Norges Bank

11 | 2025

Working Paper

Climate Policy and Gender Inequality

Norges Bank Research

Authors:
Mohamed Tahar Benkhodja
Johan Gustafsson
Xiaofei Ma
Junior Maih

Keywords
Environmental policies, E-DSGE,
Gender differences

Working papers fra Norges Bank, fra 1992/1 til 2009/2 kan bestilles på e-post: servicesenter@norges-bank.no

Fra 1999 og senere er publikasjonene tilgjengelige på http://www.norges-bank.no

Working papers inneholder forskningsarbeider og utredninger som vanligvis ikke har fått sin endelige form. Hensikten er blant annet at forfatteren kan motta kommentarer fra kolleger og andre interesserte. Synspunkter og konklusjoner i arbeidene står for forfatternes regning.

Working papers from Norges Bank, from 1992/1 to 2009/2 can be ordered by e-mail: servicesenter@norges-bank.no

Working papers from 1999 onwards are available on www.norges-bank.no

Norges Bank's working papers present research projects and reports (not usually in their final form) and are intended inter alia to enable the author to benefit from the comments of colleagues and other interested parties. Views and conclusions expressed in working papers are the responsibility of the authors alone.

ISSN 1502-8143 (online)

ISBN 978-82-8379-371-0 (online)

Climate policy and gender inequality*

Mohamed Tahar Benkhodja † Johan Gustafsson ‡ Xiaofei Ma §
Junior Maih¶

July 28, 2025

Abstract

Empirical evidence suggests that women, on average, have stronger preferences for green consumption, and are employed in less carbon-intensive sectors, when compared with men. The present paper exploits this heterogeneity to study the distributive effects of climate policy between men and women. The analyses rely on numerical experiments within an environmental dynamic stochastic general equilibrium (E-DSGE) model in which men and women differ in their preferences over carbon-intense goods, and in their comparative advantage across sectors. Calibrating the model to the French economy, we find that climate policies, such as a carbon tax, or a subsidy for the labor cost of green firms, can reduce gender-indexed income inequality. Productivity improvements in the green sector can also reduce this inequality.

Keywords: environmental policies, E-DSGE, gender differences

JEL Codes: Q58, J16, D58

---

*This paper should not be reported as representing the views of Norges Bank. The views expressed are those of the authors and do not necessarily reflect those of Norges Bank. We would like to thank Gauthier Lanot, Hanna Lindström, Camila Villard Durand, and the participants at the 2024 PET conference in Lyon, the 2024 AERNA conference in Lisbon, and the 2nd RISE Workshop in Pretoria, for insightful discussions.

†ESSCA School of Management, France. Email: tahar.benkhodja@essca.fr

‡Umea School of Business, Economics and Statistics (USBE), Sweden. Email: johan.a.gustafsson@umu.se

§ESSCA School of Management, France. Email: xiaofei.ma@essca.fr

¶Norges Bank, junior.maih@norges-binank.no

1 Introduction

By ratifying the Paris agreement[1], nations commit to structurally transform their economic activity from carbon-dependent to carbon-neutral in a global effort to combat climate change. A central issue faced by policymakers concerns the distributive effects of policies that promote such a transformation. For example, carbon taxation, which is broadly accepted as the most efficient policy to reduce emissions, can have direct heterogeneous effects on the purchasing power of households (e.g., Fremstad and Paul (2019)), but also indirect distributive effects through employment and investment channels as factor inputs are re-allocated between sectors following changes in demand and costs (e.g., Arrow et al. (1996)). Indeed, climate policy will place a larger burden on individuals with strong preferences for a carbon-intense lifestyle and on those who face large costs of switching employment from polluting to non-polluting industries. It is evident from current debates and policy documents that opinions on the actual and perceived fairness of climate policy are strong and have a real impact on policy design and implementation (Douenne and Fabre, 2020).

Without taking a normative stance in the equity–efficiency debate, nor studying the political economy of climate policy, the present paper explores the potential distributive effects of climate policy when accounting for gender heterogeneity. This consideration is motivated by studies showing that women, on average, are more concerned about climate change and environmental issues (see, e.g., Bord and O'Connor, 1997; Stern et al., 1999; Xiao and McCright, 2015), have stronger preferences for green consumption and recycling (see, e.g., Ureña et al., 2008; Bravo et al., 2013; Sánchez et al., 2016; Li et al., 2019; OECD, 2021; Migheli, 2021), and, at current wages, work in less carbon-intensive sectors, when compared to men. Furthermore, women have been found to be more supportive of climate policy in general (Rhodes et al., 2017), and display more pro-environmental behavior than men (Casaló and Escario, 2018). Consequently, climate policy will likely have distributive effects on costs and benefits between

[1]The Paris Agreement is a landmark agreement under the United Nations Framework Convention on Climate Change (UNFCCC). It aims to limit global warming to well below 2 degrees Celsius above pre-industrial levels, with efforts to limit the increase to 1.5 degrees Celsius. The agreement includes commitments by all countries to reduce emissions and work towards a low-carbon future, to adapt to the impacts of climate change, and to align financial flows with a low greenhouse gas and climate-resilient development pathway.

men and women. As the female share of economic activity is increasing globally, especially in developing economies, we argue that these differences will only grow in importance. Yet, this source of heterogeneity remains largely overlooked in the environmental economics literature.

To this end, we build an environmental dynamic stochastic general equilibrium (E-DSGE) model with polluting and non-polluting sectors, hereafter referred to as "green" and "brown" sectors. The economy is populated by male and female consumers/workers who make independent economic decisions over consumption and employment. Our main modeling contribution is that we explicitly account for both these channels as potential policy propagation channels that can affect gender inequality, both in terms of income and welfare.

We calibrate the model to match French data on gender differences in employment and consumption patterns, and then numerically explore the effects of climate policy and productivity shocks on these differences. Our main findings show that climate policies targeting the productivity of the green sector or imposing carbon taxes tend to favor women, effectively reducing the gender income gap. This bias stems from women's stronger preference for green goods and their comparative advantage in less carbon-intensive sectors. Women experience smaller declines in both consumption and income under these policies, highlighting the importance of their role in the green economy and their preferences for green products. The labor demand shifts from brown to green sectors, driven by increased green productivity and demand, disproportionately benefit women. This shift, coupled with a decline in the relative price of green goods, allows female consumers to benefit more, emphasizing the link between climate policy and gender differences. Ultimately, men are found to face larger welfare costs of both carbon taxation and subsidies for green firms. Overall, the results suggest that green fiscal policy can reduce gender income inequality as a smaller burden is placed on women's consumption and employment choices. This underscores the importance of accounting for gender effects when designing and implementing climate policy if equity and inclusiveness are prioritized outcomes.

The rest of the paper is organized as follows. We review the literature in Section 2. The model is introduced in Section 3. We calibrate the model in Section 4, and section 5 contains the numerical experiments. Section 6 concludes.

2 Related literature

Regarding the overall distributional effects of green fiscal policy, Fullerton (2011) finds that environmental taxes can cause a decline in wages relative to capital returns. This could be particularly harmful for low-income households as they typically rely more extensively on labor income. Studying the impacts of a carbon tax across different income groups in the US, Goulder et al. (2019) find that environmental taxes have regressive direct effects if low-income households are not compensated through redistributive transfers. However, general equilibrium effects on wage, capital, and transfer incomes can potentially offset the regressive impacts. Cremer et al. (2003) shows that, if environmental taxes serve a redistributive purpose, the optimal pollution tax rate is substantially lower than the marginal social damage of the pollutant. If the tax rate is set as equal to the Pigouvian rate, the high-income groups benefits at the expense of low-income groups. Williams III et al. (2015) find that carbon taxes are regressive, but that the incidence ultimately depends on how tax revenue is ultimately used. Cutting capital taxes is efficient but exacerbates inequality, while lump-sum compensations are less efficient but more progressive. Douenne et al. (2022) study whether environmental policies should be less stringent in the presence of heterogeneity in earnings-ability, initial wealth, energy demand, and sensitivity to environmental damages. The optimal carbon tax is found to be close to Pigouvian when distortive taxes are used for redistribution. However, the presence of low-income households increases the opportunity cost of abatement efforts following a higher marginal value of consumption. Känzig (2023) finds that the reduced economic activity that follows from carbon pricing in the European Union's emissions trading system is mainly harmful for low-income households because of their higher energy share, while high-income households are less affected. Li et al. (2019) use a nationwide survey on consumption behavior in China to study the impact of gender inequality on households' consumption decisions. They find that households that display a higher degree of gender inequality also make less environmentally friendly consumption decisions.

In terms of labor market effects, Arrow et al. (1996) suggest that environmental regulations would re-allocate employment across sectors, rather than reduce total employment. For example, environmental policy has been found to disproportionally affect manufacturing employment negatively (Kahn and Mansur, 2013). Then, heterogeneity in the ability to switch jobs can have important distributional consequences. Indeed, Ngai and Petrongolo (2017) find that the post-second World War marketization of services, which also constitutes a large-scale structural transformation of economic activity, has contributed to narrowing the gender wage and hours gap in the US, as women have a comparative advantage in service occupations.[2] Since women, on average, work in less carbon-intensive sectors, the green structural transformation could also contribute to reducing the effects on the gender income differential. Studying the relationship between female labor participation and C02 emissions in 16 European countries between 2000-2016, Wang (2022) finds that an increase in the ratio of female to male labor participation rates is associated with a decrease in CO2 emission per capita. However, Aragón et al. (2018) find that the closure of coal mines disproportionately affects women negatively following an inflow of mainly male workers in the local labor market. Yip (2018) studies the labor market effects of a revenue-neutral carbon tax in British Columbia. He finds that the policy mainly reduced the number of jobs available for low-educated males, resulting in persistent unemployment, while layoffs for medium-educated males were more likely temporary.

Perhaps most closely related to our paper, Somuncu (2023) studies the effects of environmental regulations on gender inequality, focusing on the employment channel when women are less mobile in the labor market compared to men. She builds a structural model on the empirical observations that women have a comparative advantage in less carbon-intensive sectors, such as services, while facing higher job switching costs. In the event of an energy tax, the gender differences in mobility costs are found to drive the distributional effects in the long run. She concludes that policies aiming to increase labor mobility have the potential to

[2] Dinkelman and Ngai (2022) finds that patterns of time use among women in African countries closely resemble historical time use in the US documented by Ruggles (2015). As such, this transformation is likely to take place in developing economies as well.

eliminate gender differences in the long run.

Our contribution is that we study the effects of climate taxes and green technological advancements in gender income and welfare inequality, accounting for both heterogeneous preferences over green and brown goods and differences in comparative advantage in carbon-intensive sectors.

3 The model

Time is discrete and denoted t. In our proposed model, we consider a closed economy populated by dynastic female and male individual types, two firm types that either produce a carbon-intensive good, or a carbon-neutral good. Following a standard in the literature, we use the labels green and brown to aggregate various sectors of the economy based on differences in carbon-intensiveness as measured by greenhouse gas emission per activity. For example, in the case of France, which serves as the target country for the calibration, sectors that are relatively carbon-intensive, and therefor fall under the brown category, are transport, agriculture, manufacturing and construction. Meanwhile, accommodation and catering, education, public and private services, and social action are examples of industries included in the green sector.[3]

Productivity is stochastic in both sectors. We follow Ngai and Petrongolo (2017) and assume that capital markets are completely missing to focus on labor market effects, where gender heterogeneity is better documented empirically.

There is also a government in charge of fiscal policy. In terms of climate policy, the government can tax carbon emissions or subsidize employment in the green sector.

3.1 Female & Male individuals

For simplicity, we follow e.g., Kitao and Mikoshiba (2020), Somuncu (2023), and Lee et al. (2024), and abstract from modeling the risk-sharing arrangements between spouses and instead

[3] Numbers for carbon-intensiveness are lifted from the INSEE database `https://www.insee.fr/fr/statistiques/2015759`.

consider male and female workers as independent economic agents. As such, the consumption and labor supply responses to changes in environmental policy will not be the outcome of within-household bargains. Ultimately, the quantitative effects documented in the calibration section are likely in the upper bound of those that would arise within a model framework with risk-sharing.

