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Green Monetary and Fiscal Policies: The Role of Consumer Preferences ^{*}

Mohamed Tahar Benkhodja [†] Xiaofei Ma [‡] Tovonony Razafindrabe [§]

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Abstract

We establish a two-sector model to simulate the potential effects of green fiscal policies and unconventional green monetary policy on the economy during a recovery or in case of a stimulus policy. We find that instruments such as a carbon tax, an implicit tax on brown loans, and a subsidy for the purchase of green goods are all beneficial to the green sector, in contrast to green quantitative easing. A carbon tax imposed directly on firms in the brown sector is the most effective tool to reduce pollution. More importantly, the marginal effects of green instruments on the economy depend on consumer preferences. Namely, the marginal effects are the most prominent when consumers start to purchase more green goods as an increasing part of their consumption basket. Furthermore, the effects of those green policies are more [effective](#) when the elasticity of substitution between green and brown goods increases. This finding suggests that raising consumers' awareness and ability to consume green goods reinforce the [effectiveness](#) of public policies designed for low-carbon transition of the economy.

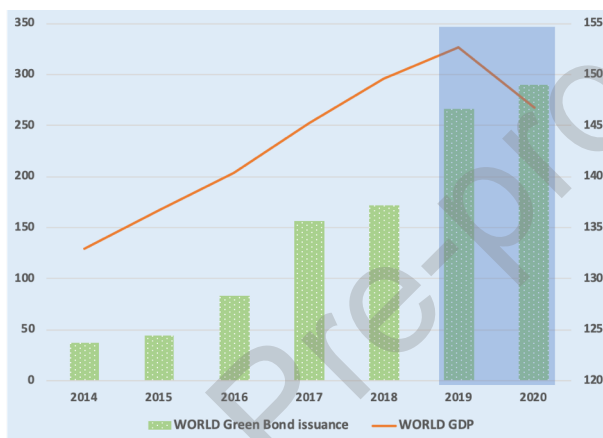
Keywords: Environmental policies, economic recovery, stimulus policy, E-DSGE, consumers' preferences, elasticity of substitution

JEL classification: Q58, E52, E62, G21, E20, E10

1 Introduction

Since the 2015 Paris Climate Agreement (PCA), the tremendous development of the "green bond market"¹ has changed the financial market landscape. More interestingly, as shown in Figure 1, the issuance of green bonds has pursued a clear upward trend that was not curbed by the health crisis and the economic recession that followed.

Figure 1: Development of the green bond market



Note: The amount of green bonds issued is in billions of USD (left y-axis). The gross world product, at constant price, is represented as an index (right y-axis). Sources: Climate Bonds Initiative and Macrobond

There is no doubt that the significant public funding provided to support economic growth or recovery², the shift in consumer preferences toward green goods³, and the positive reputational effect that a "green label" brings to investors will foster the development of the green bond market.

A worldwide consensus has emerged that the current challenge for policy makers is to combine economic growth or recovery³ with ecological transition in order to fight climate change

¹There is no clear official definition of "green bond". Different groups and institutions have produced guidelines encompassing bonds that can be classified as "green". For instance, the International Capital Market Association, a global consortium of investment banks, proposes its "Green Bond Principles"; the Climate Bond Initiative, an international organization, proposes its "Climate Bonds Standard and Certification Scheme"; and the European Commission proposes its "EU taxonomy". A simple way to distinguish green bonds from other bonds is the use of procedures to finance projects that contribute to environmental objectives such as climate change mitigation, natural resources conservation, and pollution prevention.

²For instance, Joe Biden's "build back better" plan which amounts to USD 1,900 billion for the USA, or Emmanuel Macron's "quoi qu'il en coûte" (whatever it costs) which totals EUR 100 billion for France, including at least 30 billion for ecological transition.

³In this paper, we do not make a distinction between recovery and stimulus scenarios, because our main focus is the increase in emissions when economic activities take off.

and achieve the PCA objective of limiting global warming to below 2°C. In this vein, this study proposes a unified framework using a two-sector dynamic stochastic general equilibrium (DSGE) model with financial intermediaries to evaluate the impact of fiscal and monetary policies targeting environmental objectives, which we define as "green policies", on the economy and the level of pollution. Namely, we analyze the effects of green monetary policy⁴ and fiscal instruments. We examine the current unconventional monetary policy that supports the green sector, henceforth referred to as green quantitative easing (GQE). Examples of this non-conventional green monetary policy are the central bank's purchase of "green corporate bonds" (or reduced haircuts of "green corporate bonds" as collateral when the central bank provides liquidity to the financial system), and the targeted provision of credit through corporate short-term standing facilities for firms that engage in low-carbon transition. We also examine the potential effects of three types of fiscal instrument, that is, a subsidy for the purchase of green goods, a carbon tax on polluting firms, and an implicit tax on banks' loans to the brown sector. The implicit tax on brown loans refers namely to the extra cost supported by a commercial bank when it finances the brown sector due to the resulting constrained access to liquidity. Examples include the increased prudential requirement constraint on commercial banks that are not climate-sensitive, and the increased risk weighting of commercial banks' assets when their issuers are not engaged in low-carbon transition, among others.

In total, we examine the potential effects of four instruments: GQE, a carbon tax, subsidies for green consumption, and a tax on polluting loans. We find that a carbon tax is the most effective fiscal instrument to tackle CO_2 emissions; a subsidy for the purchase of green goods is most effective to encourage green consumption; and GQE is the least effective instrument to deal with pollution issues. More interestingly, the interaction between policies and consumer preferences shows that when consumers start developing a taste for green/organic goods, forms of green taxation such as carbon tax might not have a contractive cyclical effect on the economy.

⁴We are aware that DSGE models with nominal rigidities make it possible to evaluate the effects of monetary policy through Taylor-type rules but, in this study, we use a model without price rigidities as we adopt a green monetary policy aiming at stimulating the non-polluting sector through a direct injection (via the banking sector) of money into the green sector. We represent this mechanism by a supply shock of green capital, which will serve to boost investment in the green sector. More details are provided in section 3.8.4.

Calibrating our model to France, our analysis ensures that, first, as long as households' preference for green products is sufficiently strong and their ability to switch to green goods is facilitated, neither the negative spillover of policies that encourage the development of the green sector nor taxes on the brown sector will lead to a significant distortion on the demand side.

Second, green monetary policy is not sufficient to deal with the pollution issue, namely, to reduce the emissions of polluting firms. There is even a risk of pushing up the price of green goods, which discourages consumer demand. Fiscal policies, such as a subsidy for green consumption and a carbon tax, are effective⁵ instruments to reduce emissions and pollution levels⁶. Moreover, while a carbon tax may suppress the growth of the brown sector, it also brings positive spillover effects on the development of the green sector, as green goods become relatively less expensive, which boosts demand from consumers.

Third, in terms of welfare, we find that fiscal policies such as subsidies for the consumption of green goods and tax on brown loans, can actually bring welfare gain to households. However, monetary policy such as QE has very little effect on welfare. Indeed, consumer preference is a key factor for the transmission channel of different monetary and fiscal policies on the demand side. Namely, the marginal effects of green instruments are the most prominent when consumers start to purchase more green goods as an increasing part of their consumption basket. In addition, the effects of environmental policies are more *effective* when the elasticity of substitution between green and brown goods increases. Therefore, the green monetary and fiscal policies should be combined with policies that are aimed to make it easier for households to access to the green goods such as the development of green/organic shops, online green/organic shops, organic farms, etc. This findings suggest that raising consumers' awareness and ability to consume green goods reinforce the *effectiveness* of public policies designed for low-carbon transition of the economy.

⁵Effectiveness is defined as the capacity to reduce CO_2 emissions, and the capacity to support the production of the green sector.

⁶In our simulation, we also tested the effects of loan subsidies for green firms. We find that this subsidy has relatively secondary effects on the economy compared to taxes. There is almost no effect on carbon emissions, and very little influence on consumption. Taxes on loans to polluting firms and carbon tax are much more *effective* instruments to reduce emissions and accelerate the structural change toward an eco-friendly economy.

2 Stylized facts and related literature

The land areas of farms and companies engaged in organic products have grown fourfold since 2005 (Figure 2). From 2017 to 2019, employment in the organic sector saw an annual growth rate of around 15%. Although the rising interest in green products is a common phenomenon across EU countries, the growth of engagement in organic products has been particularly resilient in France in recent years. In a recent consumer survey by AgenceBio, 43% of households confirmed a change in their consumption of organic food during the past three years. The biggest motivations for purchasing organic food are health concerns and responsibility for the planet. Among consumers, the young generation, that is, people born after 2000, constitute a large segment that is more aware of eco-responsibility. Therefore, the take-off of economic activity and environmental policies are not only short-term issues, they relate to a structural change based on the growing demand for green products from French households.

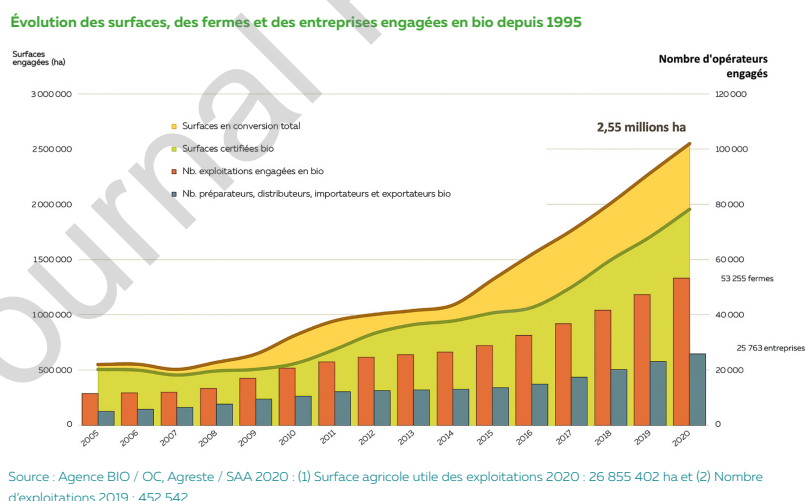


Figure 2: Land areas of farms and companies engaged in organic products in France, source: AgenceBio

In the past few years, the implementation of environmental policies in a DSGE framework has been widely studied aiming to draw conclusions about the business cycle implications of these policies. Several studies have adopted an environmental DSGE model, such as, Angelopoulos et al. (2010), Fischer and Springborn (2011), Dissou and Karnizova (2016),

Heutel (2012), and Annicchiarico and Di Dio (2015), among others.

Angelopoulos et al. (2010) modeled emissions as a by-product of production and adopted three policy regimes by examining their macroeconomic, environmental, and social welfare implications. They found that when economic uncertainty is dominant, an output or pollution tax is the optimal instrument. Fischer and Springborn (2011) used a real business cycle model to evaluate both greenhouse gas emissions reduction policies and found that a cap mitigates the effect of productivity shocks in the economy, while a tax leads to the same results but with greater volatility. In Heutel (2012), the author found that an optimal carbon tax and a quota dampen the procyclicality of CO_2 emission.

However, all of these studies have only evaluated the fiscal side of environmental policies without considering the monetary side, by which we mean the indirect role that a central bank (CB) could play in the fight against climate change. Indeed, according to a recent statement by the ECB President, Christine Lagarde, "Central banks are not responsible for climate policy and the most important tools that are needed lie outside of our mandate. But the fact that we are not in the driving seat does not mean that we can simply ignore climate change, or that we do not play a role in combating it."⁷ Thus, we attempt to give an answer on the indirect role of a Central Bank in the fight against global warming.

An emerging body of literature also centers on the role of the banking system in addressing climate change. To the best of our knowledge, at the time of writing, the main studies that address the interaction between monetary and fiscal environmental policies are Annicchiarico and Di Dio (2017), Carattini et al. (2021), Diluiso et al. (2020), and Ferrari and Nispi Landi (2021). All these develop an E-DSGE model incorporating financial frictions à la Gertler and Karadi (2011) to assess the role of different fiscal, monetary, and macroprudential policies on climate change. From these studies, a consensus emerges on the use of a carbon tax to achieve the objectives of the Paris Agreement. However, according to Diluiso et al. (2020) the effects of a carbon tax increase seem to lead to significantly higher production losses, inflation, and financial losses. Concerning the macroprudential policy, Carattini et al. (2021) show that such a policy can support economic growth once a climate policy is implemented but that

⁷https://www.ecb.europa.eu/press/key/date/2021/html/ecb.sp210125_f87e826ca5.en.html

it is insufficient on its own to fight global warming. As for monetary policy, [Ferrari and Nispi Landi \(2021\)](#) argue that under the hypothesis of imperfect substitutability, the results indicate that Green QE can reduce the flow of detrimental emissions, even if the effect is not large. This literature shows that the use of monetary policy and macroprudential policy alone is not effective to fight against climate change.

The main limitation of these studies is that none of them take into consideration the role of consumer preferences between green and brown goods to assess the effectiveness of environmental policies (monetary and fiscal), and this is what we will focus on in this paper. Indeed, our main contribution to the literature is that we examine how consumer preferences in terms of brown and green goods are affected by different environmental policies to capture the demand-side transmission channel of these policies. This adds to the supply-side transmission channel already present in the E-DSGE model literature, which is also taken into account in this study. Despite the importance of this aspect, we are not aware of any work that has taken household preferences into account. Indeed, the effectiveness of environmental policies (fiscal or monetary) is particularly central to stimulate the green sector. This preference can be simulated both by subsidizing green goods and by increasing competition in the green sector to reduce prices.

In this study, we build an E-DSGE model featuring two production sectors: the brown sector, producing so-called brown goods with intensive carbon emissions, and the green sector, producing so-called green goods with zero carbon emissions. We introduce financial frictions à la [Gertler and Karadi \(2011\)](#) and address the issue of green monetary policy, namely the GQE, by simulating a positive liquidity shock for commercial banks' financing of the green sector. Namely, we analyze the economic and environmental impacts of positive productivity shocks that benefit the whole economy, thus both production sectors, under different environmental policy scenarios (fiscal and monetary). Indeed, the co-existence in the economy of green sectors, which are the pillars of the low-carbon transition, and brown sectors leads to a trade-off between the need for economic growth and the urgent need to achieve the PCA objective. This situation raises a number of questions, such as what type of policy permits economic growth without fostering pollution? How can such a policy be

financed? How might economic agents' behavior be impacted by such a policy? Is there a policy that performs better than others? Is the low-carbon transition harmful for the economy in the short term? To this end, we propose a general framework that provides a better understanding of different public policy instruments and their impact on both the economy and the environment. This is key in order to respond to the challenge of associating the need for economic growth with environmental objectives.

The rest of the paper is organized as follows. Section 3 presents the model and section 4 explains the calibration exercise. The main results are presented in section 5. Welfare and sensitivity analyses are conducted in sections 6 and 7, respectively. Finally, concluding remarks are presented in section 8.

