_π and ϕ_y equal to 1.70 and 0.25, respectively, and the interest-rate smoothing parameter ρ_r is set to 0.5 following Lukmanova and Rabitsch (2023).

[2] Robustness checks in Section 5 assess the sensitivity of the results to key calibrated parameters.
[3] Our results are robust to a larger share of RT households, namely 0.5.

Table 1: Model Calibration

Parameter	Description	Value
A. Preferences and Technology		
β	Discount factor	0.9951
b	Degree of habit formation	0.789
ψ	Inverse Frisch elasticity of labor supply	2.734
Φ_h	Disutility of labor parameter	1.1196
χ^g	Weight of government expenditure in utility	0.3691
α	Capital share in production	0.30
δ	Depreciation rate	0.025
κ_I	Capital adjustment cost	4.163
Ω	Share of RT	0.3
B. Price and Wage Setting		
α_p	Degree of price stickiness	0.897
α_w	Degree of wage stickiness	0.920
η_p	Price elasticity of demand	6
η_w	Wage elasticity of demand	6
χ_p	Price indexation	0.142
χ_w	Wage indexation	0.746
C. Monetary Policy		
$\bar{\pi}$	Steady-state inflation target (quarterly)	1.005
ϕ_π	Inflation stabilization coefficient	1.70
ϕ_y	Output stabilization coefficient	0.25
ρ_r	Interest rate smoothing	0.50
D. Environmental Sector		
D	Steady-state damage	0.0069
ϕ_1	Abatement cost parameter	1
ϕ_2	Abatement cost parameter	2.8
δ_M	Pollution decay rate	0.0021
ϵ	Emissions per unit of output	0.45

The environmental policy parameters are set following Annicchiarico and Diluiso (2019). Therefore, the abatement cost parameters ϕ_1 and ϕ_2 are set to 1 and 2.8, the pollution decay rate δ_M is set to 0.0021. The emissions per unit of output ϵ is equal to 0.45 (Annicchiarico and Di Dio, 2015). The carbon tax rate is set in order to achieve an environmental revenues-output ratio of 2.5%, consistent with the historical average from the Eurostat database.[4] Regarding the damage function, we follow Ferrari and Nispi Landi (2024). The steady-state value of atmospheric carbon corresponds to 851 GtC, and the damage function parameters are set to $D_2 = 1.3015 \times 10^{-10}$, $D_1 = 9.0182 \times 10^{-7}$, and $D_0 = -0.0076$, implying a steady-state damage of 0.69%. In the transition analysis, we keep the damage term at its steady-state

[4]Data available at the following link: `https://doi.org/10.2908/TEN00141`

Table 2: Fiscal sector calibration

Parameter	Description	Value
by^*	Debt-to-GDP ratio (initial target)	70%
by^{**}	Debt-to-GDP ratio (final target)	60%
$g^* = g^{**}$	Public spending–output ratio	0.215
ϕ^g, ϕ^E	Debt stabilization parameters	1
ρ_h	Tax rate adjustment speed	0.01
δ_1	Tax response to output	0.50
$(\tau^k/\tau^h)^* = (\tau^k/\tau^h)^{**}$	Capital-to-labor tax ratio	0.92
Scenario 1: Fiscal Consolidation		
$\tau^{h,*}$	Labor tax rate (old)	0.331
$\tau^{h,**}$	Labor tax rate (new)	0.328
$\tau^{k,*}$	Capital tax rate (old)	0.305
$\tau^{k,**}$	Capital tax rate (new)	0.302
Scenario 2: Fiscal–Environmental Policy Mix		
$\tau^{h,*}$	Labor tax rate (old)	0.331
$\tau^{h,**}$	Labor tax rate (new)	0.322
$\tau^{k,*}$	Capital tax rate (old)	0.305
$\tau^{k,**}$	Capital tax rate (new)	0.297
$\tau^{E,*}$	Carbon tax rate (old)	0.06
$\tau^{E,**}$	Carbon tax rate (new)	0.072

value. This choice allows us to focus on the interaction between fiscal consolidation, carbon taxation, abatement incentives, and emissions dynamics, rather than on the quantification of long-run climate damages.[5] In addition, it preserves computational tractability by avoiding an additional nonlinear and highly persistent feedback along the perfect-foresight transition.

Fiscal policy parameters are calibrated following the standard literature for the euro area. In more detail, following Coenen et al. (2008), we set the debt stabilization parameters (ϕ^g, ϕ^E) to 1.[6] The tax adjustment speed ρ_h and the tax response to output δ_1 are equal to 0.01 and to 0.5, respectively. We set the public-spending-to-output ratio to 0.215, consistent with euro area data. The labor income tax rate is endogenously calibrated so that the steady-state government budget constraint is satisfied under the targeted debt-to-GDP ratio. The capital income tax rate is set to match a constant capital-to-labor tax ratio of 0.92, following Ferrara and Tirelli (2017). More specifically, because the labor tax rate is determined to satisfy the debt-to-GDP target, its steady-state value depends on the scenario. In Scenario 1, when it is

[5] This abstraction is in the spirit of transition-focused models that abstract from endogenous climate-damage feedbacks when these are not central to the analysis (Varga and Roeger, 2022; Coenen et al., 2024).

[6] Coenen et al. (2008) analyze fiscal consolidation effects in the New Area-Wide Model (NAWM) developed at the European Central Bank and set the debt stabilization parameter to one for each consolidation instrument. We assume that also the parameter related to carbon tax adjustment to debt is equal to one. This assumption allows us to compare different scenarios also in terms of speed of debt consolidation.

the only tax instrument that adjusts, the first and the second steady-state values are 0.331 and 0.328. In Scenario 2, the carbon tax increases by 20 percent; accordingly, a larger adjustment in the labor tax rate is required to meet the lower debt-to-GDP target. As a consequence, the second steady-state value is 0.322. Table 2 reports the fiscal sector calibration, steady-state targets and scenario-specific tax rates under fiscal consolidation through fiscal tools (Scenario 1) and through environmental–fiscal policy mix (Scenario 2).

3.2 Solution method

The model is solved in its nonlinear form as a deterministic, perfect-foresight transition between the initial steady state, associated with a 70% debt-to-GDP ratio, and the final steady state, associated with the 60% target, using Dynare's perfect-foresight solver (version 5.5). Agents learn about the consolidation plan at the beginning of the transition and correctly anticipate the entire path of policy instruments thereafter. The two steady states are computed from the equilibrium conditions reported in Appendix A, with the labor tax rate calibrated endogenously in each steady state so that the government budget constraint holds at the targeted debt ratio. The simulation horizon is set to $T = 200$ quarters, sufficiently long for all variables to converge to the terminal steady state; the reported transition paths are unaffected by further extensions of the horizon.

4 Results

Our analysis investigates the effects of an expenditure-based fiscal consolidation on both emissions and macroeconomic variables, in the short and the long run. Within these two contexts, we evaluate the role of fiscal policy tools as well as the effects of the environmental–fiscal policy mix. In particular, we identify two scenarios as follows:

- **Scenario 1 – Fiscal Policy:** Fiscal consolidation is achieved exclusively through adjustments in government spending (Eq. (42)).
- **Scenario 2 – Environmental–Fiscal Policy Mix:** Fiscal consolidation is implemented through a coordinated policy mix combining fiscal and environmental instruments. Government spending adjusts according to Eq. (42), while the carbon tax evolves following Eq. (43).

Table 3: Long-run effects of fiscal consolidation strategies

	Scenario 1	**Scenario 2**
$\Delta\tau^{h**}$	-0.939	-2.613
$\Delta\tau^{k**}$	-0.939	-2.613
$\Delta\tau^{E**}$	0	20
ΔE^{**}	0.131	-0.920
$\Delta y^{**} = \Delta G^{**}$	0.131	-0.045
ΔAC	0.131	32.73
Δc^{o**}	-0.014	-0.111
Δc^{rt**}	0.597	0.626
$\Delta\left(\frac{k^{**}}{h^{**}}\right)$	0.130	-0.519
Δh^{**}	0.092	0.110
Δw^{**}	0.039	-0.770
ΔCI^{**}	-0.608	-0.733

Note: The table reports steady-state effects of a permanent reduction of the debt-to-GDP ratio from 70% to 60%, implemented either through the government spending rule with residual adjustment of the labor income tax rate τ^h (Scenario 1) or through a policy mix in which the carbon tax τ^E also serves as a consolidation instrument (Scenario 2). All outcomes are expressed as percent deviations from the initial steady state.

4.1 Long-run effects

Table 3 reports the long-run effects of alternative expenditure-based fiscal consolidation strategies.

In Scenario 1, fiscal consolidation releases resources that can be used to reduce distortionary taxation. Capital and labor supply increase, implying output expansion and, consequently, higher emissions. Due to lower taxation, a positive wealth effect arises for households, stabilizing their consumption paths. While RT consumers fully enjoy it, the positive wealth effect for Ricardian households is offset by the loss of public debt service payments.

In Scenario 2, fiscal consolidation operates with a notably different mechanism. A 20% increase in the carbon tax generates additional resources, allowing for a more substantial reduction in labor and capital income taxes compared with Scenario 1.[7] In addition, under an active environmental policy, abatement costs rise significantly once the required abatement effort is taken into account. Compared with Scenario 1, labor supply increases more due to a stronger reduction in the labor tax rate. By contrast, capital supply declines as firms reduce their demand for capital in response to higher production costs. Overall, the policy mix produces a limited recessionary effect alongside a substantial reduction in emissions (via Eqs. (13), (14), and (17)). Relative to Scenario 1, RT households enjoy a greater positive wealth effect due to a stronger reduction in the labor tax rate. By contrast, Ricardian households, beyond losing public debt-service payments, bear the negative effect of the carbon tax increase.

In sum, in the long run an appropriate environmental–fiscal policy mix may be desirable, as it implies a significant reduction in emissions in the face of a limited recessionary effect. Moreover, financially constrained agents benefit from the resources released through the long-term reduction in distortionary taxation. This, in turn, leads to a stronger contraction in inequality than under Scenario 1.

4.2 Short-run effects

In this subsection, we analyze the short-run effects of the fiscal consolidation experiments. We compare Scenario 1, namely a purely expenditure-based fiscal consolidation, with Scenario 2, the environmental–fiscal policy mix, both under countercyclical monetary policy. Within each scenario, we compare the case in which the expenditure-based fiscal consolidation is accompanied by a pure announcement (PA) rule of future tax reductions, described by Eq. (44), with the case in which the government employs automatic stabilizers (AS), described by Eq. (45).

Each panel depicts the transition path from an initial steady state associated with a 70% debt-to-GDP ratio to the target of 60%.[8]

[7] Our exercise should be interpreted as a (green) fiscal consolidation rather than a full green transition. Accordingly, we raise the carbon tax by only 20 percent, enough to support fiscal consolidation while allowing us to assess whether carbon taxation can simultaneously contribute to reducing emissions.