Let $i = \{f, m\}$ denote female and male individual types respectively. Each type derives utility from total consumption $C_{i,t}$ and leisure $(1 - H_{i,t})$ where $H_{i,t}$ represents the total hours worked. Each household's objective function is given by:

$$E_0 \sum_{t=0}^{\infty} \beta^t \, U\left(C_{i,t}, H_{i,t}\right), \tag{3.1}$$

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

$$U_{i,t}\left(.\right) = \frac{C_{i,t}^{1-\gamma} - 1}{1-\gamma} - \chi_i \frac{H_{i,t}^{1+\sigma}}{1+\sigma} \tag{3.2}$$

where $\gamma > 0$, is the inverse of the elasticity of inter-temporal substitution of consumption, and $\sigma > 0$ denotes the inverse of the wage elasticity of labor supply. The total consumption $C_{i,t}$ is defined as a composite good of green and brown goods $C_{i,j,t}, j = \{g, b\}$, specified as a constant elasticity of substitution (CES) integration:

$$C_{i,t} = \left(\mu_{i,c}^{1/\epsilon_{i,c}} C_{i,g,t}^{(\epsilon_{i,c}-1)/\epsilon_{i,c}} + (1-\mu_{i,c})^{1/\epsilon_{i,c}} C_{i,b,t}^{(\epsilon_{i,c}-1)/\epsilon_{i,c}}\right)^{\epsilon_{i,c}/(\epsilon_{i,c}-1)}, \tag{3.3}$$

where the parameter $\mu_{i,c}, i = \{f, m\}$ represents the weight of green goods in the household's consumption basket at the steady state and therefore captures the household's preference for brown goods relative to green goods. The parameter $\epsilon_i, i = \{f, m\}$ is the standard constant elasticity of substitution between different types of consumption goods. Under the assumption that female consumers are more ecological-oriented, we should have $\mu_{f,c} > \mu_{m,c}$, and we will discuss the different scenarios depending on the values of $\epsilon_{i,c}, i = \{f, m\}$.

The hours of female and male workers are the sum of their hours worked in green and brown sectors:

$$H_{i,t} = H_{i,g,t} + H_{i,b,t}, \tag{3.4}$$

where $i = \{f, m\}$ and $H_{i,g,t}$ the hours worked in the green sector, $H_{i,b,t}$ the hours worked in the brown sector by female and male workers, respectively. Here we assume that when a worker changes her/his allocation of working hours in different sectors, she/he will face a quadratic mobility cost

$$\frac{\phi_i}{2}\left(\frac{H_{i,g,t}}{H_{i,b,t}} - \frac{H_{i,g,t-1}}{H_{i,b,t-1}}\right)^2, i = \{f, m\}.$$

The household's budget constraint in turn is defined by:

$$C_{i,b,t} + P_{g,t}C_{i,g,t} \leq (1-\omega)W_{i,g,t}H_{i,g,t} + (1-\omega)W_{i,b,t}H_{i,b,t} + T_{i,t} - \frac{\phi_i}{2}\left(\frac{H_{i,g,t}}{H_{i,b,t}} - \frac{H_{i,g,t-1}}{H_{i,b,t-1}}\right)^2 \tag{3.5}$$

where $T_{i,t}$ denotes lump-sum transfer, $W_{i,j,t}, i = \{f, m\}, j = \{g, b\}$ wages of female and male workers in green and brown sectors, respectively. $P_{g,t}$ is the relative price of green goods, ω is the pay-roll tax rates in green and brown sectors.

The representative consumer chooses $\{C_{i,j,t}\}, i = \{f, m\}, j = \{g, b\}$ and $H_{i,t}, i = \{f, m\}$ to maximize its lifetime utility function subject to the capital accumulation equation and the budget constraint. The solution to this optimization problem gives the following first order conditions:

$$\begin{aligned}
P_{g,t}\lambda_{i,t} &= \mu_{i,c}^{1/\epsilon_{i,c}} C_{i,t}^{1/\epsilon_{i,c}-\gamma} C_{i,g,t}^{-1/\epsilon_{i,c}} && (3.6)\\
\lambda_{i,t} &= (1-\mu_{i,c})^{1/\epsilon_{i,c}} C_{i,t}^{1/\epsilon_{i,c}-\gamma} C_{i,b,t}^{-1/\epsilon_{i,c}} && (3.7)\\
\lambda_{i,t}(1-\omega)W_{i,g,t} &= \chi_i H_{i,t}^{\sigma} + \phi_i[\lambda_t(\frac{H_{i,g,t}}{H_{i,b,t}} - \frac{H_{i,g,t-1}}{H_{i,b,t-1}}) - \beta\lambda_{t+1}(\frac{H_{i,g,t+1}}{H_{i,b,t+1}} - \frac{H_{i,g,t}}{H_{i,b,t}})]\frac{1}{H_{i,b,t}} && (3.8)\\
\lambda_{i,t}(1-\omega)W_{i,b,t} &= \chi_i H_{i,t}^{\sigma} - \phi_i[\lambda_t(\frac{H_{i,g,t}}{H_{i,b,t}} - \frac{H_{i,g,t-1}}{H_{i,b,t-1}}) - \beta\lambda_{t+1}(\frac{H_{i,g,t+1}}{H_{i,b,t+1}} - \frac{H_{i,g,t}}{H_{i,b,t}})]\frac{H_{i,g,t}}{H_{i,b,t}^2} && (3.9)
\end{aligned}$$

The consumption of green and brown goods are thus:

$$C_{g,t} = C_{f,g,t} + C_{m,g,t}, \tag{3.10}$$

$$C_{b,t} = C_{f,b,t} + C_{m,b,t}. \tag{3.11}$$

3.2 Sectors

In this section we describe the behavior of firms within the green and brown sectors, respectively. For firms, female and male labor are not perfectly substitutable, and labor in different sectors $j = \{g, b\}$ are CES integrations of female and male workers:

$$H_{j,t} = \left(\mu_{f,j,h}^{1/\epsilon_{j,h}} H_{f,j,t}^{\left(\epsilon_{j,h}-1\right)/\epsilon_{j,h}} + (1-\mu_{f,j,h})^{1/\epsilon_{j,h}} H_{m,j,t}^{\left(\epsilon_{j,h}-1\right)/\epsilon_{j,h}} \right)^{\epsilon_{j,h}/\left(\epsilon_{j,h}-1\right)} \tag{3.12}$$

where $\mu_{f,j,h}$ is the proportion of female workers in sector j, and $\epsilon_{j,h}$ is the elasticity of substitution between female and male workers.

3.2.1 The Green sector

The green sector uses CES production function using female and male labor as inputs:

$$Y_{g,t} = A_{g,t} H_{g,t}, \tag{3.13}$$

where the labor $H_{g,t}$ is used by firms to produce green goods. The technology $A_{g,t}$ is specific to the green sector and is assumed to follow a stochastic process.

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

In this part, we choose not to add damage function in the productivity of the green sector for the sake of simplicity.

The green firm maximizes its profit:

$$\max_{H_{f,g,t}, H_{m,g,t}} P_{g,t} Y_{g,t} - (W_{f,g,t} - \epsilon_{lcs,t}) H_{f,g,t} - (W_{m,g,t} - \epsilon_{lcs,t}) H_{m,g,t} \tag{3.14}$$

where $\epsilon_{lcs,t}$ represents the labor cost subsidy from the government for green firms.

The first order condition of the maximization problem is:

$$W_{f,g,t} - \epsilon_{lcs,t} = P_{g,t} A_{g,t} \mu_{f,g,h}^{\frac{1}{\epsilon_{g,h}}} H_{g,t}^{\frac{1}{\epsilon_{g,h}}} H_{f,g,t}^{-\frac{1}{\epsilon_{g,h}}} \tag{3.15}$$

$$W_{m,g,t} - \epsilon_{lcs,t} = P_{g,t} A_{g,t} (1 - \mu_{f,g,h})^{\frac{1}{\epsilon_{g,h}}} H_{g,t}^{\frac{1}{\epsilon_{g,h}}} H_{m,g,t}^{-\frac{1}{\epsilon_{g,h}}} \tag{3.16}$$

3.2.2 The Brown sector

The output produced in the brown sector follows the CES production function using female and male labor as inputs:

$$Y_{b,t} = A_{b,t} H_{b,t}, \tag{3.17}$$

where the labor $H_{b,t}$ is used by firms to produce 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:

$$\log(a_{b,t}) = (1 - \rho_{a_b}) \log(a_b) + \rho_{a_b} \log(a_{b,t-1}) + \epsilon_{a_{b,t}}, \tag{3.18}$$

As in Heutel (2012), we assume that the pollution caused by firms affects negatively the 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[4] with x_t

[4]For the reason of simplicity, we assume that there is no damage function in the green sector, as in Benkhodja et al. (2023).

the emission stock. The latter evolves according to the last period level of pollution stock x_{t-1}, the current period domestic emission e_t, and the rest of the world emission 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 of the abatement effort η_t

$$e_t = \varphi(1-\eta_t)Y_{b,t}, \tag{3.19}$$

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

$$\log(e_t^{row}) = (1-\rho_{e_t^{row}})\log(e^{row}) + \rho_{e_t^{row}}\log(e_{t-1}^{row}) + \epsilon_{e_t^{row}}. \tag{3.20}$$

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. It takes the following form:

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

with $\psi_1 > 0$ and $\psi_2 > 1$.

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 profit:

$$\max_{H_{f,b,t},H_{m,b,t},\eta_t} Y_{b,t} - Z_t - (\tau_{e,t} + \epsilon_{\tau_e,t})e_t - W_{f,b,t}H_{f,b,t} - W_{m,b,t}H_{m,b,t} \tag{3.21}$$

where $\epsilon_{\tau_e,t}$ is the carbon tax policy on the polluting sectors.

The first-order conditions of this maximization problem are given by:

$$W_{f,b,t} = A_{b,t}[1-\psi_1{\eta_t}^{\psi_2} - (\tau_{e,t}+\epsilon_{\tau_e,t})\varphi(1-\eta_t)]\mu_{f,b,h}^{\frac{1}{\epsilon_{b,h}}} H_{b,t}^{\frac{1}{\epsilon_{b,h}}} H_{f,b,t}^{-\frac{1}{\epsilon_{b,h}}} \tag{3.22}$$

$$W_{m,b,t} = A_{b,t}[1-\psi_1{\eta_t}^{\psi_2} - (\tau_{e,t}+\epsilon_{\tau_e,t})\varphi(1-\eta_t)](1-\mu_{f,b,h})^{\frac{1}{\epsilon_{b,h}}} H_{b,t}^{\frac{1}{\epsilon_{b,h}}} H_{m,b,t}^{-\frac{1}{\epsilon_{b,h}}} \tag{3.23}$$

$$\eta_t = \left[\frac{(\tau_{e,t}+\epsilon_{\tau_e,t})\varphi}{\psi_1\psi_2}\right]^{\frac{1}{\psi_2-1}} \tag{3.24}$$

3.3 Public sector

The budget constraint of the public sector is given by:

$$T_t + \epsilon_{lcs,t}\sum_{i=f,m} H_{i,g,t} = (\tau_{e,t}+\epsilon_{\tau_e,t})e_t + \omega \sum_{i=f,m;j=g,b} W_{i,j,t}H_{i,j,t}. \tag{3.25}$$

For government transfer, the total transfer equals to:

$$T_t = T_{f,t} + T_{m,t}. \tag{3.26}$$

We also assume that the lump-sum transfers to female and male consumers are identical , i.e.

$$T_{f,t} = T_t/2. \tag{3.27}$$

3.4 Market Clearing and Resource Constraint

In equilibrium, we have market clearing in the green goods market:

$$Y_{g,t} = C_{g,t} \tag{3.28}$$

and the total resource constraint :

$$P_{g,t}Y_{g,t} + Y_{b,t} = P_{g,t}C_{g,t} + C_{b,t} + Z_t + \sum_{i=f,m}\frac{\phi_i}{2}(\frac{H_{i,g,t}}{H_{i,b,t}} + \frac{H_{i,g,t-1}}{H_{i,b,t-1}})^2 \tag{3.29}$$

4 Calibration

In this section, 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 the French quarterly data. France has been particularly active over the last 20 years in the fight against global warming and in promoting the transition to a green economy. Indeed, especially since the organization of COP21, the promulgation of the law on energy transition for green growth in 2015, up to the very recent law on energy and climate adopted in 2019, the French economy is one of the most promising in the development of the organic market.

Also, given our research topic on the effects of the ecological transition on female's participation in the labor market, France represents an interesting case for two main reasons: female's participation in the labor market is increasing and the gap with males is narrowing even if there is no parity yet. Indeed, according to INSEE, in 2018, female's participation reached 68.2% against 75.8% for men (data valid for the age group $15-64$). Also, females now have more higher education qualifications than men: in 2018, 51.2% of females aged 30 to 34 are in this category compared to only 41.0% of males in this age group. This last point may be relevant as the green labor market requires new skills and would probably be a source of future recruitment for females.

Table 1 lists the values of the 21 parameters of the baseline model. 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 intertemporal substitution of consumption γ is set to 0.5, following Gruber (2013). The inverse of the elasticity of the intertemporal substitution of labor σ is set at 2 (Chetty et al., 2011). We calibrate the parameter χ so that the total labor $H_t = 1/3$. According to AgenceBio, we set the weight of green goods in the female's consumption basket $\mu_{f,c}$ at 0.2 and the weight of green goods in the male's consumption basket $\mu_{m,c} = 0.1$[5].

[5]We have approximated here the percentage of the total female and male consumed organic products every day as a proportion of the total basket of both.

Male and female constant elasticity of substitution between different types of consumption goods $\epsilon_{m,c}$, and $\epsilon_{f,c}$ are set to 10 and 15, respectively, to capture the stylized fact that women are more responsive to purchasing green goods[6]. The payroll tax rates in all sectors, ω, is equal to 0.3.