3 The model

We develop a two-sector dynamic stochastic general equilibrium (DSGE) model with financial intermediaries. The supply side of the economy is composed of the "brown sector", which produces goods with intensive carbon emissions, and the "green sector", which does not generate any pollution. On the demand side, households provide labor to both sectors and consume both green and brown goods whose weight in their consumption basket depends on their preferences. Financial intermediaries, namely commercial banks, collect deposits from households, provide loans to both brown and green firms for them to acquire new capital, and purchase government bonds.

3.1 Household

The representative household derives utility from consumption C_t and leisure $(1 - H_t)$ where H_t represents the total hours worked. Household preference is described by the following expected utility function:

$$E_0 \sum_{t=0}^{\infty} \beta^t U(C_t, H_t), \quad (1)$$

where β denotes the subjective discount factor ($0 < \beta < 1$). The instantaneous utility function, $U(\cdot)$, is specified by:

$$U(\cdot) = \frac{C_t^{1-\gamma}}{1-\gamma} - \frac{H_t^{1+\sigma}}{1+\sigma} \quad (2)$$

where $\gamma > 0$ and $\sigma > 0$. The parameter γ is the inverse of the elasticity of intertemporal substitution of consumption and σ denotes the inverse of the wage elasticity of labor supply. The total consumption C_t is defined as a constant elasticity of substitution (CES) integration of consumption in green or non-polluting ($C_{g,t}$) and brown or polluting ($C_{b,t}$) goods:

$$C_t = \left(\mu_c^{1/\varepsilon} (C_{b,t})^{(\varepsilon-1)/\varepsilon} + (1 - \mu_c)^{1/\varepsilon} (C_{g,t})^{(\varepsilon-1)/\varepsilon} \right)^{\varepsilon/(\varepsilon-1)}. \quad (3)$$

where the parameter μ_c represents the weight of brown goods in the household's consumption basket and therefore captures the household's preference for brown goods relative to green goods. The parameter ε is the standard constant elasticity of substitution between different types of consumption goods⁸.

We assume that the total hours worked H_t is defined by the following CES integration:

$$H_t = \left(\mu_h^{1/\varepsilon} (H_{b,t})^{(\varepsilon-1)/\varepsilon} + (1 - \mu_h)^{1/\varepsilon} (H_{g,t})^{(\varepsilon-1)/\varepsilon} \right)^{\varepsilon/(\varepsilon-1)}, \quad (4)$$

where $H_{g,t}$ and $H_{b,t}$ represent hours worked by the household at time t in the green and brown sectors respectively, and μ_h the share of hours worked in the brown sector.

We choose this specification to consider the fact that the hours worked in the green and brown sectors are not perfectly substitutable. Namely, we rely on the characteristics of a green labor listed by Bohnenberger (2022) to argue that the green labor cannot be considered as a perfect substitute for brown labor. A similar argument can be found in Martinez-Fernandez et al. (2010).

The unused part of the household's income is kept in the form of a deposit $D_{h,t}$ at a commercial bank in return for remuneration at interest rate R_t^d . The household's budget constraint is in turn defined by :

⁸In this paper, for simplicity, we assume the same elasticity of substitution ε for consumption goods, labor, and investment, which can be interpreted as a parameter of taste.

$$C_{b,t} + (1 - \tau_{c,t})P_{g,t}C_{g,t} + D_{h,t} \preceq (1 - \varpi) \sum_{j=b,g} W_{j,t}H_{j,t} + R_{t-1}^d D_{h,t-1} + T_t + (1 - \sigma_B)N_t \quad (5)$$

where T_t denotes lump-sum transfer, W_j wages in different sectors and $(1 - \sigma_B)N_t$ the repayment from banks in case of default. $P_{g,t}$ is the relative price of green goods relative to brown goods (the price of brown goods is normalized to 1), $\tau_{c,t}$ represents the government subsidy granted to households for the consumption of green goods, and ϖ is the income tax rate.

Given the initial value, the representative household chooses $\{C_{b,t}, C_{g,t}, H_{g,t}, H_{b,t}, D_{h,t}\}$ to maximize its lifetime utility function subject to the capital accumulation equation and the budget constraint. The solution of this optimization problem gives the following first order conditions:

$$\lambda_t = \mu_c^{\frac{1}{\epsilon}} C_t^{-\gamma + \frac{1}{\epsilon}} C_{b,t}^{-\frac{1}{\epsilon}} \quad (6)$$

$$(1 - \tau_{c,t})P_{g,t}\lambda_t = (1 - \mu_c)^{\frac{1}{\epsilon}} C_t^{-\gamma + \frac{1}{\epsilon}} C_{g,t}^{-\frac{1}{\epsilon}} \quad (7)$$

$$(1 - \varpi)W_{b,t}\lambda_t = \mu_h^{\frac{1}{\epsilon}} H_t^{\sigma + \frac{1}{\epsilon}} H_{b,t}^{-\frac{1}{\epsilon}} \quad (8)$$

$$(1 - \varpi)W_{g,t}\lambda_t = (1 - \mu_h)^{\frac{1}{\epsilon}} H_t^{\sigma + \frac{1}{\epsilon}} H_{g,t}^{-\frac{1}{\epsilon}} \quad (9)$$

$$\lambda_t = \beta E_t\{\lambda_{t+1}R_t^d\}, \quad (10)$$

3.2 Sectors

To model the production side of the economy, we assume the existence of two types of sector: the "brown sector", which concerns firms that produce goods with intensive carbon emissions, i.e. that pollute, and the "green sector", which in contrast concerns firms that produce goods with zero carbon emissions. This distinction is necessary to have a detailed picture of the impact of public policies both on economic growth and the level of pollution. The transition from a polluting firm to a green firm, which reflects energy efficiency and more generally a transition to carbon neutrality, depends on the abatement effort of the firm in our model.

3.3 Brown sector

The output produced in the brown sector follows the Cobb-Douglas production function:

$$Y_{b,t} = A_{b,t} K_{b,t-1}^{\alpha_b} H_{b,t}^{1-\alpha_b} \quad (11)$$

where the new capital $K_{b,t}$ and labor $H_{b,t}$ are used by firms to produce a brown good. We suppose that the firm sells its capital that does not depreciate at the end of each period. To produce in the next period, the firm borrows new capital $K_{b,t}$ from the commercial bank. Thus, the level of investment $I_{b,t}$ is defined as follows:

$$I_{b,t} = K_{b,t} - (1 - \delta)K_{b,t-1}. \quad (12)$$

where δ represents the capital depreciation rate. Note also that $\alpha_b \in (0, 1)$ is the share of capital used as an input in the production of brown goods. The variable $A_{b,t}$ is a technology specific to the brown sector and is defined as:

$$A_{b,t} = (1 - d(x_{t-1}))a_{b,t}$$

where x_t represents the emission stock. The productivity shock $a_{b,t}$ follows a stochastic process that is given by:

$$\log(a_{b,t}) = (1 - \rho_{a_b}) \log(a_b) + \rho_{a_b} \log(a_{b,t-1}) + \varepsilon_{a_{b,t}}, \quad (13)$$

As in [Heutel \(2012\)](#), we assume that the pollution caused by firms negatively affects output through the following damage function:

$$d(x_t) = d_0 + d_1 x_t + d_2 x_t^2$$

The damage function captures the reduction in productivity caused by pollution, with x_t being the emission stock. The latter evolves according to the last period's level of pollution stock x_{t-1} , the current period's domestic emissions e_t and the rest of the world's emissions e^{row} , as described in the following equation :

$$x_t = (1 - \delta_x)x_{t-1} + e_t + e_t^{row}$$

where δ_x is the pollution decay rate. The level of domestic emissions e_t depends on the output and on the abatement effort η_t :

$$e_t = \varphi(1 - \eta_t)Y_{b,t} \quad (14)$$

The variable e_t^{row} is the emissions in the rest of the world and is assumed to follow an AR process. That is,

$$\log(e_t^{row}) = (1 - \rho_{e_t^{row}}) \log(e^{row}) + \rho_{e_t^{row}} \log(e_{t-1}^{row}) + \varepsilon_{e_t^{row}}. \quad (15)$$

In the absence of abatement efforts, the parameter $\varphi > 0$ measures the level of emissions per unit of production. As in [Annicchiarico and Di Dio \(2015\)](#), we assume that the abatement costs Z_t are a function of the abatement effort and output. This takes the following form:

$$Z_t = \psi_1 \eta_t^{\psi_2} Y_{b,t},$$

with $\psi_1 > 0$ and $\psi_2 > 1$. Rearranging the abatement cost equation, we get $Z_t/Y_{b,t} = \psi_1 \eta_t^{\psi_2}$ which means that a higher abatement effort leads to a high cost.

Polluting firms are taxed by the government depending on the level of domestic emissions $\tau_{e,t}e_t$ where $\tau_{e,t}$ represents the so-called carbon tax. Therefore, the polluting firm maximizes its profits :

$$\max_{K_{b,t-1}, H_{b,t}, \eta_t} Y_{b,t} - Z_t - \tau_{e,t}e_t - W_{b,t}H_{b,t} - (R_{b,t}^l - 1)K_{b,t-1} \quad (16)$$

where $R_{b,t}^l$ is the rent of capital. The first order conditions of this maximization problem are given by:

$$R_{b,t}^l - 1 = \alpha_b \frac{[1 - \psi_1 \eta_t^{\psi_2} - \tau_{e,t} \varphi(1 - \eta_t)] Y_{b,t}}{K_{b,t-1}} \quad (17)$$

$$W_{b,t} = (1 - \alpha_b) \frac{[1 - \psi_1 \eta_t^{\psi_2} - \tau_{e,t} \varphi(1 - \eta_t)] Y_{b,t}}{H_{b,t}} \quad (18)$$

$$\eta_t = \left(\frac{\tau_{e,t} \varphi}{\psi_1 \psi_2} \right)^{\frac{1}{\psi_2 - 1}} \quad (19)$$

3.4 Green sector

The green sector uses the Cobb-Douglas production function :

$$Y_{g,t} = A_{g,t} K_{g,t-1}^{\alpha_g} H_{g,t}^{1-\alpha_g}, \quad (20)$$

where the new capital $K_{g,t}$ and labor $H_{g,t}$ are used by firms to produce a green good. The technology $A_{g,t}$ is specific to the green sector and is assumed to follow a stochastic process. Moreover, similar to the brown sector, a green firm borrows new capital $K_{g,t}$ from the commercial bank in order to produce in the next period. That is,

$$\log(A_{g,t}) = (1 - \rho_{A_g}) \log(A_g) + \rho_{A_g} \log(A_{g,t-1}) + \varepsilon_{A_{g,t}}, \quad (21)$$

$$I_{g,t} = K_{g,t} - (1 - \delta) K_{g,t-1}, \quad (22)$$

where $I_{b,t}$ represents the level of investment of green firms. Note that $\alpha_g \in (0, 1)$ is the share of capital used as an input in the production of green goods. In this part, we choose not to add a damage function to the productivity of the green sector for the sake of simplicity. We also run the model with a damage function, and it does not change the results ⁹.

The first order conditions of the maximization problem are:

$$R_{g,t}^l - 1 = \alpha_g \frac{P_{g,t} Y_{g,t}}{K_{g,t-1}}, \quad (23)$$

$$W_{g,t} = (1 - \alpha_g) \frac{P_{g,t} Y_{g,t}}{H_{g,t}}. \quad (24)$$

⁹Please refer to the Appendix A.3 for more details

3.5 Banks

For the modelling of the banking sector, we adopt the method used in [Gertler and Karadi \(2011\)](#) and [Auray et al. \(2018\)](#). Banks first choose the optimum total asset size, and then they choose to invest in different assets, i.e. the green sector, the brown sector, or government bonds. The banks' balance sheet is given by:

$$\begin{array}{l|l} \hline \text{Asset}_t = \text{total assets of banks} & D_{h,t} = \text{domestic deposits} \\ \hline & N_t = \text{(equity) capital} \\ \hline \end{array}$$

where Asset_t is a portfolio that contains investments in the green sector, the brown sector, and government bonds.

The balance sheet satisfies :

$$\text{Asset}_t = D_{h,t} + N_t \quad (25)$$

The dynamic of capital N_t follows :

$$N_{t+1} = \sigma_B [R_{t+1}^a \text{Asset}_t - R_t^d D_{h,t}] \quad (26)$$

where R_t^a is the composite return of the portfolio Asset_{t-1} , and R_t^d is the deposit interest rate. For the banks, there is a probability $(1 - \sigma_B)$ that a bank will default and that the capital will be repaid to households. The stochastic discount rate is $\beta_{t,t+1} = \beta U_{C,t+1}/U_{C,t}$ where $U_{C,t}$ represents the marginal utility of consumption.

From the last two equations, the dynamic of banks' capital follows :

$$N_{t+1} = \sigma_B [(R_{t+1}^a - R_t^d) \text{Asset}_t + R_t^d N_t] \quad (27)$$

The banks' optimization problem is to find the present value of the value function V_t defined as the expected sum of discounted future capital in case of the bank's default, and the discounted future value function otherwise. That is,

$$V_t = E_t \{ \beta_{t,t+1} [(1 - \sigma_B) N_{t+1} + \sigma_B V_{t+1}] \} \quad (28)$$

It is worth noting that the banks can divert a fraction α of their total assets, hence the incentive condition is :

$$V_t \geq \alpha Asset_t. \quad (29)$$

This incentive condition is binding in equilibrium. Therefore, the solution for the banks' optimization problem yields the following expression of the value function:

$$V_t = \gamma_t^a Asset_t + \gamma_t N_t \quad (30)$$

where

$$\gamma_t^a = E_t \{ \Lambda_{t,t+1} \sigma_B (R_{t+1}^a - R_t^d) \} \text{ and } \gamma_t = E_t \{ \Lambda_{t,t+1} \sigma_B R_t^d \} \quad (31)$$

Moreover, we define q_t^b , q_t^g and q_t^B as the prices of investment in the brown sector, the green sector and government bonds, and q_t^a as the price of the portfolio. The banks minimize the cost by:

$$q_t^a Asset_t = q_t^b K_{b,t} + q_t^g K_{g,t} + q_t^B B_t \quad (32)$$

subject to

$$Asset_t = \left(\mu^{1/\varepsilon} (K_{b,t})^{(\varepsilon-1)/\varepsilon} + \eta_B^{1/\varepsilon} (K_{g,t})^{(\varepsilon-1)/\varepsilon} + (1 - \mu - \eta_B)^{1/\varepsilon} B_t^{(\varepsilon-1)/\varepsilon} \right)^{\varepsilon/(\varepsilon-1)} \quad (33)$$

In this equation, μ and η_B are the steady-state relative weights of loans in polluting and non-polluting sectors in the portfolio, and ε is the elasticity of substitution between assets. The real composite portfolio return of commercial banks is given by:

$$R_t^a = 1 + [\mu E_t (1 - \tau_{b,t+1})^{\varepsilon-1} (R_{b,t+1}^l - 1)^{\varepsilon-1} + \eta_B E_t (R_{g,t+1}^l - 1)^{\varepsilon-1} + (1 - \mu - \eta_B) E_t (R_t^B - 1)^{\varepsilon-1}]^{\frac{1}{\varepsilon-1}} \quad (34)$$

where $\tau_{b,t}$ is the implied tax rate on brown loans. Given that real asset prices are inversely related to their real expected rates of return, the optimal allocation of funds that results

from the banks choice is thus given by:

$$K_{b,t} = \mu E_t \left\{ \left(\frac{(1 - \tau_{b,t+1})(R_{b,t+1}^l - 1)}{R_t^a - 1} \right)^\varepsilon \right\} Asset_t \quad (35)$$

$$K_{g,t} = \eta_B E_t \left\{ \left(\frac{R_{g,t+1}^l - 1}{R_t^a - 1} \right)^\varepsilon \right\} Asset_t + GQE_t \quad (36)$$

$$B_t = (1 - \mu - \eta_B) E_t \left\{ \left(\frac{R_t^B - 1}{R_t^a - 1} \right)^\varepsilon \right\} Asset_t \quad (37)$$

where the GQE_t represents the green quantitative easing in which the Central Bank facilitates access to liquidity to increase the financing of the green sector. It is assumed to be exogenous and to follow an autoregressive process. That is,

$$\log(GQE_t) = (1 - \rho_{GQE}) \log(GQE) + \rho_{GQE} \log(GQE_{t-1}) + \varepsilon_{GQE_t}. \quad (38)$$

3.6 Public sector

In the macroeconomic literature, it is common to classify public policy, known as fiscal policy, into three types: public investment, government spending, and tax policy. Concerning "green fiscal policy", this classification has a major difference in that public actions contribute to environmental objectives such as climate change mitigation, natural resource conservation, and pollution prevention. For instance, public investment plans that reinforce strategic sectors such as low-carbon public transport infrastructure (rail, new cycle lanes, etc.) and the renewable energy sector (solar, wind, etc.). In turn, government spending such as grants or subsidized loans may be used to create opportunities for "carbon-intensive sectors" and for newly created sectors to engage in low-carbon transition. A tax policy may also be used by the government to create such opportunities.