[8] Variables are expressed as percentage deviations from the initial steady state, except fiscal and monetary variables, which are reported in absolute values, and tax rates, which are reported in levels.

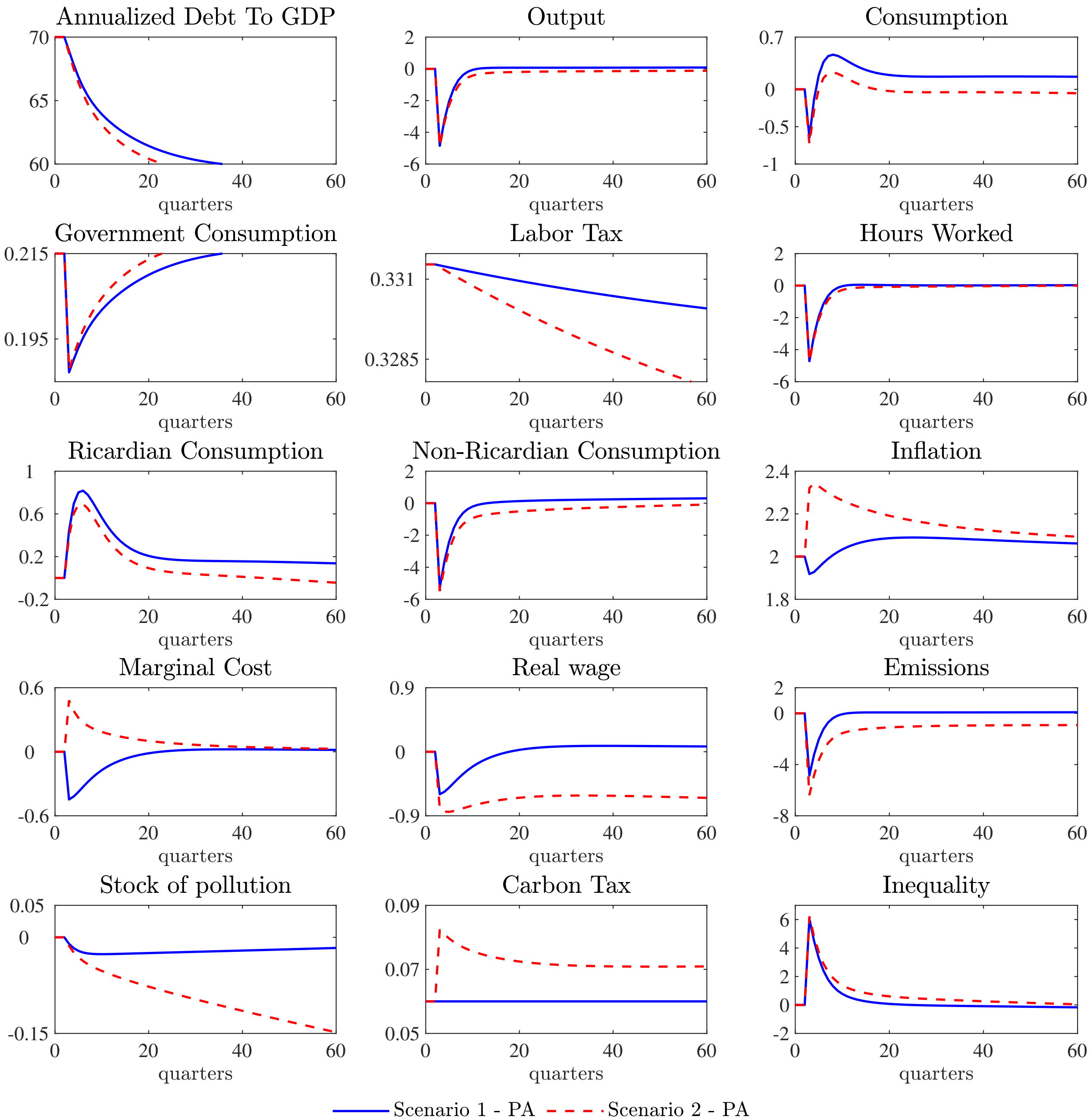

Figure 2: Transition dynamics of aggregate macroeconomic and environmental variables toward a lower debt-to-GDP ratio under pure announcement. The solid blue line shows the expenditure-based fiscal consolidation with residual adjustment of the labor income tax (Scenario 1), while the dashed red line refers to the consolidation implemented through the environmental–fiscal policy mix (Scenario 2).

4.2.1 Fiscal and Environmental–Fiscal Policy Mix under Pure Announcement

Figure 2 depicts, under a pure announcement regime of future tax reductions (Eq. (44)), the transition dynamics comparing the fiscal spending-based strategy (solid blue line) with the environmental–fiscal policy mix (dashed red line). The spending-based fiscal consolidation occurs through a temporary reduction in public spending, while the labor tax rate permanently declines. The implemented strategy is associated with an unavoidable recessionary effect in the short run[9] and allows the economy to reach the debt-to-GDP target in 35 quarters and to reduce emissions by 4.8% at the trough. In addition, while Ricardian households increase their consumption due to their expectations of future tax reductions, RT households entirely bear the public spending contraction and notably reduce their consumption. Beyond widening consumption inequality between the two household groups, this effect depresses aggregate demand, further reducing aggregate output.

The transition dynamics and the relative transmission mechanisms are markedly different when fiscal and environmental policies work simultaneously. Under this specification, the permanent reduction in the debt-to-GDP ratio is achieved through a temporary cut in public spending, a permanent decrease in the labor tax rate, and an increase in the carbon tax. Raising the carbon tax enables a deeper reduction in distortionary taxation (to the advantage of both household types), ensuring that the government budget constraint balances in the long run. In addition, it pushes up marginal costs (via Eq. (18)), implying an increase in inflation, and affects the consumption profile of Ricardian households, who own the firms. Compared with a purely expenditure-based fiscal adjustment, higher marginal costs are associated with lower real wages. Taken together, the deeper reduction in labor tax and the decline in real wages result in broadly similar consumption dynamics for rule-of-thumb households. For Ricardian households, the combined effect of a higher carbon tax and a stronger reduction in distortionary taxation tempers the increase in consumption, thereby mitigating the policy's adverse distributional effects. Overall, compared with a purely fiscal approach, the environmental–fiscal policy mix delivers similar output costs but achieves the debt target more quickly (within 22 quarters) and results in lower emissions.

4.2.2 Fiscal and Environmental–Fiscal Policy Mix under Tax Stabilizers

In Figure 3, holding the fiscal-consolidation strategies unchanged and the relative transmission channels, our analysis focuses on the role of automatic stabilizers (Eq. (45)). Results confirm the advantage of implementing the environmental–fiscal policy mix. In fact, compared with a purely fiscal policy strategy, the policy mix delivers a greater reduction in emissions for the same recessionary effect. Importantly, automatic stabilizers play a key role in cushioning the decline in RT households' consumption (Eq. (9)), therefore stabilizing aggregate demand and limiting the increase in inequality.[10] In fact, compared with the pure-

[9] See, among others, Alesina et al. (2015); Ferrara and Tirelli (2017); Alesina et al. (2019).

[10] This result is consistent with Ferrara and Tirelli (2017). However, while in their framework, where environmental considerations are absent, RT households' consumption increases during the transition, in our

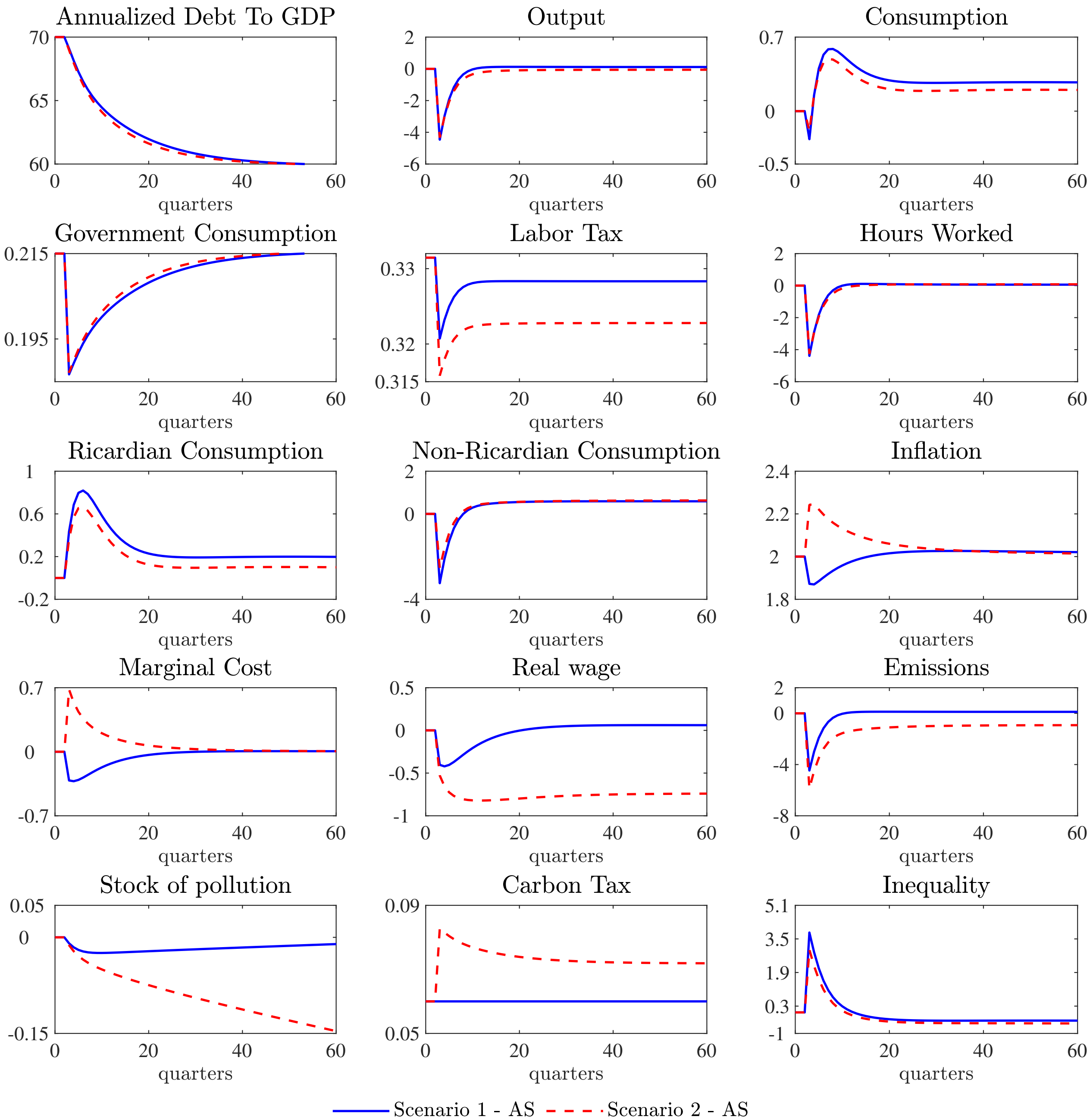

Figure 3: Transition dynamics of aggregate macroeconomic and environmental variables toward a lower debt-to-GDP ratio under automatic stabilizers. The solid blue line shows the expenditure-based fiscal consolidation with residual adjustment of the labor income tax (Scenario 1), while the dashed red line refers to the consolidation implemented through the environmental–fiscal policy mix (Scenario 2).

announcement regime, the increase in inequality is roughly halved, regardless of the policy implemented. Nevertheless, under automatic stabilizers the public debt dynamics turn out to be slower, achieving the target after about 51 quarters.