Regarding the labor market, we set the value of the proportion of female workers in the brown sector $\mu_{f,b,h}$ at 0.24. As for the work of females in the green sector, the proportion $\mu_{f,g,h}$ is equal to 0.63 [7].

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 CO2 emissions.

The environmental parameters are calibrated following the related literature. As in Heutel (2012), damage function parameters d0, d1 and d2 are set respectively at 1.3950×10^{-3}, -6.6722×10^{-6} and 1.4647×10^{-8}. The decay rate of pollution δ_x is set at 0.0035 as in Carattini et al. (2021). The second technological parameter of abatement cost is set at $\psi_2 = 2.8$ following Annicchiarico and Di Dio (2015). We adjust the value of ψ_1 and the emission/output intensity parameter φ, so that the sectorial labor supply for female and male workers is close to the French data.

https://www.agencebio.org/wp-content/uploads/2022/03/Barometre-de-consommation-et-de-perception-des-produits-bio-Edition-2022_VF.pdf

[6]Report and statistics from AgenceBio, 2022. $https : //www.agencebio.org/wp - content/uploads/2022/03/Barometre - de - consommation - et - de - perception - des - produits - bio - Edition - 2022_V F.pdf$

[7]We calibrated the share of females in the brown and green sectors at 0.24 and 0.63 respectively. To do this, we used INSEE database, selecting the share of females' work in the high-polluting and low-polluting sectors in France. For the brown sector, we calculated the average share of females in the sectors considered to be the most polluting, namely Transport 25.8%, Agriculture 29.7%, Industry 28.5%, and Construction 11.1%, (sources: https://www.insee.fr/fr/statistiques/2015759, for the most polluting sectors and https://www.insee.fr/fr/statistiques/2015759, for the share of work in the brown sector). As for the low-polluting sectors, we have calculated the share of females' work in the sectors considered to be the cleanest, i.e. Accommodation and catering 49.3%, Education 68.5%, Public administration 53.6%, Services mainly to businesses 47.7%, Health 74.7%, Medical-social accommodation and social action 82.7%).

Table 1. Calibration of structural parameters

Description	Parameters	Values	Source
The subjective discount factor	β	0.997	steady state interest rate of 1.2%
The inverse of the elasticity of intertemporal substitution of consumption	γ	0.5	Gruber (2013)
The inverse of the wage elasticity of labor supply	σ	2	Chetty et al. (2011)
The weight of labor in households' utility function	χ	61.67	steady state labor supply intensity of 0.33
The weight of green goods in the female's consumption basket	$\mu_{f,c}$	0.2	French data
The weight of green goods in the male's consumption basket	$\mu_{m,c}$	0.1	French data
Male elasticity of substitution between different types of consumption goods	$\epsilon_{m,c}$	10	Author's assumption
Female elasticity of substitution between different types of consumption goods	$\epsilon_{f,c}$	15	Author's assumption
The payroll tax rates in green and brown sectors	ω	0.3	French data
Carbon tax rate	τ_e	0.009	Benkhodja et al. (2023)
The proportion of female workers in the green sector	$\mu_{f,g,h}$	0.63	French data
The proportion of female workers in the brown sector	$\mu_{f,b,h}$	0.24	French data
Constant elasticity of substitution between female/male labor in green sector	$\epsilon_{g,h}$	100	Author's assumption
Constant elasticity of substitution between female/male labor in brown sector	$\epsilon_{b,h}$	100	Author's assumption
The level of emissions per unit of production	φ	0.002	Author's calibration
First technological parameter of abatement cost	ψ_1	0.002	Author's calibration
Second technological parameters of abatement cost	ψ_2	2.8	Annicchiarico and Di Dio (2015)
Constant in damage function	d_0	1.3950×10^{-3}	Heutel (2012)
Linear term in damage function	d_1	-6.6722×10^{-6}	Heutel (2012)
Quadratic term in damage function	d_2	1.4647×10^{-8}	Heutel (2012)
The pollution depreciation rate	δ_x	0.0035	Carattini et al. (2021)
Labor mobility costs for females	ϕ_f	0.01	Author's assumption
Labor mobility costs for males	ϕ_m	0.01	Author's assumption

5 Simulation

We proceed to simulate the effects of the technological and policy shocks to evaluate whether they can impact gender income inequality. To this end, we assume that each scenario is characterized by quasi-permanent shocks. This is motivated by (i) that green technological shocks, such as climate-friendly innovations, are likely to be permanent. (ii) The policy amendments that follow from the Paris agreement require that green policies are in place for a long time. (iii) The persistence of shocks matter for the substitution vs. wealth effects of green policies. Specifically, we study the following four different shocks to the calibrated economy:

1. A +0.01% quasi-permanent shock on the productivity in green sector

2. A +0.01% quasi-permanent shock on the productivity in conventional brown sector

3. A +0.01% quasi-permanent shock on the carbon tax

4. A +0.01% quasi-permanent shock on the subsidy for labor cost in green sector

To capture quasi-permanent shocks, for each scenario, we set the shock persistence parameter to 0.999. In our calibration, we recall that the differences between female and male are:

1. The percentage of green goods is higher in female consumer's consumption basket
2. By the authors' assumption, female consumer is more motivated and flexible to try a new green product, captured by a higher elasticity of substitution between green and brown goods [8]
3. In the French labor market, by the authors' estimation, there are more women working in the non-polluting sector, and more men in the conventionally polluting sector [9]
4. We assume that female and male workers have the same elacticity of substitution between a green and a brown job.

Figure 1 - 8 show the simulation results. All variables in the IRFs represent the percentage (%) deviation from their steady-state values.

First, Figure 1 and 2 show the simulation results of +0.01% quasi-permanent shock on the productivity in green sector. In Figure 2, we see that under green productivity shock, the production in green sector increases by 1%, which is highly due to the increase of labor force in the green sector. The IRFs related to the green sector is more sensitive than that of the brown sector, because in our calibration, the total production, i.e. GDP, is mainly composed by the conventional brown sector[10]. Because the basis of green sector is small, when there is a shock, the changes on percentage is relatively large compared to the brown sector.

With positive green TFP shock, the green sector produces more. Therefore, there is more supply of green goods in the market, and the relative price of green goods falls. Consumers thus

[8] For this point, we will do sensitivity analysis in the following session.

[9] We will do sensitivity analysis in the following session.

[10] For example, in the calibration, from the French data, in the market, the consumption of green goods is about 15% of the total consumption of consumers. In our calculated steady-state, the labor force in green sector is also 15% of the total labor force.

consume more green goods and less brown goods than before. As a result, the production of brown goods declines. Naturally, the brown sector recrutes less and labor in the brown sector falls. The green sector produces more thus recrutes more, therefore labor in the green sector increases. Since the brown sector produces less, the CO_2 emission falls.

In Figure 1, the IRFs illustrate gender differences. On the consumption side, when the relative price of green goods falls, because female consumers are more flexible and willing to shift to green products, the green consumption of women increases more than that of men. Then we come to the labor market, which is the most interesting dynamic and interaction between female and male agents. Due to the positive green TFP shock, wages for both men and women in the green sector increase. From our calibration, female labor is the majority in the green/non-polluting sector, therefore the marginal wage increase for women is higher than that of men (equation 3.16). This implies that there is a more important income effect for women than for men. In economic theory, when the wage increases, worker can purchase/enjoy more consumption and leisure, thus the working hours decrease. This is the income/wealth effect. On the other hand, when wage increases, leisure becomes more expensive, thus worker tends to reduce the time of leisure, i.e. to increase working hours. This is the substitution effect. In this scenario with positive green TFP shock, both female and male working hours increase in the green sector, indicating that substitution effect is dominant. In the green sector, our simulation also shows that the substitution effect is more prominent for men than for women, as men's working hours increase more than that of women. This is because that the income effect is more prominent for women, which neutralizes a part of the substitution effect.