In the model, the budget constraint of the public sector is given by:

$$\begin{aligned} & T_t + R_{t-1}^B B_{t-1} + \tau_{c,t} P_{g,t} C_{g,t} \\ & = \varpi W_{g,t} H_{g,t} + \varpi W_{b,t} H_{b,t} + \tau_{e,t} e_t + \tau_{b,t} (R_{b,t}^l - 1) K_{b,t-1} + B_t \end{aligned} \quad (39)$$

The public sector's income comes from taxes on households' wages $\varpi W_{g,t}H_{g,t} + \varpi W_{b,t}H_{b,t}$, a tax on the emissions $\tau_{e,t}e_t$, a tax on banks' loans to the brown sector $\tau_{b,t}(R_{b,t}^l - 1)K_{b,t-1}$ and bonds emissions B_t . In turn, the public sector spends its resources on lump-sum transfers, interest payments on previously issued government bonds, and government subsidies for households' purchases of green goods. Thus, for the government, there are three instruments considered in this model for environmental policy : a carbon tax $\tau_{e,t}$, an implicit tax on brown loans $\tau_{b,t}$, and a subsidy for the purchase of green goods $\tau_{c,t}$.

3.7 Resource Constraint

The resource constraint indicates that the total production of green and brown goods equals the total consumption by the household, the investment of green/brown firms, and the abatement cost:

$$Y_t = P_{g,t}Y_{g,t} + Y_{b,t} = P_{g,t}C_{g,t} + C_{b,t} + I_{g,t} + I_{b,t} + Z_t. \quad (40)$$

3.8 Green monetary and fiscal policies: A summary

In this model, we examine the potential effects of four instruments: a carbon tax, a subsidy for green consumption, a tax on polluting loans, and green quantitative easing (GQE). The first three instruments are qualified as fiscal policies, while the last one is qualified as a green monetary policy.

3.8.1 Carbon tax

Polluting firms are taxed by the government depending on the level of their domestic emissions e_t . The total amount of taxes $\tau_{e,t}e_t$, where $\tau_{e,t}$ represents the so-called carbon tax, incurs a supplementary cost for polluting firms, as shown in profit equation 16. More importantly, the first order condition 19 shows that the abatement effort of polluting firms increases with carbon taxes. In this case, the government's carbon tax policy plays an incentive role for polluting firms to reduce their carbon emissions.

3.8.2 Subsidy of green consumption

The government grants a subsidy, represented by $\tau_{c,t}$, to households for their consumption of green goods. This subsidy impacts households' budget constraint (5) by reducing the price of green goods effectively paid by households.

Dividing equation (7) over (6) in the first order conditions of the representative household's optimization problem, we get:

$$\frac{C_{g,t}}{C_{b,t}} = \left(\frac{1}{\mu_c} - 1\right)[P_{g,t}(1 - \tau_{c,t})]^{-\epsilon}. \quad (41)$$

This shows that the ratio between green and brown consumption depends on the relative price of green goods $P_{g,t}$. The cheaper the relative price of green goods, the more green goods consumers consume. A subsidy for the purchase of green goods $\tau_{c,t}$ also has an impact. The more green goods are subsidized, the more green goods consumers consume. The consumption of green goods also depends on the proportion of brown goods in consumers' consumption basket μ_c . The lower this proportion of brown goods μ_c , the more green goods consumers consume.

More interestingly, the ratio of green and brown consumption depends on the elasticity of substitution ϵ . When the relative after-tax price of green goods $P_{g,t}(1 - \tau_{c,t}) > 1$, the higher the value of ϵ , and the fewer green goods consumers consume. Why so? Intuitively, when green goods are more expensive than brown goods, a higher degree of substitutability between green goods and brown goods encourages consumers to shift toward goods that are relatively cheap, i.e. the brown goods in this case. On the other hand, if the government grants enough subsidies for green consumption to make $P_{g,t}(1 - \tau_{c,t}) < 1$, then the higher the value of ϵ , and the more consumers will shift to green goods. That is, a fiscal policy that subsidizes the purchase of green goods could be combined with making green goods more accessible to households. Examples include encouraging the creation of green/organic shops in residential districts, promoting online green/organic shops and organic farms, etc.

3.8.3 Tax on polluting loans

In order to create an incentive for commercial banks to lend to the green sector, a tax rate charged on loans granted to the brown sector is introduced into the model. The tax rate on brown loans $\tau_{b,t}$ reduces the real composite portfolio return of commercial banks, as shown in equation 34. Examples include prudential policies with active monitoring of climate risk through stress-test scenarios. Accordingly, a change in regulation might be applied by relaxing requirement constraints on climate-sensitive financial institutions and/or increasing the risk weighting of assets whose issuers are not engaged in low-carbon transition. These restrictive measures represent implicit taxes that affect the cost of financing commercial banks and are captured by the tax rate on brown loans in our model.

3.8.4 Green quantitative easing

Green quantitative easing, which we call GQE_t and is introduced in equation 36, is a non-conventional monetary policy tool with which the Central Bank (CB) facilitates access to liquidity to increase the financing of the green sector. It is worth noting that the CB does not have a mandate to fight climate change¹⁰. Nonetheless, climate change engenders risks to the stability of the financial system through its impact on the value of financial institutions' assets. Therefore, through its action to safeguard financial stability, the CB seeks to avoid climate-related risks and hence actively supports the low-carbon transition of the economy. For this purpose, the tools of the CB could be adjusted to take into consideration climate-related risks. For instance, the non-conventional monetary policy tools implemented for the economic recovery should be directed toward the purchase of "green corporate bonds" or the reduction of their haircuts as collateral to provide liquidity to the financial system (e.g., the ECB's corporate sector purchase program (CSPP) holdings which amounted to EUR 283 billion on 9 July 2021), or toward the targeted provision of credit through corporate short-term standing facilities for firms that engage in low-carbon transition. Moreover, monetary authorities have implemented a series of micro and macroprudential policies that aim to relax prudential requirements, such as capital and liquidity coverage requirements,

¹⁰As stated by Christine Lagarde, "Central banks are not responsible for climate policy and the most important tools that are needed lie outside of our mandate. But the fact that we are not in the driving seat does not mean that we can simply ignore climate change, or that we do not play a role in combating it."

to increase the liquidity of commercial banks that engage in low-carbon transition. Therefore, given the specific features of GQE, we do not apply the standard Taylor rule under sticky prices. Instead, we assume an exogenous specification of GQE through a direct injection (via the banking sector) of money into the green sector. We represent this mechanism by an exogenous supply shock of green capital, which serves to boost investment in the green sector as specified in equation 34.¹¹

4 Calibration and deterministic steady state

In what follows, we calibrate the model using the standard values of the structural parameters related to the business cycle literature, the steady state values of our key variables, and French quarterly data. We choose France for two main reasons. First, fiscal policy in the euro area is mainly national (including fiscal environmental policy)¹². Second, France is one of the most promising countries in the development of the organic market given its strong potential in the production of organic goods and its environmental policy.¹³ Table 1 lists the values of the 21 parameters of the baseline model¹⁴

$$\{\beta, \gamma, \sigma, \varepsilon, \varpi, \sigma_b, \alpha_b, \delta_x, \varphi, \psi_1, \psi_2, \delta, d_0, d_1, d_2, \alpha_g, \alpha, \mu, \eta_B, \mu_c, \mu_h\}.$$

The subjective discount factor β is set at 0.997 which implies an annual steady-state deposit interest rate of about 1.2%, consistent with the historical average from 2008 to 2022 according to data from the World Bank and the Banque de France. The inverse of the elasticity of the intertemporal substitution of labor σ is set at 2. From the steady state calculation, the part of FOCs of households, we obtain the value of the inverse of elasticity of intertemporal substitution of consumption $\gamma = 4.89$. From the market clearing condition of green goods, we derive the capital depreciation rate $\delta = 0.065$ ¹⁵. From the banks' incentive condition,

¹¹Under this specification, monetary policy has an impact on real economic activity even under flexible price setting because GQE is directly approximated by a real supply shock of green capital.

¹²Indeed, each country in the euro area implements the EU's environmental policy with a different level of taxation.

¹³World organic trade ranks France third in terms of market size

¹⁴The baseline model assumes that there are no environmental policy shocks.

¹⁵In the market clearing condition of green goods, the production of green goods equals to the sum of consumption of green goods and green investments which is assumed to be 30% of total investment. The proportion of 30% is arbitrary in our calibration, as we do not have sufficient data to justify the proportion of green investment. However, it is not shocking if we compare it with the promise of Banque de France in

we obtain the fraction of total asset $\alpha = 0.2353$ ¹⁶. The share of capital, α_g and α_b , used as an input in the production of green and brown sectors respectively, are set at 0.3 and 0.35, not far from the traditional calibration of capital share of around one third. Also, as argued by Carattini et al. (2021), the share of capital in the brown sector is slightly more capital intensive¹⁷.

Regarding the environmental parameters, we follow the calibration of Annicchiarico and Di Dio (2015), Heutel (2012), Carattini et al. (2021) and Benmir and Roman (2020). For the damage function parameters, we follow Heutel (2012) so that $d_0 = 1.3950^{-3}$, $d_1 = -6.6722 \times 10^{-6}$ and $d_2 = 1.4647 \times 10^{-8}$. As in Carattini et al. (2021), the decay rate of pollution δ_x is set at 0.0035, and the steady state level of the stock of pollution x at 2030 GtC implying a steady state value of the damage variable $d(x) = 0.0482$. The parameter μ_c represents the weight of brown goods in the consumer basket. Its value reflects the importance given by households to the consumption of brown goods. We simulate different values of μ_c in this model in order to consider the change in household preferences (see section 1, page 6). In the baseline model, we set $(1 - \mu_c) = 0.1$ reflecting the proportion of organic food in overall food consumption¹⁸ in a survey carried out by AgenceBio, the official organic study institution in France. The share of work in the brown sector μ_h is set at 0.49 to meet the steady-state requirement of households' FOC of working hours in the green and brown sectors. Indeed, if we consider the agricultural, industrial and tertiary (trade and transport) sectors as the main pollutants¹⁹, the share of work in these sectors is about 40% in France, which is not far from the value we choose²⁰. As in Annicchiarico and Di Dio (2015), we set ψ_1 and ψ_2 at 0.1850 and 2.8, respectively.

Regarding the financial parameters, we set the value of the parameter measuring the default risk σ_b at 0.972 as in Gertler and Karadi (2011). This implies that the bank survives, on

2020 that 20% of its investments will be engaged in ecologically responsible investments.

¹⁶The calculation of the values of these parameters are given in the technical notes available upon request.

¹⁷Although the paper by Carattini et al. (2021) calibrate the model on U.S data, this argument is also valid for the French economy because in the most brown sectors (more than 50% of CO2 emissions, Insee <https://www.insee.fr/fr/statistiques/2015759>) such as transport, agriculture and manufacturing sector, the share of capital is much higher than in the green sectors.

¹⁸https://www.agencebio.org/wp-content/uploads/2021/03/AgenceBio-DossierdePresse-Barometre2021_def-1.pdf

¹⁹<https://www.citepa.org/en/data/>

²⁰<https://www.insee.fr/fr/statistiques/4277675?sommaire=4318291#titre-bloc-3>

average, 9 years with an annual risk of default of about 11%. The elasticity of substitution between assets ε is calibrated at 4. The parameters μ and η_B denote the share of loans in polluting and non brown sectors in France. According to the Banque de France, the outstanding loans to resident companies by sector show that the share of loans granted to the brown sector (agricultural, industrial and tertiary (trade and transport) sectors) is about 30%. Then, the value of μ is set at 0.3. In addition, the share of public debt held by the banking sector (represented by bonds in our model) is about 10% ²¹. We, therefore, set $(1 - \mu - \eta) = 0.1$. The value of the share of loans granted to the green sector is, then, set at 0.6.

Based on french data, the steady state value of the carbon tax τ_e is set at 0.009 representing a level equivalent to 44.6 euros for one metric ton of CO_2 emissions. The steady state green/brown sector interest rate values are set at 1.01, representing an annual value of about 4%. The parameter φ that represents the emission/output intensity is set at 0.48 corresponding to GHG intensity in France in 2019. The household's income tax ϖ , is set at 0.15, corresponding to the average French income tax rate²²

Finally, we set standard values for the autoregressive parameters and standard deviations for both TFP shocks such as $\rho_{ab} = \rho_{ag} = 0.95$ and $\sigma_{ap} = \sigma_{ag} = 0.01$.