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model the policy mix mainly stabilizes the cyclical fluctuations of their consumption, rather than generating a sizeable expansion.

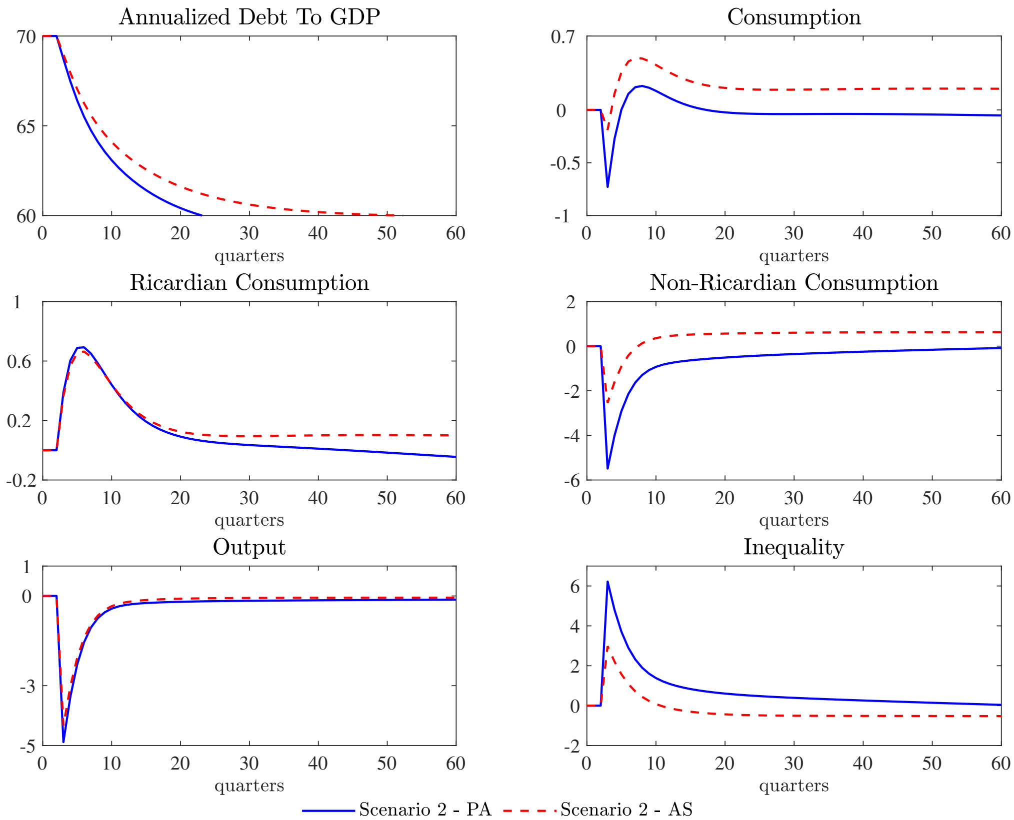

Figure 4: Transition dynamics of selected variables under policy mix. The solid blue line shows fiscal consolidation under pure announcement (PA), while the dashed red line refers to the fiscal consolidation under automatic stabilizers (AS).

4.2.3 Environmental–Fiscal Policy Mix: *Pure Announcement* vs *Tax Stabilizers*

Figure 4 compares the environmental–fiscal policy mix strategies under both tax reduction schemes (Eqs. (44)–(45)). In light of the previous results, which identify the policy mix as the most effective strategy, our analysis suggests that the appropriate approach to reduce both public debt and emissions in an equitable and environmentally sustainable way is the environmental–fiscal policy mix combined with automatic stabilizers. While the policy mix reduces emissions primarily through an increase in the carbon tax, automatic stabilizers operate through RT households' budget constraint (Eq. (9)), thereby shaping their consumption dynamics.

4.3 Welfare analysis

In this section, we perform a welfare analysis of the two alternative fiscal consolidation strategies examined. For our purposes, we use the consumption equivalent measure (CEM, denoted by γ^j) as a metric of welfare costs, which is defined as the fraction of pre-consolidation consumption that households would be willing to give up to be indifferent between the pre-consolidation allocation and the one prevailing under the consolidation plan. Formally, γ^j solves the following condition:

$$V_j^0 = \frac{1}{(1-\beta)}\left[ln\left(1-b\right)\left(1-\gamma^j\right)c_j^{old} - \frac{\Phi_h}{1+\psi}(h_j^{old})^{1+\psi} + \chi^g lnG^{old}\right] \tag{47}$$

The full derivation is provided in Appendix C. The welfare results are summarized in Table 4.

In the long run, both consolidation strategies implemented are welfare improving for RT agents while they are welfare costly for Ricardians. In fact, Ricardians consume less, work more and bear additional costs stemming from the carbon tax.[11] By contrast, RT households gain from tax reductions and higher wages under Scenario 1, whereas in Scenario 2 they benefit primarily from a substantial tax reduction, which offsets the contraction in wages. Adopting the carbon tax as an additional instrument for debt consolidation in Scenario 2 entails larger welfare losses for Ricardian households than in Scenario 1, because of the combined effect of higher hours worked, lower consumption, lower government spending, and a higher carbon tax. This latter effect offsets the welfare gains from the labor tax cut. In contrast, RTs continue to experience welfare gains supported by the sizable reduction in taxes. Specifically, in the post-consolidation period, RT households are adversely affected by higher hours worked and lower government consumption, and they are also hit, although indirectly, by the higher carbon tax through its negative effect on firms and on wages. Nevertheless, their post-consolidation consumption rises, driven by the larger reduction in distortionary taxation.

In the short run, our welfare results reflect the transition dynamics and the inequality results explained above. Fiscal consolidation is costly for RT households, while Ricardian households experience welfare gains under the pure-announcement regime and mild losses under automatic stabilizers. The best strategy for Ricardian households is the policy mix associated with the pure announcement tax reduction scheme, as their consumption is more stimulated, reflecting a smaller tax reduction and a slower convergence of public spending toward its second steady state. RT households prefer the policy mix as well, but associated with the automatic stabilizer regime, as the joint effect of lower distortionary taxation and automatic stabilizers provides stronger support to disposable income during the transition.

[11] Ferrara and Tirelli (2017) find that fiscal consolidation gives rise to a positive effect on Ricardians' welfare, which is due to the increase of public spending, as they work more and consume less in the post-consolidation. In our model, the carbon tax mitigates this effect.

Table 4: Welfare effects of fiscal consolidation plans

	Welfare measure	Ricardian	RT
Scenario 1	WR_{LR}	0.0511	-1.4771
	$WR_{SR} - PA$	-0.0321	0.8840
	$WR_{SR} - AS$	0.1184	0.6860
Scenario 2	WR_{LR}	0.4796	-1.3628
	$WR_{SR} - PA$	-0.3163	0.9882
	$WR_{SR} - AS$	0.0446	0.5576

Note: All values are expressed in percentage terms. Negative values indicate welfare gains: the consolidation plan is welfare improving when $WR < 0$ (see Appendix C).

Overall, fiscal consolidation implemented through an environmental–fiscal policy mix delivers a more desirable welfare configuration in terms of aggregate welfare and the welfare differential between the two groups of agents.

5 Robustness Checks

5.1 The Role of Monetary Policy

Monetary policy plays a particularly important role in our framework, as it can mitigate the combined macroeconomic effects of fiscal consolidation and environmental policy interventions. Indeed, the reduction in public expenditure depresses aggregate demand and output. In addition, the increase in emissions taxation raises firms' marginal costs and creates inflationary pressures. In this environment, the monetary authority faces a trade-off between stabilizing inflation and cushioning the recessionary effects of the consolidation process. To explore this trade-off, we test the robustness of our main findings under alternative monetary policy regimes. The results discussed so far are obtained under a countercyclical monetary policy regime, in which the interest-rate rule responds to both inflation and the output gap. In this section we examine the role of monetary policy in the environmental–fiscal policy mix scenario under automatic stabilizers. We take countercyclical monetary policy as our baseline scenario and compare it with a pure inflation targeting framework and with the case in which the central bank reacts more aggressively to inflation fluctuations and less to the output gap (i.e., a hawkish regime). This robustness exercise is important for three reasons. First, it allows us to verify whether the environmental and macroeconomic consequences of