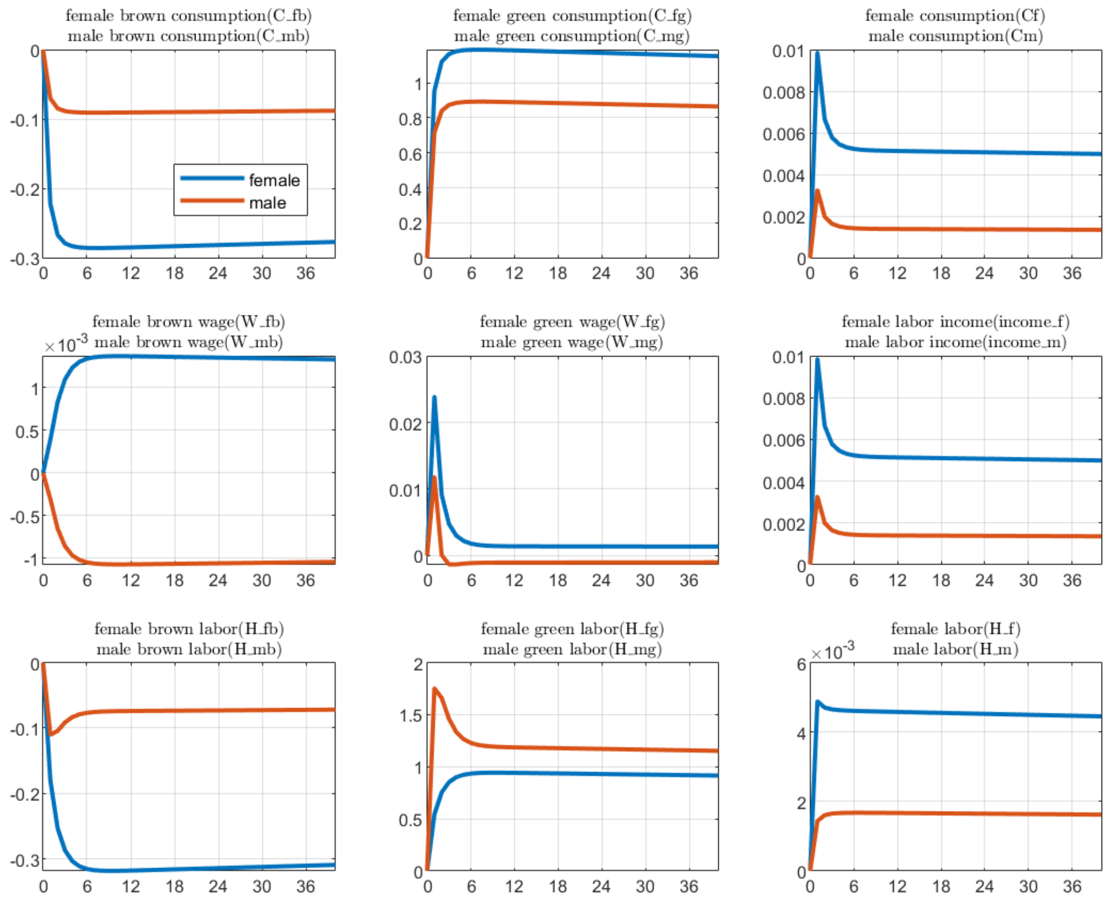

Figure 1: IRFs of +0.01% quasi-permanent green TFP shock - 1

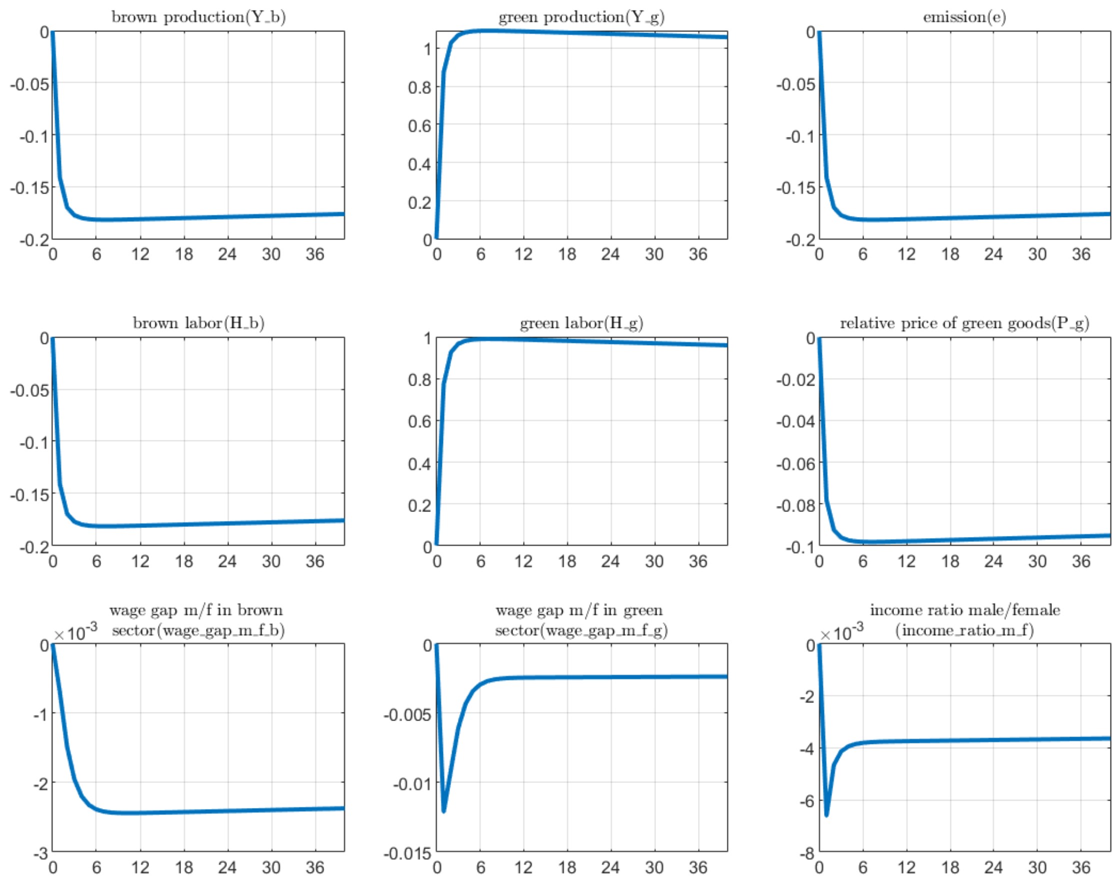

Figure 2: IRFs of +0.01% quasi-permanent green TFP shock - 2

In the brown sector, female labor decreases more than that of male labor, because more female labor force leave the brown sector to work in the green sector. Since there is a lack of female labor in the brown sector, this labor supply effect becomes dominant, thus wage for female worker increases instead of decreasing. For male worker, the labor demand effect is dominant, i.e. since the brown sector is shrinking, firms recrute less and the wage of male worker decreases. In general, both female and male labor force increase, with female labor force increases more than that of male worker. The general female income level increases more that the male income level. Then we can come back to Figure 2, the income ratio between male and female falls. The wage gap (wage ratio) between male and female decreases in both green and brown sectors. To conclude, the income ratio between men and women decreases when there is positive green productivity shock.

Then, Figure 3 and 4 show the simulation results of +0.01% quasi-permanent shock on the productivity in brown sector. In Figure 4, we see that under brown productivity shock, the production in brown sector increases by 0.3%, which is highly due to the increase of labor force in the brown sector. With positive brown TFP shock, the brown sector produces more. Therefore, there is more supply of brown goods in the market, and the relative price of green goods rises. Consumers thus consume more brown goods and less green goods than before. As a result, the production of green goods declines. Naturally, the green sector recrutes less and labor in the green sector falls. The brown sector produces more thus recrutes more, therefore labor in the brown sector increases. Since the brown sector produces more, the CO_2 emission increases.

In Figure 3, the IRFs illustrate gender differences. On the consumption side, when the relative price of green goods increases, in our assumption, female is more flexible to substitute between green and brown goods[11], the green consumption of women decreases more than that of men. Then we come to the labor market, due to the positive brown TFP shock, wages for both men and women in the brown sector increase. From our calibration, male labor is the majority in the brown/polluting sector, therefore the marginal wage increase for men is higher than that of women (equation 3.24). This implies that there is a more important income effect for men than for women. In this scenario with positive brown TFP shock, both female and male working hours increase in the brown sector, indicating that substitution effect is dominant. Our simulation also shows that the substitution effect is more prominent for women than for men, as women's working hours increase more than that of men. This is because that the income effect is more prominent for men, which neutralizes a part of the substitution effect.

[11] For this assumption, we will do sensitivity test in the coming session.

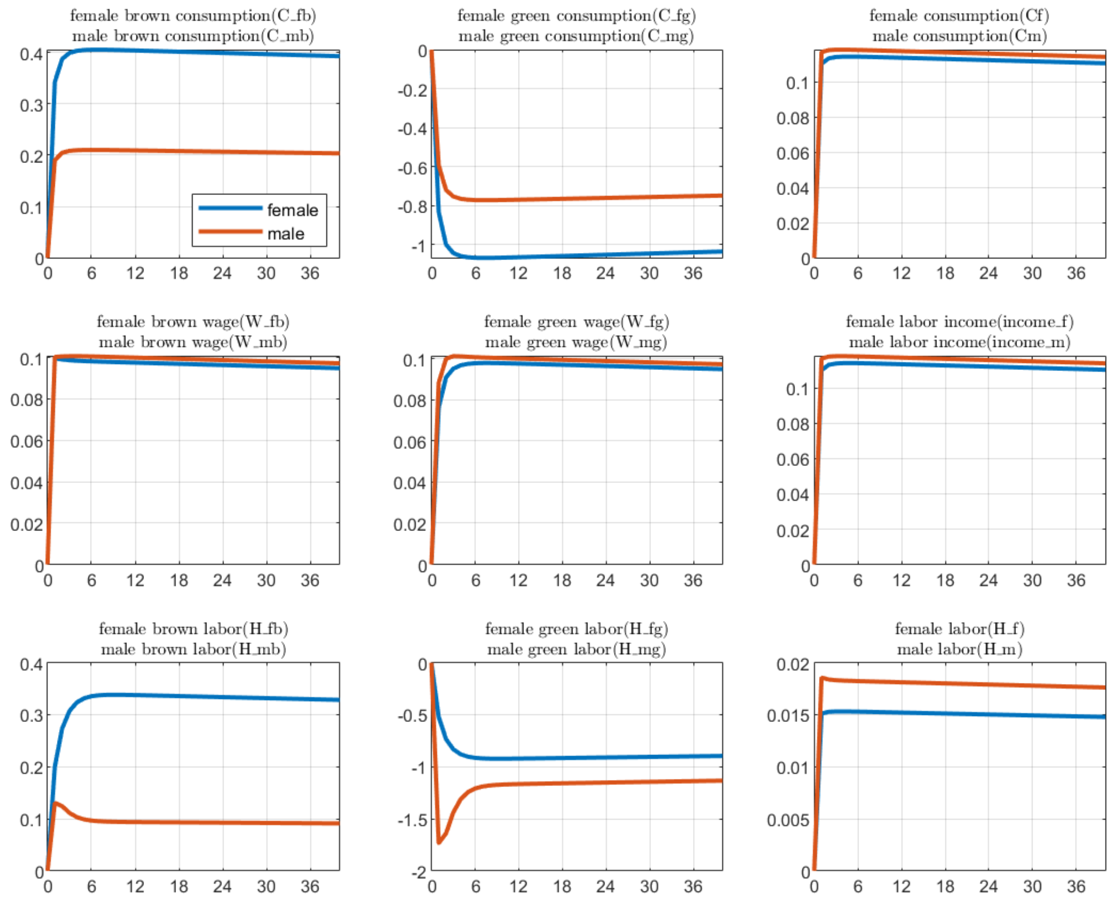

Figure 3: IRFs of +0.01% quasi-permanent brown TFP shock - 1

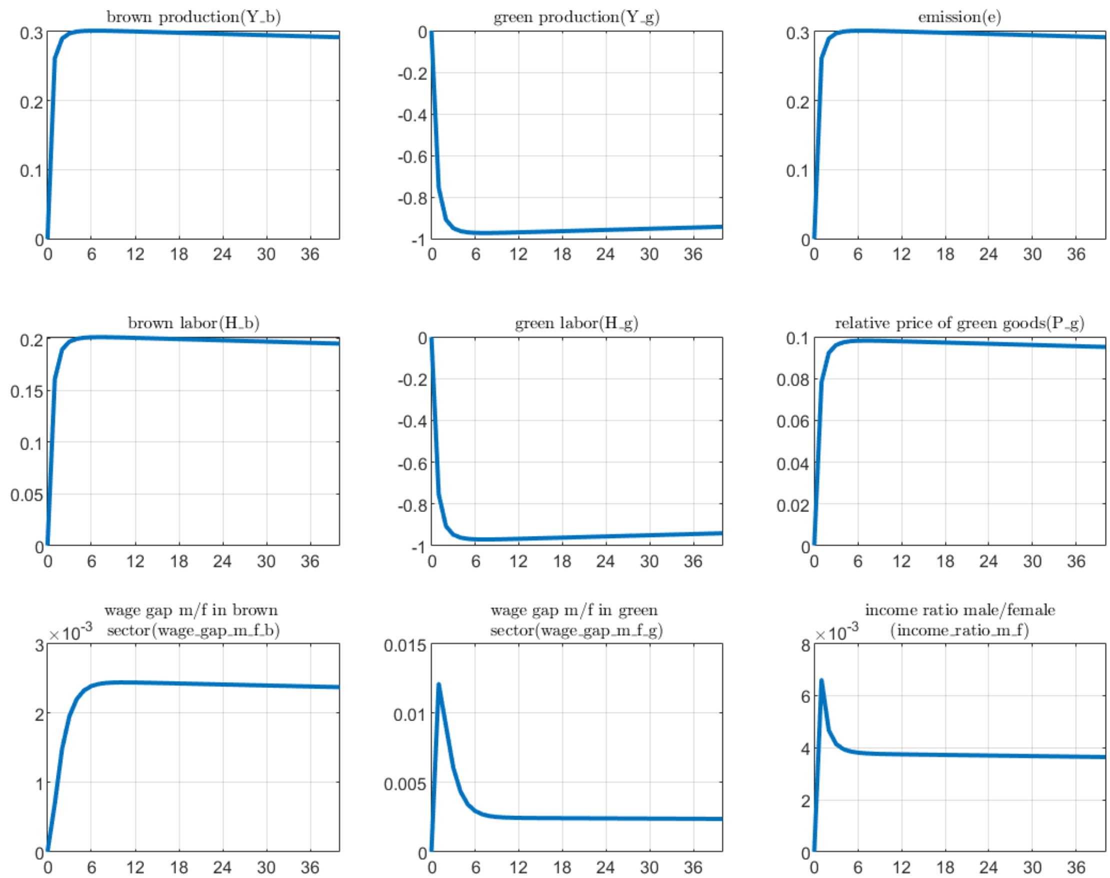

Figure 4: IRFs of +0.01% quasi-permanent brown TFP shock - 2

In the green sector, male labor decreases more than that of female labor, because more male labor force leave the green sector to work in the brown sector. Since there is a lack of male labor in the green sector, this labor supply effect becomes dominant, thus wage for male worker increases instead of decreasing. For female worker, the labor supply effect is also dominant, i.e. the wage of female worker increases, but slightly less than that of male worker. In general, both female and male labor force increase, with male labor force increases more than that of female worker. The general male income level increases slightly more that the female income level. Then we can come back to Figure 4, the income ratio between male and female rises. The wage gap (wage ratio) between male and female increases in both green and brown sectors. To conclude, the income ratio between men and women increases when there is positive brown productivity shock.

Next, Figure 5 and 6 show the simulation results of +0.01% quasi-permanent shock on the carbon tax in the brown sector. In Figure 6, we see that under the carbon tax shock, the production of brown sector decreases by 0.2%, which is highly due to the decrease of labor force in the brown sector.

With positive carbon tax shock, the brown sector produces less. Therefore, there is less supply of brown goods in the market, brown goods become more expensive and the relative price of green goods falls. There is relatively more demand for green goods from the consumers, and the green production increases. The brown sector recrutes less and labor in the brown sector falls. The green sector produces more thus recrutes more, therefore labor in the green sector increases. Since the brown sector produces less, the CO_2 emission falls.

In Figure 5, the IRFs illustrate gender differences. On the consumption side, when the relative price of green goods falls, because female consumers are more flexible and willing to shift to green products, the green consumption of women increases more than that of men. For the labor market, because green firms produce more, there is more demand of labor from green firms. Therefore, wages for both men and women in the green sector increase. In our simulation, men and women move from brown sector to green sector, and the labor supply effect for male worker is more prominent than that of female worker. This is why the marginal wage increase for men is smaller than that of women. This implies that there is a more important income effect for women than for men. In this scenario with positive green carbon tax shock, both female and male working hours increase in the green sector, indicating that substitution effect is dominant. Our simulation also shows that the substitution effect is more important for men than for women, as men's working hours increase more than that of women. This is because that the income effect is more prominent for women, which neutralizes a part of the substitution effect.