²¹<https://www.economie.gouv.fr/facileco/comptes-publics/dette-publique#>

²²The current tax rate is based on progressive calculation. This means that income is broken down into several brackets whose tax rate varies from 0% for the bracket below 10064 euros to 30% for the bracket from 27794 to 42000. Knowing that 78% of the income tax comes from the last salary bracket, we set the tax rate at 0.15. See <https://www.impots.gouv.fr/portail/particulier/questions/comment-calculer-mon-taux-dimposition-dapres-le-bareme-progressif-de-limpot>

Table 1: Calibration of structural parameters

Description	Parameters	Values
Structural Parameters		
Discount factor	β	0.997
The inverse of the wage elasticity of labor supply	σ	2
The inverse of the elasticity of intertemporal substitution of consumption	γ	4.89
Capital depreciation rate	δ	0.065
Share of capital used as an input in the production of brown sector	α_b	0.35
Parameter measuring the default risk	σ_b	0.972
Decay rate of pollution	δ_x	0.0035
Parameter that measures the emission per unit of production	φ	0.48
Income tax	ϖ	0.15
First technological parameter of abatement cost	ψ_1	0.1850
Second technological parameters of abatement cost	ψ_2	2.8
Share of capital used as an input in the production of green sector	α_g	0.3
Constant in damage function	d_0	0.0014
Linear term in damage function	d_1	6.6722×10^{-6}
Quadratic term in damage function	d_2	1.4647×10^{-8}
Weight of loans in brown sector	μ	0.3
Weight of loans in green sector	η_B	0.6
Elasticity of substitution between assets	ε	4
The fraction of total asset diverted by the representative bank	α	0.2353
Weight of brown good in the consumer basket	μ_c	0.9
Share of work in the brown sector	μ_h	0.49

5 Simulation

Recall that concerning monetary policy, we use the term green quantitative easing (GQE) to capture the unconventional monetary policy by which the CB provides money to private banks so that they can lend more to the green sector. In turn, concerning fiscal policy, we have three instruments in the model: a carbon tax, a subsidy for the consumption of green goods, and an implicit tax on brown loans, that is, banks that lend to the brown sector. Figure 3 shows the results. In all of the IRFs, the simulation is based on quarterly frequency. The responses are log-deviations from the variables' steady state values.

In Figure 3, we simulate the effects of GQE from the CB, with a size of about 1% of quarterly national GDP²³. The red curve represents the scenario in which the Central Bank provide Green Quantitative Easing to private banks. The GQE increases loans to green firms; as green firms use green capital to produce, this actually increases the demand for green goods in the market. As a result, the relative price of green goods rises, which discourages the demand from consumers. Therefore, lending to the green sector becomes more expensive, that is, the interest rate of green loans rises (equation 24).²⁴

The green curves represent the potential effects of 1pp increase in carbon tax rate $\tau_{e,t}$. The increase immediately reduces the emissions e_t , thus the stock of pollution x_t . The reduction of pollution stock ameliorates the productivity level $A_{b,t}$ because there is less damage due to pollution. Moreover, the carbon tax is especially beneficial to the green sector as it is relatively less costly to produce green goods; lending to the green sector becomes more profitable, therefore, loans to the green sector increase. As a result, production in the green sector increases. Because there is relatively more abundant supply of green goods, the relative price in green sector $P_{g,t}$ falls, which encourages consumers to buy green goods and the consumption of such goods grows.

²³This represents the amount of the recent package of 30 billion euros announced by the French President to support ecological transition : <https://www.economie.gouv.fr/plan-de-reliance>. We have tested different size of GQE, and we find that qualitatively the results remain the same.

²⁴In our simulation results, the size of GQE is not the most important factor. Instead, the key message from GQE is the inflationary effects in the green sector, i.e. the rise of $P_{g,t}$, which makes the effects of GQE qualitatively different from the 3 fiscal instruments.

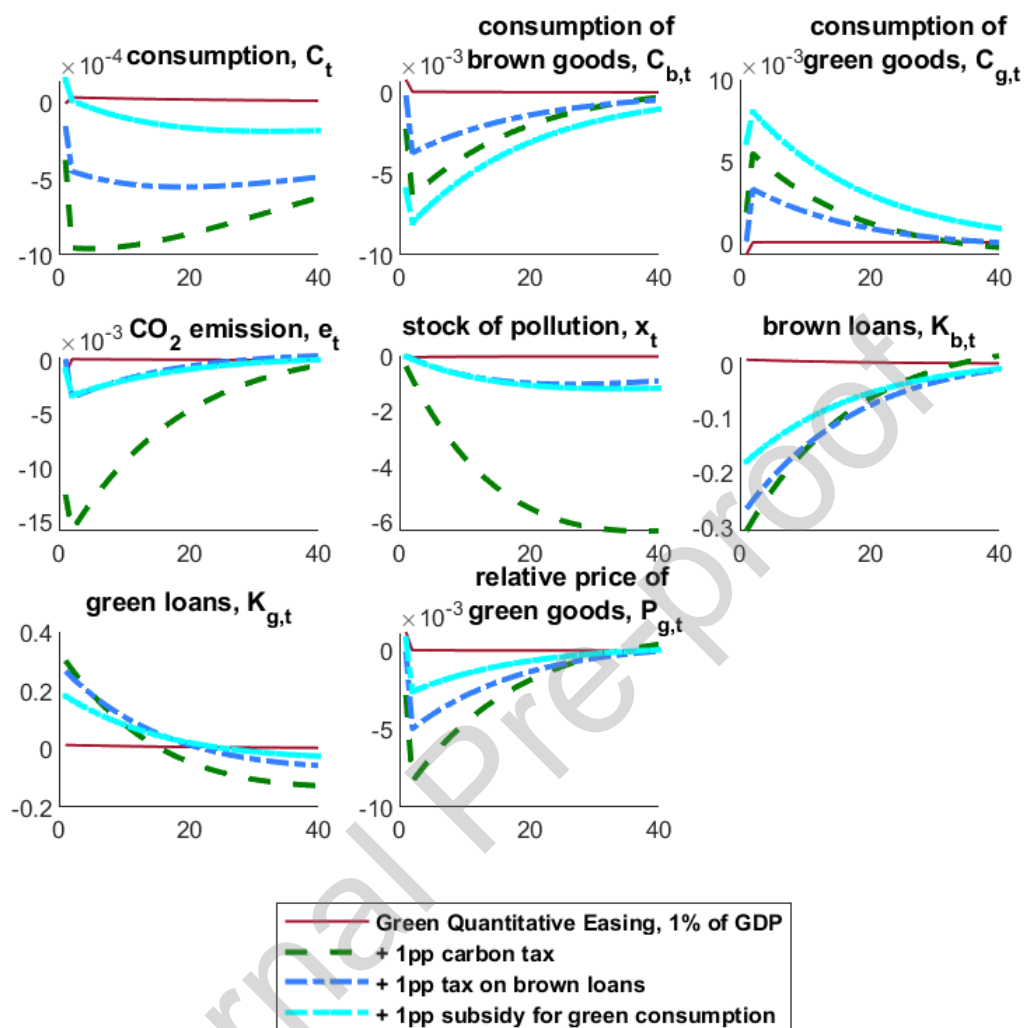


Figure 3: Comparison among GQE, carbon tax, tax on brown loans and subsidy for green consumption. The responses are quarterly log-deviations from the variables' steady state values.

The dark blue curves represent potential effects of 1pp increase in tax on polluting loans for the private bank. The effects are similar to the carbon tax (the green dashed curve), except that the latter are stronger. The light blue curves represent effects of 1pp increase in subsidy for green consumption. It seems that the subsidy for the purchase of green goods is

most **effective** to encourage the consumption of green goods, thus reducing the demand for brown goods. As a result, the emissions and pollution stocks fall.

To conclude, green instruments imposed on the private bank side are beneficial for the development of the green sector, but not sufficiently **effective** to cope with emissions/pollution. These results are in line with those of [Ferrari and Nispi Landi \(2021\)](#), who show that the GQE policy has a negligible effect on pollution. The carbon tax imposed directly on firms in the brown sector seems to be the most **effective** tool to reduce emissions and at the same time improves the productivity in the sector thanks to the fall of pollution stock. Carbon tax, brown loan tax and subsidy for purchase of green goods are all beneficial to the green sector.

6 Consumer Preferences and Welfare Analysis

6.1 Consumer preferences for green goods

6.1.1 Role of $(1 - \mu_C)$, the proportion of green goods in consumers' baskets

In this section, we test the effectiveness of different policy instruments depending on consumer preferences for green goods, that is the value of $(1 - \mu_C)$. Here we simulate a recovery or a stimulus policy scenario in both green and brown sectors. This is captured by +1pp increase of productivity in both sectors as in the previous section, combined with government subsidy for the households' purchases of green goods. **We first simulate the sensitivity test for green consumption subsidy, as this is the most effective instrument to stimulate households' consumption of green goods, as shown in Figure 3.**

Figure 4 shows the simulation of a recovery or a stimulus policy scenario with different weights of green goods in households' consumption, with subsidy for green consumption goods. It shows that when the households have increasing consumption in green goods, that is, the proportion of such consumption increases from 10% to 50%, we see that the marginal effects of subsidy on the consumption of green goods $C_{g,t}$ also increases.

It also shows that when the consumption of green goods continues to grow, with the pro-

portion increasing from 50% to 70%, the marginal effects of subsidy on the consumption of green goods $C_{g,t}$ decline but remain positive.

Intuitively, when people begin to be aware of consuming green goods, like today, the marginal effects of green instruments on households' consumption are the most prominent. When the proportion of green goods reaches about half of the consumption panel, then the effects are still positive, but become less [effective](#) than before.

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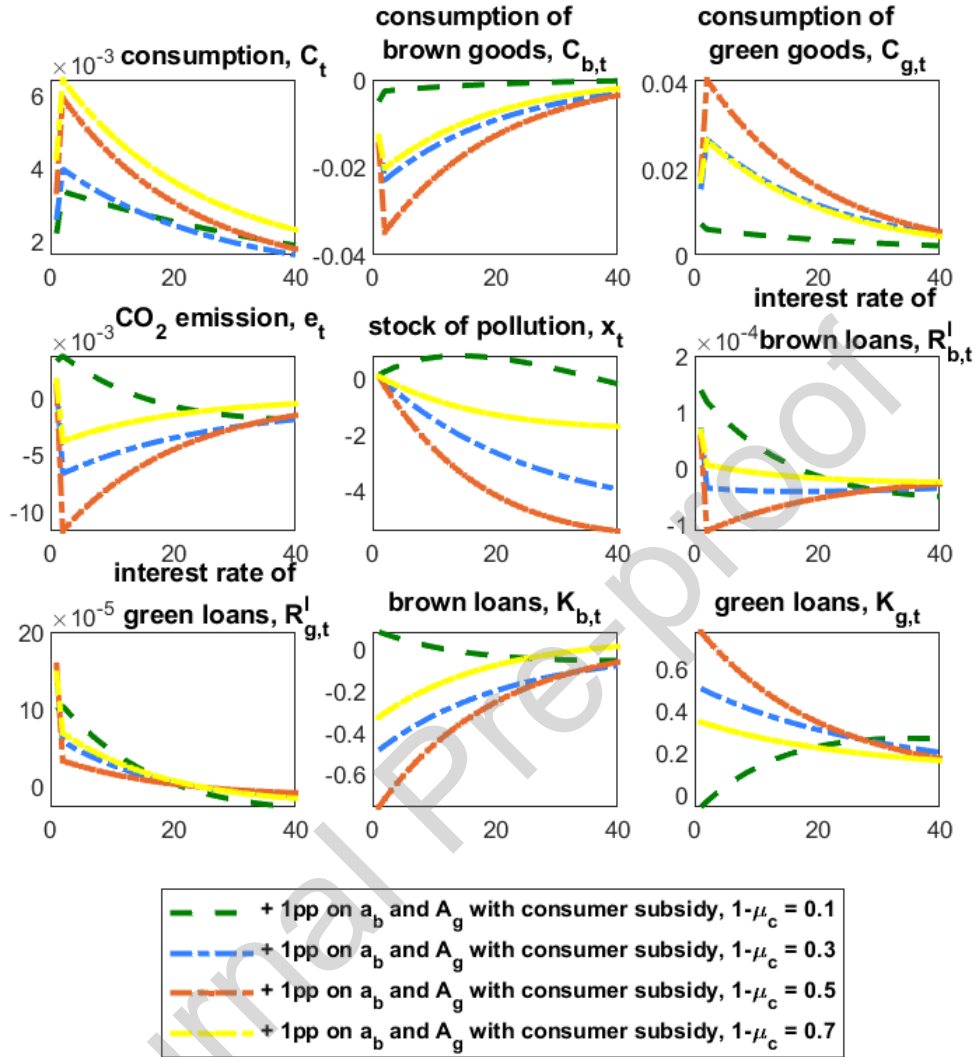


Figure 4: Effects of consumer preferences ($1 - \mu_c$) on the effectiveness of subsidy. The responses are quarterly log-deviations from the variables' steady state values.

We've also tested the role of ($1 - \mu_c$) on the other three policy instruments : Green Quantitative Easing, carbon tax, and tax on brown loans. We find the similar results, i.e. marginal effects of these polices increase with the proportion of green consumption when ($1 - \mu_c$) is around 50%. When this proportion continues to grow, the marginal effects of green policies are still positive but become less effective. The IRFs corresponding to those simulations can

be found in Appendix section A.1.

6.1.2 Role of ϵ , the elasticity of substitution between green and brown goods

In this subsection, we try to test the sensitivity of our results with regard to the elasticity of substitution between green and brown goods. This elasticity of substitution is a common parameter for hours of work in green/brown sector, and green/brown loans for banks. We first simulate the scenario in which the consumers just start to buy green goods, i.e. with the benchmark calibration by setting the proportion of green goods to 10% of households' consumption.

Figure 5 shows the results. It is still a recovery or a stimulus policy scenario in both green and brown sectors. This is captured by +1 pp growth in the productivity of green and brown sectors. Meanwhile, we simulate the effects of subsidy for the purchase of green goods. The blue curve shows the scenario in which the elasticity of substitution is set to $\epsilon = 4$, the benchmark calibration. The green curve represents the scenario with $\epsilon = 5$. The red curve represents the scenario with $\epsilon = 6$. The results show that the effects of subsidy for green goods are more **effective** when the value of elasticity of substitution ϵ increases.

Intuitively, when the green and brown good become more substitutable, the environmental policy becomes more **effective**. Therefore, it is recommended that the government combine environmental policies with measures that improve the accessibility to green/organic goods. For instance, this can be reached by implementing local policies that encourage the creation of organic shops in each residential district, the creation of online organic shops, etc. and that make the green/organic goods more accessible to households.