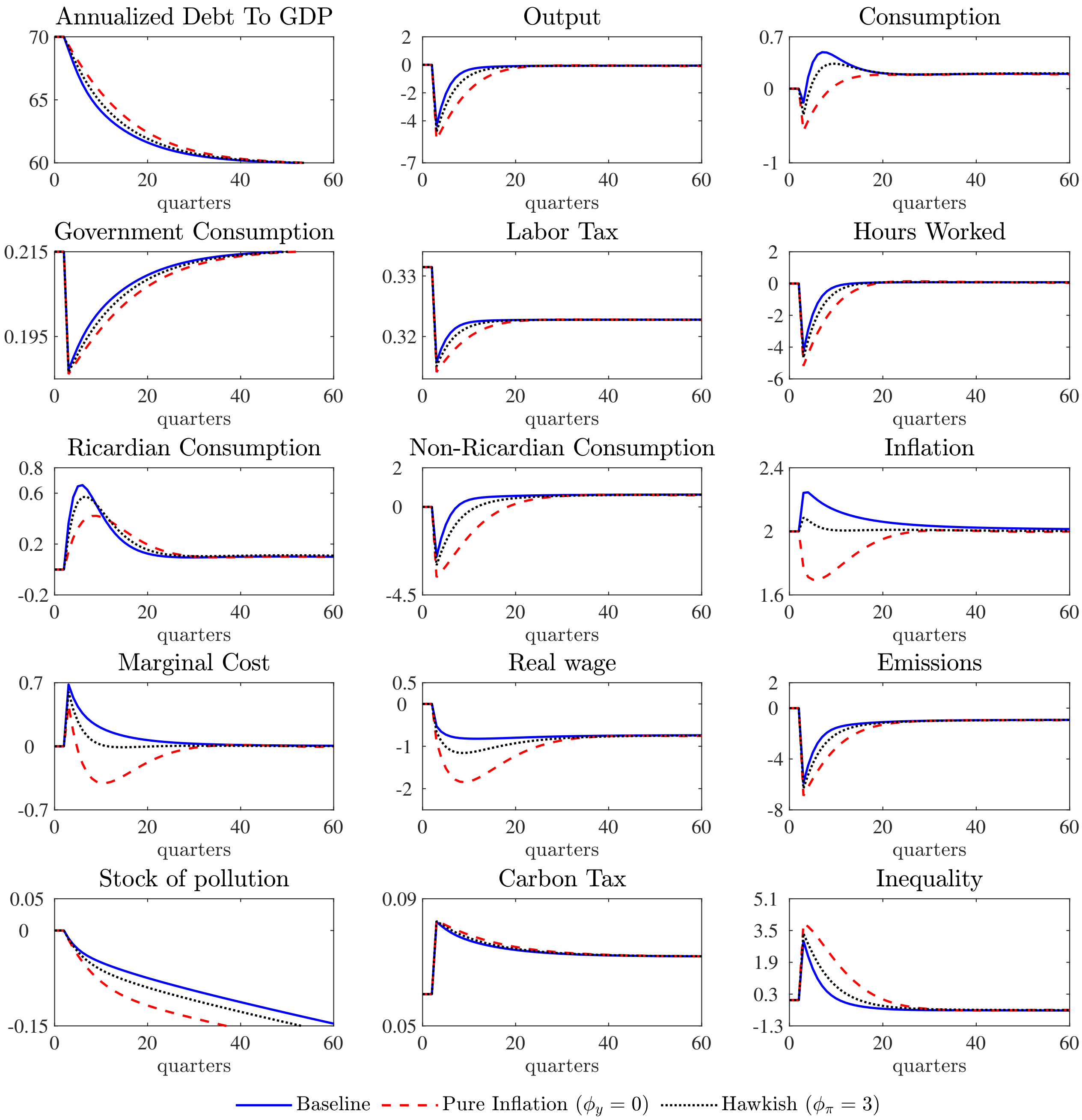

Figure 5: Transition dynamics under different monetary policy regimes in the environmental–fiscal policy mix and automatic stabilizers. The solid blue line denotes the baseline, the dashed red line represents pure inflation targeting and the dotted black line denotes the hawkish regime.

the environmental–fiscal policy mix depend on the monetary policy stance. Second, it clarifies the transmission channel through which monetary policy affects heterogeneous households: by stabilizing output and labor income, the response to the output gap indirectly supports rule-of-thumb consumption and limits the rise in inequality. Third, it provides a policy-relevant comparison between inflation stabilization and broader macroeconomic stabilization

Table 5: Short-run welfare effects across monetary policy regimes

Monetary regime	Ricardian	RT
Baseline	0.0446	0.5576
Pure inflation	0.1511	1.0207
Hawkish	0.0789	0.7273

Note: All WR_{SR} values are expressed in percentage terms. Negative values indicate welfare gains: a regime is welfare improving when $WR < 0$ (see Appendix C).

in the presence of a fiscal consolidation that also pursues environmental objectives.

As shown in Figure 5, although pure inflation targeting achieves the largest emissions reduction, it produces the worst macroeconomic and distributional outcomes, with pronounced output losses, a deep decline in RT households' consumption, and higher inequality. Similar but milder effects arise under the hawkish regime. The welfare results in Table 5 confirm this pattern: both agents suffer large losses under pure inflation targeting, while even a modest response to the output gap substantially reduces these costs. Thus, the hawkish regime performs better than strict inflation targeting but worse than the countercyclical monetary regime, which is therefore preferable. Although it delivers a more moderate emissions reduction, it directly mitigates output losses, indirectly supports consumption dynamics for both household groups, and achieves lower welfare costs (see Table 5). Taken together, these findings highlight the complementary role of countercyclical monetary policy within the environmental–fiscal policy mix.

5.2 The Role of the Scale of Fiscal Consolidation

Figure 6 examines whether the effects of fiscal consolidation depend on the initial level of public debt. In addition to the benchmark consolidation from 70 to 60 percent of GDP, we consider economies starting from higher debt-to-GDP ratios, namely 90 and 110 percent. Results show that the initial fiscal position is quantitatively important. As the initial debt ratio increases, fiscal consolidation generates stronger recessionary effects. This outcome is mainly driven by the sharper short-run contraction in public expenditure required to stabilize debt, while labor taxation declines and the emissions-related tax increases.

The adjustment is heterogeneous across households. Ricardian households, being forward-looking, increase consumption more strongly than in the low-debt benchmark, as they anticipate the future benefits associated with debt reduction and a lower labor tax burden. By

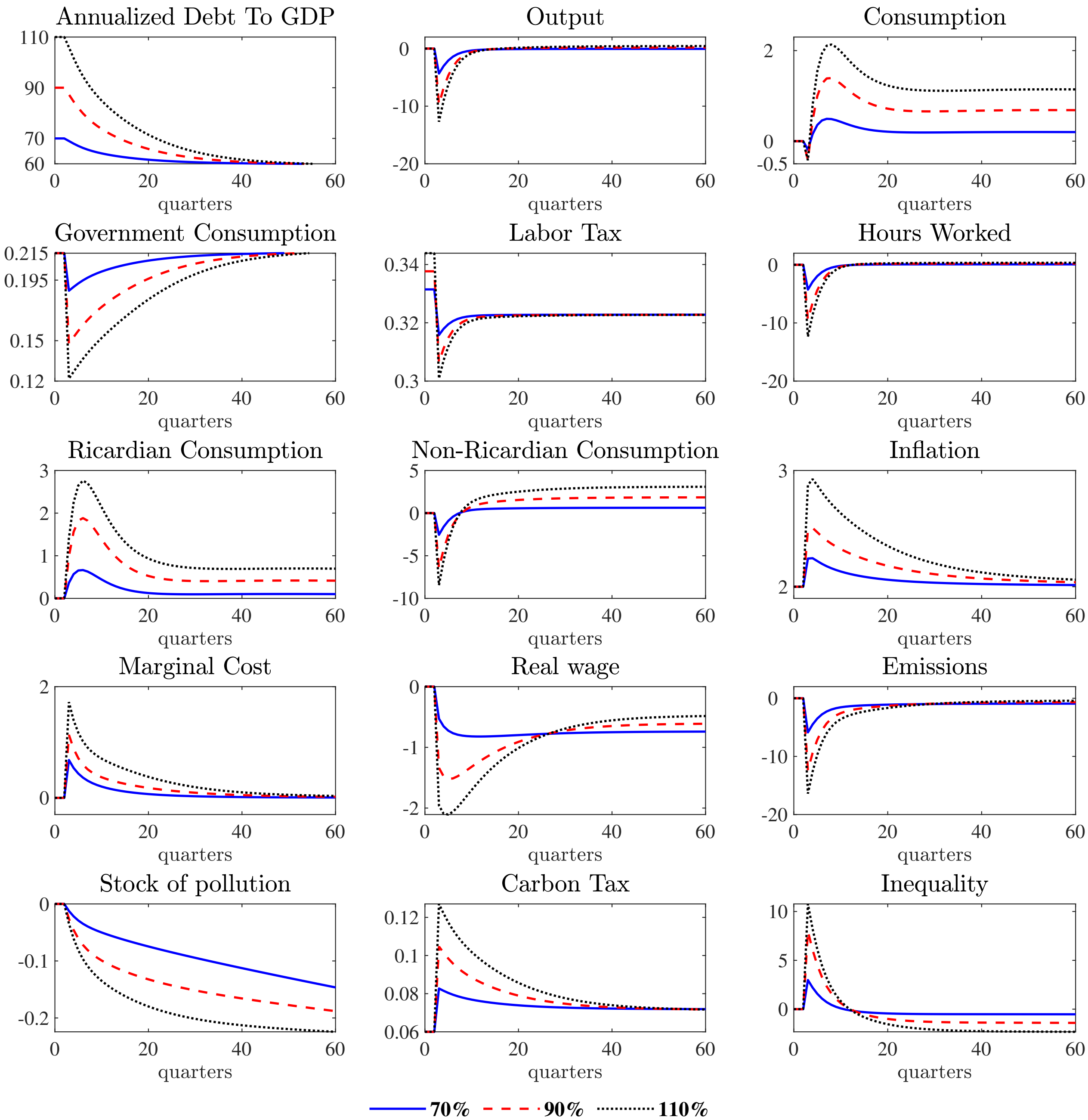

Figure 6: Transition dynamics for different initial debt-to-GDP ratios. The solid blue line denotes the baseline scenario with an initial debt-to-GDP ratio of 70%; the dashed red line refers to the 90% case; the dotted black line to the 110% case.

contrast, rule-of-thumb households are more exposed to current income effects. The stronger increase in emissions taxation and marginal costs compresses real wages in the short run, leading to a larger decline in their consumption. Over the longer horizon, however, the reduction in labor taxation gradually supports their disposable income and consumption.

Therefore, when fiscal consolidation starts from a higher debt level, the economy experiences a larger contraction in output and emissions, together with stronger increases in marginal costs and inflation. Aggregate consumption is nevertheless supported by the response of Ricardian households. These asymmetric effects imply a marked short-run increase in consumption inequality, followed by a gradual reduction as the benefits of lower labor taxation materialize for non-Ricardian households.

5.3 The Role of Environmental Awareness

The welfare analysis reported in Section 4.3 assumes that households derive utility from private consumption, leisure, and public spending. In this section, we assess the robustness of those results by extending the welfare criterion to account for environmental awareness, so that households also experience disutility from emissions. The purpose of this analysis is twofold. First, it examines whether the welfare ranking of the two fiscal consolidation strategies, as well as that of the alternative implementation regimes, remains unchanged once the environmental externality is internalized at the household level. Second, it provides a clearer assessment of how alternative consolidation plans affect welfare in the presence of environmentally aware households, allowing us to disentangle the environmental channel from the public-provision channel in shaping the welfare effects of the adjustment. To this end, we introduce environmental awareness following Chan and Punzi (2023). The CEM is derived from the following condition:[12]

$$V_j^0 = \frac{1}{(1-\beta)}\left[ln\left(1-b\right)\left(1-\gamma^j\right)c_j^{old} - \frac{\Phi_h}{1+\psi}(h_j^{old})^{1+\psi} + \chi^g lnG^{old} - \chi^E\frac{(E^{old})^{1+\psi^E}}{1+\psi^E}\right] \quad (48)$$

where χ^E denotes the weight given to environmental issues, which we set to 0.4, following Chan and Punzi (2023) and Angelopoulos et al. (2013). The parameter $\psi^E > 0$ controls the scale elasticity of the disutility from emissions and we set it to 1 as in Chan and Punzi (2023).

Table 6 reports the results. Panel A considers a welfare specification in which households' evaluation accounts for the disutility from emissions, in addition to private consumption and hours worked, thereby isolating the environmental channel. Panel B reports the baseline welfare specification augmented with environmental awareness, where households derive utility from private consumption, leisure, and public spending, while also incurring disutility from emissions.

[12]The derivation is consistent with Appendix C, with the addition of environmental awareness.

Table 6: Welfare effects under environmental awareness.

