Making Environmental Policies Acceptable[*]

François Langot[†]   Selma Malmberg[‡]   Fabien Tripier[§]   Jean-Olivier Hairault[¶]

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Abstract

We assess the short-term consequences of a carbon tax in the French economy and compare alternative accompanying policies that could make it acceptable. We use a heterogeneous agent New-Keynesian model to assess the macroeconomic and redistributive effects of a carbon tax. The carbon tax acts as a negative supply shock to the economy, causing a slowdown in economic growth, an increase in inflation and a rise in household consumption inequalities. We then show how these short-term recessionary effects would be mitigated by a more accommodative monetary policy that would also reduce inequalities. We show that this policy mix dominates *(i)* a purely fiscal policy that would redistribute to households the revenues of the carbon tax or *(ii)* an expansionary policy using the tax carbon surpluses to finance energy renovations.

Keywords: HANK model, Carbon tax, Policy evaluation.

JEL codes: C54, C63, E32, E65, H12, Q43.

1 Introduction

The energy transition aims to profoundly modify the structure of the economies in order to fight against global warming and achieve the objectives defined by the Paris Climate Agreement of December 12, 2015. If the urgency of the situation calls for the rapid implementation of the actions necessary to achieve this agreement, the policies, like the transformations of the economy that they aim to bring about, are intended to be put in place and produce their effects for decades to come. However, the analysis of the energy transition over the long term should not neglect the importance of the constraints of social acceptance of these policies faced by policymakers.[1] These blockages are particularly well illustrated by the French protests of "red caps" (against the "eco-tax" in 2013) and "yellow vests" (against the carbon tax in 2018) that have lead government to abandon the implementation of these environmental taxes.

Our contribution aims to assess the role of short-term macroeconomic policies to support the implementation of policies initiating the energy transition. We apply our analysis to France where the carbon tax implementation has been blocked since 2018. We define the short run as a horizon where the technology is given, as well as the capital stock. We also let outside of our analysis the study of the crucial role of the international coordination of climate policies that, by making credible the commitment of each government, can change the long-run decisions of changing the production process. This restrictive approach allows us to focus on the tools available in the short run aimed to damp the depressive impact of the carbon tax increase and thus to evaluate their efficiency on the short run adjustments.[2]

The energy transition policy considered is a tax applied to the price of energy products purchased by households and businesses. By abuse of language, we name this tax "carbon tax", because the taxes on energy products represent more than 90% of the environment tax collected by the French government (see e.g. the data of the French Ministry of ecological transition). We start from the current situation where taxation on energy products is indexed to a carbon price of 44.60€/ton of CO_2 (its price in 2018 before the blockage induced by the "yellow vests") and which must grow gradually to meet France's emission commitments. We favor a scenario where we carry over to the

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[1]See Carattini et al. (2018) for a survey on resistance to carbon tax and Douenne and Fabre (2022) for an analysis of the French case.

[2]Therefore, we over-estimate the recessive impact of the carbon tax because investments changing the production process in the long-term could support the demand even in the short term.

2024-2027 period the increases that should have occurred between 2019 and 2022. This leads us to a gradual increase in the tax, each year, which will allow us to achieve an increase of 10 tax rate points.[3]

In order to evaluate the short-run impacts of a carbon tax increase, we use a Heterogeneous-Agent New-Keynesian (HANK) model because it allows us to study at the same time both the impacts on the macroeconomic aggregate variables (such as output, inflation or public debt) and the dynamics of inequalities across households. Moreover, a HANK model predicts the observed depressive effect of positive shock on energy price, contrary to a Representative-Agent New-Keynesian, as shown in Auclert et al. (2023).[4] Hence, the implementation of this tax acts on the economy as a negative supply shock, increasing the price of the goods consumed[5], raising production costs and contracting economic activity. The transmission of this price increase to wages, through the price-wage spiral, is likely to reinforce the initial inflationary tensions in a context of economic contraction. In order to properly capture the greater sensitivity of the poorest to energy prices, we introduce an incompressible consumption of energy products leading the share of the energy products in the consumption basket to decrease with incomes as in the data, but also the price elasticity to increase with incomes, making it difficult for the poorest to avoid energy price increases.

Mitigating the recessionary and inflationary effects of this environmental policy is crucial to make the energy transition acceptable. In this article, we show how a more accommodating monetary policy led by the European Central Bank (ECB) can mitigate these short-term effects. With our HANK model, this accommodating monetary policy makes it possible to reduce inequalities because it reduces real interest rates, thus breaking one of the main channels for increasing inequalities. This policy is not without costs: it generates additional inflation of one annual point on average over 4 years. This more accommodating monetary policy can be interpreted as easier access to credit

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[3]The transition to a carbon price of 44.6 to 86.2€/ton of CO_2 corresponds to an increase in the taxes paid on diesel (natural gas for households) from 0.59 to 0.78€/liter (0.0845 to 0.1602€/10 KWh PCS) and therefore approximately an increase in the tax rate of 10 points ($\Delta\tau_z = \frac{p_z(\tau_{z,end}-\tau_{z,ini})}{p_z} \approx 12.6\%|9.25\%$ for $z \in \{$diesel, gas$\}$), with a price of a liter of diesel at €1.50 and a KWh of gas at €0.082 and a consumption basket with the same weights to these two types of energy ($\Delta\tau = $ mean$(12.6, 9.25) \approx 10\%$). Data from the French government's project budgetary law 2018, before the "yellow vest" contests.

[4]In the representative agent model, the energy shock leads demand to shift towards the consumption of domestically produced goods, which counterfactually sustains growth.

[5]We favor a scenario where the "green transition" is inflationary, based on the idea that the oil and gas industry prices are flexible, but that the consumer price index is sticky. In this context, the only way to make dirty goods relatively more expensive is to have dirty sectors' prices go up, thus generating inflation. This view may be called into question if empirical evidence supports that energy prices are more rigid than the prices of final consumer goods. See Del Negro et al. (2023) for a discussion of this point.

for green projects, therefore reducing the average response of the ECB without jeopardizing its mandate.

In order to complete this analysis, we compare this first policy mix to two other policies. In the first alternative scenario, we assume that the government uses the revenue from the carbon tax to redistribute to households a transfer that is all the higher as they are modest. This redistribution, as it accompanies a carbon tax which dissuades households from consuming energy, can redirect demand towards the purchase of "green" products. In the second, we assume that the government uses the revenue from the carbon tax to spend on energy renovations of housing. These government expenditures are then supposed to allow households to reduce their incompressible energy consumption.

Building on our HANK model and the methodology for ex-ante policy evaluation developed in Langot et al. (2023), we study the impacts of a carbon tax on the French economy by providing the gaps between different scenarios where carbon taxes are implemented and the path of the government forecasts on which it has committed in its 2022 budget law where the carbon tax is kept to its 2018 level until 2027 at least. The originality of our study is to jointly carry out an analysis of the major macroeconomic aggregates and the dynamics of economic inequalities at the heart of the social acceptance of the energy transition.

Hence, our contribution enriches the analysis carried out by the ECB of the role of monetary policy in the face of climate change by taking into account the dynamics of inequalities.[6] The ECB committed in 2021 to fully take into account the impact of climate change and the transition to a low-carbon economy. The ECB's publication on climate change and monetary policy (Drudi et al. (2021)) describes the room for adjustment of monetary policy to accompany the carbon tax. By mitigating the recessive effect of this tax, monetary policy adjustments can relate to the choice of the price index used for its inflation target and to the choice to allow inflation to temporarily deviate from its target. The ECB emphasizes that its ability to mitigate the short-term recessionary effects of the energy transition depends crucially on how the carbon tax is implemented. It also alerts that a late and abrupt implementation of the tax increases the cost of the tax and limits the possibilities of mitigating monetary policy, compared to early and gradual implementation.

Our contribution completes this analysis of monetary policy by integrating the issue of inequal-

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[6]See e.g. Coenen et al. (2023) who use a large DSGE model of the Euro Area with "dirty" and "clean" energy.

ities in the evaluation of short-term mitigation policies for the energy transition. Indeed, while the ECB mentions the challenge of policies to redistribute the proceeds of the carbon tax to the most vulnerable categories, household inequalities are not included in the assessments presented in Drudi et al. (2021) or Coenen et al. (2023). However, as we have already mentioned, the exposure of the most disadvantaged households to the energy transition is an essential element for its social acceptance and therefore its feasibility. In addition, inequalities between households are likely to profoundly modify the transmission mechanisms of economic policies.[7]

The remainder of the article is organized as follows. Section 2 presents the model and briefly discusses its calibration. Section 3 analyzes the quantitative results of the calibrated model and section 4 concludes.

2 Model

The model presented here is an extension of Langot et al. (2023) and Auclert et al. (2023) where a carbon tax is added. These models are close to Auclert et al. (2018) and Auclert et al. (2021b) except that they account for the use of energy in the production function. The originality of our approach is to introduce energy in the household consumption basket together with an incompressible level. This allows us to match the following stylized facts: the larger share of energy in the basket of the poorest, as well as the lower price elasticity of the poorest to price energy.

2.1 Households

In each household, the worker's productivity can take values $e' \in \mathcal{E}$ at each date conditionally to a previous value $e \in \mathcal{E}$. The transition matrix between productivity levels is $\mathcal{P}(e', e)$.

Each household consumes home goods c_H, paid at a price P_H, and energy goods c_{FE} paid at the price P_{FE}. The value of a household's total expenditures for consumption is Pc, where total

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[7]See Kaplan et al. (2018) or Auclert et al. (2018) for the role of household heterogeneity New-Keynesian models that include business cycle feature in models à la Aiyagari (1994). See Achdou et al. (2022) for methods used to solve continuous time models with heterogeneous agents and Reiter (2009), (2010), and Auclert et al. (2021a) for methods used for discrete-time models. See Känzig (2023), Pieroni (2023), Benmir and Roman (2022) and Auclert et al. (2023) for extensions of this literature to climate and energy issues.

expenditures for consumption c are paid at price P. Therefore, the value of total consumption is

$$Pc \equiv P_H c_H + (1 - s_H)(1 + \tau_P)P_{FE}c_{FE},$$

where s_H denotes the subsidy of energy purchases induced by policy distortions and τ_P the carbon tax rate.

We assume that the household's problem is constrained by an incompressible level of energy consumption $\underline{c}_{FE}$. Energy gives utility if and only if $c_{FE} \geq \underline{c}_{FE}$. By denoting $\widetilde{c}_{FE} \equiv c_{FE} - \underline{c}_{FE}$, we deduce that $Pc - (1 - s_H)(1 + \tau_P)P_{FE}\underline{c}_{FE} = P_H c_H + (1 - s_H)(1 + \tau_P)P_{FE}\widetilde{c}_{FE}$ where $P_H c_H + (1 - s_H)(1 + \tau_P)P_{FE}\widetilde{c}_{FE}$ gives the value of expenditures net of the ones needed to finance the incompressible consumption. The consumption basket is given by:

$$c = \left(\alpha_E^{\frac{1}{\eta_E}} (\widetilde{c}_{FE})^{\frac{\eta_E - 1}{\eta_E}} + (1 - \alpha_E)^{\frac{1}{\eta_E}} (c_H)^{\frac{\eta_E - 1}{\eta_E}} \right)^{\frac{\eta_E}{\eta_E - 1}}, \text{ with } \widetilde{c}_{FE} \equiv c_{FE} - \underline{c}_{FE}$$

The consistent definition of the Consumer Price Index (CPI denoted P), such that $Pc = P_H c_H + (1 - s_H)(1 + \tau_P)P_{FE}\widetilde{c}_{FE}$, is given by:

$$P = \left[\alpha_E((1 - s_H)(1 + \tau_P)P_{FE})^{1-\eta_E} + (1 - \alpha_E)P_H^{1-\eta_E} \right]^{\frac{1}{1-\eta_E}}$$

This implies that $c = p_H c_H + (1 - s_H)(1 + \tau_P)p_{FE}\widetilde{c}_{FE}$ with $p_H = P_H/P$ and $p_{FE} = P_{FE}/P$. The decision rules of the household are deduced from

$$V_t(e, a_-) = \max_{c,a} \left\{ u(c) - v(n) + \beta \sum_{e'} V_{t+1}(e', a)\mathcal{P}(e, e') \right\}$$

$$(1 + \tau_c)c + a = (1 + r_t)a_- + (1 - \tau_l)wen + \tau\bar{\tau}(e) + d\bar{d}(e) - (1 + \tau_c)(1 - s_H)(1 + \tau_P)p_{FE}\underline{c}_{FE}$$

$$a \geq 0,$$

where all nominal variables are deflated by the CPI and where $1 + r = \frac{1+gei_-}{1+\pi}$ stands for the real interest rate, i is the nominal interest rate, and $\pi = \frac{P}{P_-} - 1$ the inflation rate. The fiscal system is characterized by τ_c the tax rate on consumption spending, τ_l the tax rate on labor income, and $\bar{\tau}(e)$ transfers to households which are dependent on the household productivity e such that $\bar{\tau}'(e) < 0$. τ_P denotes the carbon tax rate. The variable d refers to the transfers of the firm's dividends to

households, which are increasing with household productivity, $\bar{d}'(e) > 0$. The labor supply n is determined by unions (see below). Finally, we assume that:

$$u(c) = \frac{c^{1-\sigma}}{1-\sigma} \quad \text{and} \quad v(n) = \varphi \frac{n^{1+\nu}}{1+\nu}$$

Solving household's problem. The household's problem is solved to determine the intertemporal choices $\{c, a\}$. Therefore, each household chooses the level of its consumption basket c and buys it at price P from retailers. The intratemporal choices are managed by firms that create final goods that combine home goods and energy services by satisfying the households' preferences. This allows us to introduce a Phillips curve on the CPI via an adjustment cost on price adjustment paid by the retailers. As for goods, the intratemporal choices between tasks that are combined to obtain the aggregate hours worked n are determined by unions, which also set nominal wages by supporting adjustment costs. This also leads to a Phillips curve on nominal wages.