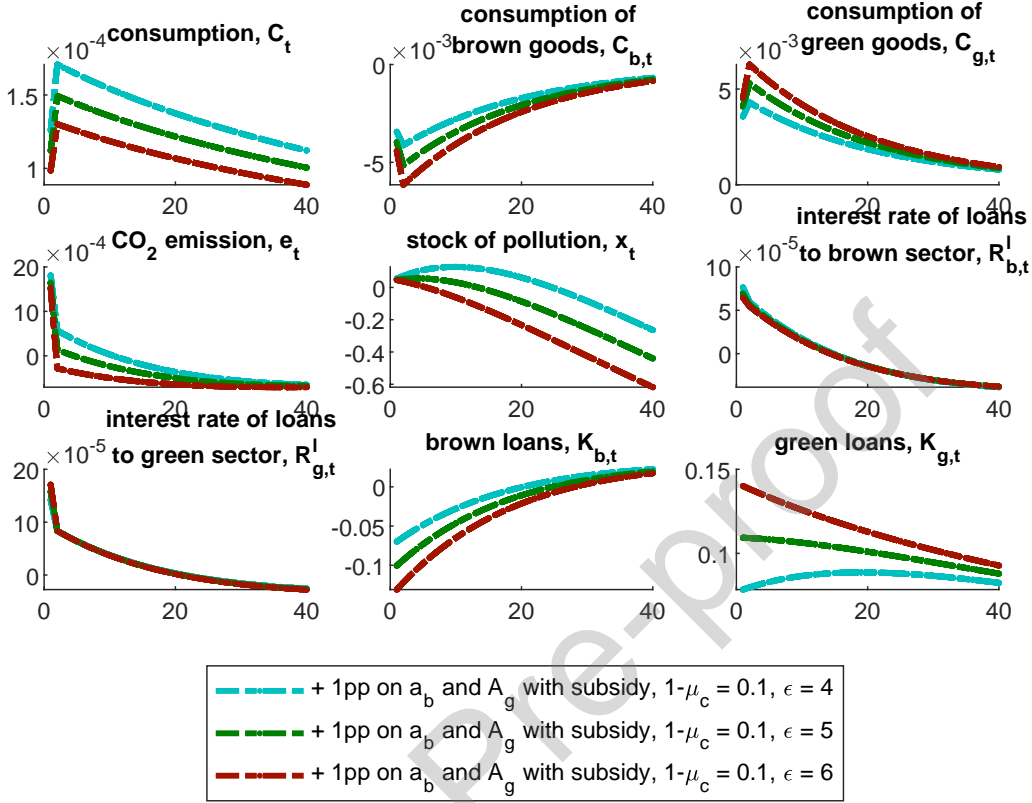


Figure 5: Sensitivity test to the elasticity of substitution ϵ , with the proportion of green consumption $(1 - \mu_c) = 10\%$. The responses are quarterly log-deviations from the variables' steady state values.

We've also tested the role of ϵ on the other three policy instruments : Green Quantitative Easing, carbon tax, and tax on brown loans. We find the similar results, i.e. marginal effects of carbon tax and brown loan tax increase with the elasticity of substitution. As the relative price of green goods $P_{g,t}$ decreases, the higher the substitution between green and brown goods, the higher the growth in green sector is, as consumers shift toward goods that are less expensive than before. For the GQE, the effects are reversed as the relative price of green goods $P_{g,t}$ increases in this case. The IRFs corresponding to those simulations can be found in Appendix section A.2.

6.2 Welfare analysis

In this section, we focus on the impact of a recovery or a stimulus policy scenario on households' welfare. We solve the model using a second-order approximation of the single utility function. The baseline scenario is therefore characterized by a positive productivity shock in the brown sector. Following this, we perform the welfare analysis under different types of environmental policies (carbon tax, Green QE, subsidy for green consumption, and tax on brown loans) compared to the baseline scenario. In a second step, taking consumer preferences into account, we simulate the impact of the previous scenario on welfare by considering different values of weight of green good in the consumption basket²⁵. We set $(1 - \mu_c)$ at 0.7, 0.5, 0.3 and 0.1 to express strong vs weak consumer preferences for green goods. All results are reported in Table 2a²⁶.

In our paper, the level of carbon tax is exogenous and calibrated to the actual carbon tax level in France instead of the optimum level of carbon tax (which in practice is difficult to achieve). Indeed, in our welfare analysis, all the values of GQE and green fiscal policies are exogeneous, and none of them are calibrated to maximize welfare. Therefore, this exercise is not to choose or compare the welfare-maximizing policy for each instrument, but rather a comparison of magnitude across different instruments with different consumer preferences.

The welfare effects from green quantitative easing (GQE) are negative due to the rise of relative price of green goods. The effects are weaker when the proportion of green consumption $(1 - \mu_c)$ increases. For the carbon tax, the welfare effects are negative but get weaker when the proportion of green consumption increases. This shows that consumer's preferences toward green goods help stimulate the demand side and mitigate the potential impacts from taxation.

The subsidy for purchasing green goods gives positive results in terms of welfare with an increasingly higher level, from +0.089% to +0.562%, when the value of $(1 - \mu_c)$ goes from 0.1 (low preference for green goods) to 0.5 (the consumer basket is made up of 50% green

²⁵The parameter μ_c represents the weight of the brown good in the consumption basket, so $(1 - \mu_c)$ denotes the weight of the green good.

²⁶In appendix section A.5, we provide more detailed results in Table 2b and 2c.

goods and 50% brown goods), respectively. When the preference $(1 - \mu_c) = 0.7$, the welfare effects become smaller (+0.078%). In line with the IRFs results (section 6.1.1), this indicates a relative efficiency of the subsidy policy that reaches its maximum at almost a balanced preference level between green and brown goods.

Tax on brown loans also generates positive welfare; the highest level is reached when $(1 - \mu_c) = 0.3$ (+0.228%).

Table 2a: Welfare results, % deviation from baseline

green policies	$(1 - \mu_c) = 0.1$	$(1 - \mu_c) = 0.3$	$(1 - \mu_c) = 0.5$	$(1 - \mu_c) = 0.7$
+1pp carbon tax	-2.745%	-2.503%	-2.104%	-1.499%
GQE, 1% GDP	-0.024%	-0.023%	-0.023%	-0.012%
+1pp subsidy for green consumption	+0.089%	+0.551%	+0.562%	+0.078%
+1pp tax on brown loans	+0.081%	+0.228%	+0.186%	+0.012%

The parameter μ_c represents the weight of the brown good in the consumption basket, so $(1 - \mu_c)$ denotes the weight of the green good.

We also simulate the welfare effects under different value of elasticity of substitution between green and brown goods ϵ , the main results (table 2b and 2c in Appendix A.5) show that the effectiveness of subsidy to green consumption decreases when the value of ϵ increases. This could be due to the fact that when the households have more access to green goods (organic shops, etc.), the price effects become less prevalent.

Thus, two conclusions can be drawn. First, the subsidy policy gives interesting results in terms of welfare. In particular, it would be interesting to implement such a policy before households' consumption preferences for the brown good are rather balanced. Tax on brown loans also provides interesting results when the share of green goods in the consumption basket is not strong. Second, the implementation of environmental policies should take consumers' preferences for green goods and the elasticity of substitution between green and brown goods into account. That is, the demand side plays a major role in the effectiveness of environmental policies.

7 Sensitivity analysis : effects of the weight on green capital

In this section, we test the sensitivity to the composition of capital in green and brown sector. In other words, banks lend to firms, when a firm receives money from the bank, it can choose to invest in green or brown capital for its production. The integrated capital is a CES function of green and brown capital:

$$K_{g1,t} = \left(\mu_b^{1/\varepsilon} (x_b K_{g,t})^{(\varepsilon-1)/\varepsilon} + (1 - \mu_b)^{1/\varepsilon} \left(\frac{(1 - x_b) K_{g,t}}{P_{g,t}} \right)^{(\varepsilon-1)/\varepsilon} \right)^{\varepsilon/(\varepsilon-1)} \quad (42)$$

$$K_{b1,t} = \left(\mu_b^{1/\varepsilon} (x_b K_{b,t})^{(\varepsilon-1)/\varepsilon} + (1 - \mu_b)^{1/\varepsilon} \left(\frac{(1 - x_b) K_{b,t}}{P_{g,t}} \right)^{(\varepsilon-1)/\varepsilon} \right)^{\varepsilon/(\varepsilon-1)} \quad (43)$$

where μ_b is the weight of brown goods in the capital, and $(1 - \mu_b)$ is the weight of green goods in capital. We assume that firms use a proportion x_b of its borrowings to invest in brown goods, and the rest to invest in green goods. $K_{g1,t}$ is the integrated capital in the green sector, and $K_{b1,t}$ is that in the brown sector. We test the sensitivity of GQE with different values of x_b , the proportion of green capital, and μ_b , the weight of green capital.

In Figure 6, the red curve represents the scenario in which firms invest 30% of their loans in green capital, the green curve represents that in which firms invest 50%, and the blue curve represents the scenario in which firms invest 70%. We find that the more green capital the firms use, the more negative the effects of GQE on the green sector.

In Figure 7, the red curve represents the scenario in which green capital is weighted as 10% in firms' preferences, the green curve represents that in which it is 30%, and the blue curve represents the scenario in which it is 50%. The sensitivity of GQE effects to μ_b is secondary compared to the sensitivity to x_b . We can see that the effects of unconventional GQE are always not favorable for the growth of the green sector, as the increasing demand of green capital²⁷ drives the relative price of green goods $P_{g,t}$ up, which discourages the demand from the consumer side.

²⁷Equivalent to green goods in our model.

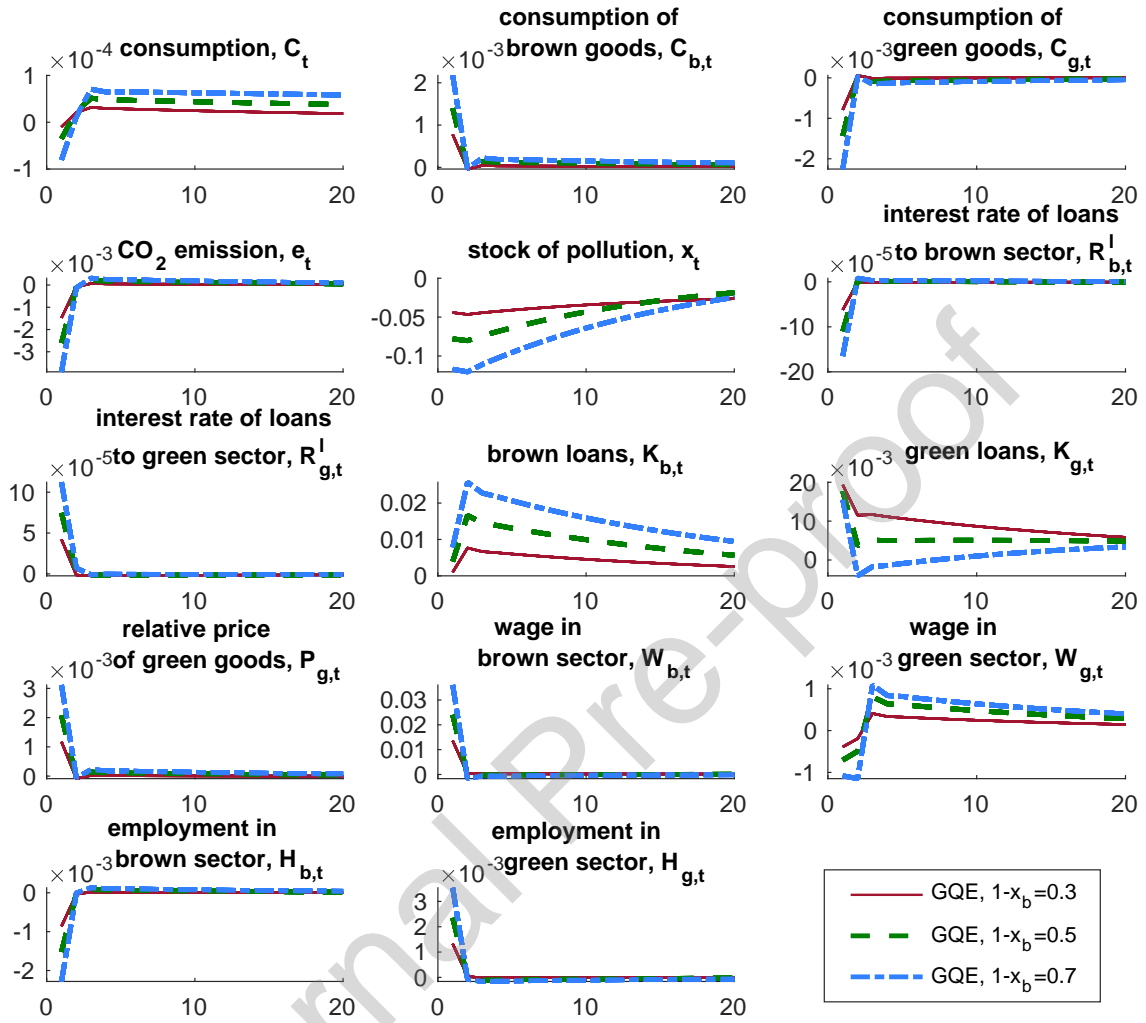


Figure 6: Effects of GQE, sensitivity on the proportion of green capital. The responses are quarterly log-deviations from the variables' steady state values.

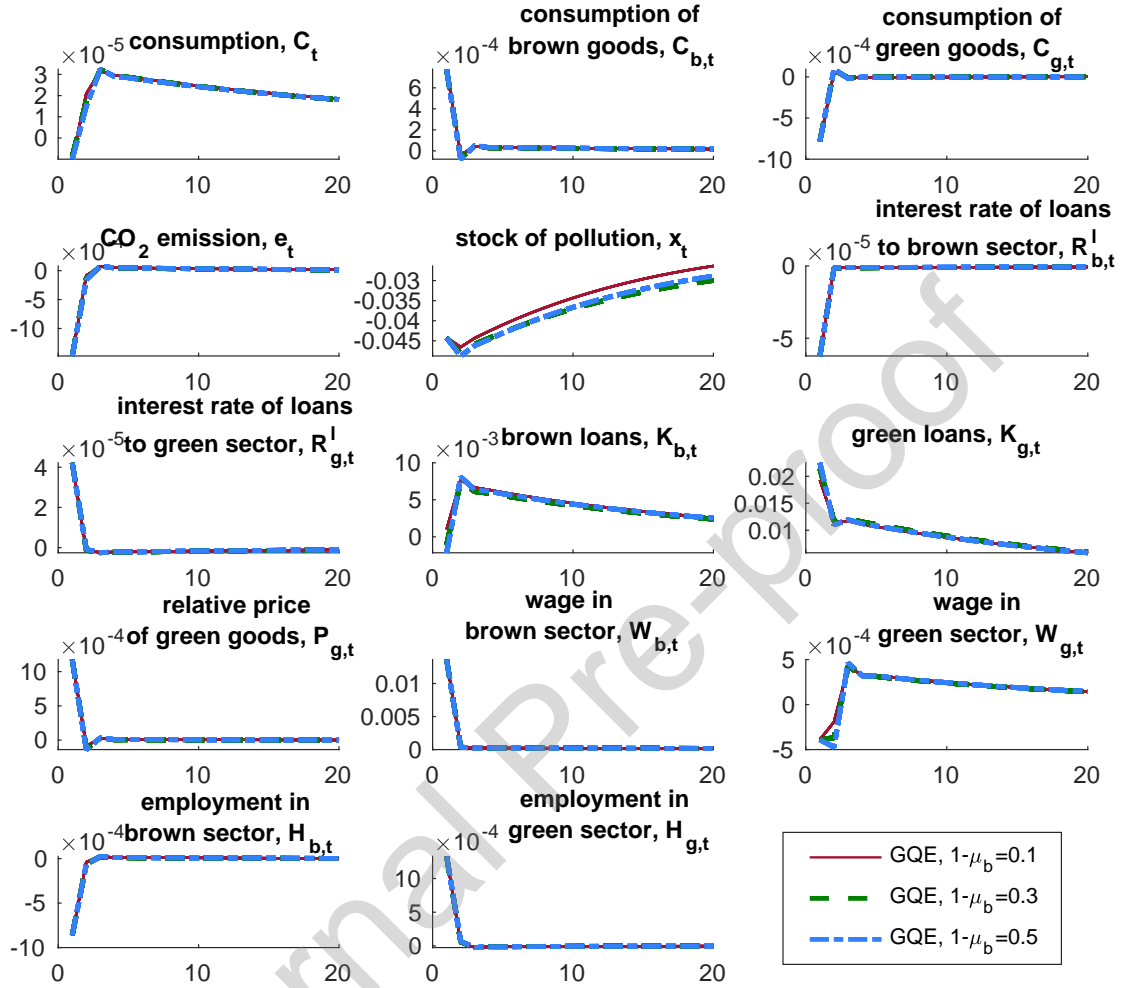


Figure 7: Effects of GQE, sensitivity on the weight of green capital. The responses are quarterly log-deviations from the variables' steady state values.