Panel A. Environmentally aware households (emissions only)

	Welfare measure	Ricardian	RT
Scenario 1	WR_{LR}	0.2573	-1.2697
	$WR_{SR} - PA$	-0.4389	0.4755
	$WR_{SR} - AS$	-0.5166	0.0481
Scenario 2	WR_{LR}	-0.1728	-2.0257
	$WR_{SR} - PA$	-0.3360	0.9718
	$WR_{SR} - AS$	-0.5400	-0.0286

Panel B. Environmentally aware households (emissions and public spending)

	Welfare measure	Ricardian	RT
Scenario 1	WR_{LR}	0.1393	-1.3884
	$WR_{SR} - PA$	-0.0913	0.8244
	$WR_{SR} - AS$	0.0725	0.6397
Scenario 2	WR_{LR}	-0.1372	-1.9842
	$WR_{SR} - PA$	-0.3915	0.9160
	$WR_{SR} - AS$	-0.0217	0.4923

Note: All values are expressed in percentage terms. Negative values indicate welfare gains: the consolidation plan is welfare improving when $WR < 0$ (see Appendix C). Panel A refers to the specification in which only emissions enter the utility function; Panel B to the specification in which both emissions and public spending enter utility.

Two results emerge relative to the benchmark specification. First, environmental awareness reshapes the short-run welfare assessment more than the long-run one. In more detail, when only emissions are valued, the transitional contraction in activity lowers emissions, which environmentally aware households internalize as a welfare gain; this attenuates the short-run losses of RT households, bringing them close to zero under automatic stabilizers, and reinforces the gains of Ricardian households. The long-run ranking, by contrast, is broadly preserved, since emissions return toward their steady-state level as activity recovers, so that the environmental dividend is transitional rather than permanent. An exception concerns Ricardian households, who, when environmentally aware, also obtain long-run gains under Scenario 2.

Second, adding the valuation of public spending moderates these gains: because the consolidation compresses public spending along the transition, households who value public provision internalize its reduction as a cost, which partially offsets the environmental gains. The net welfare improvement remains positive but smaller than under the previous environmental awareness case, in both the short and the long run, and in both scenarios. These results suggest that the environmental–fiscal policy mix in Scenario 2 benefits more from the inclusion of environmental awareness than the purely fiscal adjustment in Scenario 1. The reason is that the active environmental component amplifies the transitional decline in emissions, which environmentally aware households value. This further supports the main conclusion that the policy mix delivers a more desirable welfare configuration.

Two policy implications follow. First, the welfare case for fiscal consolidation is strengthened once emissions enter the social objective, but the strengthening is concentrated in the short run and is therefore transitional: the environmental dividend is most visible precisely when output and consumption costs are most acute, a feature relevant to the political economy of consolidation. Second, automatic stabilizers remain the preferred implementation regime: they cushion the transitional burden on financially constrained households while preserving the environmental gains valued by aware agents, yielding a configuration in which both household types can attain welfare improvements. Taken together, these results indicate that the welfare merits of an environmentally consequential consolidation depend jointly on its environmental consequences, on its implementation regime, and on the composition of the fiscal adjustment, not on debt reduction alone.

5.4 The Role of the Carbon-Tax Instrument

In the baseline environmental–fiscal policy mix, we perform a moderate green fiscal adjustment through a 20 percent increase in the carbon tax. To check whether our results depend on this calibration, we assess their robustness with respect to the carbon-tax response coefficient ϕ^E and the final carbon-tax increase.[13] Table 7 shows that the main results are robust. In particular, changes in ϕ^E do not significantly alter the transition dynamics or the welfare ranking. Similarly, alternative final carbon-tax increases leave the qualitative results unchanged. Moreover, a higher carbon tax strengthens emissions reduction and reduces short-run welfare costs, confirming its role as a complementary consolidation tool. As expected, it also generates stronger inflationary pressures.

[13]The full set of transition dynamics is reported in Appendix D.

Table 7: Robustness to carbon-tax calibration

	Peak y	Peak E	Peak π	Peak CI	WR^{o}_{SR}	WR^{rt}_{SR}
Panel A. Carbon-tax response coefficient ϕ^E						
$\phi^E = 0.5$	-4.338	-5.519	2.159	2.980	0.047	0.578
$\phi^E = 1.0$	-4.335	-5.869	2.242	2.982	0.045	0.558
$\phi^E = 1.5$	-4.328	-6.225	2.327	2.979	0.043	0.537
Panel B. Different τ^E *percentage increase*						
+10%	-4.410	-5.504	2.136	3.407	0.079	0.605
+20%	-4.335	-5.869	2.242	2.982	0.045	0.558
+30%	-4.289	-6.253	2.348	2.585	0.012	0.516

6 Conclusions

This paper examines the macroeconomic, environmental, and distributional implications of alternative spending-based fiscal consolidation strategies in a Two-Agent New Keynesian model. Our central result is that fiscal consolidation outcomes critically depend on policy design and coordination in a context where environmental issues do matter. We implement an expenditure-based fiscal consolidation experiment associated with a permanent reduction in the labor income tax rate and compare it with a fiscal consolidation strategy based on an environmental–fiscal policy mix, in which both standard fiscal instruments and environmental taxation are used to consolidate public debt.

Our results show that the environmental–fiscal policy mix delivers better outcomes in both the long and the short run. In particular, the policy mix leads to a significant reduction in emissions while generating recessionary effects comparable to those associated with the fiscal-only instrument. It also produces a stronger reduction in inequality. In this context, the adoption of automatic stabilizers is preferable. The joint effect of the policy mix, which operates through Ricardian households' budget constraint, and tax stabilizers, which operate through RT households' budget constraint, allows the economy to reduce debt and emissions while limiting distributional consequences. Monetary policy also plays a crucial complementary role. In fact, a countercyclical monetary policy provides stronger support to RT consumption, thereby containing inequality and limiting welfare costs for both types of agents.

More broadly, this paper suggests that debt reduction and decarbonization should not be treated as separate policy objectives. An appropriate coordination among fiscal, environmental and countercyclical monetary policies should be adopted to achieve fiscal consolidation while simultaneously addressing environmental objectives and containing social costs.

Our analysis is based on a calibrated framework, and extensive robustness checks confirm that the main findings are preserved across alternative calibrations. We leave Bayesian estimation of the model for future research.

Appendix A Equilibrium conditions

$$k_{t+1}^o = (1-\delta)k_t^o + i_t^o \left[1 - S\left(\frac{i_t^o}{i_{t-1}^o}\right)\right] \tag{A.1}$$

$$\lambda_t^o = \frac{1}{c_t^o - bc_{t-1}^o} - \frac{b\beta}{c_{t+1}^o - bc_t^o} \tag{A.2}$$

$$\lambda_t^o = \beta\left(\lambda_{t+1}^o \frac{r_{t,t+1}}{\pi_{t+1}}\right) \tag{A.3}$$

$$\lambda_t^o q_t = \beta\lambda_{t+1}^o \left\{(1-\tau_t^k)\left[r_{t+1}^k u_{t+1} - a(u_{t+1})\right] + (1-\delta)q_{t+1} + \tau_t^k\delta\right\} \tag{A.4}$$

$$q_t\left\{1 - \frac{\kappa_I}{2}\left(\frac{i_t^o}{i_{t-1}^o} - 1\right)^2 - \kappa_I\frac{i_t^o}{i_{t-1}^o}\left(\frac{i_t^o}{i_{t-1}^o} - 1\right)\right\} + \beta\mathbb{E}_t\left[\frac{\lambda_{t+1}^o}{\lambda_t^o}q_{t+1}\left(\frac{i_{t+1}^o}{i_t^o}\right)^2\kappa_I\left(\frac{i_{t+1}^o}{i_t^o} - 1\right)\right] = 1 \tag{A.5}$$

$$r_t^k = a'(u_t) = \gamma_1 + \gamma_2(u_t - 1) \tag{A.6}$$

$$c_t^{rt} = \left(1 - \tau_t^h\right) w_t h_t^d \tag{A.7}$$

$$\lambda_t^{rt} = \frac{1}{c_t^{rt} - bc_{t-1}^{rt}} - \frac{b\beta}{c_{t+1}^{rt} - bc_t^{rt}} \tag{A.8}$$

$$w_t = (1-\alpha)(1-D_t)mc_t k_{t-1}^{\alpha} h_t^{-\alpha} \tag{A.9}$$

$$r_t^k = \alpha(1-D_t)\ mc_t k_{t-1}^{\alpha-1} h_t^{1-\alpha} \tag{A.10}$$

$$U_t = \left(\frac{\tau_t^E \epsilon}{\phi_1\phi_2}\right)^{\frac{1}{\phi_2 - 1}} \tag{A.11}$$

$$MC_t = mc_t + \phi_1 U_t^{\phi_2} + \tau_t^E\epsilon(1-U_t) \tag{A.12}$$

$$p_t^* = \frac{P_t^*}{P_t} = \frac{\eta_p}{\eta_p - 1} \frac{\mathbb{E}_t \sum_{s=0}^{\infty} \alpha_p^s Q_{t,t+s}^R y_{t+s}^d \left(\frac{\prod_{k=1}^s \pi_{t+k}}{\prod_{k=1}^s \pi_{t+k-1}^{\chi_p} \pi^{1-\chi_p}} \right)^{\eta_p} MC_{t+s}}{\mathbb{E}_t \sum_{s=0}^{\infty} \alpha_p^s Q_{t,t+s}^R y_{t+s}^d \left(\frac{\prod_{k=1}^s \pi_{t+k}}{\prod_{k=1}^s \pi_{t+k-1}^{\chi_p} \pi^{1-\chi_p}} \right)^{\eta_p - 1}} \tag{A.13}$$

$$f_t^1 = \frac{(\eta_w - 1)}{\eta_w} w_t^* \mathbb{E}_t \sum_{s=0}^{\infty} (\beta \alpha_w)^s \lambda_{t+s} (1 - \tau_{t+s}^h) h_{t+s}^d \left(\frac{w_{t+s}}{w_t^*} \right)^{\eta_w} \left(\prod_{k=1}^{s} \frac{\pi_{t+k}}{\pi_{t+k-1}^{\chi_w} \pi^{(1-\chi_w)}} \right)^{\eta_w - 1} \tag{A.14}$$

$$f_t^2 = -({w^*}_t)^{-\eta_w} \mathbb{E}_t \sum_{s=0}^{\infty} (\beta \alpha_w)^s (1 - \tau_{t+s}^h) h_{t+s}^d (w_{t+s})^{\eta_w} U_{t+s}^h \left(\prod_{k=1}^{s} \frac{\pi_{t+k}}{\pi_{t+k-1}^{\chi_w} \pi^{(1-\chi_w)}} \right)^{\eta_w} \tag{A.15}$$

$$f_t^1 = f_t^2 \tag{A.16}$$

$$y_t = \int_0^1 \left(\frac{P_{z,t}}{P_t} \right)^{-\eta_p} y_t^d dz = s_t^p y_t^d \tag{A.17}$$