2.2 Supply

We assume that intermediate goods Y_H are produced with energy E and labor N:

$$Y_H \le Z \left(\alpha_f^{\frac{1}{\sigma_f}} E^{\frac{\sigma_f-1}{\sigma_f}} + (1-\alpha_f)^{\frac{1}{\sigma_f}} N^{\frac{\sigma_f-1}{\sigma_f}} \right)^{\frac{\sigma_f}{\sigma_f-1}}$$

Final goods Y_F are produced with intermediate goods Y_H and energy Y_{FE}:

$$Y_F = \left(\alpha_E^{\frac{1}{\eta_E}} Y_{FE}^{\frac{\eta_E-1}{\eta_E}} + (1-\alpha_E)^{\frac{1}{\eta_E}} Y_H^{\frac{\eta_E-1}{\eta_E}} \right)^{\frac{\eta_E}{\eta_E-1}}$$

This combination between home goods (Y_H) and energy services (Y_{FE}) corresponds to the households' preference, composed by goods c_H and $\widetilde{c}_{FE}$ and satisfying the constraint $c_{FE} \ge \underline{c}_{FE}$ through the term $p_{FE}\underline{c}_{FE}$ in the households' budgetary constraint.

Each retailer i produces consumption goods using final goods according to a linear production function: $Y_i = Y_{i,F}$. The produced consumption good i is an imperfect substitute to the consumption good $i' \ne i$. The elasticity of substitution between these consumption goods is ε_d and the basket is

defined by:

$$Y = \left(\int Y_i^{\frac{\varepsilon_d - 1}{\varepsilon_d}} di \right)^{\frac{\varepsilon_d}{\varepsilon_d - 1}} \quad \text{for } Y \in \{c, G\}$$

These retailers sell the goods Y_i to consumers and the government. They determine their optimal prices in a monopolistic market where there are price adjustment costs.

2.2.1 Intermediate Goods

Intermediate goods Y_H are produced with energy E and labor N. The optimal decisions of these firms are solutions of the following program:

$$\min_{E,N} \{ WN + (1 - s_F)(1 + \tau_P) P_{FE} E \} \quad s.t. \quad Y_H \leq Z \left(\alpha_f^{\frac{1}{\sigma_f}} E^{\frac{\sigma_f - 1}{\sigma_f}} + (1 - \alpha_f)^{\frac{1}{\sigma_f}} N^{\frac{\sigma_f - 1}{\sigma_f}} \right)^{\frac{\sigma_f}{\sigma_f - 1}}$$

The optimal demands of production factors are

$$N = (1 - \alpha_f) \left(\frac{W}{MC_H} \right)^{-\sigma_f} Y_H, \qquad E = \alpha_f \left(\frac{(1 - s_F)(1 + \tau_P) P_{FE}}{MC_H} \right)^{-\sigma_f} Y_H,$$

with a marginal cost defined as follows

$$MC_H = Z^{-\frac{1}{\sigma_f}} \left(\alpha_f ((1 - s_F)(1 + \tau_P) P_{FE})^{1 - \sigma_f} + (1 - \alpha_f) W^{1 - \sigma_f} \right)^{\frac{1}{1 - \sigma_f}}$$

Assuming perfect competition in this market, profits and free entry condition leads to:

$$\Pi_H = (P_H - MC_H) Y_H = 0 \quad \Rightarrow \quad P_H = MC_H \quad \Leftrightarrow \quad p_H = mc_H, \quad \text{with } p_H = \frac{P_H}{P} \text{ and } mc_H = \frac{MC_H}{P}$$

2.2.2 Final Goods

Final goods Y_F are produced with intermediate goods Y_H and energy Y_{FE}. The optimal decision of these firms are solutions of the following program:

$$\min_{Y_H, Y_{FE}} \{ P_H Y_H + (1 - s_H)(1 + \tau_P) P_E Y_{FE} \} \quad s.t. \quad Y_F \leq \left(\alpha_E^{\frac{1}{\eta_E}} (Y_{FE})^{\frac{\eta_E - 1}{\eta_E}} + (1 - \alpha_E)^{\frac{1}{\eta_E}} (Y_H)^{\frac{\eta_E - 1}{\eta_E}} \right)^{\frac{\eta_E}{\eta_E - 1}}$$

The optimal decisions satisfy

$$Y_{FE} = \alpha_E \left(\frac{(1-s_H)(1+\tau_P)P_{FE}}{MC_F} \right)^{-\eta_E} Y_F, \qquad Y_H = (1-\alpha_E) \left(\frac{P_H}{MC_F} \right)^{-\eta_E} Y_F,$$

with the marginal cost $MC_F = \left(\alpha_E((1-s_H)(1+\tau_P)P_E)^{1-\eta_E} + (1-\alpha_E)(P_H)^{1-\eta_E} \right)^{\frac{1}{1-\eta_E}}$. Assuming perfect competition in this market, profits and free entry condition leads to:

$$\Pi_F = (P_F - MC_F)Y_F = 0 \quad \Rightarrow \quad P_F = MC_F \quad \Leftrightarrow \quad p_F = mc_F, \quad \text{with } p_F = \frac{P_F}{P} \text{ and } mc_F = \frac{MC_F}{P}$$

2.2.3 Retailers

The retailers buy final goods on a perfectly competitive market and sell them to the household after transforming them into imperfect substitutes. Retailers obtain a markup, but they support an adjustment cost when they change their prices. The price-setting rule is deduced from optimal behaviors of a continuum of identical firms producing differentiated goods and entering competition monopolistically:

$$\Pi_t(P_{i,-}) = \max_{P_i} \left\{ \frac{P_i - P_F}{P} y_i - \frac{\psi_P}{2} \left(\frac{P_i}{P_{i,-}} - 1 \right)^2 Y + \frac{1}{1+r_+} \Pi_{t+1}(P_i) \right\} \quad \text{s.t. } y_i = \left(\frac{P_i}{P} \right)^{-\varepsilon_d} Y$$

This leads to the following NKPC:

$$\pi_t = \kappa_P \left(mc_t - \frac{1}{\mu} \right) + \frac{1}{1+r_{t+1}} \frac{Y_{t+1}}{Y_t} \pi_{t+1}$$

with $mc_t = \frac{P_{Ft}}{P_t}$, $\kappa_P = \frac{\varepsilon_d}{\psi_P}$ and $\mu = \frac{\varepsilon_d}{\varepsilon_d-1}$.[8] The firm profit (its dividends) is defined by

$$D_t = P_t Y_t - P_{Ft} Y_{Ft} - \frac{\psi_P}{2} \left(\frac{P_t}{P_{t-1}} - 1 \right)^2 P_t Y_t,$$

knowing that with a linear production, we have $Y = Y_{FT}$.

For the redistribution of firms' dividends, we assume that $D_t(e_t) = D_t \Psi(e_t)$, where the share of dividend $\Psi(e_t)$ redistributed to each household depends on its productivity e. In the following, we assume that $\Psi(e_t) = e_t$, implying an increasing share with productivity e.

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[8]Remark that for π "small", we have $(\pi_t + 1)\pi_t \approx \pi_t \equiv \frac{P_t}{P_{t-1}} - 1$.

2.3 Unions

Unions represent the workers' interests. A union set a unique wage by task k whatever the levels of productivity $e \in \mathcal{E}$ and wealth $a \in \mathcal{A}$. The union's program is:

$$U_t^k(W_{k,-}) = \max_{W_k} \int_e \int_a \left[u(c(e,a)) - v(n(e,a)) \right] d\Gamma_a d\Gamma_e - \frac{\psi_W}{2} \left(\frac{W_k}{W_{k,-}} - 1 \right)^2 + \beta U_{t+1}^k(W_k)$$

$$\text{s.t. } N_k = \left(\frac{W_k}{W} \right)^{-\varepsilon} N \quad \text{with } W = \left(\int_k W_k^{1-\varepsilon} dk \right)^{\frac{1}{1-\varepsilon}}$$

where the equilibrium distribution of households satisfies $\int_e \int_a d\Gamma_a d\Gamma_e = 1$. The purchasing power (income after wages and consumption taxes) of the household i is:

$$\frac{1 - \tau_l}{1 + \tau_c} e_i w n_i = \frac{1 - \tau_l}{1 + \tau_c} e_i \int_k \frac{W_k}{P} n_{ik} dk$$

If we assume that unions consider only a representative worker, $n_{ik} = n_{i'k} \equiv N_k$, then

$$\frac{1 - \tau_l}{1 + \tau_c} e_i w n_i = \frac{1 - \tau_l}{1 + \tau_c} e_i \int_k \frac{W_k}{P} \left(\frac{W_k}{W} \right)^{-\varepsilon} N dk$$

and the union's objective is:

$$U_t^k(W_{k,-}) = \max_{W_k} \int_e \int_a u(c(e,a)) d\Gamma_a d\Gamma_e - v(N) - \frac{\psi_W}{2} \left(\frac{W_k}{W_{k,-}} - 1 \right)^2 + \beta U_{t+1}^k(W_k)$$

$$\text{s.t. } N_k = \left(\frac{W_k}{W} \right)^{-\varepsilon} N_t \quad \text{with } W = \left(\int_k W_k^{1-\varepsilon} dk \right)^{\frac{1}{1-\varepsilon}}$$

Defining $\mu_w \equiv \frac{\varepsilon}{\varepsilon-1}$ and $\kappa_w \equiv \frac{\varepsilon}{\psi_W}$. The union sets the nominal wage leading to a New-Keynesian Phillips curve:

$$\pi_{Wt} = \kappa_w \left(N_t v'(N_t) - \frac{1}{\mu_w} \frac{1 - \tau^l}{1 + \tau^c} \frac{W_t}{P_t} N_t u'(C_t) \right) + \beta \pi_{Wt+1}$$

2.4 Government

The government collects revenue (R_t from usual taxes and R_t^c from the carbon tax) and incurs expenditure (S_t), given respectively by:

$$P_t R_t = P_t \tau_{lt} w_t N_t^S + P_t \tau_{ct} C_t + \tau_{ct} P_t p_{FEt} \underline{c}_{FE}$$

$$P_t R_t^c = P_t \tau_{Pt}(1 + \tau_{ct}) p_{FEt} \underline{c}_{FE} + P_t \tau_{Pt}(1 - s_{Ht}) p_{FEt} Y_{FEt} + P_t \tau_{Pt}(1 - s_{Ft}) p_{FEt} E_t$$

$$P_t S_t = P_t G_t + P_t \tau_t + s_{Ht} P_t p_{Et}(1 + \tau_{Pt}) Y_{FEt} + s_{Ft} P_t p_{Et}(1 + \tau_{Pt}) E_t + s_{Ht}(1 + \tau_{ct})(1 + \tau_{Pt}) P_t p_{FEt} \underline{c}_{FE}$$

The differences between revenue and expenditure are financed by issuing public debt B_t that evolves as follows:

$$B_t = (1 + i_{t-1}) B_{t-1} - P_t R_t - P_t R_t^c + P_t S_t$$

$$\Rightarrow b_t = (1 + r_t) b_{t-1} - R_t + S_t$$

where $b = B/P$ is the real public debt. In order to ensure the stability of the public debt dynamics, we assume that the lump sum transfer incorporates a fiscal brake, such that:

$$\tau_t = T_t - \theta \left(\frac{b_{t-1}}{b} - 1 \right) + \vartheta_t$$

It leads to the transfer being reduced when debt is larger than its steady-state level. T_t is the observed dynamics of transfers paid by the government to households and ϑ_t is a shock on lump-sum transfers.

2.5 Monetary Policy

The monetary policy of the central bank, here the ECB, is summarized by the following Taylor rule:

$$i_t = \rho_r i_{t-1} + (1 - \rho_r) \left(r_{ss} + \phi_\pi \pi_t^{EU} \right) + \widetilde{\varepsilon}_t$$

with the European inflation defined as $\pi_t^{EU} = \mu_{FR} \pi_t + (1 - \mu_{FR}) \pi_t^{REU}$, where π_t^{REU} denotes the inflation in the rest of the Euro area, and μ_{FR} the share of the French economy. Assuming

that inflation in the rest of the Euro area is correlated with the French inflation, i.e. $\pi_t^{REU} = \rho_\pi \pi_t + \pi_t^{REU*}$, the Taylor rule becomes:

$$i_t = \rho_r i_{t-1} + (1 - \rho_r)\left(r_{ss} + \phi_\pi(\mu_{FR} + (1 - \mu_{FR})\rho_\pi)\pi_t\right) + \varepsilon_t$$

with $\pi_t = \frac{P_t}{P_{t-1}} - 1$ and $\varepsilon_t = \widetilde{\varepsilon}_t + \phi_\pi(1 - \rho_r)(1 - \mu_{FR})\pi_t^{REU*}$ and $corr(\pi_t^{REU*}, \pi_t) = 0$. Hence, ε_t is not a "pure" monetary shock but a composite shock that also contains inflation shocks that occur in the rest of the Euro Area. Besides, the Fisher rule leads to $1 + i_t = (1 + r_t)(1 + \pi_{t+1})$.