8 Conclusion

We establish a two-sector model, calibrated to France, to simulate the potential effects of unconventional green monetary policy and fiscal policies on the economy. We find that the carbon tax imposed directly on firms in the brown sector is the most *effective* tool to reduce pollution. Instruments such as carbon tax, the implicit tax on brown loans, and subsidy for the purchase of green goods are all beneficial to the green sector in contrast

to GQE. Finally, the marginal effects of green instruments on the green sector depend on consumer preferences. Namely, they are the most prominent when consumers start to purchase more green goods as an increasing part of their consumption basket. However, when the consumption of green goods reaches about half of the consumption panel, the marginal effects of green policies are still positive but become less *effective*. Furthermore, the effects of environmental policies are more *effective* when the elasticity of substitution between green and brown goods increases. In other words, the green monetary and fiscal policies should be combined with measures that improve the accessibility to green/organic goods such as the promotion of green/organic shops, online green/organic shops, organic farms, ... which make it easier for households to access to the green goods.

In our opinion, considerable research remains to be done concerning the shift of consumer preferences toward green goods. For example, how can the Central Bank and governments adjust their monetary and fiscal policies to better adapt to this structural change? For the private sector, how could banks and companies adjust their utility functions? In the job market, how could households adjust their occupational choices, and utility function? Also, will these changes relate to demographic factors in an economy, such as the younger generation, the female participation rate, and the level of immigration? We leave these questions for future research.

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A Appendix

A.1 Role of $(1 - \mu_C)$, the proportion of green goods in consumers' basket

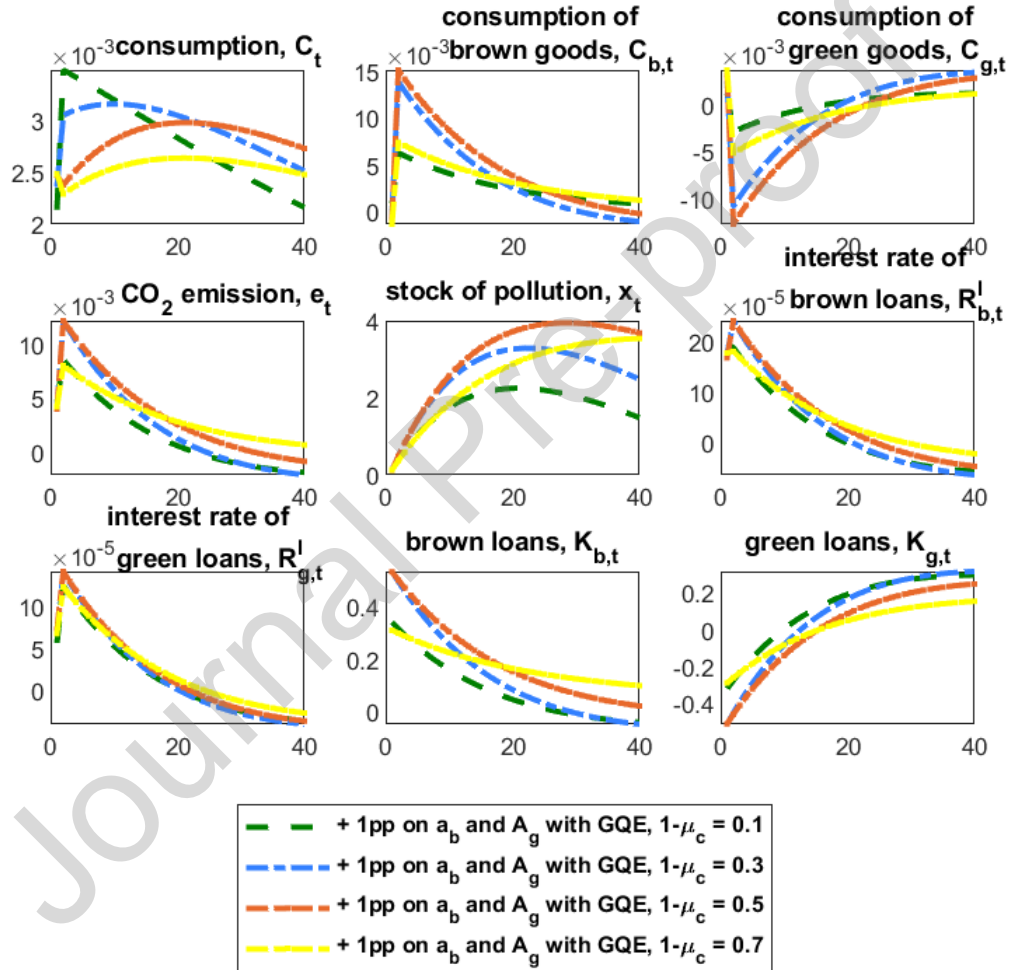


Figure 8: Effects of consumer preferences $(1 - \mu_c)$ on the effectiveness of GQE. The responses are quarterly log-deviations from the variables' steady state values.

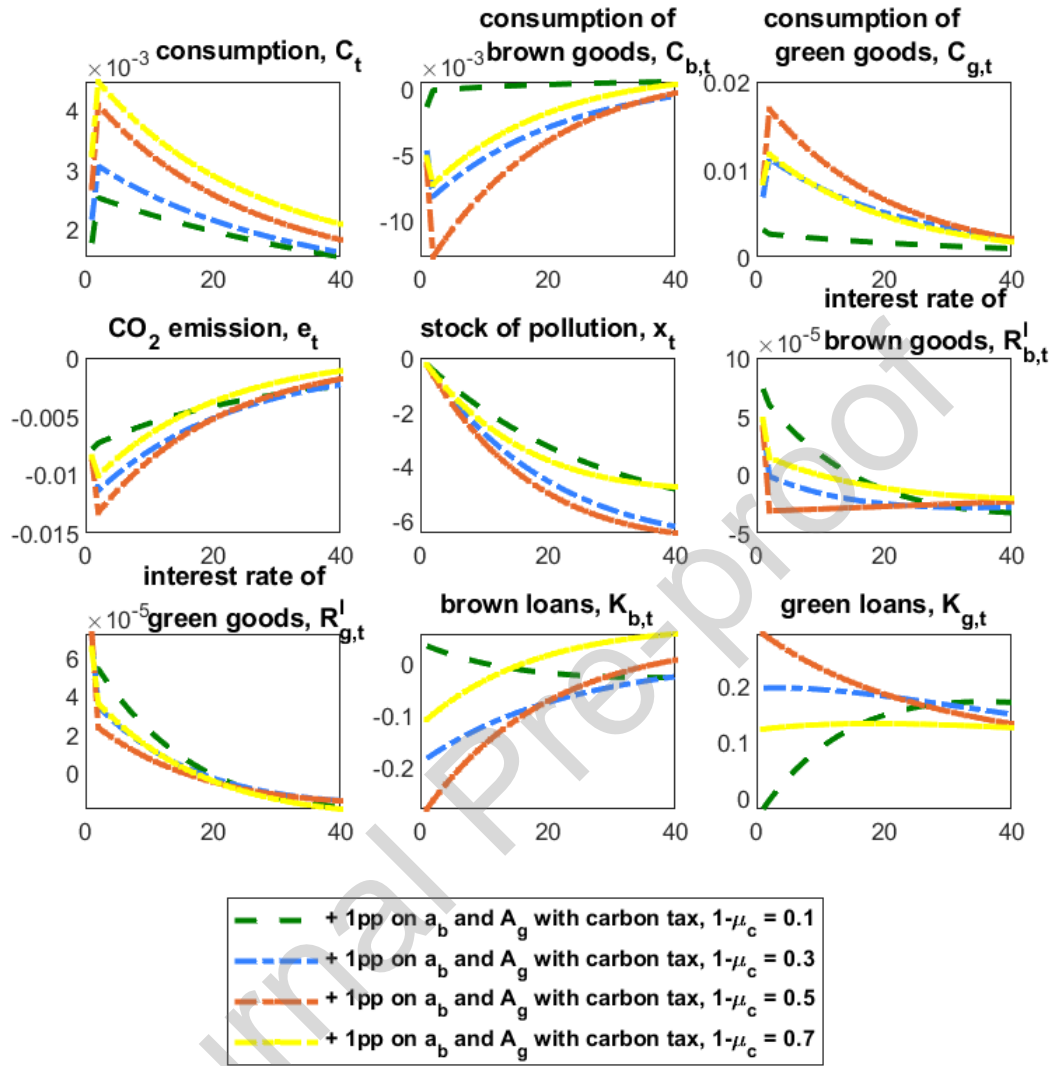


Figure 9: Effects of consumer preferences ($1 - \mu_c$) on the effectiveness of carbon tax. The responses are quarterly log-deviations from the variables' steady state values.

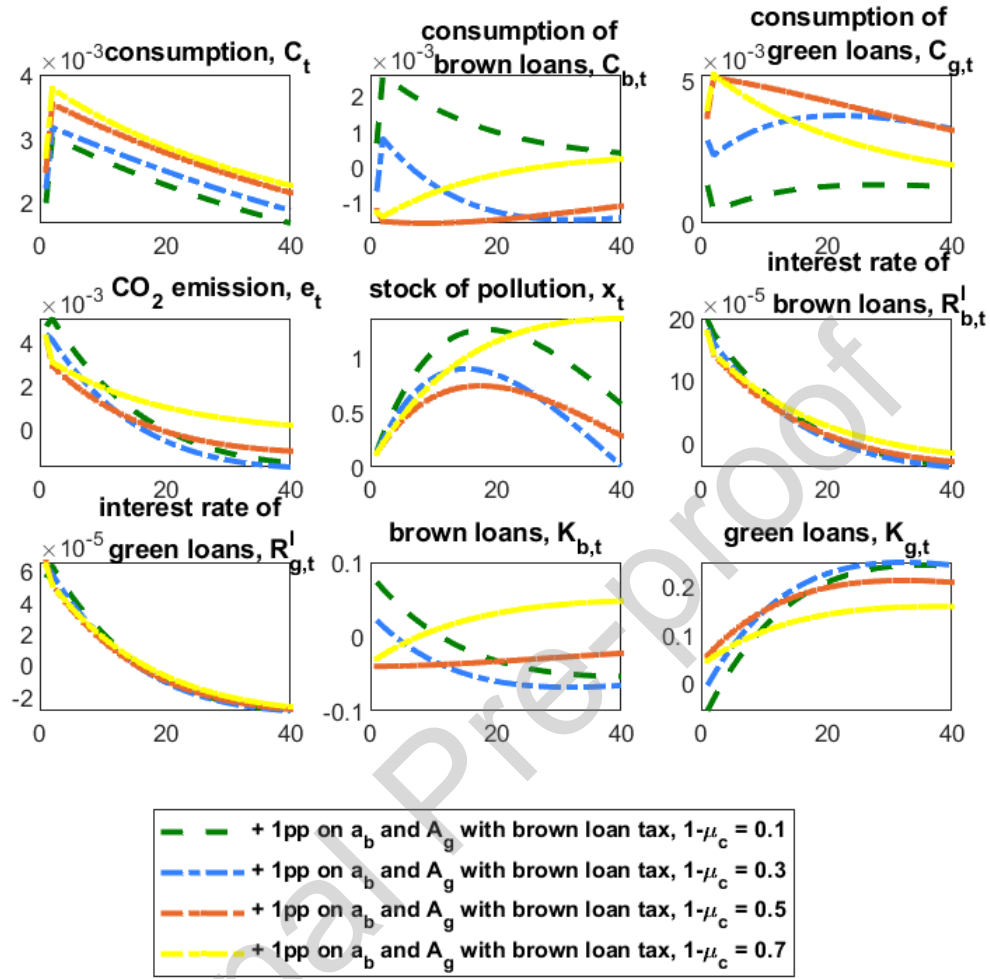


Figure 10: Effects of consumer preferences ($1 - \mu_c$) on the effectiveness of brown loan tax. The responses are quarterly log-deviations from the variables' steady state values.