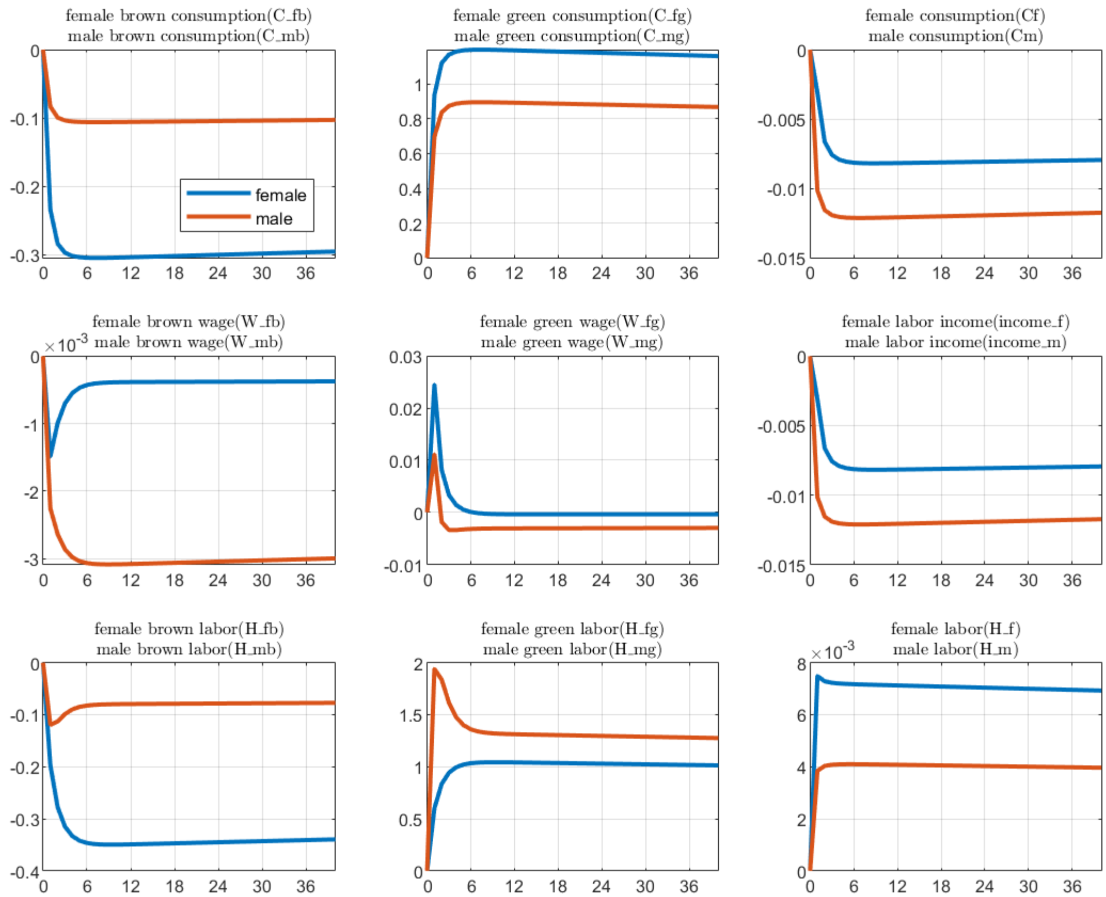

Figure 5: IRFs of +0.01% quasi-permanent carbon tax shock- 1

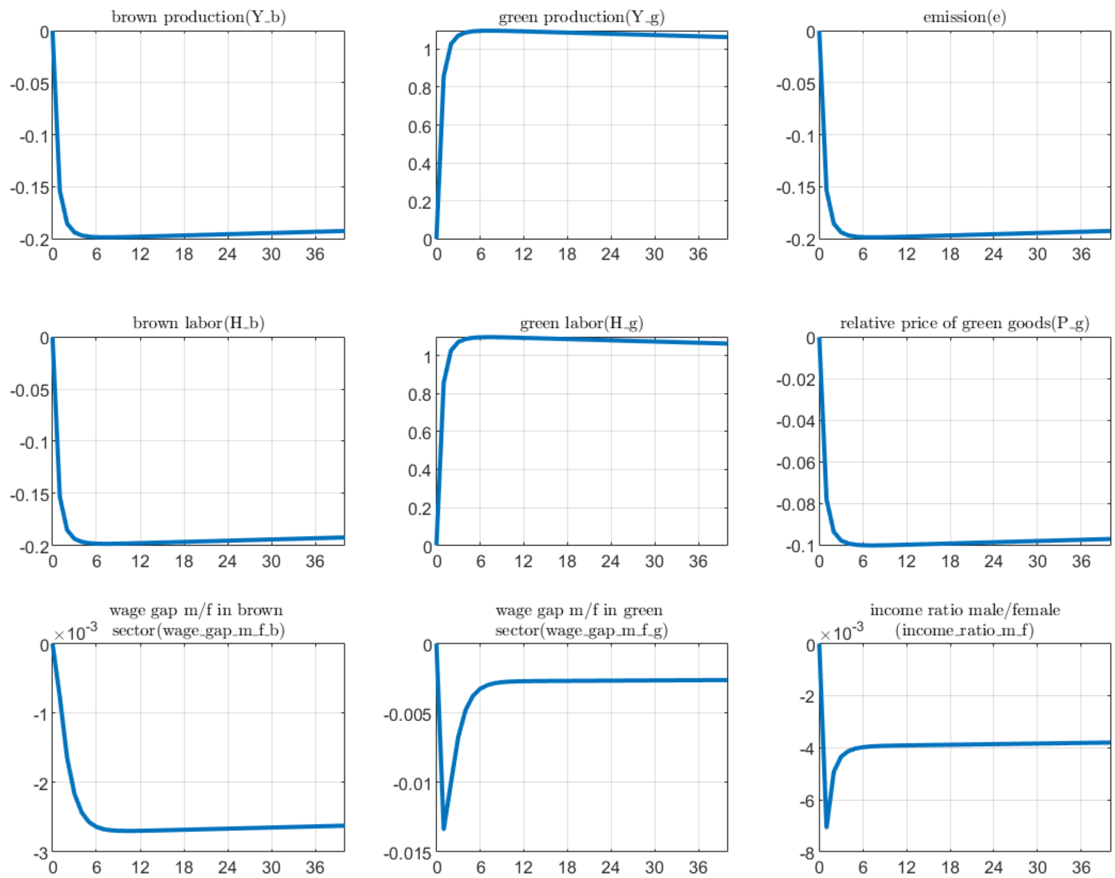

Figure 6: IRFs of +0.01% quasi-permanent carbon tax shock - 2

In the brown sector, female labor decreases more than that of male labor, because more female labor force leave the brown sector to work in the green sector. Since there is a relative lack of female labor in the brown sector, wage of female worker decreases less than that of male worker. In general, both female and male labor force increase, with female labor force increases more than that of male worker. The general female income level decreases less than the male income level. Then we can come back to Figure 6, the income ratio between male and female falls. The wage gap (wage ratio) between male and female decreases in both green and brown sectors. To conclude, the income ratio between men and women decreases when there is positive carbon tax shock.

Lastly, Figure 7 and 8 show the simulation results of +0.01% quasi-permanent shock on labor cost subsidy in the green sector. In other words, government subsidize green firms' labor cost. In Figure 8, we see that under the labor cost subsidy shock, the production of green sector increases by 1%, which is highly due to the increase of labor force in the green sector.

With positive labor cost subsidy shock, the green sector recrutes and produces more. Therefore, there is more supply of green goods in the market, green goods become cheaper and the relative price of green goods falls. There is relatively less demand for brown goods from the consumers, and the brown production falls. The brown sector recrutes less and labor in the brown sector falls. The green sector produces more thus recrutes more, therefore labor in the green sector increases. Since the brown sector produces less, the CO_2 emission falls.

In Figure 7, the IRFs illustrate gender differences. On the consumption side, when the relative price of green goods falls, because female consumers are more flexible and willing to shift to green products, the green consumption of women increases more than that of men. For the labor market, because green firms produce more, there is more demand of labor from green firms. Therefore, wages for both men and women in the green sector increase. In our simulation, men and women move from brown sector to green sector, and the labor supply effect for male worker is more prominent than that of female worker. This is why the marginal wage increase for men is smaller than that of women. This implies that there is a more important income effect for women than for men. In this scenario with positive labor cost subsidy shock, both female and male working hours increase in the green sector, indicating that substitution effect is dominant. Our simulation also shows that the substitution effect is more important for men than for women, as men's working hours increase more than that of women. This is because that the income effect is more prominent for women, which neutralizes a part of the substitution effect.

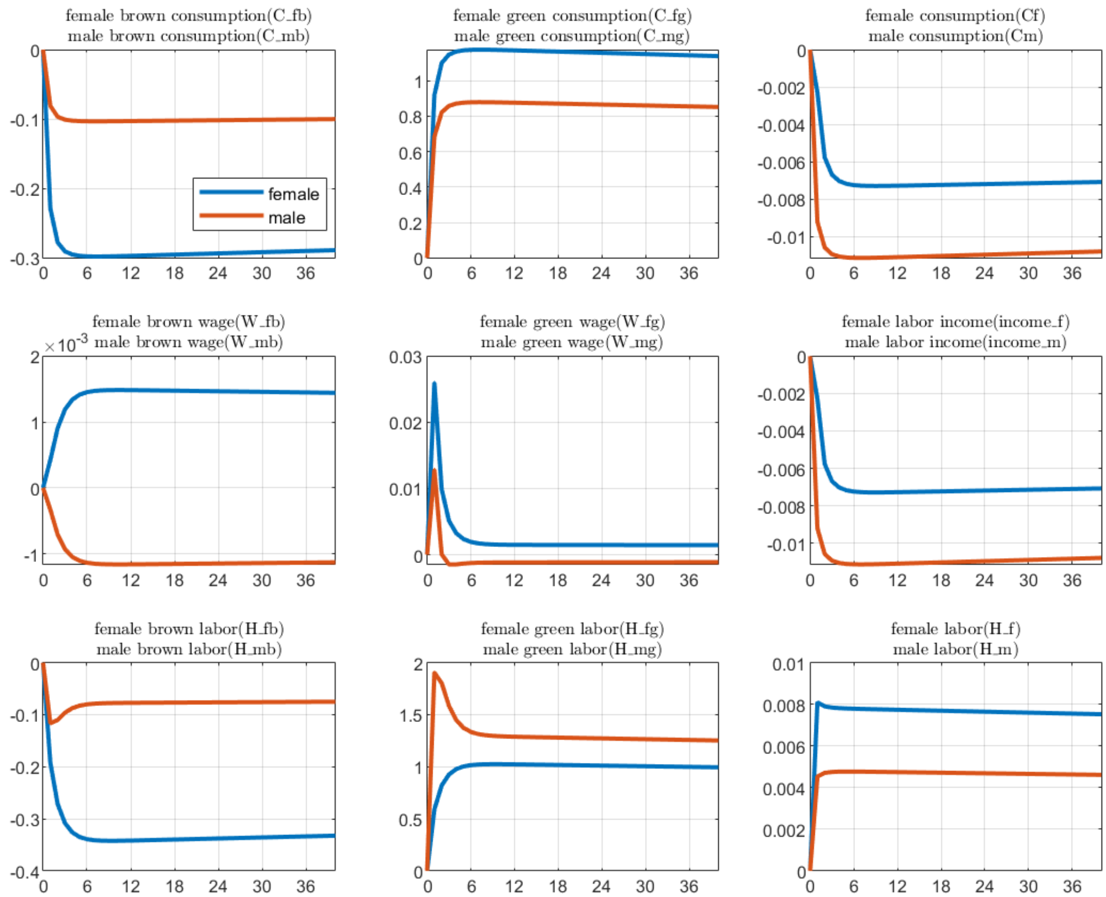

Figure 7: IRFs of +0.01% quasi-permanent labor cost subsidy for green firms - 1

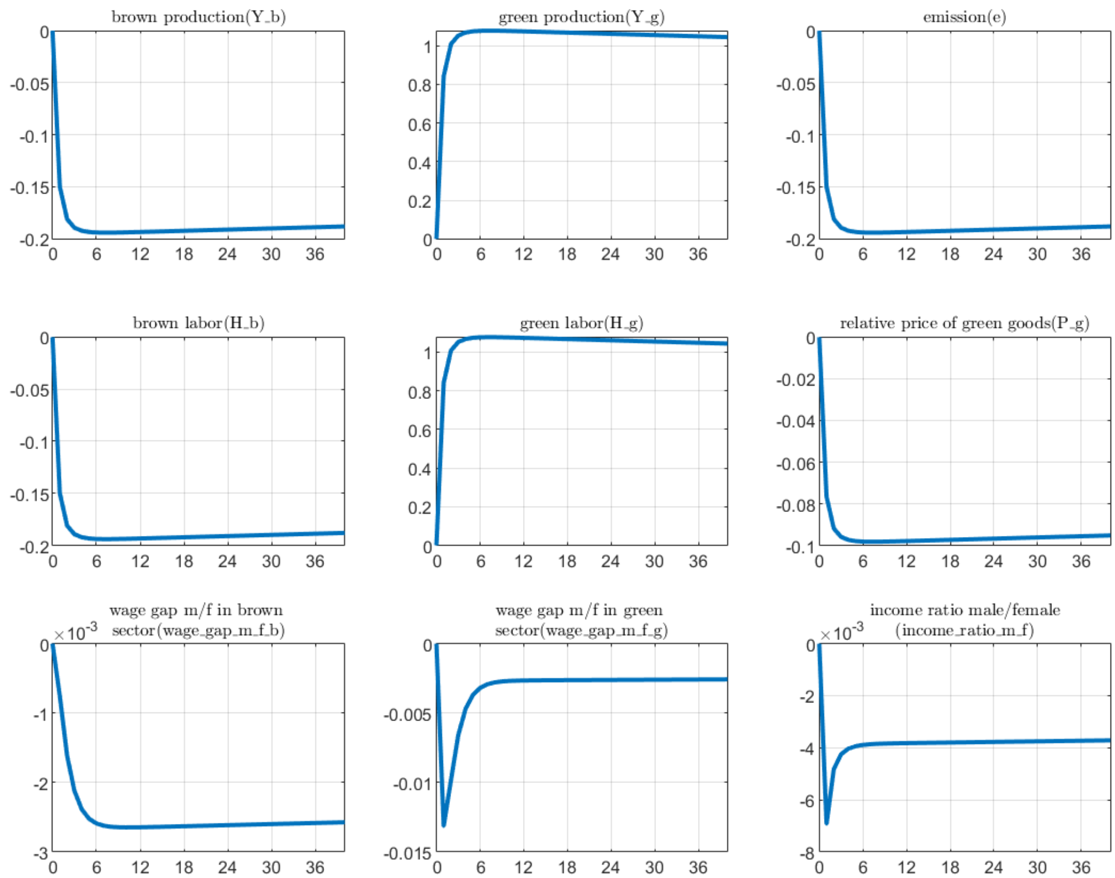

Figure 8: IRFs of +0.01% quasi-permanent labor cost subsidy for green firms - 2

In the brown sector, female labor decreases more than that of male labor, because more female labor force leave the brown sector to work in the green sector. Since there is a relative lack of female labor in the brown sector, wage of female worker increases instead of decreasing. Wage of male worker decreases because there is less labor demand from the brown firms. In general, both female and male labor force increase, with female labor force increases more than that of male worker. The general female income level decreases less than the male income level. Then we can come back to Figure 8, the income ratio between male and female falls. The wage gap (wage ratio) between male and female decreases in both green and brown sectors. To conclude, the income ratio between men and women decreases when there is positive labor cost subsidy shock.