2.6 Equilibrium

The market clearing conditions used to determine the unknowns $\{N, w, p_{FE}\}$ are:

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\begin{aligned}
\text{asset market:} \quad & b = \mathcal{A} \equiv \int_{a_-} \int_e a(a_-, e) d\Gamma(a_-, e) \\
\text{labor market:} \quad & N = \mathcal{N} \equiv \int_{a_-} \int_e n(a_-, e) d\Gamma(a_-, e) \\
\text{energy market:} \quad & \overline{E} = \mathcal{E} \equiv Y_{FE} + \underline{c}_{FE} + E
\end{aligned}
$$

where we assume that the energy price P_{FEt} is exogenous and therefore the supply $\overline{E}$ adjusts to satisfy the demand for this price.[9]

2.7 Calibration

All structural parameters are calibrated using external information. The parameters of the exogenous shocks $\{P_{FE}, G, T, \beta, \mu, \vartheta\}$ are estimated using data for real GDP, inflation rate, public debt over GDP ratio, energy price, government expenditures, government transfers and the model restrictions over the sample 2Q1995 to 4Q2019 using the data set $\{Y_t, \pi_t, \frac{b_t}{Y_t}, G_t, T_t, P_{FE,t}\}_{t=2Q1995}^{4Q2019}$. The shock s_H reproduce the dynamics of the subsidies provided by the government to consumers for their energy expenditures over the period 1Q2022 to 4Q2023.[10]

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[9]The market clearing condition on the goods market can be used to check the Walras law:

$$Y\left(1 - \frac{\psi_P}{2}\pi^2\right) = p_{FE}\overline{E} + \mathcal{C} + G$$

[10]The parameters values are presented in Appendix A. The details of the calibration-estimation method can be found in Langot et al. (2023).

The quantitative analysis uses the "government forecasts" from 1Q2022 to 4Q2027, based on a mixture of non-structural models using a very large set of information (statistical information and informal knowledge), and the restrictions of our HANK model in order to reveal the time series of shocks realizations allowing the model to reproduces the government forecasts (output, inflation and public debt, conditionally to the paths for government's expenditures and receipts). These time-specific realizations of these shocks can be interpreted as the evolution of the economic conditions necessary to make credible the government's forecasts under the null hypothesis that our HANK model is "true". Given that the law already contains the "tariff shield" that reduces the price of energy products in 2022 and 2023, the benchmark scenario introduces this policy as well as all the other new policies announced in the Finance Act of November 2022. This reference scenario does not introduce a carbon tax, whatever the horizon, because no vote has been taken on this point. These commitments of the French government are then used to reveal the estimated sequence of shocks until 4Q2027. Keeping as given this set of shocks (all things being equal), the policy evaluations of the carbon tax are conducted by making counterfactual simulations where we add an increasing carbon tax from 2024 accompanied or not by other policies. These counterfactual scenarios are compared to the benchmark scenario. This quantitative method can be implemented thanks to the dynamic response of the model obtained after computing the sequence-space Jacobian of the system as proposed in Auclert et al. (2021a). This shock identification allows us to uncover the benchmark scenario defined as the sequence of the model's structural shocks that make its endogenous variables consistent with the government's forecasts to which the government must commit itself in the Finance Act. Next, to evaluate an alternative policy, we keep the paths of all exogenous variables as given by the benchmark and only change the policy tool under consideration.[11]

3 Policy analysis

The first subsection presents the tax carbon paths that we consider. As it is discussed in the ECB's publication on climate change (Drudi et al. (2021)), we assume that two scenarios are possible: *(i)*

[11]See Langot et al. (2023) for more details. In this paper, we use a Taylor rule incorporating more persistence. Indeed, in Carvalho et al. (2021), the estimate of the parameter ρ_r over the Greenspan-Bernanke period (3Q1987 to 4Q2007) is 0.83 with a standard deviation of 0.05, which leads to a statistically acceptable bound of 0.93. In Smets and Woutrrs (2003), an estimation on European data suggests that $\rho_r = 0.942$. Therefore, we set $\rho_r = 0.95$ because over the recent period, in particular since the COVID crisis, the ECB has often been slower in adjusting its interest rate and it is assumed that it will continue to adjust more slowly than the FED.

a "reasonable" scenario where the carbon tax is implemented from 2024 and rises gradually (2.5% in 2024, 5% in 2025, 7.5% in 2026 and 10% in 2026), and *(ii)* a more "brutal" one, where the carbon tax is implemented later and therefore directly set to a high rate (0% until 2027 and then 12%). We consider that the carbon tax is a unique rate applied to the prices of fossil products purchased by households and firms. The calibration of its increase corresponds to the gradual rise in carbon price from 44.6 to 86.2 €/ton of CO_2, the increase that would have been applied for four consecutive years starting from 2019 (the year after the blocking induced by the "yellow vest" movement). The
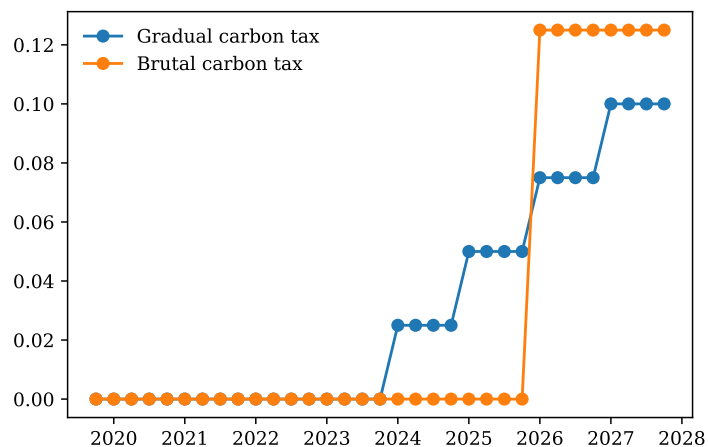
Figure 1: Carbon tax scenarios.

latter scenario would be consistent with a late response by the policymaker in the introduction of this tax. Figure 1 displays those two paths.

This new tax may be accompanied by a set of policies to complement it:

- **Accommodative monetary policy** modelled as a surprise change in the ECB's parameter ϕ_π contemporaneously to the carbon tax's introduction.

- **Redistributive policy** that transfers to households the additional revenues generated by the carbon tax.

- **A stimulus via energy renovations**, financed by a part of the revenues from the carbon tax and calibrated to compensate for the incompressible consumption of households.

The following subsections cover our model's results.

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3.1 Impact of a carbon tax

The choice of the benchmark scenario is crucial for the evaluation of counterfactual economic policy scenarios. In order to anchor our policy evaluation in a relevant economic context, the benchmark scenario corresponds to the trajectories planned by the French government in the 2023 Finance Act (for the period 2023-2027) concerning the main macroeconomic aggregates, public finances and the price of oil. Therefore, the impact of the introduction of a carbon tax is compared to a benchmark scenario in which this tax rate remains at 0% over 2024 onward. Note that in the French context, because the tariff shield is planned to stop at the end of 2023, energy prices perceived by households are expected to surge from 1Q2024.

Scenario	GDP growth			Inflation rate			Debt-to-GDP ratio
	2022	2023	2024-25	2022	2023	2024-25	Long-term (2027)
No tariff shield in 2022 and 2023	1.18%	0.92%	2.55%	7.5%	3.5%	3.1%	110.7%
Tariff shield in 2022 and 2023	2.85%	1.00%	1.65%	6.5%	3.8%	3.51%	112.8%

Columns 2024-25: average rates over 2024 and 2025

Table 1: Growth, inflation and indebtedness without carbon tax

Benchmark: no carbon tax. The 2023 Finance Act ends the tariff shield as of 4Q2023. The end of this subsidy for energy products implies an increase in their cost leading to an inflation excess of 0.4 percentage points in 2024-25 (the inflation gap between "Tariff shield " and "No tariff shield"), despite the expected decline of energy prices (see table 1). The tariff shield in 2022 and 2023 has sustained GDP growth: the growth rate reaches 2.85% instead of 1.18% in 2022 and 1% instead of 0.92% in 2023 (see Table 1).[12] Indeed, as the tariff shield contains inflation, the price-wage spiral is not initiated and the labor costs are reduced. After the end of the tariff shield, the GDP growth rate increases driven by the expected decline of energy prices, but this increase is dampened by the stop of the tariff shield that mechanically pushes up net energy prices. Therefore the growth is lower than without the tariff shield where the intertemporal substitution effects are larger due to the large impacts of the energy price increase in 2022 and 2023. The counterpart of the tariff shield is an annual budgetary cost of 2% of GDP, i.e. 58 billion euros. This situation constitutes

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[12]Without the tariff shield, the average growth rate of output for 2022-2023 would have been 1.04% against 1.92% with the tariff shield.

our reference scenario in which the carbon tax is not implemented.[13]

Gradual carbon tax.   The introduction of the carbon tax immediately reduces GDP (see Table 2).[14] In 4Q2025, the GDP growth rate would only be 1.50% over the year, whereas it would have

Scenario	Variable	2024	2025	2026	2027
No carbon tax	GDP growth	1.60%	1.70%	1.70%	1.80%
	Inflation rate	4.12%	2.90%	2.09%	1.77%
	Debt-to-GDP ratio	112.1%	112.2%	112.4%	112.6%
	Firm energy consumption index	96.9	101.1	102.0	102.7
	Household energy consumption index	99.5	100.2	100.3	100.4
Gradual carbon tax	GDP growth	1.50%	1.61%	1.61%	1.71%
	Inflation rate	4.15%	2.96%	2.13%	1.82%
	Debt-to-GDP ratio	112.2%	112.2%	112.4%	112.4%
	Firm energy consumption index	96.9	100.1	100.0	99.8
	Household energy consumption index	99.5	100.0	100.0	100.0
Brutal carbon tax	GDP growth	1.60%	1.70%	1.21%	1.83%
	Inflation rate	4.12%	2.90%	2.26%	1.83%
	Debt-to-GDP ratio	112.1%	112.2%	112.5%	112.4%
	Firm energy consumption index	96.9	101.1	97.1	97.9
	Household energy consumption index	99.5	100.2	99.6	99.7

Table 2: Carbon Tax Policy: Gradual Versus Brutal Implementation

been 1.60% without the implementation of the carbon tax. Despite this slowdown in economic activity, the equilibrium nominal interest rate increases from 8.05% to 8.10% in 2024 and 8.14% in 2025 (see also figures in Appendix B)) because inflation slightly rises. This more restrictive monetary policy reinforces the fall in GDP, hours and consumption. As inflation is contained, the price-wage spiral has not started and the very weak nominal wage increases lead to losses of purchasing power: the real hourly wage is reduced (figure in the Appendix B). The government benefits for its part from the carbon tax via the revenue it collects. This enables some debt reduction: the debt-to-GDP ratio decreases from 112.6% to 112.4% (see also figure in the Appendix B). The additional budget revenue generated by the carbon tax is worth 0.08 points of GDP in 2024, 0.16 points in 2025, 0.24 points in 2026 and 0.32 points in 2027. Table 2 also shows that the carbon tax makes it possible to significantly reduce the energy consumption of households and businesses (see the figure in the Appendix B). The response is stronger for businesses than for households, -2.8% versus -0.4% respectively in 2027 with respect to 2024 (see Table 2). If we compare with the scenario without a carbon tax, the energy consumption of households and businesses is reduced, thanks to the carbon

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[13]This scenario is described in the figures of Appendix B by the trajectories (solid lines) of economic variables over the period 2023-2027.

[14]Appendix B gathers the aggregate dynamics of these various scenarios over the 2024-2028 period.

tax, by 0.001675% and 0.1328% respectively in 2024, by 0.5774% and 3.8090% in 2025, by 1.1532% and 7.5628% in 2026 then by 1.7275% and 11.2615% in 2027.

Brutal carbon tax. If the carbon tax is implemented more brutally in an attempt to make up for a decision that was too late, the loss of growth in 2026 would be very significant (1.21% instead of 1.70% without a carbon tax). This context of very weak growth obviously makes it possible to further reduce the energy consumption of households and businesses than in the case of the gradual introduction of a carbon tax (see Table 2). However, this very weak growth makes carbon taxation less acceptable and thus highlights the virtues of an earlier and gradual carbon tax implementation in France.

3.2 Accommodating monetary policy

The carbon tax could simultaneously be accompanied by a change in the ECB's behavior. We consider here that the ECB becomes more accommodating by lowering the Taylor rule sensitivity ϕ_π from 1.5 (benchmark) to 1.25. We assume this change will occur in 1Q2024 and stay the same ever since, despite the carbon tax increasing gradually over the years.[15] Hence, the scenario of gradual implementation of the carbon tax without changes to the monetary policy rule is compared to a scenario where the ECB adopts this accommodating monetary policy rule that is less reactive to inflation (last lines of Table 3).

3.2.1 Aggregates, Carbon Tax and Monetary Policy

The slightest reaction of the nominal rate leads to a fall in the real interest rate stimulating household consumption demand (see the figure in Appendix C). The decline of the real interest rate comes from the combination of the sluggishness of the nominal interest rate adjustments (the parameter $\rho_r = 0.95$) and the low sensitivity of the ECB to inflation (the parameter $\phi_\pi = 1.25$). Table 3 shows that the economy then experiences an expansion in its output: in 2024, the GDP growth rate is 1.8%, larger than what it could be without the carbon tax (1.6%), and thus obviously larger than if the carbon tax is not accompanied from an accommodating monetary policy (1.5%). After this initial boost for growth, the growth rates in the economy with an accommodating attitude of the

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[15]This weaker reaction of the ECB to inflation can be rationalized either by a reaction to an inflation rate smoothed over several quarters, or by an inflation rate excluding all or part of the price increases of energy products.