$$s_t^P = (1 - \alpha_p)(p_t^*)^{-\eta_p} + \alpha_p \left(\frac{\pi_t}{\pi_{t-1}^{\chi_p} \pi^{1-\chi_p}} \right)^{\eta_p} s_{t-1}^P \tag{A.18}$$

$$1 = \alpha_p \pi_t^{\eta_p - 1} \left(\pi_{t-1}^{\chi_p} \pi^{1-\chi_p} \right)^{1-\eta_p} + (1 - \alpha_p)(p_t^*)^{1-\eta_p} \tag{A.19}$$

$$h_t^s = \int_0^1 h_t^j \, dj = h_t^d \int_0^1 \left(\frac{W_t^j}{W_t} \right)^{-\eta_w} dj = s_t^w h_t^d \tag{A.20}$$

$$s_t^w = (1 - \alpha_w) \left(\frac{w_t^*}{w_t} \right)^{-\eta_w} + \alpha_w \left(\frac{w_{t-1}}{w_t} \right)^{-\eta_w} \left(\frac{\pi_t}{\pi_{t-1}^{\chi_w} \pi^{(1-\chi_w)}} \right)^{\eta_w} s_{t-1}^w \tag{A.21}$$

$$w_t^* = \left\{ \frac{w_t^{(1-\eta_w)} - \alpha_w w_{t-1}^{(1-\eta_w)} \left(\frac{\pi_{t-1}^{\chi_w} \pi^{1-\chi_w}}{\pi_t} \right)^{(1-\eta_w)}}{(1 - \alpha_w)} \right\}^{\frac{1}{(1-\eta_w)}} \tag{A.22}$$

$$y_t = (1 - D_t)(u_t k_t)^\alpha h_t^{(1-\alpha)} \tag{A.23}$$

$$y_t^d = c_t + i_t + g_t + a(u_t)k_t + AC_t, \tag{A.24}$$

$$AC_t = \phi_1 U_t^{\phi_2} \int_0^1 y_{z,t} dz = \phi_1 U_t^{\phi_2} s_t^p y_t^d \tag{A.25}$$

$$E_t = \int_0^1 E_{z,t} dz = \int_0^1 (1 - U_t)\epsilon y_t(z) dz = (1 - U_t)\epsilon \int_0^1 y_t(z) dz = (1 - U_t)\epsilon s_t^p y_t^d \tag{A.26}$$

$$M_t = (1 - \delta_M) M_{t-1} + E_t \tag{A.27}$$

$$D_t = D_0 + D_1 M_t + D_2 M_t^2 \tag{A.28}$$

$$c_t = (1 - \Omega) c_t^o + \Omega c_t^{rt} \tag{A.29}$$

$$i_t = (1 - \Omega) i_t^o \tag{A.30}$$

$$k_t = (1 - \Omega) k_t^o \tag{A.31}$$

$$\lambda_t = \Omega \lambda_t^{rt} + (1 - \Omega) \lambda_t^o \tag{A.32}$$

$$G_t + \frac{b_t}{\pi_t} = \tau_t^k [r_t^k u_t - a(u_t) - \delta] k_t + \tau_t^h w_t h_t + \tau_t^E E_t + \frac{b_{t+1}}{R_t} \tag{A.33}$$

$$\left(\frac{g_{y,t}}{g_y}\right) = \left(\frac{b_{y,t}}{b_y^{**}}\right)^{-\phi^g} \tag{A.34}$$

$$\left(\frac{\tau_t^E}{\tau^E}\right) = \left(\frac{b_{y,t}}{b_y^{**}}\right)^{\phi^E} \tag{A.35}$$

$$\tau_t^h = (1-\rho_h)\tau_{t-1}^h + \rho_h \tau^h \tag{A.36}$$

$$\frac{\tau_t^h}{\tau^h} = \left(\frac{y_t}{y^{**}}\right)^{\delta_1} \tag{A.37}$$

$$\left(\frac{R_t}{R^{**}}\right) = \left(\frac{R_{t-1}}{R^{**}}\right)^{\rho_r} \left[\left(\frac{\pi_t}{\pi^{**}}\right)^{\phi_\pi} \left(\frac{y_t}{y^{**}}\right)^{\phi_y}\right]^{(1-\rho_r)} \tag{A.38}$$

Appendix B Derivation of rigidities

B.1 Wage setting

Nominal wage rigidity is modeled according to the Calvo (1983) mechanism. In each period, $(1-\alpha_w)$ is the constant probability faced by the typical union j to be able to maximize the wage. The union j sets the optimal wage w_t^* in order to maximize the weighted average of agents' lifetime utilities:

$$\mathbb{E}_t \sum_{s=0}^{\infty} (\beta\alpha_w)^s \left\{ \begin{array}{l} (1-\Omega)\left[\lambda_{t+s}^o (1-\tau_{t+s}^h) h_t^d \int_0^1 w_t^j \left(\frac{w_t^j}{w_t}\right)^{-\eta_w} dj \right. \\ \left. -\lambda_{t+s}^o w_{t+s} (1-\tau_{t+s}^h) h_t^d \int_0^1 \left(\frac{W_t^j}{W_t}\right)^{-\eta_w} dj \right] \\ +\Omega\left[\lambda_{t+s}^{rt} (1-\tau_{t+s}^h) h_t^d \int_0^1 w_t^j \left(\frac{w_t^j}{w_t}\right)^{-\eta_w} dj \right. \\ \left. -\lambda_{t+s}^{rt} w_{t+s} (1-\tau_{t+s}^h) h_t^d \int_0^1 \left(\frac{W_t^j}{W_t}\right)^{-\eta_w} dj \right] \end{array} \right\}$$

All unions resetting at t choose the same wage, i.e.

$$\mathbb{E}_t \sum_{s=0}^{\infty} (\beta\alpha_w)^s \left\{ \begin{array}{l} \left[(1-\Omega)\lambda^o_{t+s} + \Omega\lambda^{rt}_{t+s}\right](1-\tau^h_{t+s})h^d_{t+s}w^{\eta_w}_{t+s}\left(w^*_t \prod_{k=1}^{s} \frac{\pi^{\chi_w}_{t+k-1}\pi^{1-\chi_w}}{\pi_{t+k}}\right)^{1-\eta_w} \\ \quad - \left[(1-\Omega)\lambda^o_{t+s} + \Omega\lambda^{rt}_{t+s}\right](1-\tau^h_{t+s})w_{t+s}h^d_{t+s}w^{\eta_w}_{t+s}\left(w^*_t \prod_{k=1}^{s} \frac{\pi^{\chi_w}_{t+k-1}\pi^{1-\chi_w}}{\pi_{t+k}}\right)^{-\eta_w} \end{array} \right\}$$

Considering that $(1-\Omega)\lambda^o_{t+s} + \Omega\lambda^{rt}_{t+s} = \lambda_{t+s}$ as the average marginal utility and rearranging, we obtain that the union's problem is given by the following expression:

$$\max_{w^*_t} \mathbb{E}_t \sum_{s=0}^{\infty} (\beta\alpha_w)^s \left(\prod_{k=1}^{s} \frac{\pi^{\chi_w}_{t+k}\pi^{1-\chi_w}}{\pi_{t+k}}\right)^{-\eta_w} (1-\tau^h_{t+s})h^d_{t+s}w^{\eta_w}_{t+s}\lambda_{t+s}\times$$
$$\left\{(w^*_t)^{1-\eta_w}\left(\prod_{k=1}^{s} \frac{\pi^{\chi_w}_{t+k}\pi^{1-\chi_w}}{\pi_{t+k}}\right) + \frac{U^h_{t+s}}{\lambda_{t+s}}(w^*_t)^{-\eta_w}\right\}$$

The first order condition with respect to the optimal wage w^*_t is:

$$\mathbb{E}_t \sum_{s=0}^{\infty} (\beta\alpha_w)^s h^d_t \left(\frac{w^*_t}{w_{t+s}}\right)^{-\eta_w} \left(\prod_{k=1}^{s} \frac{\pi^{\chi_w}_{t+k-1}\pi^{1-\chi_w}}{\pi_{t+k}}\right)^{-\eta_w} \lambda_{t+s}\times$$
$$\left\{\frac{\eta_w - 1}{\eta_w}(1-\tau^h_{t+s})w^*_t\left(\prod_{k=1}^{s} \frac{\pi^{\chi_w}_{t+k-1}\pi^{1-\chi_w}}{\pi_{t+k}}\right) + \frac{U^h_{t+s}}{\lambda_{t+s}}\right\} = 0$$

$$\frac{(\eta_w - 1)}{\eta_w} w^*{}_t \mathbb{E}_t \sum_{s=0}^{\infty} (\beta\alpha_w)^s \lambda_{t+s} (1-\tau^h_{t+s})h^d_{t+s}\left(\frac{w_{t+s}}{w^*_t}\right)^{\eta_w}\left(\prod_{k=1}^{s} \frac{\pi_{t+k}}{\pi^{\chi_w}_{t+k-1}\pi^{1-\chi_w}}\right)^{\eta_w - 1}$$
$$= -(w^*{}_t)^{-\eta_w}\mathbb{E}_t \sum_{s=0}^{\infty} (\beta\alpha_w)^s (1-\tau^h_{t+s})h^d_{t+s}(w_{t+s})^{\eta_w}U^h_{t+s}\left(\prod_{k=1}^{s} \frac{\pi_{t+k}}{\pi^{\chi_w}_{t+k-1}\pi^{1-\chi_w}}\right)^{\eta_w}$$

By defining

$$f^1_t \equiv \frac{(\eta_w - 1)}{\eta_w} w^*_t \mathbb{E}_t \sum_{s=0}^{\infty} (\beta\alpha_w)^s \lambda_{t+s} (1-\tau^h_{t+s})h^d_{t+s}\left(\frac{w_{t+s}}{w^*_t}\right)^{\eta_w}\left(\prod_{k=1}^{s} \frac{\pi_{t+k}}{\pi^{\chi_w}_{t+k-1}\pi^{(1-\chi_w)}}\right)^{\eta_w - 1}$$

and

$$f_t^2 \equiv -(w^*{}_t)^{-\eta_w} \mathbb{E}_t \sum_{s=0}^{\infty} (\beta\alpha_w)^s (1-\tau_{t+s}^h) h_{t+s}^d (w_{t+s})^{\eta_w} U_{t+s}^h \left(\prod_{k=1}^{s} \frac{\pi_{t+k}}{\pi_{t+k-1}^{\chi_w} \pi^{(1-\chi_w)}} \right)^{\eta_w}$$

Recursively, we obtain:

$$f_t^1 = \frac{(\eta_w - 1)}{\eta_w} w_t^* (1-\tau_t^h) h_t^d \left(\frac{w_t}{w_t^*} \right)^{\eta_w} \lambda_t + \beta\alpha_w \mathbb{E}_t \left(\frac{w_{t+1}^*}{w_t^*} \right)^{\eta_w - 1} \left(\frac{\pi_{t+1}}{\pi_t^{\chi_w} \pi^{(1-\chi_w)}} \right)^{\eta_w - 1} f_{t+1}^1 \tag{B.39}$$

$$f_t^2 = -\left(\frac{w_t}{w_t^*} \right)^{\eta_w} h_t^d U_t^h + \beta\alpha_w \mathbb{E}_t \left(\frac{w_{t+1}^*}{w_t^*} \right)^{\eta_w} \left(\frac{\pi_{t+1}}{\pi_t^{\chi_w} \pi^{(1-\chi_w)}} \right)^{\eta_w} f_{t+1}^2 \tag{B.40}$$