A.2 Role of ϵ , the elasticity of substitution between green and brown goods

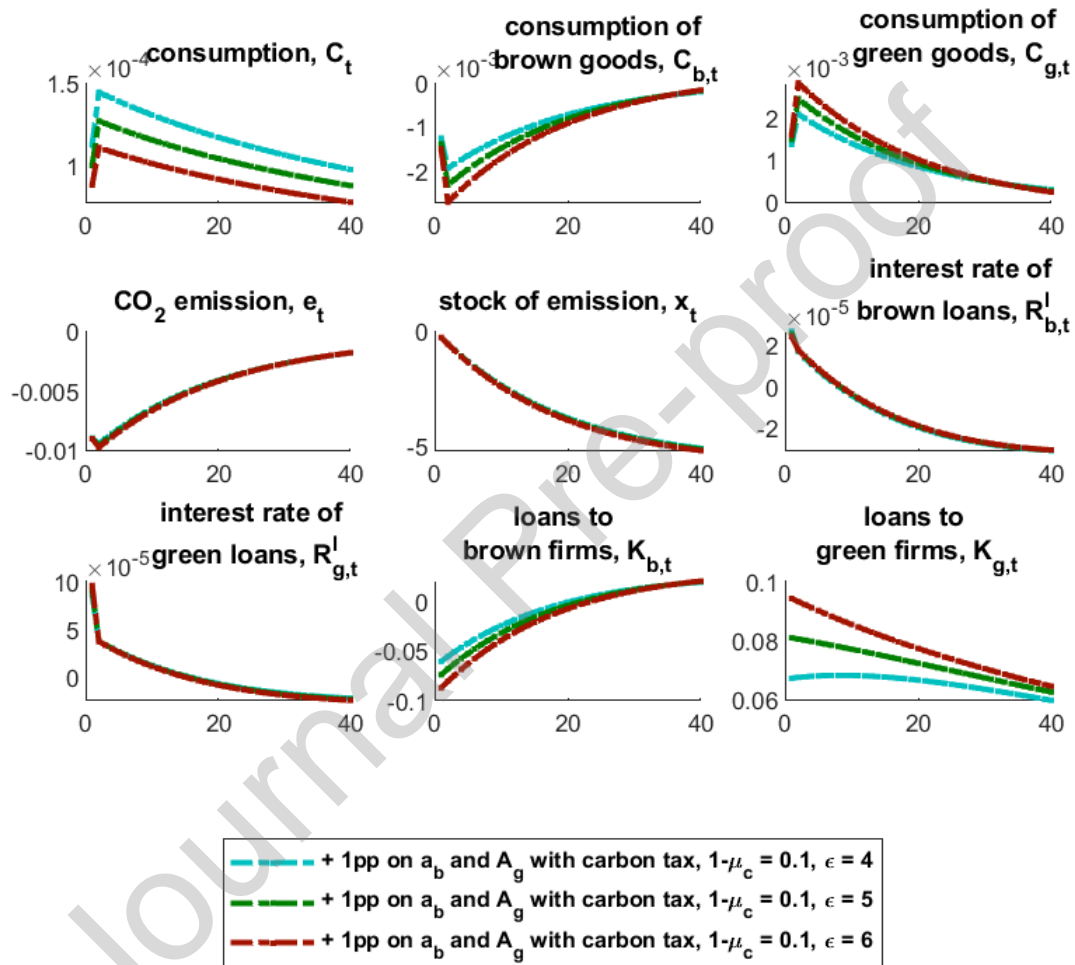


Figure 11: Effects of consumer preferences ϵ on the effectiveness of carbon tax. The responses are quarterly log-deviations from the variables' steady state values.

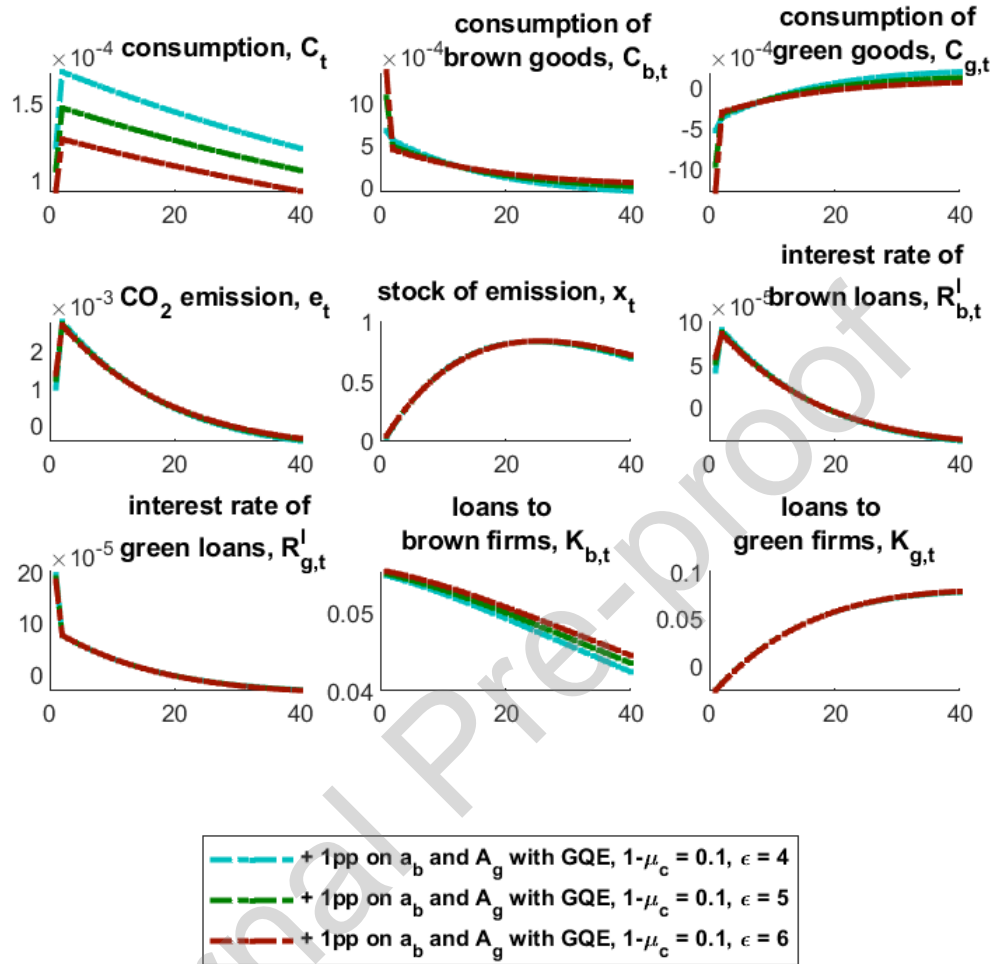


Figure 12: Effects of consumer preferences ϵ on the effectiveness of GQE. The responses are quarterly log-deviations from the variables' steady state values.

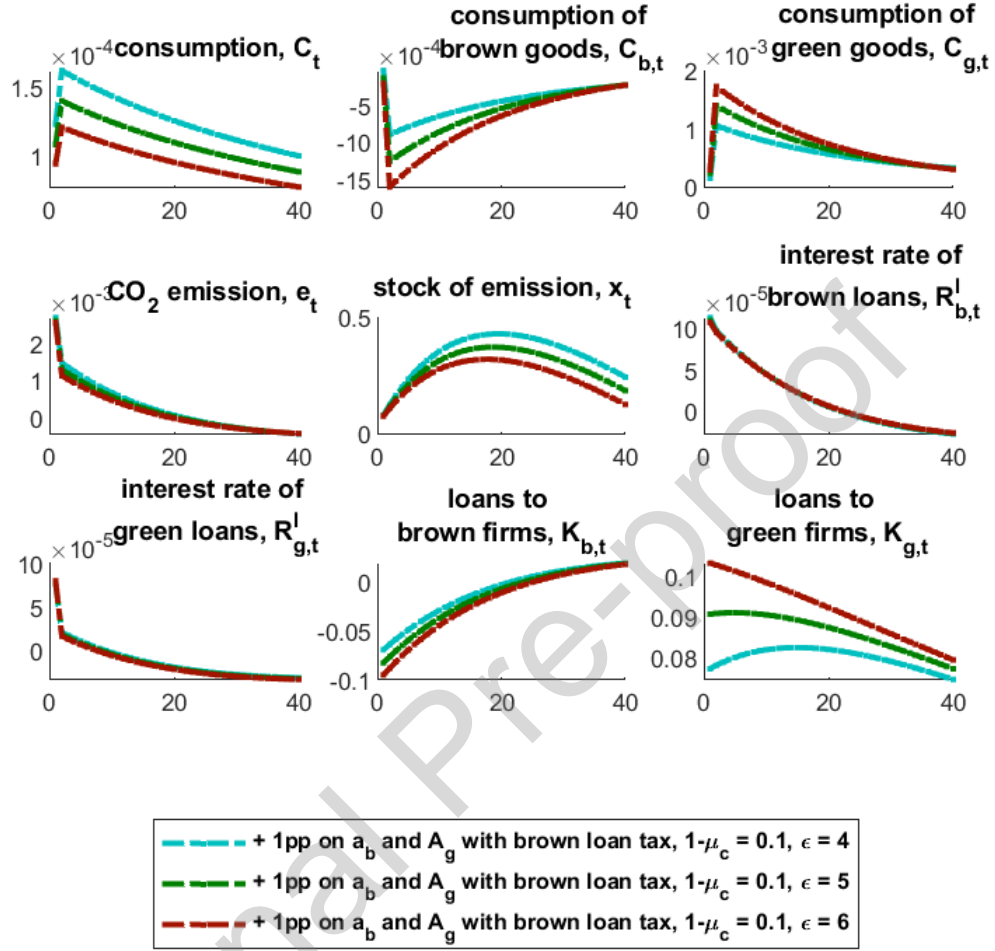


Figure 13: Effects of consumer preferences ϵ on the effectiveness of brown loan tax. The responses are quarterly log-deviations from the variables' steady state values.

A.3 The IRFs with damage function in the green sector

In this section, we assume that the stock of pollution not only affect the brown sector, but also the green sector. Thus, we have the productivity of green sector as

$$A_{g,t} = (1 - d(x_{t-1}))a_{g,t}, \quad (44)$$

where $d(x_{t-1})$ is the damage function and x_{t-1} the stock of pollution at time $t - 1$. In this case, the productivity in green sector is no longer exogenous and becomes endogeneous.

In our simulation, we try to make a comparison between the scenario with and without damage function in the green sector. We simulate the effects of four instruments : green quantitative easing GQE, carbon tax, tax on brown loans, and subsidy for the consumption of green goods. Figure 14 to 17 shows the results. The green curves represent the case with damage function in the green sector, and the red curves represent the case without damage function in the green sector. We can see that the effects of green monetary and fiscal instruments are very similar with or without damage function. For the fiscal instruments in figure 15 to 17, with damage function in the productivity, the green sector benefits slightly more from the fall of pollution stock, compared to the scenario without damage function.

More precisely, the three fiscal instruments, i.e. carbon tax, tax on brown loans, and subsidy for the consumption of green goods are **effective** to reduce CO_2 emission thus reduce the stock of pollution. Therefore, according to equation 44, the value of damage function $d(x_{t-1})$ decreases and the productivity $A_{g,t}$ increases. Hence the wage in green sector increases and employment $H_{g,t}$ rises more in the scenario with damage function. The relative price $P_{g,t}$ falls more compared to the scenario without damage function, because thanks to the rise of productivity in the green sector, there is more supply of green goods in the market and the relative price in equilibrium falls. As a result, the consumption of green goods $C_{g,t}$ rises more compared to the scenario without damage function.

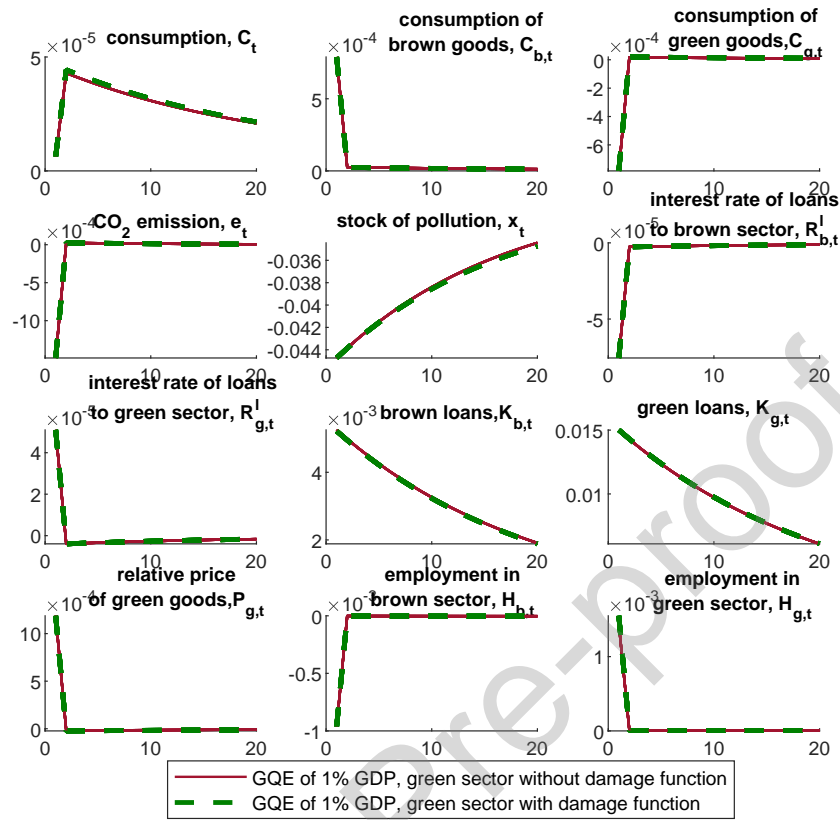


Figure 14: Effects of GQE, with and without damage function in the green sector. The responses are quarterly log-deviations from the variables' steady state values.

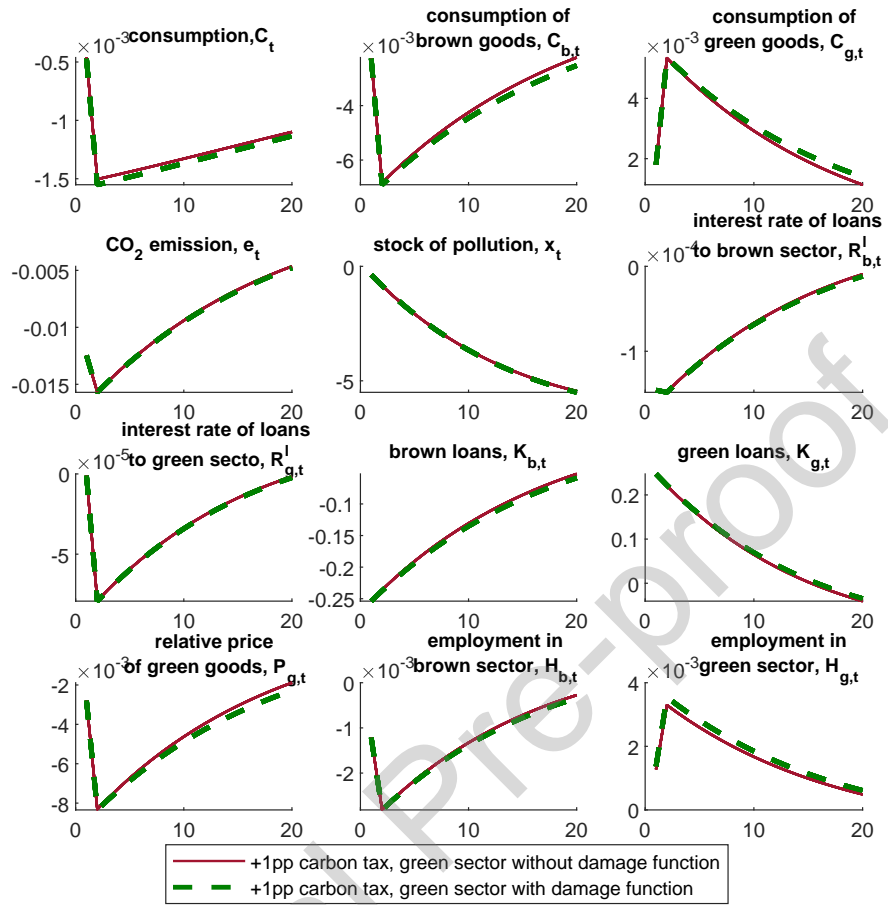


Figure 15: Effects of carbon tax, with and without damage function in the green sector. The responses are quarterly log-deviations from the variables' steady state values.