All in all, we see that under green productivity shock, and environmental policies, income ratio between male and female workers fall.

5.1 Welfare Analysis

In this section, we simulate the welfare effects of sectoral productivity shocks, and environmental policies on female and male consumers. First, we propose a Business-As-Usual scenario (BAU), by assuming that the TFP growth in both green and brown sector is around 0.36%. This number comes from the average quarterly GDP growth in France from 1991 to 2024.

We calculate the welfare by the following equation:

$$WF_{i,t} = UT_{i,t} + \beta WF_{i,t+1}, i = \{f, m\}$$

where $UT_{i,t}$ is the utility function of female and male consumers:

$$UT_{i,t} = U_i\left(.\right) = \frac{C_{i,t}^{1-\gamma} - 1}{1-\gamma} - \chi \frac{H_{i,t}^{1+\sigma}}{1+\sigma}$$

Table 2 shows the results of the welfare analysis compared to BAU. We see that under positive TFP shock in green sector, a female consumer has more welfare gain than a male consumer. Under positive TFP shock in brown sector, a male consumer has more welfare gain than a female consumer. Under environmental fiscal policy shocks, i.e. carbon tax or labor cost subsidy for green firms, a female consumer also has slight welfare gain, while a male consumer has welfare loss.

Table 2: Welfare analysis with quasi-permanent shocks, % deviation from BAU

TFP shocks	welfare effects on female consumers,%	welfare effects on male consumers,%
+0.01% green TFP shock	+2.43	+1.05
+0.01% brown TFP shock	+7.61	+8.34
environmental policies	**welfare effects on female consumers,%**	**welfare effects on male consumers,%**
+0.01% carbon tax	+0.48	−1.27
+0.01% labor cost subsidy for green firms	+0.58	−0.81

Following a green TFP shock, female consumers record a 2.43% increase in welfare, indicating a substantial benefit from improved productivity in the green sector. In line with IRF results, this is explained by women's strong preference for green goods and their greater involvement in the green sector. Male consumers also benefit from a 1.05% increase in welfare, albeit less than that of women, which may be explained by the fact that, although positive, men's participation in the green sector is less than that of women.

After a brown TFP shock, female consumers see their welfare increase by 7.61%, suggesting that productivity gains in the brown sector are also significantly benefiting women, partly due to their involvement in the brown sector but also to their consumption habits related to this sector. Male consumers experience an 8.34% increase in welfare, which is higher than that for women, indicating beneficial effects but different impacts according to gender. The welfare effects of brown TFP shock is more influential than the green TFP shock, this is because brown sector is still the dominant sector in the economy.

The simulation of a carbon tax shock shows that the effects on a female consumer's welfare present a slight gain of 0.48%, and for male consumers, there is a welfare loss of -1.27%. Implementing a labor cost subsidy for green firms shows that female consumers experience a slight welfare gain of 0.58%, and male consumers face a welfare loss of -0.81%. This is because that fiscal policies, such as carbon tax and green labor subsidy, stimulate the growth of green sector, and reduce the production in brown sector. Female consumers have more preference to consumer green goods and has a larger proportion working in the green sector according to our calibration, therefore they benefit more from the environmental policy which offset the contractive effects in the brown sector.

Overall, from the welfare perspective, we see that green TFP shock and environmental policies benefit more female consumers than male consumers.

5.2 Sensitivity Analysis

Our simulation shows that ecological transition, remarked by green productivity growh or climate policies can reduce the income gap between male and female consumers/workers. How much of this result is due to different consumption preferences between women and men, i.e. women are more pro-green consumption ? How much of this result is due to the occupational preferences, i.e. there are more women working in the green/non-polluting sector in our calibration ? In this section, we try to do sensitivity test based on the consumption preference parameters, and labor parameters of female and male.

5.2.1 Sensitivity test on consumption preferences

In this part, we fix the labor parameters, and do the sensitivity test on consumption preference parameters, i.e. the weight of green goods in women's consumption basket $\mu_{f,c}$, and elasticity of substitution between green and brown goods ϵ_f. In this part, we fix the labor parameters, and do the sensitivity test on consumption preference parameters, i.e. the weight of green goods in women's consumption basket $\mu_{f,c}$, and elasticity of substitution between green and brown goods for women $\epsilon_{f,c}$.

5.2.1.1 Sensitivity test on weight of green consumption $\mu_{f,c}$

We first fix the value of other parameters, and only vary the weight of green consumption of the female consumer $\mu_{f,c}$. Figure 9 - 11 illustrate the results. They represent the gender income ratio between men and women under positive green TFP shock, carbon tax shock, and green labor subsidy, respectively. From the results, we see that the higher the proportion of green goods in female consumers' consumption basket, i.e. the value of parameter $\mu_{f,c}$ in our model, the more influence the green shock/environmental policies on gender income ratio.

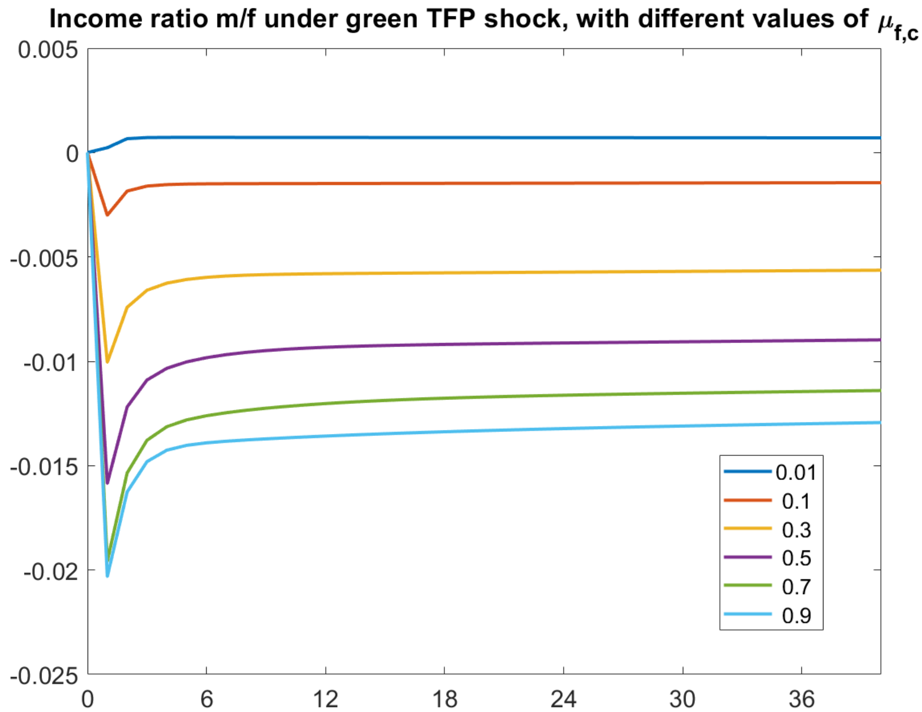

Figure 9: IRF of income ratio between male and female under +0.01% quasi-permanent green TFP shock, with different values of $\mu_{f,c}$

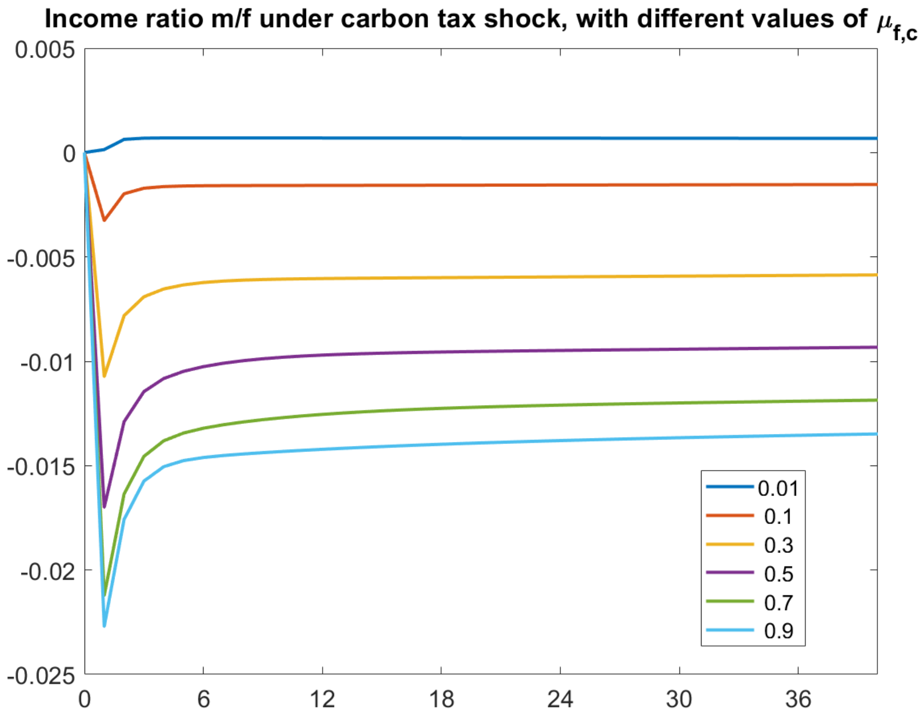

Figure 10: IRF of income ratio between male and female under +0.01% quasi-permanent carbon tax shock, with different values of $\mu_{f,c}$

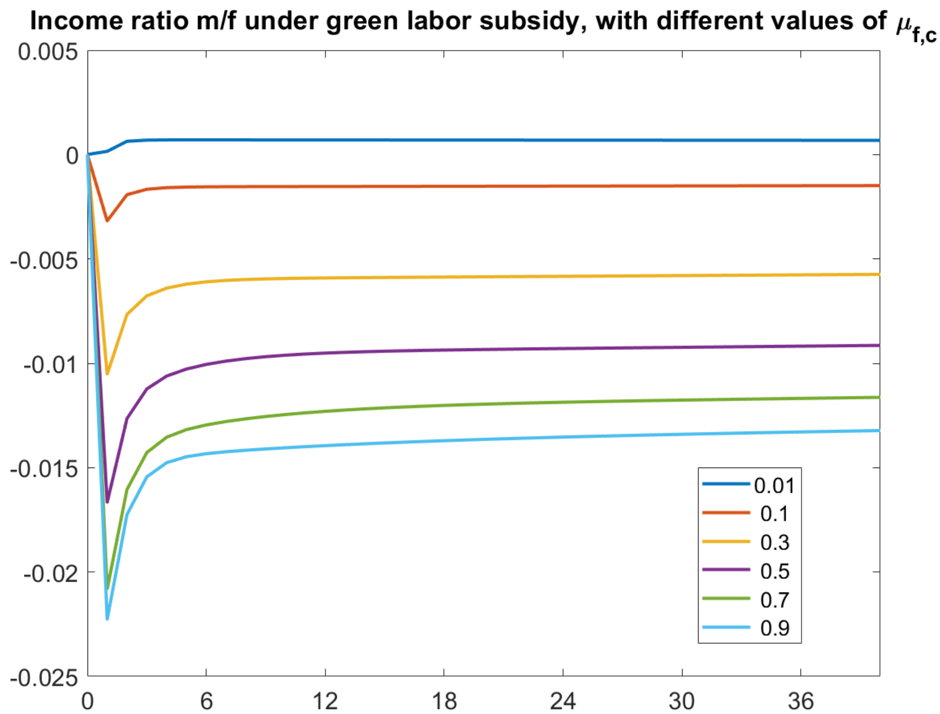

Figure 11: IRF of income ratio between male and female under +0.01% quasi-permanent green labor subsidy shock, with different values of $\mu_{f,c}$

5.2.1.2 Sensitivity test on elasticity of substitution between green and brown goods $\epsilon_{f,c}$

We then fix the value of other parameters, and only vary the elasticity of substitution between green and brown goods $\epsilon_{f,c}$ for women. Figure 12 - 14 illustrate the results. They represent the gender income ratio between men and women under positive green TFP shock, carbon tax shock, and green labor subsidy, respectively. From the results, we see that the higher the elasticity of substitution between green and brown goods for women, i.e. the value of parameter $\epsilon_{f,c}$ in our model, the more influence the green shock/environmental policies on gender income ratio. In other words, the higher the elasticity of substitution, the more women are willing to consume green goods when there is a green TFP shock, or an environmental policy which makes the price of green goods relatively cheaper.