The optimal wage satisfies

$$f_t^1 = f_t^2 \tag{B.41}$$

B.2 Price setting

Sticky prices are modeled à la Calvo (1983). In each period, the typical firm z faces a probability $(1-\alpha_p)$ to be able to reoptimize the price. In order to set the optimal price P_t^* in t, firms maximize the discounted value of expected future nominal profits, by considering the demand of goods:

$$\max_{P_t^*} \mathbb{E}_t \sum_{s=0}^{\infty} \alpha_p^s \frac{P_t}{P_{t+s}} Q_{t,t+s}^R \left(P_t^* \prod_{k=1}^{s} \pi_{t+k-1}^{\chi_p} \pi^{1-\chi_p} - P_{t+s} MC_{t+s} \right) y_{t,t+s}$$

subject to:

$$y_{t+s} = \left(\frac{P_t^* \prod_{k=1}^{s} \pi_{t+k-1}^{\chi_p} \pi^{1-\chi_p}}{P_{t+s}} \right)^{-\eta_p} y_{t+s}^d$$

where $Q_{t,t+s}^R = \beta \frac{\lambda_{t+s}^o}{\lambda_t^o}$ is the stochastic discount factor for real payoffs, y_{t+s} is the demand faced in $t+s$ by a firm which last reset the price in t and y_{t+s}^d denotes the aggregate absorption at time $t+s$.

The firm solves the following:

$$\mathbb{E}_t \sum_{s=0}^{\infty} \alpha_p^s Q_{t,t+s}^R \frac{P_t}{P_{t+s}} \left(P_t^* \prod_{k=1}^{s} \pi_{t+k-1}^{\chi_p} \pi^{1-\chi_p} - P_{t+s} MC_{t+s} \right) \left(\frac{P_t^* \prod_{k=1}^{s} \pi_{t+k-1}^{\chi_p} \pi^{1-\chi_p}}{P_{t+s}} \right)^{-\eta_p} y_{t+s}^d$$

Rearranging:

$$\mathbb{E}_t \sum_{s=0}^{\infty} \alpha_p^s Q_{t,t+s}^R P_t y_{t+s}^d \left(\frac{\prod_{k=1}^{s} \pi_{t+k-1}^{\chi_p} \pi^{1-\chi_p}}{\prod_{k=1}^{s} \pi_{t+k}} \right)^{(-\eta_p)} \times$$
$$\left[\left(\frac{P_t^*}{P_t} \right)^{1-\eta_p} \left(\frac{\prod_{k=1}^{s} \pi_{t+k-1}^{\chi_p} \pi^{1-\chi_p}}{\prod_{k=1}^{s} \pi_{t+k}} \right) - \left(\frac{P_t^*}{P_t} \right)^{-\eta_p} MC_{t+s} \right]$$

The first order condition with respect to P_t^* is:

$$\mathbb{E}_t \sum_{s=0}^{\infty} \alpha_p^s P_t Q_{t,t+s}^R y_{t+s}^d \left(\frac{\prod_{k=1}^{s} \pi_{t+k-1}^{\chi_p} \pi^{1-\chi_p}}{\prod_{k=1}^{s} \pi_{t+k}} \right)^{(-\eta_p)} \times$$
$$\left[\left(\frac{1}{P_t} \right)^{1-\eta_p} (1-\eta_p) P_t^{*-\eta_p} \left(\frac{\prod_{k=1}^{s} \pi_{t+k-1}^{\chi_p} \pi^{1-\chi_p}}{\prod_{k=1}^{s} \pi_{t+k}} \right) - \left(\frac{1}{P_t} \right)^{-\eta_p} (-\eta_p) (P_t^*)^{-\eta-1} MC_{t+s} \right] = 0$$

Rearranging

$$\mathbb{E}_t \sum_{s=0}^{\infty} \alpha_p^s Q_{t,t+s}^R y_{t+s}^d \left(\frac{\prod_{k=1}^{s} \pi_{t+k-1}^{\chi_p} \pi^{1-\chi_p}}{\prod_{k=1}^{s} \pi_{t+k}} \right)^{(-\eta_p)} \left(\frac{P_t^*}{P_t} \right)^{-\eta_p-1} \left(\frac{P_t^*}{P_t} \right) \left(\frac{1}{\prod_{k=1}^{s} \pi_{t+k}} \right) =$$
$$\frac{\eta_p}{\eta_p-1} \mathbb{E}_t \sum_{s=0}^{\infty} \alpha_p^s Q_{t,t+s}^R y_{t+s}^d \left(\frac{\prod_{k=1}^{s} \pi_{t+k-1}^{\chi_p} \pi^{1-\chi_p}}{\prod_{k=1}^{s} \pi_{t+k}} \right)^{(-\eta_p)} \left(\frac{P_t^*}{P_t} \right)^{-\eta_p-1} MC_{t+s}$$

The optimal price equation is:

$$p_t^* = \frac{P_t^*}{P_t} = \frac{\eta_p}{\eta_p-1} \frac{\mathbb{E}_t \sum_{s=0}^{\infty} \alpha_p^s Q_{t,t+s}^R y_{t+s}^d \left(\frac{\prod_{k=1}^{s} \pi_{t+k}}{\prod_{k=1}^{s} \pi_{t+k-1}^{\chi_p} \pi^{1-\chi_p}} \right)^{\eta_p} MC_{t+s}}{\mathbb{E}_t \sum_{s=0}^{\infty} \alpha_p^s Q_{t,t+s}^R y_{t+s}^d \left(\frac{\prod_{k=1}^{s} \pi_{t+k}}{\prod_{k=1}^{s} \pi_{t+k-1}^{\chi_p} \pi^{1-\chi_p}} \right)^{\eta_p-1}} \tag{B.42}$$

which corresponds to Equation (20) in the main text.

Appendix C Welfare Analysis

We compute welfare costs using welfare-based ratios and consumption-equivalent measures (CEM) for Ricardians and for RTs, following Ascari and Ropele (2012) and Ferrara and Tirelli (2017). Since the value function is not cardinal, the CEM is adopted to quantify the costs of consolidation plans in terms of consumption. Welfare is the sum of the present discounted value of flow utilities for each household type, considering the pre-consolidation value V_j^{old} (Eq. (C.43)) and the value when the consolidation plan is implemented V_j^0 (Eq. (47)). Throughout, $j \in \{o, rt\}$ indexes Ricardian and rule-of-thumb households, respectively.

$$V_j^{old} = \frac{1}{(1-\beta)} \left[ln\left(1-b\right) c_j^{old} - \frac{\Phi_h}{1+\psi} (h_j^{old})^{1+\psi} + \chi^g ln G^{old} \right] \tag{C.43}$$

The consumption-equivalent measure γ^j indicates how much households suffer in terms of consumption losses as a result of fiscal consolidation and it solves Equation (47) in the main text. The CEM is given by the following expression:

$$\gamma^j = 1 - exp\left[(1-\beta)\left(V_j^0 - V_j^{old}\right)\right] \tag{C.44}$$

In turn, the welfare ratio is given by the ratio of consumption-equivalent welfare losses to the size of the transition:

$$WR^j = \left(\frac{\gamma^j}{b_y^{*,old} - b_y^{*,new}} \right) \tag{C.45}$$

Since γ^j denotes how much the transition is costly, the fiscal consolidation plan is welfare improving when $WR^j < 0$.

To assess the welfare ratio occurring when the consolidation is achieved, we compute the long-run CEM γ_{LR}^j which is related to the value function in the first (V_j^{old}) and in the second steady states (V_j^{new}):

$$\gamma_{LR}^j = 1 - exp\left[(1-\beta)\left(V_j^{new} - V_j^{old}\right)\right] \tag{C.46}$$

and the long-run WR reads as:

$$WR_{LR}^j = \left(\frac{\gamma_{LR}^j}{b_y^{*,old} - b_y^{*,new}} \right) \tag{C.47}$$

The short-run welfare-ratio WR^j_{SR} is given by the difference between the total welfare of consolidation WR^j and the long-run values WR^j_{LR}, as follows

$$WR^j_{SR} = WR^j - WR^j_{LR} = \left(\frac{exp\left[(1-\beta)\left(V^0_j - V^{old}_j\right)\right] - exp\left[(1-\beta)\left(V^{new}_j - V^{old}_j\right)\right]}{b^{*,old}_y - b^{*,new}_y} \right) \tag{C.48}$$

Appendix D Additional Robustness Figures

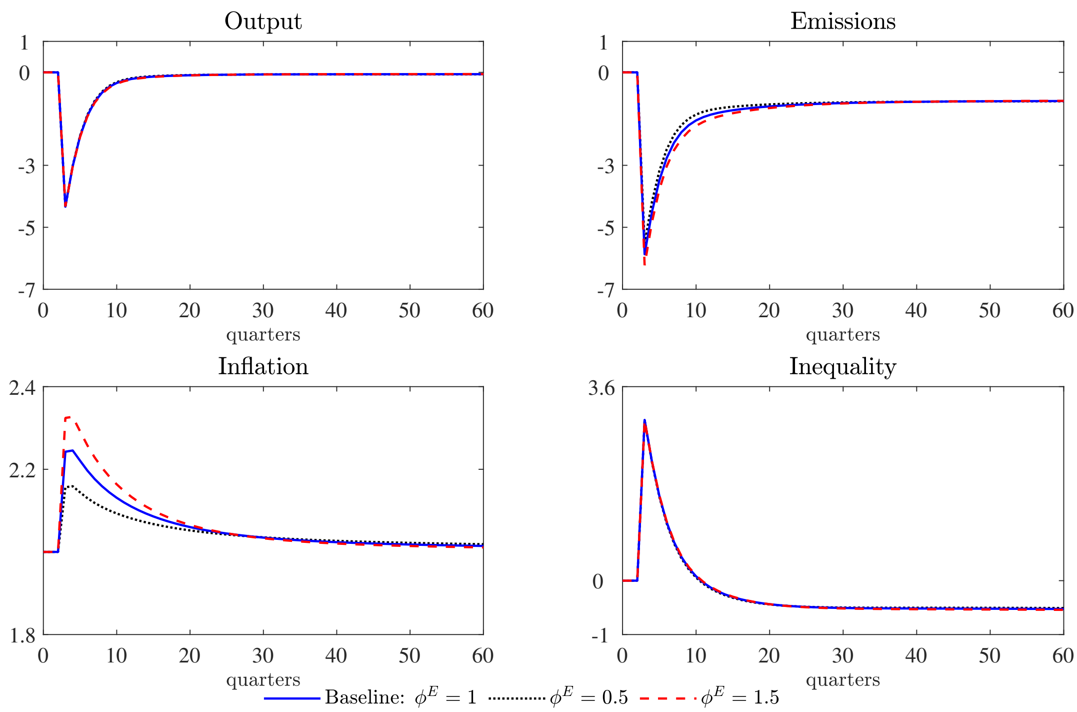

Figure D.1: Transition dynamics for different carbon-tax response coefficient ϕ^E. The solid blue line denotes the baseline calibration, the dashed red line a higher response coefficient, and the dotted black line a lower response coefficient.