Scenario	Variable	2024	2025	2026	2027
No carbon tax	GDP growth	1.60%	1.70%	1.70%	1.80%
	Inflation rate	4.12%	2.90%	2.09%	1.77%
	Debt-to-GDP ratio	112.1%	112.2%	112.4%	112.6%
	Firm energy consumption index	96.9	101.1	102.0	102.7
	Household energy consumption index	99.5	100.2	100.3	100.4
Gradual carbon tax	GDP growth	1.50%	1.61%	1.61%	1.71%
	Inflation rate	4.15%	2.96%	2.13%	1.82%
	Debt-to-GDP ratio	112.2%	112.2%	112.4%	112.4%
	Firm energy consumption index	96.9	100.1	100.0	99.8
	Household energy consumption index	99.5	100.0	100.0	100.0
Gradual carbon tax and accommodating monetary policy	GDP growth	1.81%	1.49%	1.57%	1.74%
	Inflation rate	4.33%	3.34%	2.16%	1.68%
	Debt-to-GDP ratio	111.3%	110.6%	110.2%	109.7%
	Firm energy consumption index	96.9	100.1	99.9	99.7
	Household energy consumption index	99.5	100.0	100.0	100.0

Table 3: Gradual Carbon Tax and Accommodating Monetary Policy

ECB are lower than in the other scenarios, but the output path keeps over the ones of the other scenarios (see the figure in Appendix C). This economic expansion is taking place in a strongly inflationary environment tolerated by a more accommodating central bank in this scenario. The costs in terms of inflation are quite large: on average over the 4 years, inflation is 0.6 points higher than it would be in an economy without a carbon tax. This result is explained by the sharp fall in the real interest rate when the central bank controls inflation less strictly. In response to this negative wealth effect, the labor supply increases, which allows firms to produce the largest demand also induced by the fall in the real interest rate. Concerning the government budget, in addition to collecting the revenue from the carbon tax, the sharp drop in the real interest rate allows it to reduce the burden of its interests and therefore greatly the public debt from 112.6% to 109.7% (see also Appendix C). Moreover, a less reactive monetary policy allows to reach the level of activity of the economy without the carbon tax, leading to higher government revenues. Note that the additional budget revenues generated by the carbon tax for the years 2024 to 2027 are the same as with the carbon tax alone, the energy consumption gap being roughly the same as the GDP gap.

It is important to emphasize that this support for the economy through monetary policy does not hinder the environmental objective of the carbon tax. Indeed, the consumption of energy products decreases more when monetary policy is accommodative. If we compare with the scenario without a carbon tax, the energy consumption of households and businesses is reduced, thanks to the carbon tax, by -0.004219% and 0.06322% respectively in 2024, by 0.6266% and 4.1369% in 2025, by 1.2233% and 8.0256% in 2026 then by 1.7912% and 11.6782% in 2027. This reduction

in energy consumption is greater than in the case where the carbon tax is not accompanied by an accommodating monetary policy. This is a remarkable achievement because the GDP is larger when an accommodating monetary policy is implemented. This result is explained by the larger increase in energy than in labor costs when the central bank controls inflation less strictly. Labor is then more competitive, which allows firms to reduce the use of their other factor of production, energy.

At this stage, our simulations confirm the main arbitration between growth and inflation described by the ECB for the revision of its monetary policy strategy in the face of climate change (Drudi et al. (2021)). Our work places them in the context of the French economy. Our model completes this analysis by studying the dynamics of consumption inequalities between households.

3.2.2 Inequalities, Carbon Tax and Monetary Policy

The advantage of our model is that it allows us to analyze the dynamics of inequalities from the implementation of the carbon tax, i.e. from 1Q2024. We focus on the dynamics of consumption inequality that best approximates welfare inequalities between households.[16]
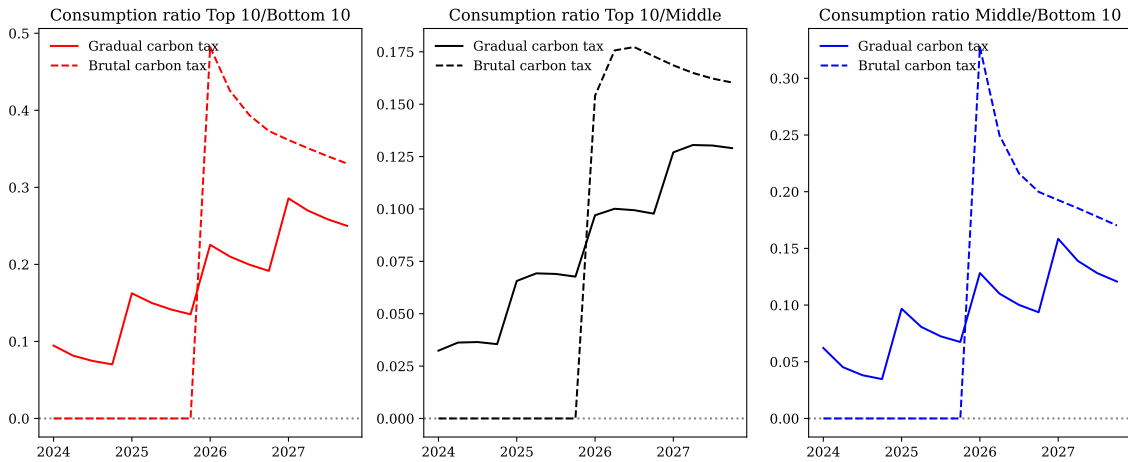
We plot $\left.\frac{C(T10)}{C(B10)}\right|_{\text{Scenario}} - \left.\frac{C(T10)}{C(B10)}\right|_{\text{Bench}}$ where $C(T10)$ is the consumption of the top 10% earners, $C(B10)$ is the consumption of the bottom 10% earners and $C(Middle)$ is the consumption of the median earners. Remark that $\left.\frac{C(T10)}{C(B10)}\right|_{\text{Bench}} = 2.35$, $\left.\frac{C(T10)}{C(Middle)}\right|_{\text{Bench}} = 1.45$ and $\left.\frac{C(Middle)}{C(B10)}\right|_{\text{Bench}} = 1.61$

Figure 2: Dynamics of Inequalities with a Carbon Tax

The reference scenario, without the implementation of the carbon tax, is characterized by an

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[16]The consumption is the unique argument of the utility function that depends on the individual agent's state (a, e). Indeed the labor supply is homogeneous among workers given the unions' behaviors.

increase in inequalities.[17] Therefore, to identify the impact of the carbon tax on inequality, we evaluate how the inequalities change when the carbon tax is implemented. These changes are expressed as the gaps between inequalities in the benchmark scenario and inequalities in the alternative scenarios where a carbon tax is implemented. Our measures of inequalities are $\frac{C(T10)}{C(B10)}$ which is the ratio between the consumption of the top 10% of households denoted by $C(T10)$ and the bottom 10% of households denoted by $C(B10)$, as well as the ratio $\frac{C(Middle)}{C(B10)}$ which is the ratio between the consumption of median households noted $C(Middle)$ and $C(B10)$.

The left panel of Figure 2, shows that the carbon tax increases the consumption inequalities (as shown by the solid line in the figure). This is also the case if we consider the inequalities between the median ("Middle") households and the least advantaged households (see the solid line in the right panel of Figure 2). On the other hand, the inequalities between the 10% most advantaged households and the median households are stable over the period considered (see the solid line in the middle panel of Figure 2). Hence, the implementation of the carbon tax reinforces inequalities in consumption whatever the measure considered.

The increase in inequalities induced by the carbon tax is explained by *(i)* the macroeconomic recession that reduces hours worked which contract stronger the incomes of the poorest, and *(ii)* by the highest exposure of the poorest to an increase in energy price: they have the largest MPC, the largest share of consumption devoted to energy products and the lowest price elasticity to energy products (see Figure 8).

The impact of accommodating monetary policy on inequalities. A less reactive monetary policy makes it possible to reduce inequalities (see Figure 3, dotted lines) through its effects on the macroeconomic activity described above. Indeed, as the least advantaged households have the highest propensity to consume (see Figure 8), their consumption reacts more strongly to the increased activity generated by a more accommodative monetary policy. Monetary policy, through its effects on the consumption of the least privileged households, therefore plays an essential role in the social acceptance of the implementation of the carbon tax.

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[17]This increase in inequality is linked to the drop in transfers and public spending planned by the French government in order to reduce its debt-to-GDP ratio.
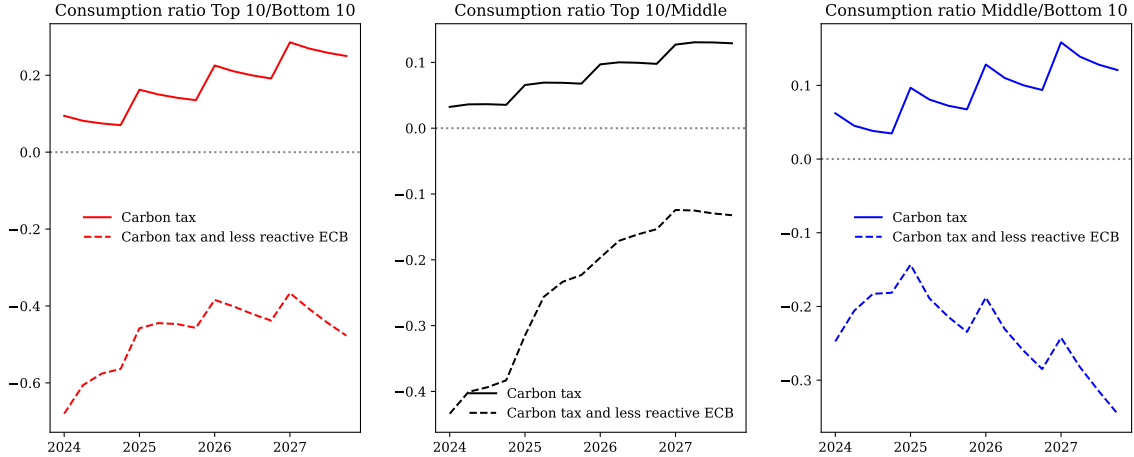
Consumption ratio Top 10/Bottom 10	Consumption ratio Top 10/Middle	Consumption ratio Middle/Bottom 10

We plot $\left.\frac{C(T10)}{C(B10)}\right|_{\text{Scenario}} - \left.\frac{C(T10)}{C(B10)}\right|_{\text{Bench}}$ where $C(T10)$ is the consumption of the top 10% earners, $C(B10)$ is the consumption of the bottom 10% earners and $C(Middle)$ is the consumption of the median earners. Remark that $\left.\frac{C(T10)}{C(B10)}\right|_{\text{Bench}} = 2.35$, $\left.\frac{C(T10)}{C(Middle)}\right|_{\text{Bench}} = 1.45$ and $\left.\frac{C(Middle)}{C(B10)}\right|_{\text{Bench}} = 1.61$

Figure 3: Dynamics of Inequalities with a Carbon Tax and Accommodating Monetary Policy

3.3 When Carbon Tax Revenues Are Used to Finance Redistributive Transfers

While the previous policy requires cooperation between several economic policymakers (the governments for the carbon tax and the ECB for the interest rate), a more "simple" policy consists of exploiting the additional revenues generated by the carbon tax to redistribute transfers to households in order to help them mitigate the carbon tax' downside effects. In practice, we assume that these transfers concern the entire population, but in a progressive manner: the amounts received are greater the lower the productivity. While energy prices rise due to the carbon tax, these transfers received by households prompt them to redirect their consumption towards less polluting goods.

The use of the carbon tax revenue to redistribute income to households is efficient because the GDP growth rate is larger than in an economy where only the tax on carbon is implemented. Nevertheless, GDP growth is slightly less strong than in the absence of a carbon tax (see Table 4), but above all, the trajectory of GDP remains significantly below that of an economy where no climate policy would be implemented (see Figure D). Let us remark that this policy is less efficient than a carbon tax accompanied by an accommodating monetary policy. This policy fuels inflation (see Table 4). Therefore, it leads to a rise in real interest rates.[18] In fact, the debt burden is higher and therefore the debt-to-GDP ratio is equivalent to what would happen without carbon tax

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[18]The ECB is no longer accommodating in this scenario, which leads the nominal interest rate to overreact to inflation.

Scenario	Variable	2024	2025	2026	2027
No carbon tax	GDP growth	1.60%	1.70%	1.70%	1.80%
	Inflation rate	4.12%	2.90%	2.09%	1.77%
	Debt-to-GDP ratio	112.1%	112.2%	112.4%	112.6%
	Firm energy consumption index	96.9	101.1	102.0	102.7
	Household energy consumption index	99.5	100.2	100.3	100.4
Gradual carbon tax	GDP growth	1.50%	1.61%	1.61%	1.71%
	Inflation rate	4.15%	2.96%	2.13%	1.82%
	Debt-to-GDP ratio	112.2%	112.2%	112.4%	112.4%
	Firm energy consumption index	96.9	100.1	100.0	99.8
	Household energy consumption index	99.5	100.0	100.0	100.0
Gradual carbon tax and redistribution	GDP growth	1.58%	1.66%	1.66%	1.76%
	Inflation rate	4.18%	3.03%	2.23%	1.94%
	Debt-to-GDP ratio	112.1%	112.1%	112.3%	112.5%
	Firm energy consumption index	96.9	100.2	100.1	99.9
	Household energy consumption index	99.5	100.0	100.0	100.0

Table 4: Carbon Tax Policy and Redistribution

revenue. As previously, the additional budget revenues generated by the carbon tax for 2024 to 2027 are about the same as with the carbon tax only, the gap in energy consumption being approximately the same as the gap in GDP. In addition, this support for households leads to a drop in energy consumption (see Table 4). If we compare with the scenario without a carbon tax, the energy consumption of households and businesses is reduced, thanks to the carbon tax, by 0.002761% and 0.1329% respectively in 2024, by 0.5588% and 3.6854% in 2025, by 1.1165% and 7.3200% in 2026 then by 1.6729% and 10.9030% in 2027. These reductions in energy consumption are less significant than when the carbon tax is implemented alone, which is a strong limit to this type of support policy for energy taxation.