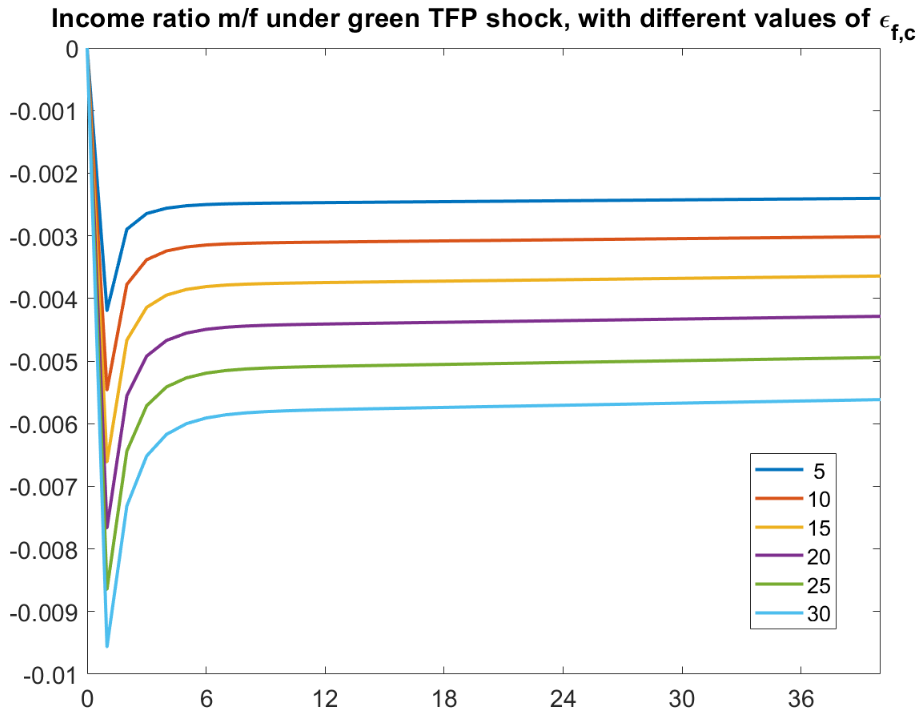

Figure 12: IRF of income ratio between male and female under +0.01% quasi-permanent green TFP shock, with different values of $\epsilon_{f,c}$

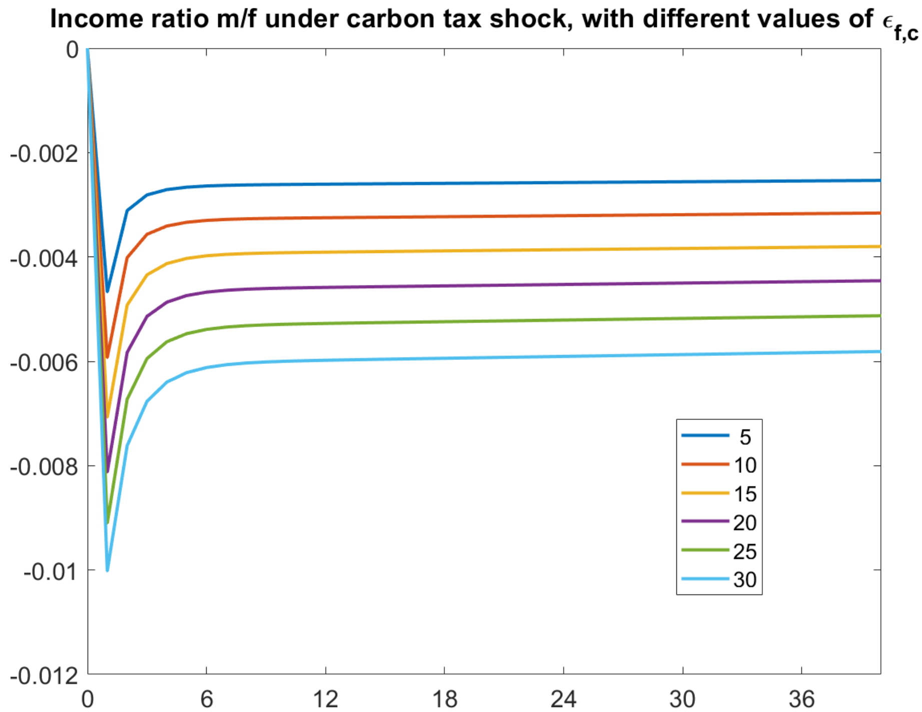

Figure 13: IRF of income ratio between male and female under +0.01% quasi-permanent carbon tax shock, with different values of $\epsilon_{f,c}$

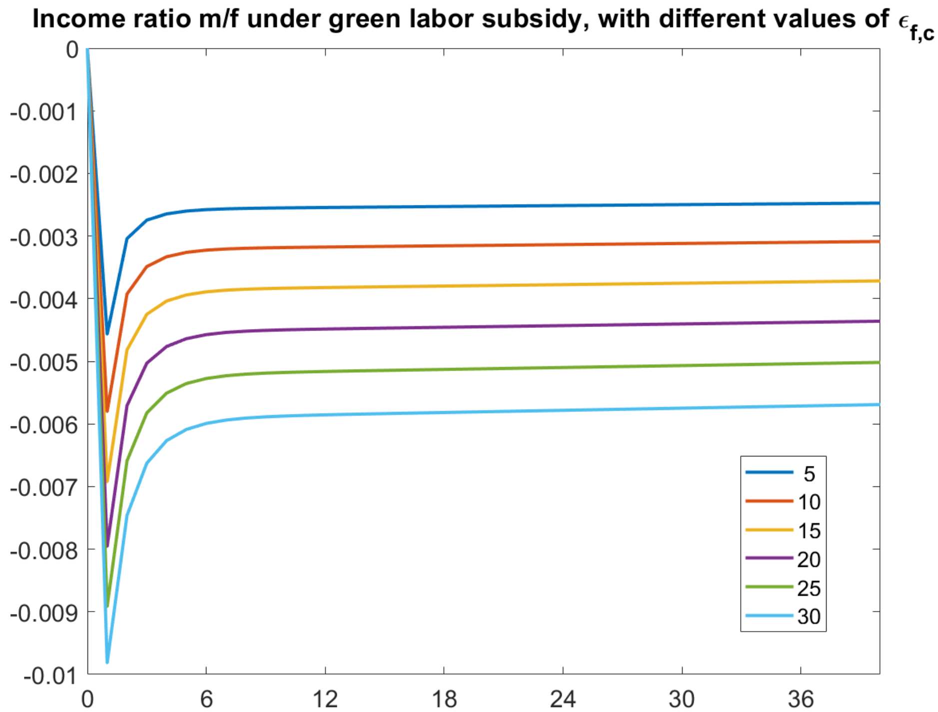

Figure 14: IRF of income ratio between male and female under +0.01% quasi-permanent green labor subsidy shock, with different values of $\epsilon_{f,c}$

5.2.2 Sensitivity test on firm's labor preferences

In this part, we fix the parameters on consumption, and do the sensitivity test on firm's labor preference parameters, i.e. the weight of female workers in green sector $\mu_{f,g,h}$, and elasticity of substitution between female and male workers in green sector $\epsilon_{g,h}$.

5.2.2.1 Sensitivity test on weight of female labor in the green sector $\mu_{f,g,h}$

As in the previous section, we first fix the value of other parameters, and only vary the proportion of female workers in green sector $\mu_{f,g,h}$. Figure 15 - 17 illustrate the results. They represent the gender income ratio between men and women under positive green TFP shock, carbon tax shock, and green labor subsidy, respectively. From the results, we see that the higher proportion of women workers in green sector, i.e. the value of parameter $\mu_{f,g,h}$, the more influence the green shock/environmental policies on gender income ratio. Intuitively, the higher the proportion of women working in green sector, when there is a positive TFP/policy shock on the green sector, the wage in this sector increases, i.e. women's average wage increases more than men's, thus reduces the income ratio between men and women.

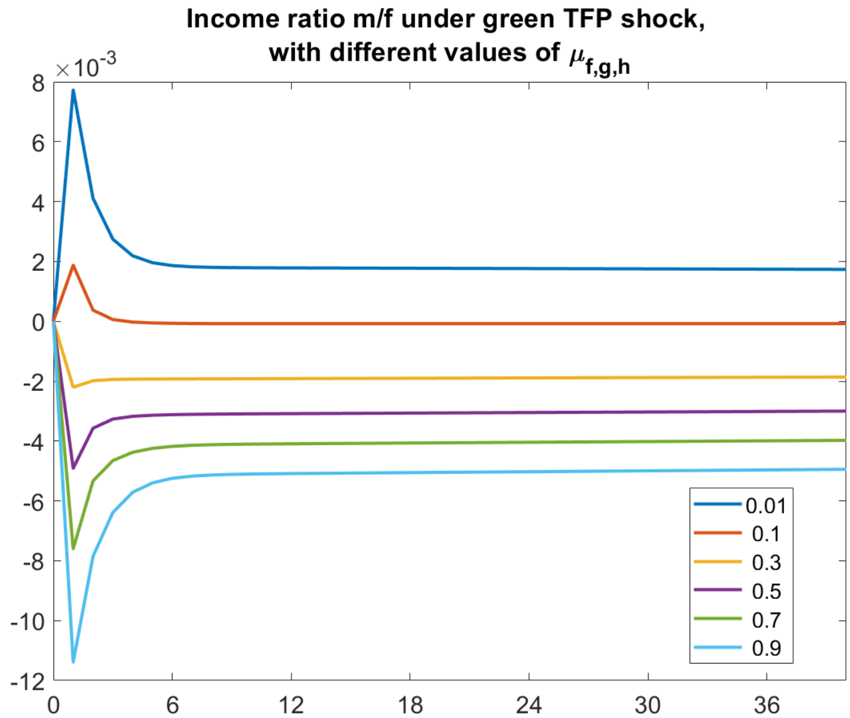

Figure 15: IRF of income ratio between male and female under +0.01% quasi-permanent green TFP shock, with different values of $\mu_{f,g,h}$

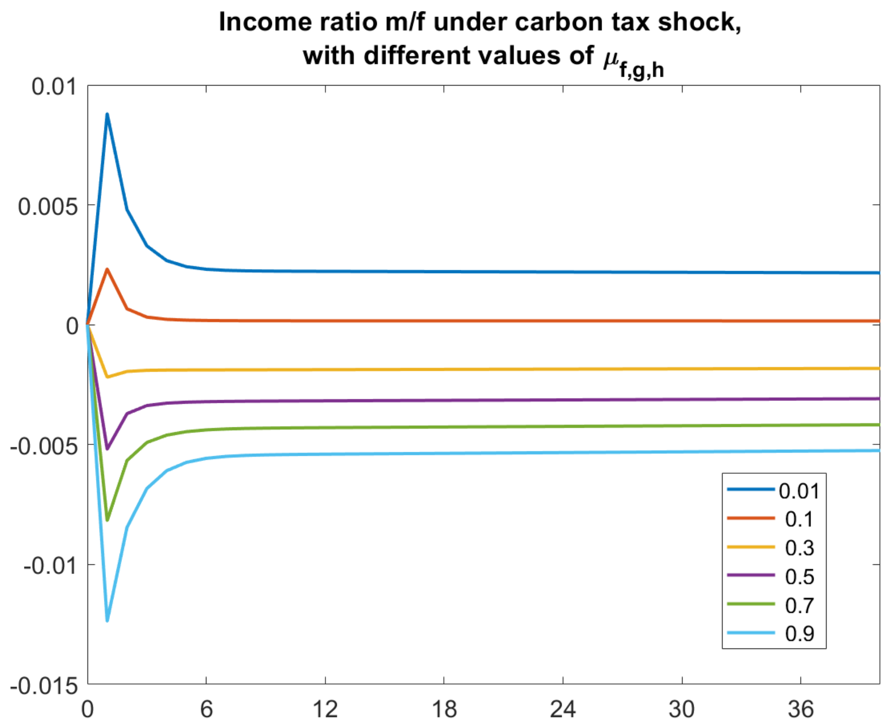

Figure 16: IRF of income ratio between male and female under +0.01% quasi-permanent carbon tax shock, with different values of $\mu_{f,g,h}$