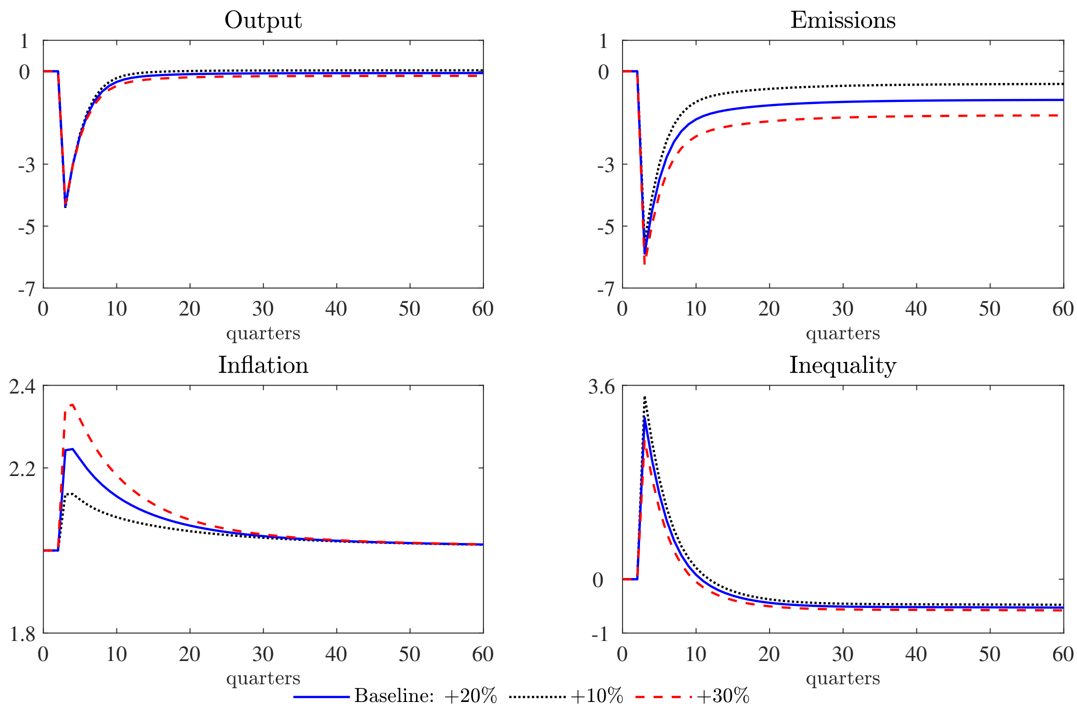

Figure D.2: Transition dynamics for different percentage increase in carbon tax. The solid blue line denotes the baseline calibration, the dashed red line a higher percentage increase, and the dotted black line a lower percentage increase.

References

Albonico, A., Paccagnini, A., & Tirelli, P. (2019). Limited asset market participation and the euro area crisis: An empirical DSGE model. Economic Inquiry, 57(3), 1302–1323. https://doi.org/10.1111/ecin.12791

Alesina, A. & Ardagna, S. (2010) Large changes in fiscal policy: taxes versus spending, NBER Chapters. In: Tax Policy and the Economy. National Bureau of Economic Research, Inc., 24, pp. 35–68. https://doi.org/10.1086/649828

Alesina, A., Favero, C.A., & Giavazzi, F. (2015). The output effect of fiscal consolidation plans. Journal of International Economics, 96(S1), S19–S42. https://doi.org/10.1016/j.jinteco.2014.11.003

Alesina, A., Favero, C.A. & Giavazzi, F. (2019) Effects of austerity: expenditure- and tax-based approaches. The Journal of Economic Perspectives, 33(2), 141–162. https://doi.org/10.1257/jep.33.2.141

Angelopoulos, K., Economides, G., & Philippopoulos, A. (2013). First- and second-best allocations under economic and environmental uncertainty. International Tax and Public Finance, 20(3), 360–380. https://doi.org/10.1007/s10797-012-9234-z

Annicchiarico, B., & Di Dio, F. (2015). Environmental policy and macroeconomic dynamics in a new Keynesian model. Journal of Environmental Economics and Management, 69, 1–21. https://doi.org/10.1016/j.jeem.2014.10.002

Annicchiarico, B., & Diluiso, F. (2019). International transmission of the business cycle and environmental policy. Resource and Energy Economics, 58, 101112. https://doi.org/10.1016/j.reseneeco.2019.07.006

Aphecetche, T. (2024). Fiscal Challenges in the Green Transition: A Global Perspective (No. 081). Directorate General Economic and Financial Affairs (DG ECFIN), European Commission. https://doi.org/10.2765/10294

Ascari, G., & Ropele, T. (2012). Disinflation in a DSGE perspective: Sacrifice ratio or welfare gain ratio? Journal of Economic Dynamics and Control, 36(2), 169–182. https://doi.org/10.1016/j.jedc.2011.11.001

Avgousti, A., Caprioli, F., Caracciolo, G., Cochard, M., Dallari, P., Delgado-Téllez, M., ... & Theofilakou, A. (2023). The climate change challenge and fiscal instruments and policies in the EU. ECB Occasional Paper, (2023/315). http://dx.doi.org/10.2139/ssrn.4424152

Bachner, G., & Bednar-Friedl, B. (2019). The effects of climate change impacts on public budgets and implications of fiscal counterbalancing instruments. Environmental Modeling & Assessment, 24(2), 121–142. https://doi.org/10.1007/s10666-018-9617-3

Baret, M., & Menuet, M. (2024). Fiscal and environmental sustainability: is public debt environmentally friendly?. Environmental and Resource Economics, 87(6), 1497–1520. https://doi.org/10.1007/s10640-024-00847-0

Boly, M., Combes, J. L., Menuet, M., Minea, A., Motel, P. C., & Villieu, P. (2022). Can public debt mitigate environmental debt? Theory and empirical evidence. Energy Economics, 111, 105895. https://doi.org/10.1016/j.eneco.2022.105895

Calvo, G. A. (1983). Staggered prices in a utility-maximizing framework. Journal of Monetary Economics, 12(3), 383–398. https://doi.org/10.1016/0304-3932(83)90060-0

Carnazza, G., Renström, T. I., & Spataro, L. (2023). Is public debt environmentally friendly? The role of EU fiscal rules on environmental quality: An empirical assessment (No. 2023.26). https://services.bepress.com/feem/paper1428

Caselli, F., Lagerborg, A., & Medas, M. P. A. (2024). Green fiscal rules? Challenges and policy alternatives. International Monetary Fund. https://doi.org/10.5089/9798400280726.001

Chan, Y. T., & Punzi, M. T. (2023). E-DSGE model with endogenous capital utilization rate. Journal of Cleaner Production, 414, 137640. https://doi.org/10.1016/j.jclepro.2023.137640

Christiano, L. J., Eichenbaum, M., & Evans, C. L. (2005). Nominal rigidities and the dynamic effects of a shock to monetary policy. Journal of Political Economy, 113(1), 1–45. https://doi.org/10.1086/426038

Coenen, G., Lozej, M., & Priftis, R. (2024). Macroeconomic effects of carbon transition policies: an assessment based on the ECB's New Area-Wide Model with a disaggregated energy sector. European Economic Review, 167, 104798. https://doi.org/10.1016/j.euroecorev.2024.104798

Coenen, G., Mohr, M., & Straub, R. (2008). Fiscal consolidation in the euro area: Long-run benefits and short-run costs. Economic Modelling, 25(5), 912–932. https://doi.org/10.1016/j.econmod.2007.11.011

Darvas, Z., & Wolff, G. B. (2023). A Green Fiscal Pact for the EU: increasing climate investments while consolidating budgets. Climate Policy, 23(4), 409–417. https://doi.org/10.1080/14693062.2022.2147893

Debortoli, D., & Galí, J. (2025). Heterogeneity and aggregate fluctuations: Insights from tank models. NBER Macroeconomics Annual, 39(1), 307–357. https://doi.org/10.1086/735272

Ferrara, M., & Tirelli, P. (2017). Equitable fiscal consolidations. Economic Modelling, 61, 207–223. https://doi.org/10.1016/j.econmod.2016.11.022

Ferrari, A., & Nispi Landi, V. (2023). Toward a Green Economy: The Role of the Central Bank's Asset Purchases. International Journal of Central Banking, 19(5), 287–340. https://www.ijcb.org/journal/v19n5/toward-green-economy-role-central-banks-asset-purchases

Ferrari, A., & Nispi Landi, V. (2024). Whatever it takes to save the planet? Central banks and unconventional green policy. Macroeconomic Dynamics, 28(2), 299–324. https://doi.org/10.1017/S1365100523000032

Gao, S. (2024). An exogenous risk in fiscal-financial sustainability: Dynamic stochastic general equilibrium analysis of climate physical risk and adaptation cost. Journal of Risk and Financial Management, 17(6), 244. https://doi.org/10.3390/jrfm17060244

Garcia-Macia, M. D., Lam, M. W. R., & Nguyen, A. D. (2024). Public Debt Dynamics During the Climate Transition (No. 2024/071). International Monetary Fund. https://doi.org/10.5089/9798400270635.001

Kellner, M., & Runkel, M. (2024). Climate policy and optimal public debt. International Tax and Public Finance, 31(6), 1584–1610. https://doi.org/10.1007/s10797-023-09814-9

Lukmanova, E., & Rabitsch, K. (2023). Evidence on monetary transmission and the role of imperfect information: Interest rate versus inflation target shocks. European Economic Review, 158, 104557. https://doi.org/10.1016/j.euroecorev.2023.104557

Rausch, S. (2013). Fiscal consolidation and climate policy: An overlapping generations perspective. Energy Economics, 40, S134-S148. https://doi.org/10.1016/j.eneco.2013.09.009

Seghini, C., & Dees, S. (2025). The green transition and public finances. Macroeconomic Dynamics, 29, e152. https://doi.org/10.1017/S1365100525100576

Semik, S., & Zimmermann, L. (2022). Determinants of substantial public debt reductions in Central and Eastern European Countries. Empirica, 49(1), 53–70. https://doi.org/10.1007/s10663-021-09529-2

Varga, J., & Roeger, W. (2022). E-QUEST: A multisector dynamic general equilibrium model with energy and a model-based assessment to reach the EU climate targets. Economic Modelling, 114, 105911. https://doi.org/10.1016/j.econmod.2022.105911