This redistributive policy is very disappointing when we measure its impact on the evolution of consumption inequalities (see Figure 4). It certainly makes it possible to reduce them compared to the scenario with a carbon tax but fails to bring them back to what they would have been without a carbon tax. Indeed, this inflationary policy increases the medium-long-term real interest rate (anti-redistributive effect) which cancels out the direct effect of this redistributive policy. It would then be desirable to accentuate its redistributive nature, but this would lead to an even further increase in inflation. In fact a satisfactory adjustment of this policy seems very delicate and therefore not very robust.
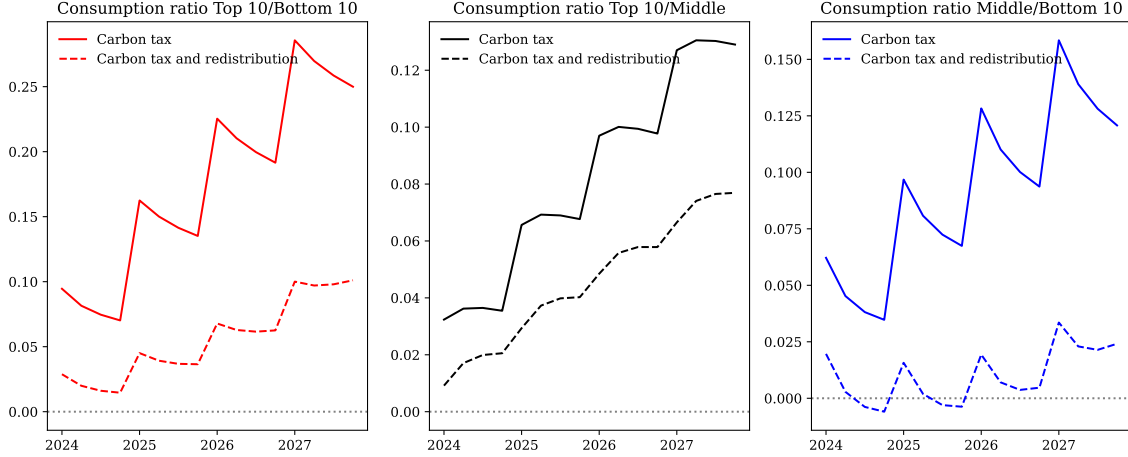
We plots $\left.\frac{C(T10)}{C(B10)}\right|_{\text{Scenario}} - \left.\frac{C(T10)}{C(B10)}\right|_{\text{Bench}}$ where $C(T10)$ is the consumption of the top 10% earners, $C(B10)$ is the consumption of the bottom 10% earners and $C(Middle)$ is the consumption of the median earners. Remark that $\left.\frac{C(T10)}{C(B10)}\right|_{\text{Bench}} = 2.35$, $\left.\frac{C(T10)}{C(Middle)}\right|_{\text{Bench}} = 1.45$ and $\left.\frac{C(Middle)}{C(B10)}\right|_{\text{Bench}} = 1.61$

Figure 4: Dynamics of Inequalities with a Carbon Tax and Redistribution

3.4 When Carbon Tax Revenues Are Used to Finance Energy Renovation

In this last scenario, the resources of the carbon tax are also considered as additional government spending. As with all government spending, they are addressed to national producers, pushing up the demand (the good basket of the government is the same as the household one). These "new" expenditures are targeted: we assume they improve the housing's energy efficiency by reducing the incompressible energy consumption of households.

Data ("Enquête Budget des familles 2017, INSEE (2020)") shows that the share of consumption expenditure devoted to housing (rent and energy) is higher the lower the household's income (panel (a) of Figure 5), which is also true if we consider only the energy consumption expenditure for housing (panel (c) of Figure 5). On the contrary, the share of transport expenditure in total consumption increases with income (panel (b) of Figure 5), whereas the share of energy expenditure for transport in total consumption does not decrease sharply with income (panel (d) of Figure 5). Thus, if the government want investment in the energy transition to be highly redistributive, it is preferable to target it on energy expenditure for housing.

This strong decrease in income of the share of energy expenditure for housing in total consumption can be generated in our model by the incompressible consumption parameter $\underline{c}_{FE}$. Indeed, as $\underline{c}_{FE}$ is identical for all households, it generates a decreasing share of energy consumption with the

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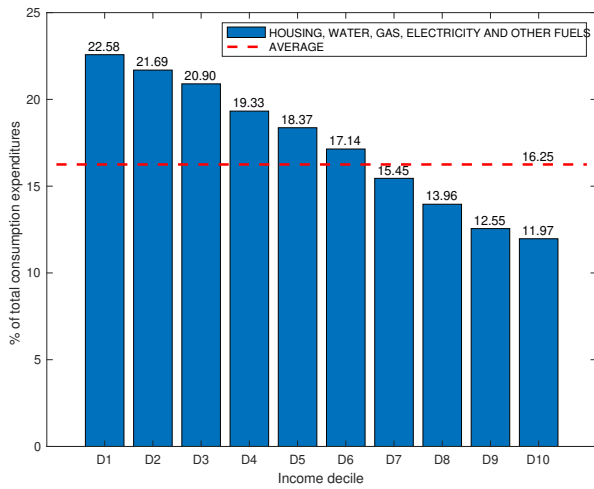
(a) Housing, water, gas, electricity and others fuels
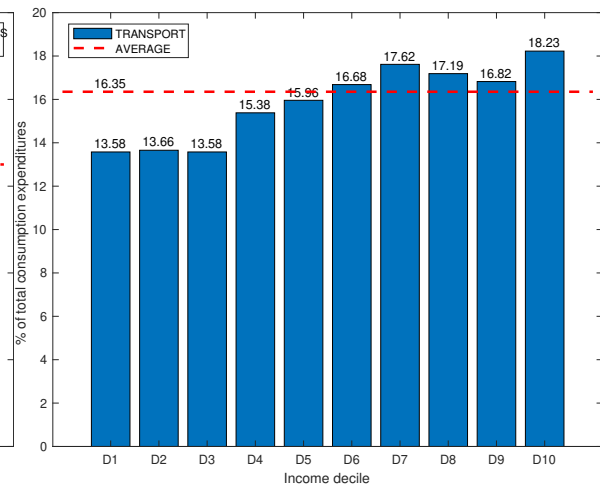
(b) Transports
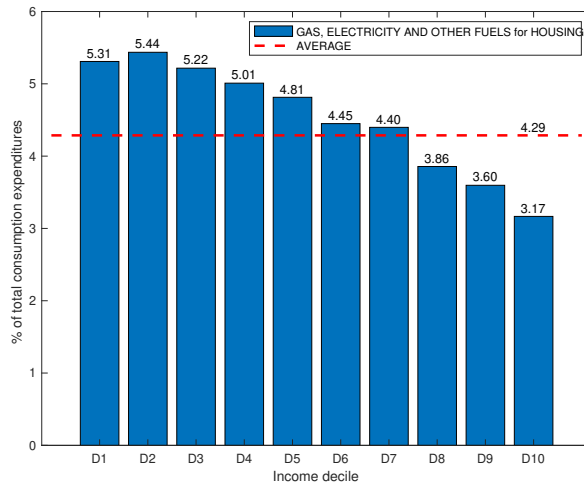
(c) Gas, electricity and others fuels for Housing
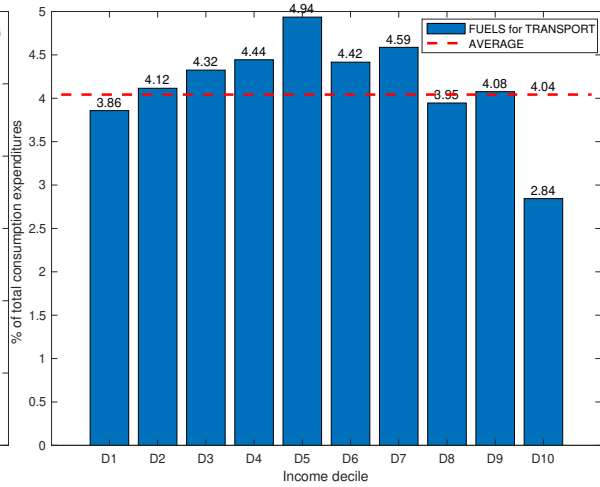
(d) Fuel for Transport

Figure 5: Housing, transport, energy for housing and transport: shares in total consumption

level of income, as it is observed for the energy consumption of households. Hence, the investment in building insulation aims to reduce incompressible energy consumption. This energy renovation policy benefits all households, by lowering their incompressible energy consumption by 20%.[19] With this calibration, each euro spent by the government on energy renovation investments only reduces the incompressible energy consumption by 35 cents. Of course, to this direct effect of lower energy consumption is added the induced effects linked to the carbon tax (price distortions) and the other general equilibrium effects. Although the absolute gain is the same for every household, this measure is progressive since the poorest devote a higher share of their consumption towards energy. Figure 6 shows how this energy renovation affects energy expenditures across the distribution of
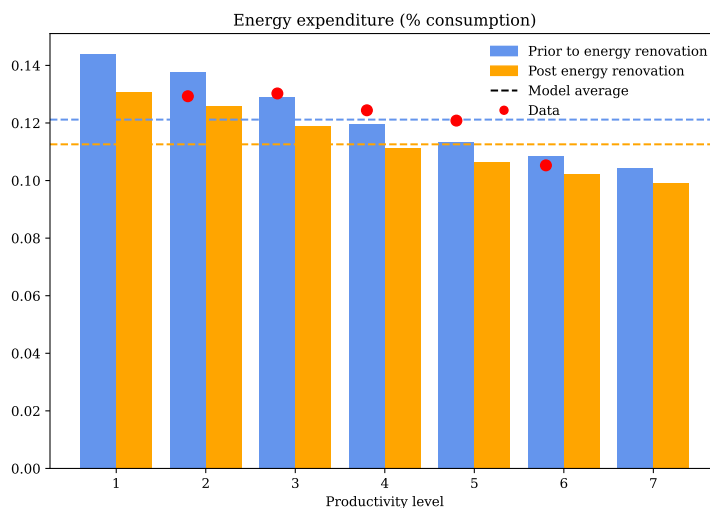
Figure 6: Energy share in consumption

labor earnings: the share of energy expenditure in their total expenditure decreases by 1.5 points for the most modest but by only 0.2 points for the wealthiest.

This measure makes it possible to catch up on the growth deficit caused by the carbon tax: we go from 1.5% to 1.56% in 2024, then from 1.61% to 1.68% in 2025 (see Table 5 and Figure E for a longer-term perspective). It should also be noted that this green recovery makes it possible to

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[19]Today in France, 7 million homes are poorly insulated, or 24% of the stock of 29 million homes, and 14% of French people are cold in their homes (see French ministry of ecology (2021)). By renovating and thus reducing poorly insulated houses, the French government forecasts that it is possible to reduce the total energy consumption for housing by 15% to 31% by 2028 and by 50 to 72% by 2050. (see Forecasts of the French ministry of ecology (2021)). In the model, the reduction in incompressible consumption made possible by public investments is calibrated on an ad hoc basis because we do not have reliable information allowing us to "correctly" assess the impact of these "new" expenditures.

approximately reach the GDP trajectory of an economy not fighting against global warming whose growth rates for these two years will be 1.6% in 2024 and 1.7% in 2025 (see Table 5 and Figure E). Nevertheless, this policy is less efficient than a carbon tax accompanied by an accommodating monetary policy (see Tables 3 and 5). Of course, this stimulus through "green" public spending is inflationary. However, this rise in inflation remains moderate, which means that employment and therefore growth sustained by "green" demand stimulus are not crowding out by supply contractions. By 2027, the energy consumption of businesses and households is reduced by 2.7% (from 102.7 to 100) and 0.4% (from 100.4 to 100) in this economy experiencing sustained growth (see Table 5).

Scenario	Variable	2024	2025	2026	2027
No carbon tax	GDP growth	1.60%	1.70%	1.70%	1.80%
	Inflation rate	4.12%	2.90%	2.09%	1.77%
	Debt-to-GDP ratio	112.1%	112.2%	112.4%	112.6%
	Firm energy consumption index	96.9	101.1	102.0	102.7
	Household energy consumption index	99.5	100.2	100.3	100.4
Gradual carbon tax	GDP growth	1.50%	1.61%	1.61%	1.71%
	Inflation rate	4.15%	2.96%	2.13%	1.82%
	Debt-to-GDP ratio	112.2%	112.2%	112.4%	112.4%
	Firm energy consumption index	96.9	100.1	100.0	99.8
	Household energy consumption index	99.5	100.0	100.0	100.0
Gradual carbon tax	GDP growth	1.56%	1.68%	1.67%	1.77%
and energy renovation	Inflation rate	4.18%	3.04%	2.25%	1.96%
	Debt-to-GDP ratio	112.1%	112.1%	112.4%	112.6%
	Firm energy consumption index	96.9	100.2	100.1	100.0
	Household energy consumption index	99.5	100.0	100.0	100.0

Table 5: Carbon Tax Policy and Energy Renovation

If we compare with the scenario without a carbon tax, the energy consumption of households and businesses is reduced, thanks to the carbon tax, by 0.0021% and 0.12% respectively in 2024, by 0.55% and 3.61% in 2025, by 1.10% and 7.18% in 2026 then by 1.66% and 10.71% in 2027. These reductions in energy consumption are very slightly less than when the carbon tax is implemented alone, as the increase in activity generated by investment in energy renovation offsets the initial energy-saving effect of the renovations.