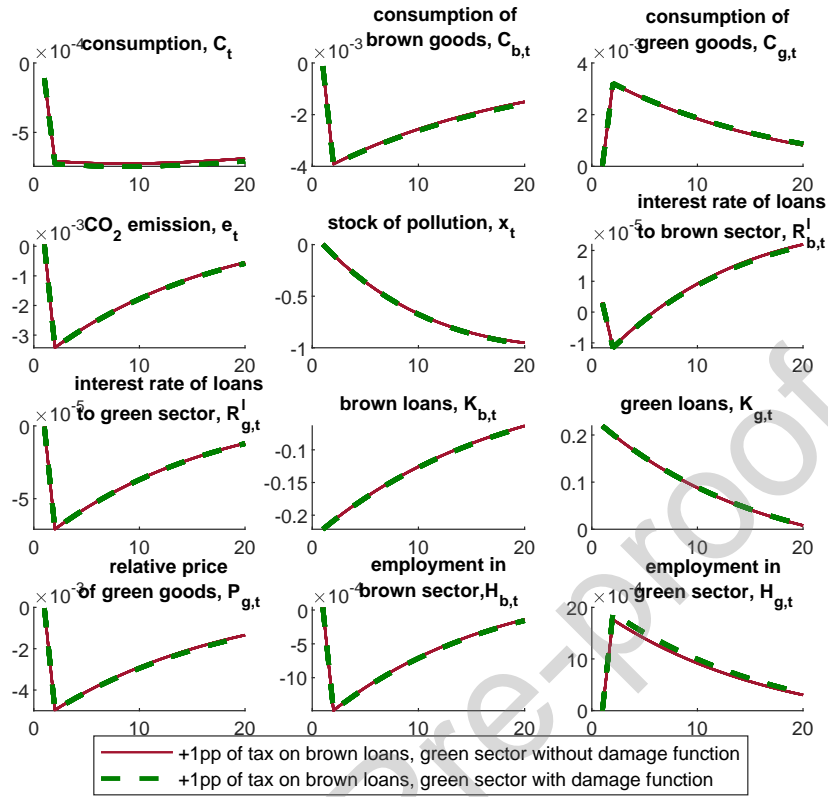


Figure 16: Effects of tax on brown loans, with and without damage function in the green sector. The responses are quarterly log-deviations from the variables' steady state values.

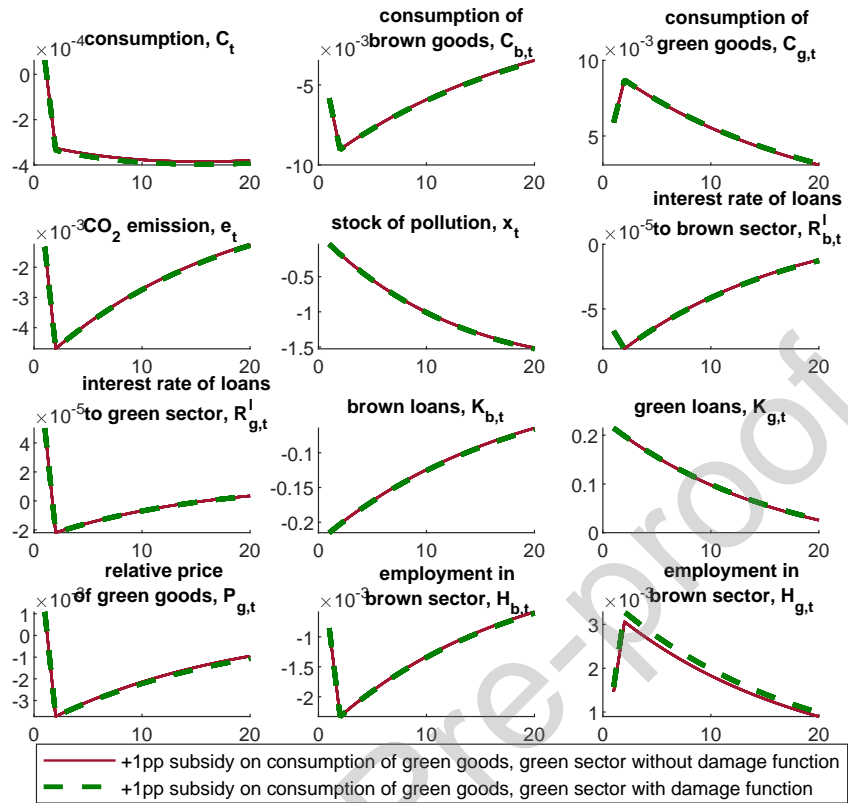


Figure 17: Effects of subsidy for green consumption, with and without damage function in the green sector. The responses are quarterly log-deviations from the variables' steady state values.

A.4 Resource Constraint / Market Clearing

To find the resource constraint of our economy, we combine the household budget constraint with the government budget constraint, the bank's profit function, and the first-order conditions of green and brown firms.

The household's budget constraint is :

$$C_{b,t} + P_{g,t}C_{g,t} - \tau_{c,t}P_{g,t}C_{g,t} + D_{h,t} = W_{g,t}H_{g,t} - \varpi W_{g,t}H_{g,t} + W_{b,t}H_{b,t} - \varpi W_{b,t}H_{b,t} + R_{t-1}^d D_{h,t-1} + T_t + (1 - \sigma_B) N_t$$

Using the government budget constraint, we can replace T_t :

$$C_{b,t} + P_{g,t}C_{g,t} - \tau_{c,t}P_{g,t}C_{g,t} + D_{h,t} = W_{g,t}H_{g,t} - \varpi W_{g,t}H_{g,t} + W_{b,t}H_{b,t} - \varpi W_{b,t}H_{b,t} + R_{t-1}^d D_{h,t-1} + \varpi W_{g,t}H_{g,t} + \varpi W_{b,t}H_{b,t} + \tau_{e,t}e_t + \tau_{b,t}(R_{b,t}^l - 1)K_{b,t-1} + B_t - R_{t-1}^B B_{t-1} - \tau_{c,t}P_{g,t}C_{g,t} + (1 - \sigma_B) N_t$$

Simplifying, we get :

$$C_{b,t} + P_{g,t}C_{g,t} + D_{h,t} = W_{g,t}H_{g,t} + W_{b,t}H_{b,t} + R_{t-1}^d D_{h,t-1} + \tau_{e,t}e_t + \tau_{b,t}(R_{b,t}^l - 1)K_{b,t-1} + (B_t - R_{t-1}^B B_{t-1}) + (1 - \sigma_B) N_t$$

The (expected) profit of private bank enter to the representative household's revenue. According to household's budget constraint, we note that the bank's (expected) profit is equivalent to $(1 - \sigma_B)N_t$, which should be identical to the gross return on asset minus the cost of liabilities and brown loan tax :

$$\begin{aligned}
C_{b,t} + P_{g,t}C_{g,t} &= W_{g,t}H_{g,t} + W_{b,t}H_{b,t} - (D_{h,t} - R_{t-1}^d D_{h,t-1}) + \\
&+ \tau_{e,t}e_t + \tau_{b,t}(R_{b,t}^l - 1)K_{b,t-1} + (B_t - R_{t-1}^B B_{t-1}) + (R_{b,t}^l - 1)K_{b,t-1} \\
&+ (R_{g,t}^l - 1)K_{g,t-1} - \tau_{b,t}(R_{b,t}^l - 1)K_{b,t-1} + (D_{h,t} - R_{t-1}^d D_{h,t-1}) \\
&- (B_t - R_{t-1}^B B_{t-1}) - I_{b,t} - I_{g,t}
\end{aligned}$$

and then

$$C_{b,t} + P_{g,t}C_{g,t} = W_{g,t}H_{g,t} + W_{b,t}H_{b,t} + \tau_{e,t}e_t - I_{b,t} - I_{g,t} + (R_{b,t}^l - 1)K_{b,t-1} + (R_{g,t}^l - 1)K_{g,t-1}$$

Using the first order conditions of green and brown producers, we find :

$$\begin{aligned}
C_{b,t} + P_{g,t}C_{g,t} &= (1 - \alpha_g)P_{g,t}Y_{g,t} + (1 - \alpha_b)[1 - \psi_1\eta_t^{\psi_2} - \tau_{e,t}\varphi(1 - \eta_t)]Y_{b,t} + \\
&+ \tau_{e,t}e_t - I_{b,t} - I_{g,t} + \alpha_b[1 - \psi_1\eta_t^{\psi_2} - \tau_{e,t}\varphi(1 - \eta_t)]Y_{b,t} + \alpha_g P_{g,t}Y_{g,t},
\end{aligned}$$

Then :

$$\begin{aligned}
C_{b,t} + P_{g,t}C_{g,t} &= P_{g,t}Y_{g,t} + Y_{b,t} - \psi_1\eta_t^{\psi_2}Y_{b,t} - \tau_{e,t}\varphi(1 - \eta_t)Y_{b,t} + \\
&+ \tau_{e,t}e_t - I_{b,t} - I_{g,t},
\end{aligned}$$

Finally, knowing that, $e_t = \varphi(1 - \eta_t)Y_{b,t}$ and $Z = \psi_1\eta_t^{\psi_2}Y_{b,t}$ we get :

$$P_{g,t}Y_{g,t} + Y_{b,t} = C_{b,t} + P_{g,t}C_{g,t} + I_{b,t} + I_{g,t} + Z,$$

which is identical to market clearing condition equation 40.

A.5 Welfare results under alternative consumer's preferences

Table 2b: Welfare results

	$\varepsilon = 4$		$\varepsilon = 5$		$\varepsilon = 6$	
	Mean	%Change	Mean	%Change	Mean	%Change
$(1 - \mu_C) = 0.1$						
Productivity shocks	-14.0540	-	-13.4995	-	-12.9771	-
Carbon tax	-14.4399	-2,745%	-13.8711	-2,752%	-13.3303	-2,721%
Green QE	-14.0560	-0,024%	-13.5036	-0,030%	-12.9821	-0,038%
Consumption subsidy	-14.0414	+0,089%	-13.4963	+0,023%	-12.9797	-0,020%
Tax on brown loans	-14.0426	+0,081%	-13.4957	+0,028%	-12.9767	+0,003%
$(1 - \mu_C) = 0.2$						
Productivity shocks	-14.1013	-	-13.5338	-	-13.0073	-
Carbon tax	-14.4738	-2,641%	-13.8871	-2,610%	-13.3369	-2,533%
Green QE	-14.1045	-0,022%	-13.5372	-0,025%	-13.0112	-0,029%
Consumption subsidy	-14.0611	+0,285%	-13.5179	+0,117%	-13.0030	+0,033%
Tax on brown loans	-14.0802	+0,149%	-13.5255	+0,061%	-13.0039	+0,026%
$(1 - \mu_C) = 0.3$						
Productivity shocks	-14.1730	-	-13.5831	-	-13.0508	-
Carbon tax	-14.5278	-2,503%	-13.9164	-2,453%	-13.3579	-2,353%
Green QE	-14.1763	-0,023%	-13.5862	-0,022%	-13.0542	-0,026%
Consumption subsidy	-14.0948	+0,551%	-13.5499	+0,244%	-13.0355	+0,117%
Tax on brown loans	-14.1406	+0,228%	-13.5699	+0,097%	-13.0440	+0,052%
$(1 - \mu_C) = 0.4$						
Productivity shocks	-14.2241	-	-13.6221	-	-13.0882	-
Carbon tax	-14.5559	-2,332%	-13.9304	-2,263%	-13.3702	-2,154%
Green QE	-14.2277	-0,025%	-13.6250	-0,021%	-13.0913	-0,023%
Consumption subsidy	-14.1242	+0,702%	-13.5776	+0,326%	-13.0646	+0,180%
Tax on brown loans	-14.1876	+0,256%	-13.6065	+0,114%	-13.0793	+0,068%

Table 2c: Welfare results

	$\varepsilon = 4$		$\varepsilon = 5$		$\varepsilon = 6$	
	Mean	%Change	Mean	%Change	Mean	%Change
$(1 - \mu_C) = 0.5$						
Productivity shocks	-14.1953	-	-13.6178	-	-13.0935	-
Carbon tax	-14.4941	-2,104%	-13.8926	-2,017	-13.3447	-1,918%
Green QE	-14.1987	-0,023%	-13.6205	-0,019	-13.0964	-0,022%
Consumption subsidy	-14.1155	+0,562%	-13.5782	+0,290	-13.0710	+0,171%
Tax on brown loans	-14.1688	+0,186%	-13.6051	+0,093	-13.0855	+0,061%
$(1 - \mu_C) = 0.6$						
Productivity shocks	-14.1178	-	-13.5754	-	-13.0648	-
Carbon tax	-14.3734	-1,810%	-13.8102	-1,729%	-13.2806	-1,651%
Green QE	-14.1204	-0,018%	-13.5778	-0,017%	-13.0675	-0,020%
Consumption subsidy	-14.0780	+0,281%	-13.5527	+0,167%	-13.0517	+0,100%
Tax on brown loans	-14.1062	+0,082%	-13.5688	+0,048%	-13.0601	+0,035%
$(1 - \mu_C) = 0.7$						
Productivity shocks	-14.0578	-	-13.5298	-	-13.0254	-
Carbon tax	-14.2686	-1,499%	-13.7249	-1,442	-13.2062	-1,388%
Green QE	-14.0596	-0,012%	-13.5320	-0,016	-13.0281	-0,020%
Consumption subsidy	-14.0468	+0,078%	-13.5234	+0,047	-13.0233	+0,016%
Tax on brown loans	-14.0560	+0,012%	-13.5286	+0,008	-13.0243	+0,008%
$(1 - \mu_C) = 0.8$						
Productivity shocks	-14.0288	-	-13.5001	-	-12.9944	-
Carbon tax	-14.2003	-1,222%	-13.6609	-1,191%	-13.1448	-1,157%
Green QE	-14.0299	-0,007%	-13.5021	-0,014%	-12.9972	-0,021%
Consumption subsidy	-14.0311	-0,016%	-13.5036	-0,025%	-13.0001	-0,043%
Tax on brown loans	-14.0311	-0,016%	-13.5020	-0,014%	-12.9959	-0,011%

Financial Disclosure Statement

I certify that all my affiliations with or financial involvement in, within the past 5 years and foreseeable future, any organization or entity with a financial interest in or financial conflict with the subject matter or materials discussed in the manuscript are completely disclosed (e.g. employment, consultancies, honoraria, stock ownership or options, expert testimony, grants or patents received or pending, royalties).

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Green Monetary and Fiscal Policies: The role of consumer preferences

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