Public investments allowing the energy renovation of residential buildings contribute to a large share of household energy expenditure, which cannot be reduced in the short term. Hence, these investments are more effective than a redistribution policy because they support demand more strongly (part of the redistributed transfers is oriented towards savings) and allow a reorientation of expenditure towards goods produced on the national territory (as incompressible consumption is being reduced).

The counterpart of the additional inflation created by this policy is the slight rise in real interest rates that it entails, which increases the government's debt burden and could increase the long-term debt-to-GDP ratio. Nevertheless, this effect is overcompensated by the stronger growth leaving the debt-to-GDP ratio unchanged (it would be 112.6% in 2027 just as in the scenario without any climate policy, see Table 5 and Figure E). As before, the additional budget revenues generated by the carbon tax for 2024 to 2027 are almost identical to the scenario with only the carbon tax, the gap in energy consumption being approximately the same as the gap in GDP.
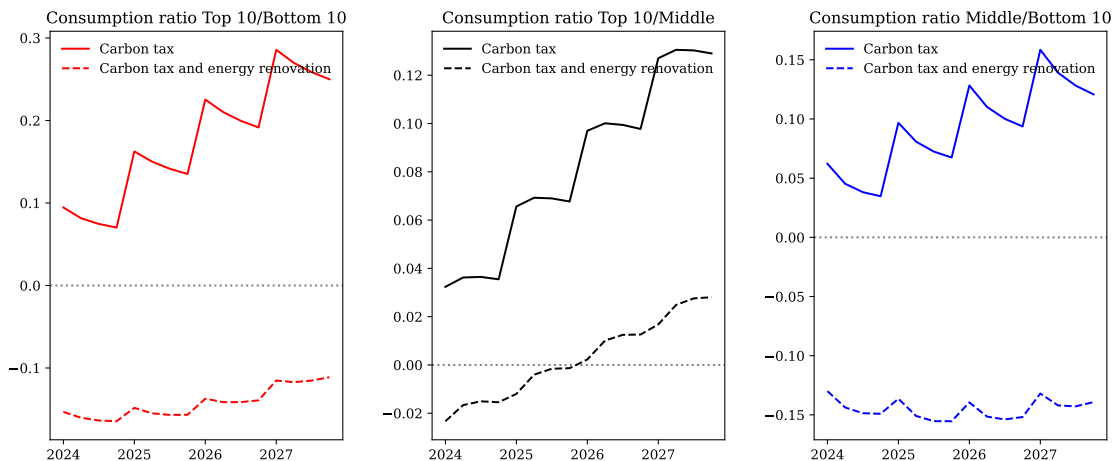
We plots $\frac{C(T10)}{C(B10)}\big|_{\text{Scenario}} - \frac{C(T10)}{C(B10)}\big|_{\text{Bench}}$ where $C(T10)$ is the consumption of the top 10% earners, $C(B10)$ is the consumption of the bottom 10% earners and $C(Middle)$ is the consumption of the median earners. Remark that $\frac{C(T10)}{C(B10)}\big|_{\text{Bench}} = 2.35$, $\frac{C(T10)}{C(Middle)}\big|_{\text{Bench}} = 1.45$ and $\frac{C(Middle)}{C(B10)}\big|_{\text{Bench}} = 1.61$

Figure 7: Dynamics of Inequalities with a Carbon Tax and Energy Renovation

Regarding inequalities, the performance of this policy is quite good: even if it does not reduce their absolute levels, it does reduce them relative to what they would have been without a carbon tax. This reduction in inequalities is less strong than that obtained with an accommodating monetary policy, because the latter, by directly reducing the real interest rate, breaks an essential source of widening inequalities (see Piketty (2013)). Note that the drop in inequalities between the most modest (B10) and the wealthiest (T10) is the result of a reduction in inequalities between the most modest (B10) and individuals around the median wage (see the left and right panels of Figure 7). Indeed, the gaps between individuals around the median wage and the wealthiest (see the middle panel of Figure 7) are very slightly greater than in the absence of a carbon tax. This result underscores the strong redistributive effect of consumption subsidies that reduce incompressible

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energy consumption.

4   Conclusion

In this article, we show that it is possible to make a carbon tax "acceptable" by accompanying it with measures to support growth, and therefore employment while reducing inequalities. We have studied three policies that all have advantages and disadvantages but overall go in the direction of making environmental policies acceptable. All these policies are evaluated in the context of a HANK model, that allows us to analyze both macro and inequality indicators.

We show that the most effective policy to simultaneously sustain the GDP growth and reduce both inequalities as well as the energy consumption of firms and households consists of accompanying the carbon tax with a more accommodating monetary policy. Indeed, this policy mix reduces the real interest rates which makes it possible to break one of the channels of the increase in inequalities. Nevertheless, the cost of this policy is one additional point of inflation on average over four years. Quite surprisingly, this policy mix reduces the inequalities more than the two other policies incorporating in their design a redistributive component. The policy that integrates a public investment financing the energy renovation supports sufficiently the demand (the path of the GDP is close to an economy without a carbon tax) but it is less redistributive than the one accompanying the carbon tax by an accommodating monetary policy.

This result puts the central bank's rate policy back at the center of the debate on support measures for fighting global warming. That said, this ranking of policies should not prevent us from considering a more ambitious policy mix, combining monetary policy and energy renovation expenditure. But, our partial analysis already highlights the strengths and weaknesses of some policies and the tradeoffs faced by policymakers in the short run.

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A Calibration

The structural parameters of the model are calibrated to reproduce some stylized facts about the French economy or a set using external information (see Table 6).

Parameter	Value	Target
Preferences		
Discount factor β	0.9922	Real interest rate $r = 0.5\%$ per quarter
Disutility of labor θ	0.6343	Aggregate labor $L = 1$
Frisch elasticity of labor supply φ	0.5	Auclert et al. (2021a)
Elasticity of intertemporal substitution σ	1	Log-utility
Incompressible energy consumption $\underline{c}$	0.0370	20% of the households' energy consumption
Wage markup μ_w	1.1	Auclert et al. (2021a)
Elasticity of substitution between production inputs η_E	0.5	Negative impact on GDP of energy price shock
Share parameter (energy, intermediate good) α_E	0.025	Sharing rule: a half of energy to households
Production		
Elasticity of substitution between production inputs σ_f	η_E	Simplifying assumption
Share parameter (energy, labor) α_f	0.075	Sharing rule: a half of energy to firms
Firm markup μ	1.2	Auclert et al. (2021a)
Aggregate targets		
Share of GDP spent on energy se	3.18%	Share of energy in GDP
Public debt B	4.749	Debt-to-GDP ratio 100% with annual GDP
Public spending G	0.2374	Public spending-to-GDP ratio 20%
Transfers	0.2968	Transfers-to-GDP ratio 25%
VAT rate τ_c	20%	French VAT
Income tax rate τ_l	20%	French employee tax rate
Nominal rigidity		
Price rigidity κ	0.95	Arbitrary higher than Auclert et al. (2018)
Wage rigidity κ_w	0.1	Auclert et al. (2018)
Monetary policy		
Taylor rule coefficient $\phi_\pi(\mu_{FR} + (1 - \mu_{FR})\rho_\pi))$	1.2	With $\phi_\pi = 1.5$ and $\mu_{FR} = 20\%$, the $\rho_\pi = 0.75$
Persistence of monetary policy ρ_r	0.95	Carvalho et al. (2021)
Heterogeneity		
Persistence of productivity shocks ρ	0.966	Fonseca et al. (2023) data for France
Volatility of productivity shocks σ	0.5	To match consumption inequalities

Table 6: Calibrated parameters

This calibration results in 19.6% of households being financially constrained. The Marginal Propensity to Consume (MPC) per level of income are reported in panel (a) of Figure 8. As expected, the agents with low incomes consume a larger fraction of their income increases. Panel (b) of Figure 8 shows that the agents devote a larger share of their expenditures to energy, as in the data. Finally, panel (c) of Figure 8 shows that the agents with low incomes have more difficulty reducing their energy consumption when the price increases. This result comes from the largest share of incompressible consumption in their energy consumption.

(a) Marginal Propensity to Consume   (b) Energy share in consumption   (c) Price elasticity of energy demand
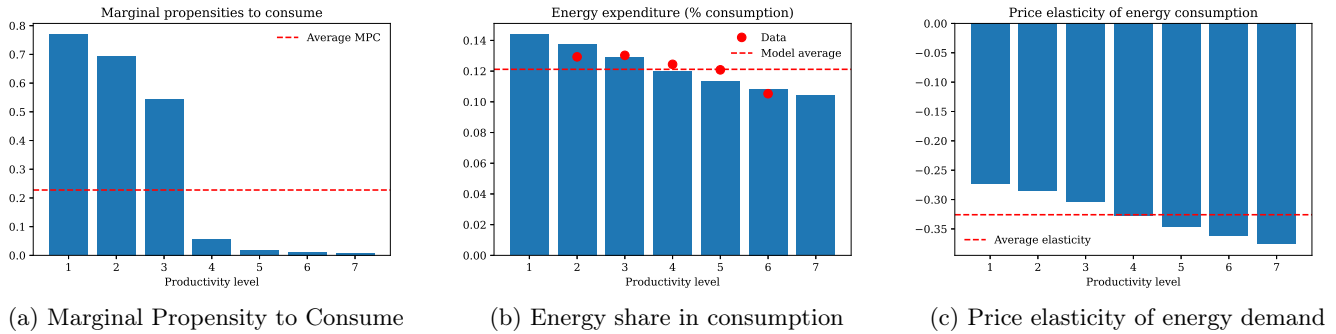
Figure 8: Heterogeneity in household's behaviors (per income level)

Parameters of aggregate shocks. As in all dynamic models, the impact of each shock depends on how the agents expect them to persist. The autocorrelations of these $AR(1)$ processes and the standard deviations of their innovations are reported in Table 7.

Shock	Z	Persistence ρ^Z Mode	Persistence ρ^Z Mean	Standard dev. σ^Z Mode	Standard dev. σ^Z Mean	Variance $\frac{(\sigma^Z)^2}{1-(\rho^Z)^2}$
Energy price	p_{FE}	0.816	0.798 (0.036)	0.012	0.013 (0.0023)	0.000465
Government spending	G	0.920	0.916 (0.014)	0.0035	0.0036 (0.0003)	0.000081
Transfers	T	0.872	0.862 (0.024)	0.0049	0.0051 (0.0004)	0.000101
Taxes	ϑ	0.778	0.777 (0.024)	0.151	0.148 (0.011)	0.055275
Price markup	μ	0.793	0.792 (0.024)	0.057	0.059 (0.005)	0.009339
Preference	β	0.887	0.888 (0.0158)	0.0046	0.0047 (0.0006)	0.000104

Table 7: Estimated parameters of the $AR(1)$ processes

The values for ρ^Z, $\forall Z \in \{\beta, \mu, \vartheta, G, T, P_{FE}\}$, are estimated using a Bayesian method based on the data set $\{Y, \pi, \frac{b}{Y}, G, T, P_{FE}\}$ over the sample 2Q1995 to 4Q2019.[20] The autocorrelation functions of these variables are deduced from the model solution (see Langot et al. (2023)).

For the energy consumption subsidy (the tariff shield between 1Q2022 and 4Q2023), we assume that households expect the government not to remove it all at once, as provided for in the law, but to take a year to remove all these subsidies. Thus, households act in the belief that there is a persistence of this subsidy after 4Q2023.

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[20]All data are stationarized by extracting a linear trend, except the debt-to-GDP ratio where only its average over the sample is extracted.

B   Carbon tax: Aggregates since 1Q2024

Model forecasts for each scenario

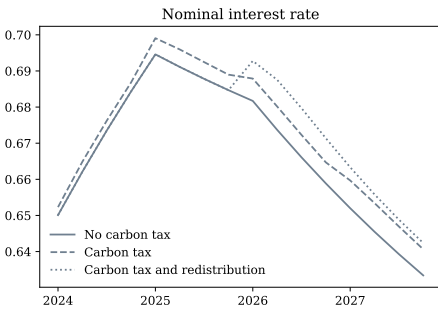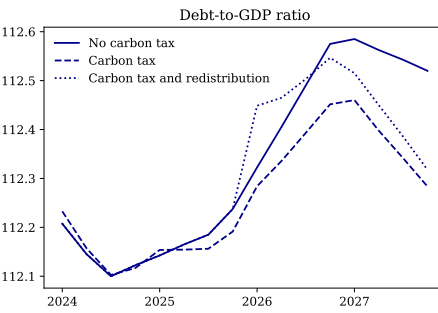## Gaps between each scenario and benchmark

Output

Inflation

Real wage

Debt-to-GDP ratio

Nominal interest rate


Real interest rate

Firm energy

Household energy
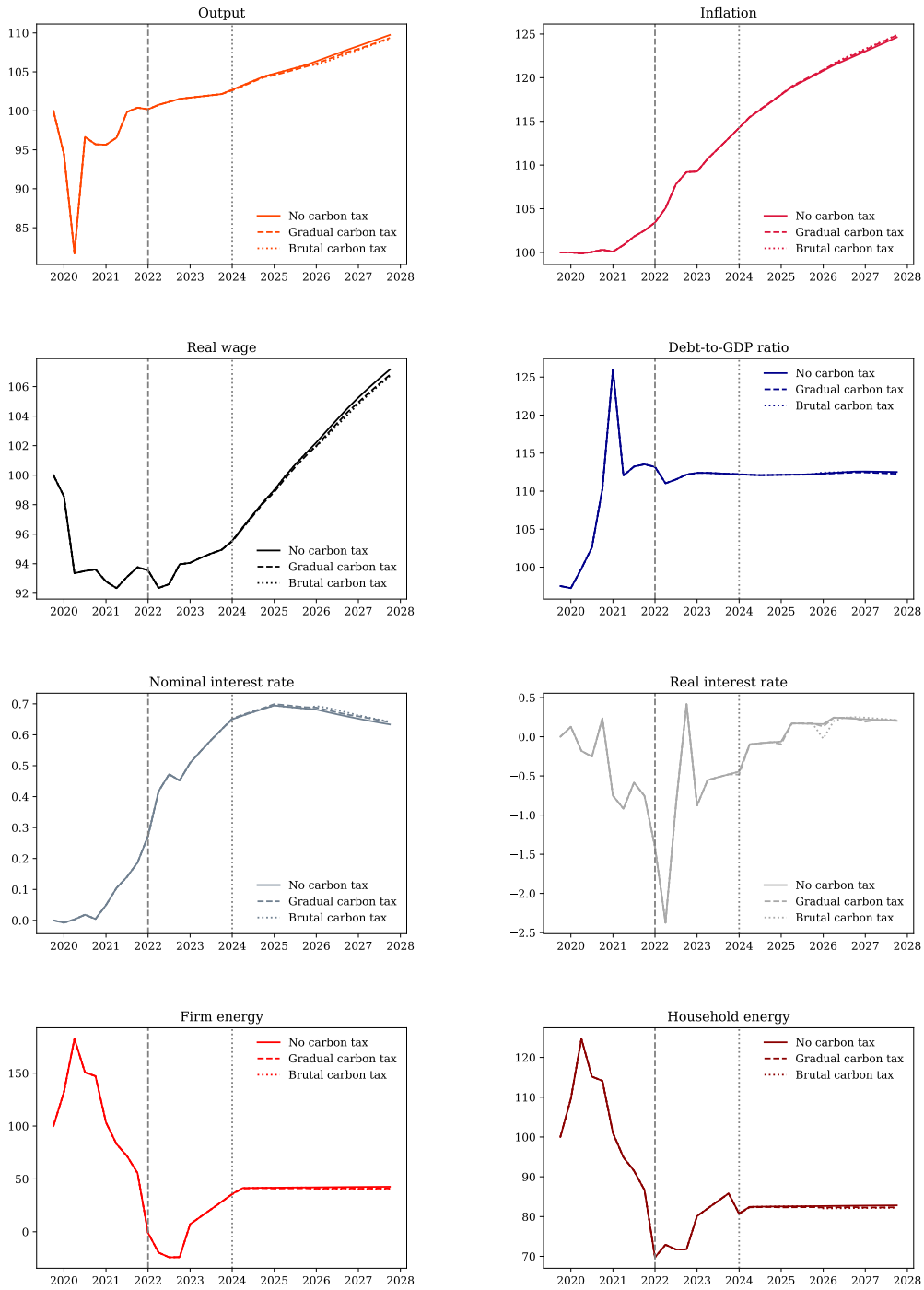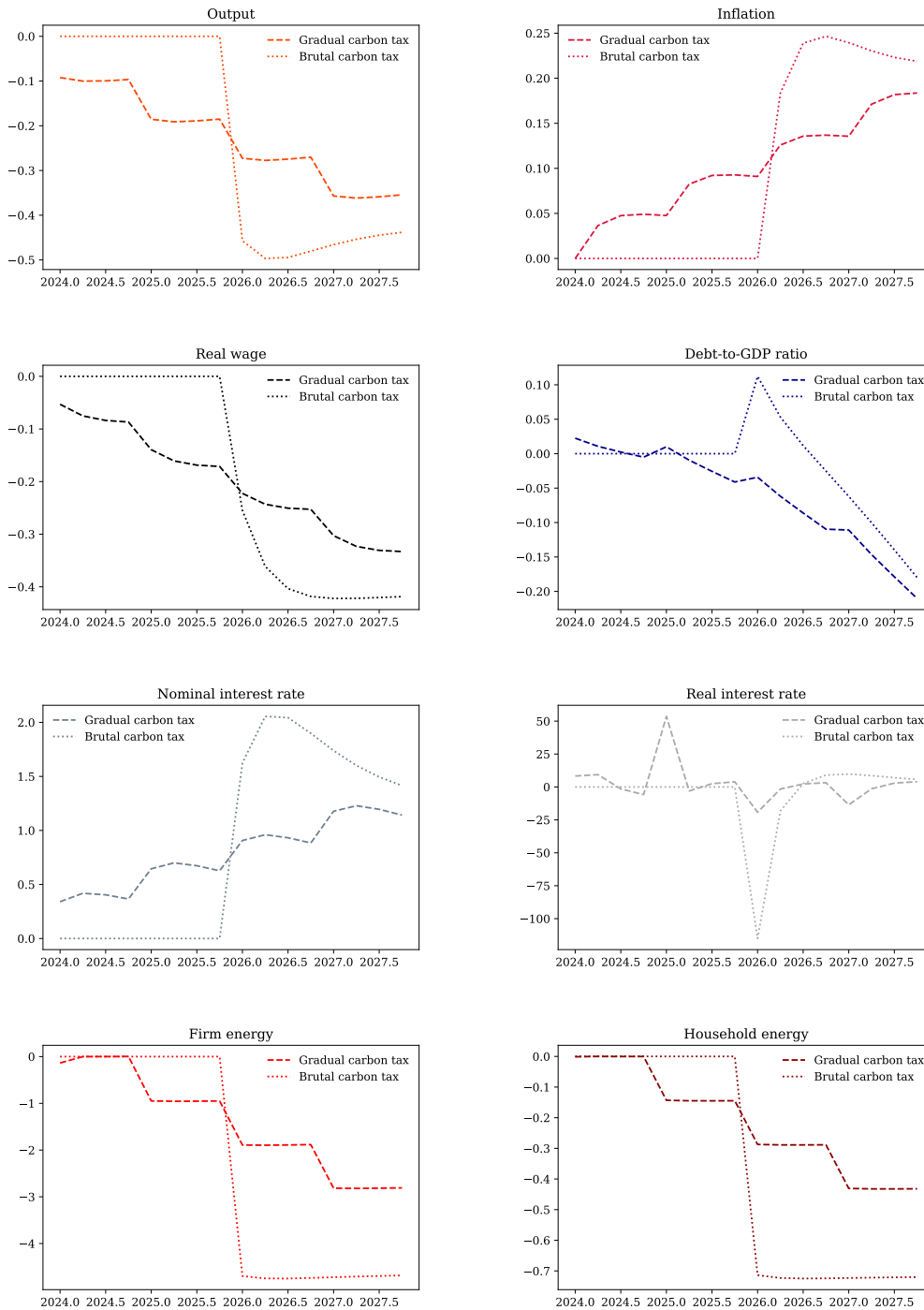
Each time series represents $x|_{\text{scenario}} - x|_{\text{bench}} \; \forall x$

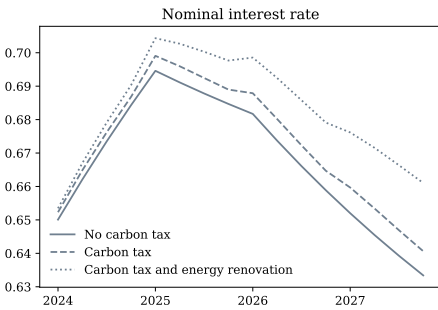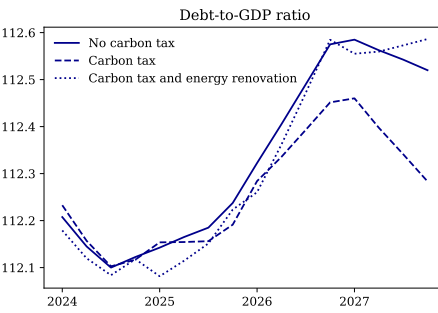# C   Accomodating monetary policy: Aggregates since 1Q2024
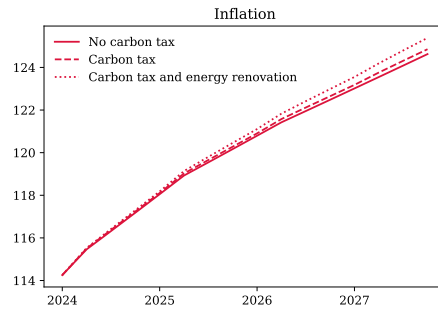
Model forecasts for each scenario
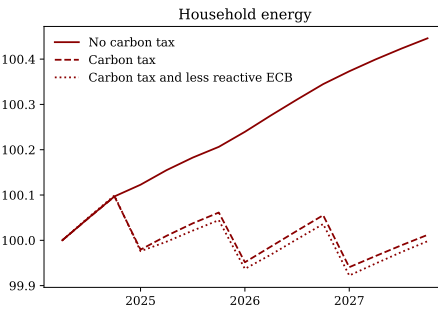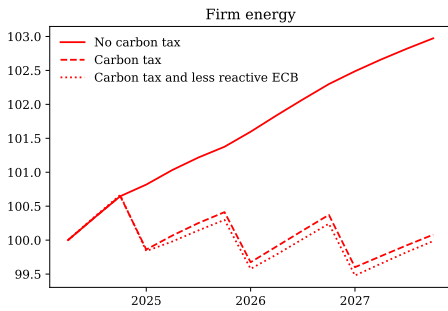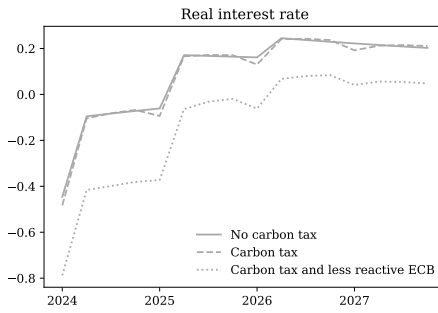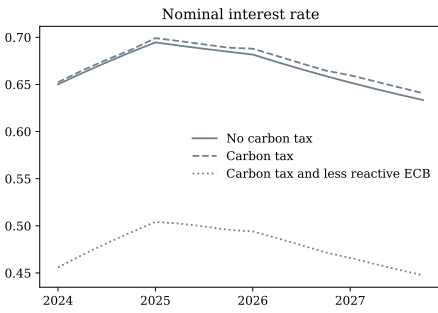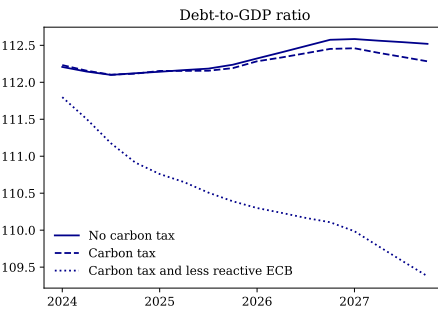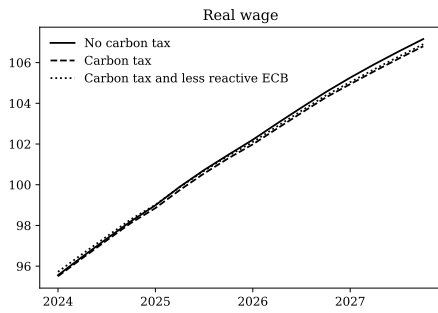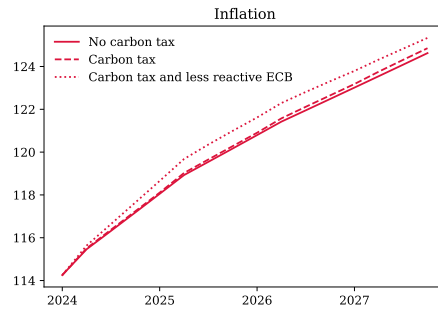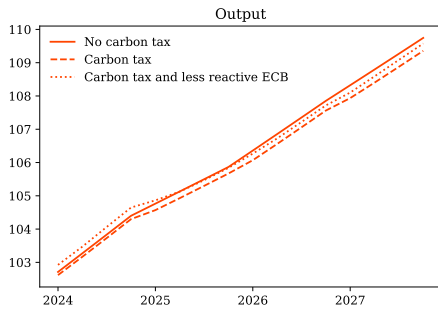
Gaps between each scenario and benchmark
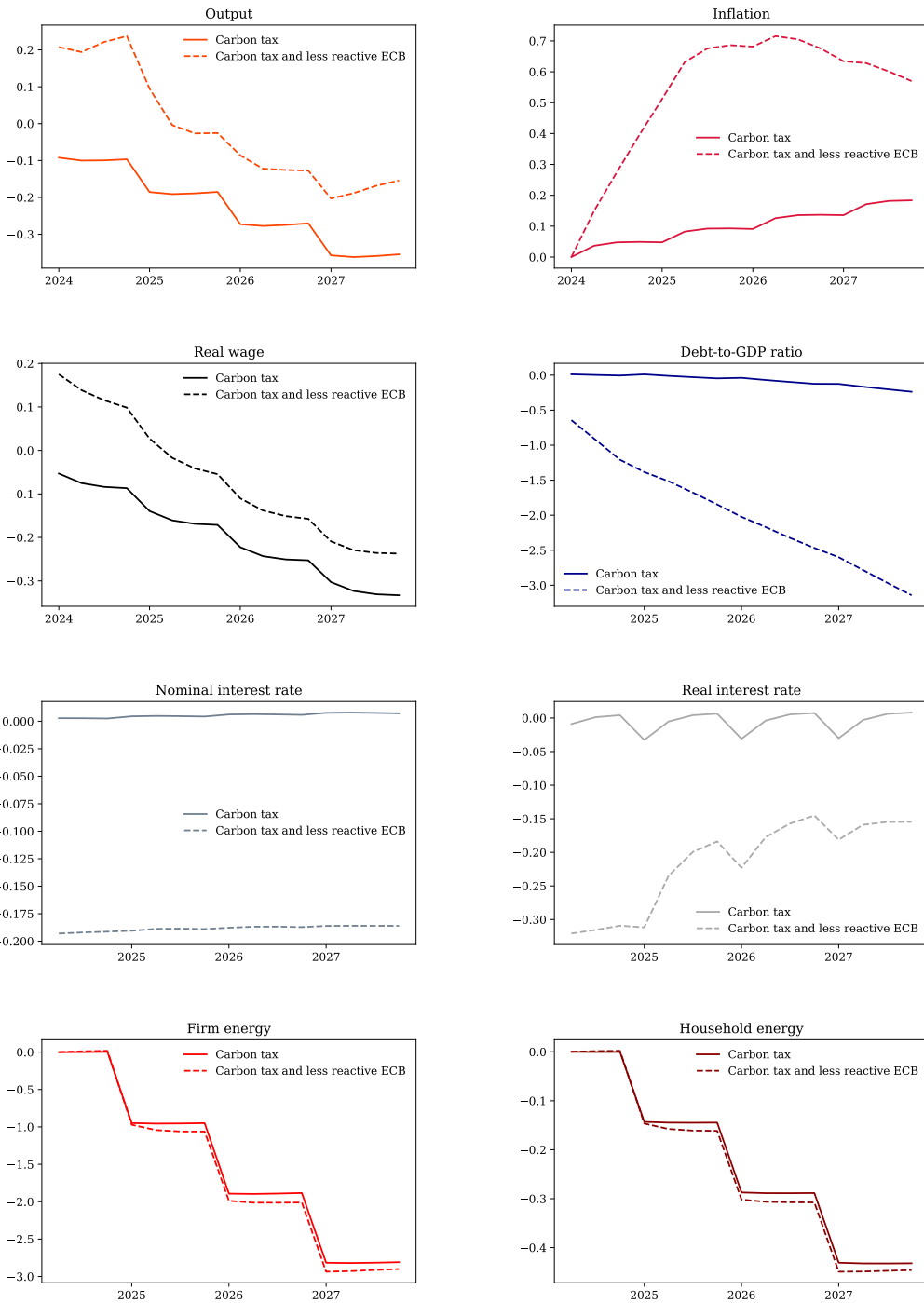
Each time series represents $x|_{\text{scenario}} - x|_{\text{bench}} \; \forall x$

D Redistribution: Aggregates since 1Q2024
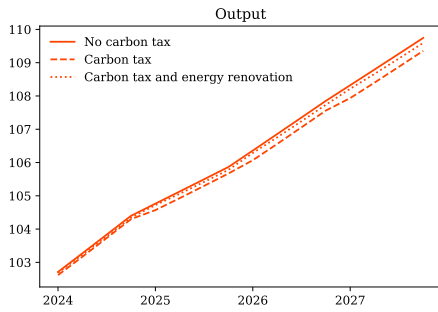
Model forecasts for each scenario
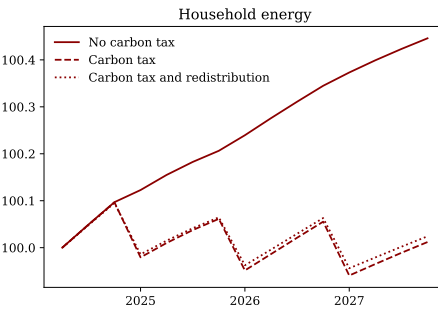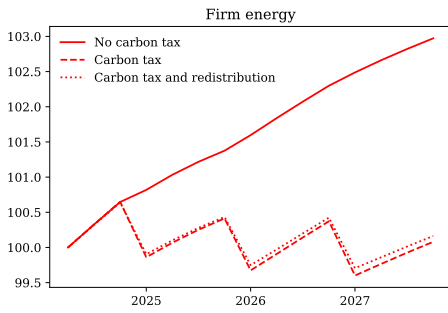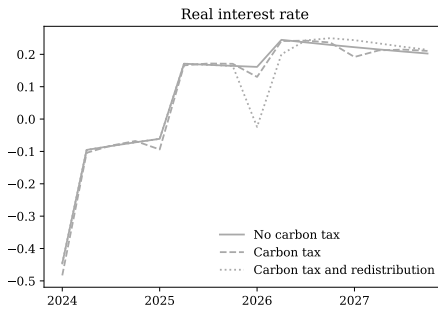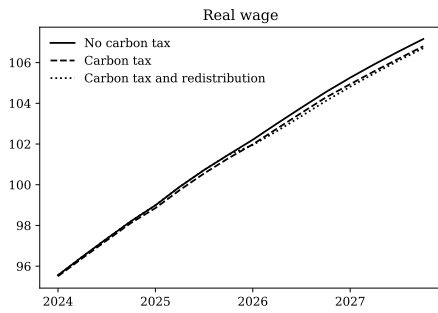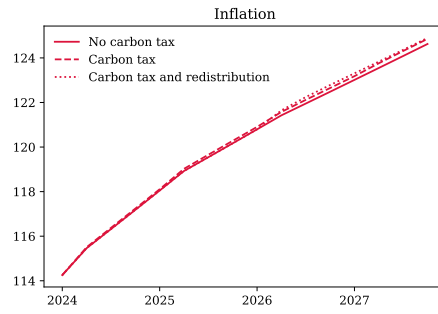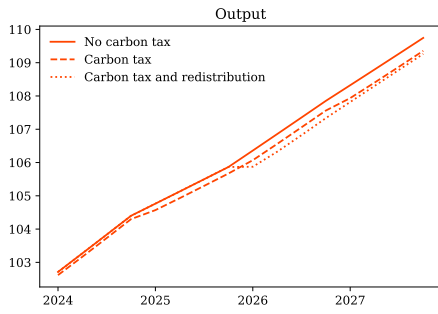
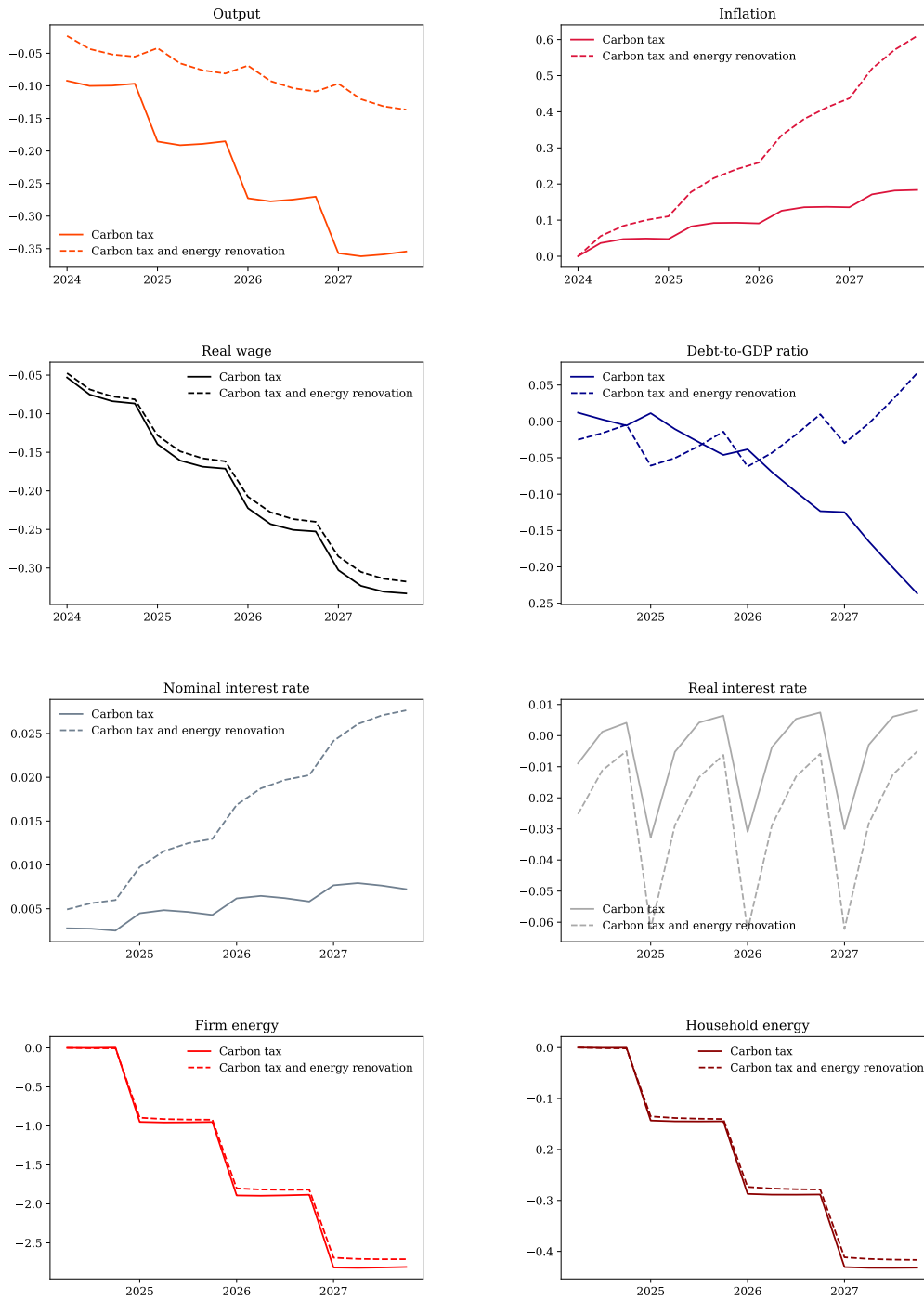## Gaps between each scenario and benchmark
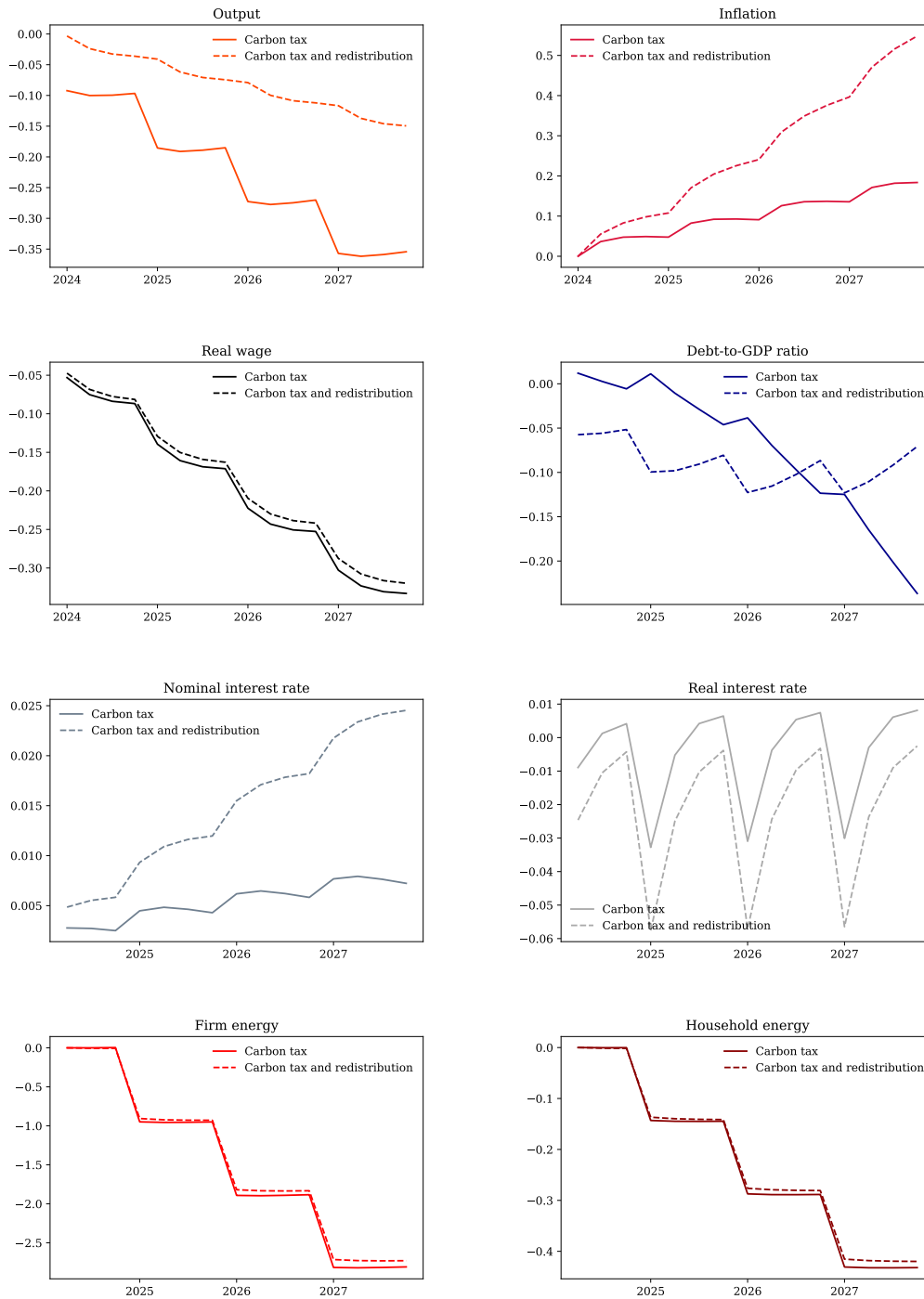
Each time series represents $x|_{\text{scenario}} - x|_{\text{bench}} \ \forall x$

E Energy renovation: Aggregates since 1Q2024

Model forecasts for each scenario

Gaps between each scenario and benchmark

Each time series represents $x|_{\text{scenario}} - x|_{\text{bench}} \ \forall x$