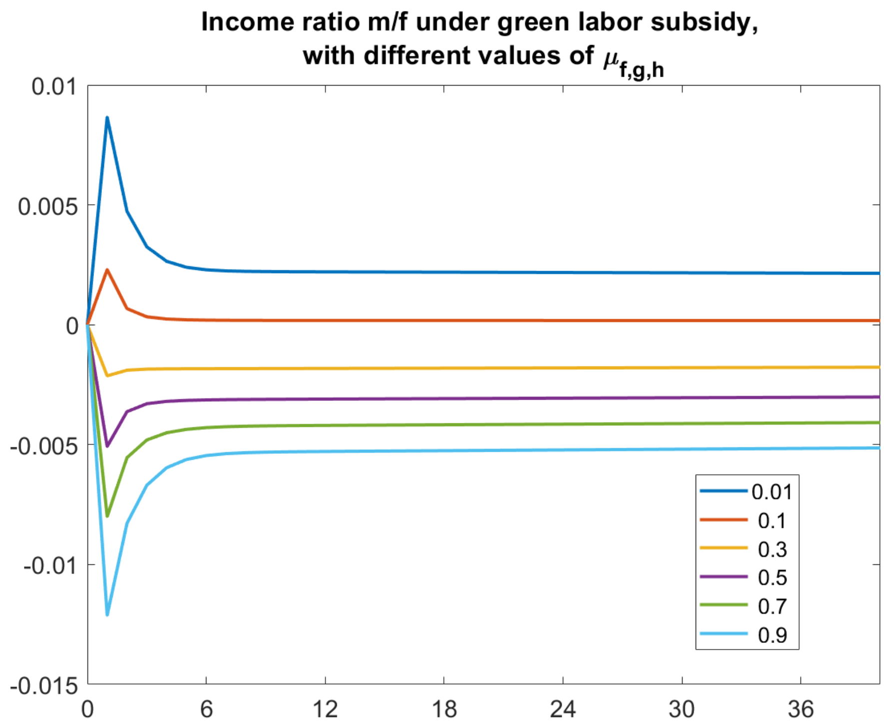

Figure 17: IRF of income ratio between male and female under +0.01% quasi-permanent green labor subsidy shock, with different values of $\mu_{f,g,h}$

5.2.2.2 Sensitivity test on the elasticity of substitution between female and male labors in the green sector $\epsilon_{g,h}$

We then fix the value of other parameters, and only vary the elasticity of substitution between men and women workers in green sector $\epsilon_{g,h}$. Figure 18 - 20 illustrate the results. They represent the gender income ratio between men and women under positive green TFP shock, carbon tax shock, and green labor subsidy, respectively. From the results, we see that the higher the elasticity of substitution between men and women labor in green sector, i.e. the value of parameter $\epsilon_{g,h}$ in our model, the more influence the green shock/environmental policies on gender income ratio. From equation 3.16, divide the second equation, F.O.C of men's wage in green sector by the first equation, we get :

$$\frac{W_{m,g,t} - \epsilon_{lcs,t}}{W_{f,g,t} - \epsilon_{lcs,t}} = \left(\frac{1-\mu_{f,g,h}}{\mu_{f,g,h}}\right)^{\frac{1}{\epsilon_{g,h}}} \left(\frac{H_{m,g,t}}{H_{f,g,t}}\right)^{-\frac{1}{\epsilon_{g,h}}} = \left(\frac{\frac{1-\mu_{f,g,h}}{\mu_{f,g,h}}}{\frac{H_{m,g,t}}{H_{f,g,t}}}\right)^{\frac{1}{\epsilon_{g,h}}} \tag{5.1}$$

From equation 5.1, we see that in green sector, the wage ratio of men and women depends on the value of $\epsilon_{g,h}$. If $\frac{\frac{1-\mu_{f,g,h}}{\mu_{f,g,h}}}{\frac{H_{m,g,t}}{H_{f,g,t}}} > 1$, then the higher the value of $\epsilon_{g,h}$, the lower the LHS,, i.e. the wage ratio between men and women in green sector. The reasoning is similar for wage ratio in brown sector.

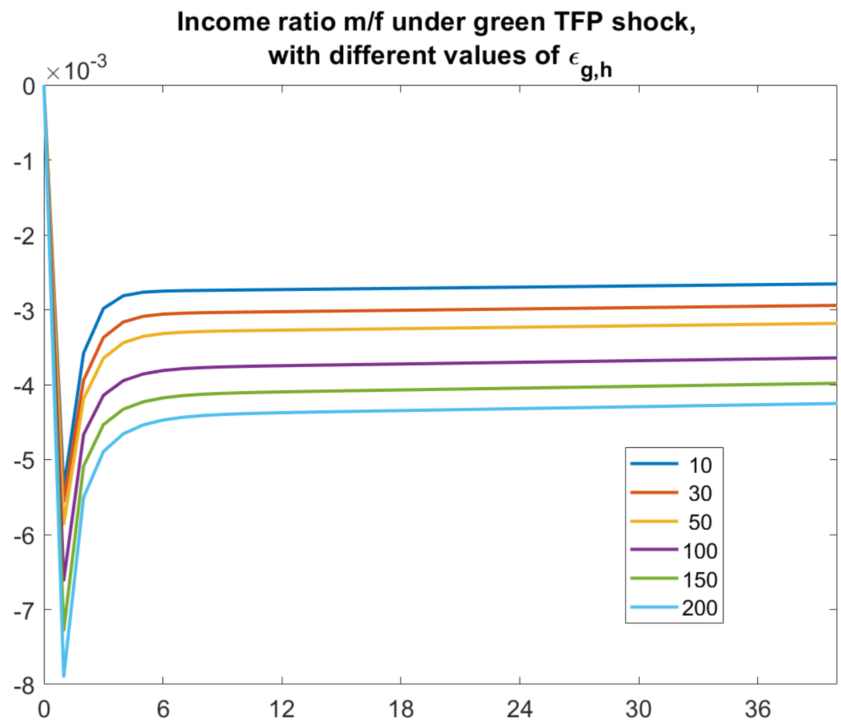

Figure 18: IRF of income ratio between male and female under +0.01% quasi-permanent green TFP shock, with different values of $\epsilon_{g,h}$

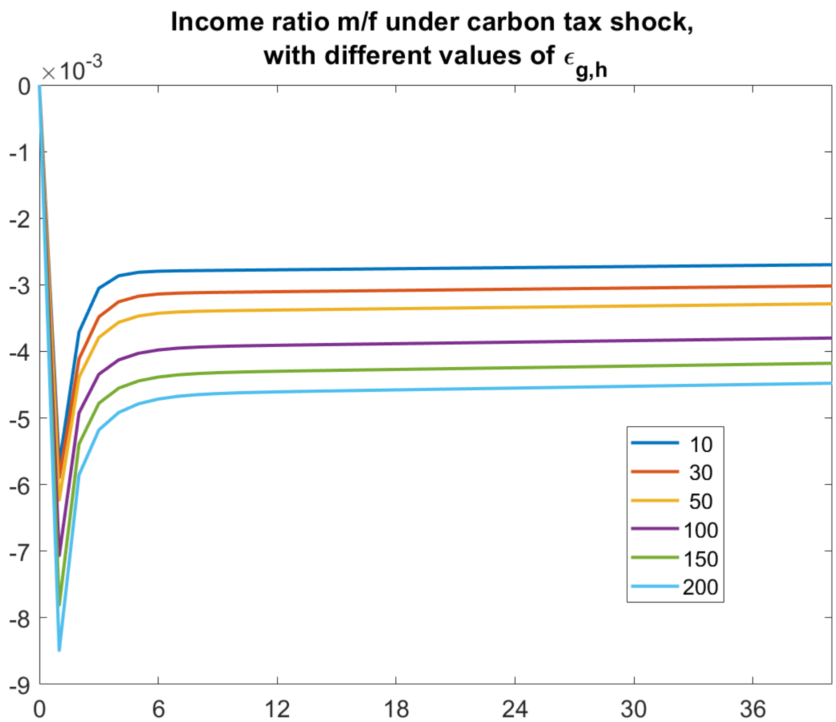

Figure 19: IRF of income ratio between male and female under +0.01% quasi-permanent carbon tax shock, with different values of $\epsilon_{g,h}$

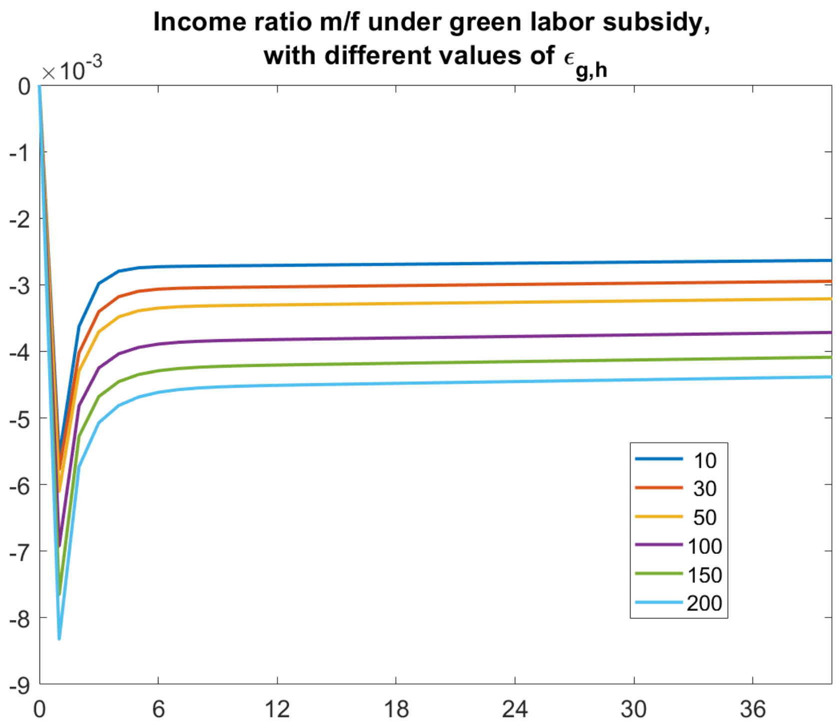

Figure 20: IRF of income ratio between male and female under +0.01% quasi-permanent green labor subsidy shock, with different values of $\epsilon_{g,h}$

6 Conclusion

It is well-known that climate policy can have distributive effects on the economy. While the literature has studied these effects in models with income heterogeneity, we argue that gender differences could also constitute a meaningful source of heterogeneity in this regard. One reason is that women, on average, are more prone to consume less carbon-intense goods, and also have a comparative advantage in the relatively less carbon-intense service sector, when compared to men. These observations suggest that the burden of climate policies, such as a carbon tax, is non-uniformly distributed between men and women. Consequently, gender inequality and climate policies likely affect each other.

The present paper introduces gender heterogeneity to an environmental dynamics stochastic general equilibrium (E-DSGE) model. In the model, men and women differ in their consumer preferences over carbon-intense "brown" goods, and carbon-neutral "green goods", as well as in their comparative advantage of working in these sectors.

We calibrate the model to the French economy and then carry out several numerical experiments relating to the effects of climate policies on the income ratio of male over female consumers. Our results highlight the complex interactions between environmental policies, sectoral shifts in the economy, and gender dynamics.

First, the positive TFP shock in the green sector illustrates how increasing productivity and demand for green goods can lead to beneficial shifts in the labor market and consumption patterns. This scenario highlights the importance of policies aimed at boosting green sector productivity, such as investments in green technologies and innovation. Not only does this benefit the environment, but it also has a significant positive impact on females' labor force participation, helping to reduce gender income inequality. Policies should therefore support skill development and education tailored towards sectors where females can have a comparative advantage, emphasizing the green economy.

Second, the implementation of a carbon tax effectively reduces CO2 emissions by shifting production and consumption towards greener alternatives. However, this policy also has different implications for the labor market and income levels. The reduction in demand for brown goods and the subsequent shift in labor demand towards the green sector, where females have a comparative advantage, suggests that carbon taxes can also contribute to lessening gender income inequality. This outcome highlights the need for carefully designed complementary policies, such as retraining programs for the brown sector workers and targeted support for low-income households to mitigate potential negative impacts on overall income levels.

Third, subsidizing labor costs for green firms is shown to effectively encourage sectoral growth and labor mobility, particularly benefiting female labor participation. This policy leads to increased green output and employment while shifting consumption towards greener goods. However, the reduction in overall consumption due to reduced lump-sum transfers indicates a trade-off between promoting green sector growth and maintaining overall consumption levels. Policymakers should consider balancing these subsidies with measures that support overall welfare, such as targeted income support or investment in public services that complement the green transition.

Fourth, the differential impacts of these policies on male and female labor participation and income highlights the importance of gender-sensitive policy design. Recognizing and leveraging the comparative advantage of female workers in the green sector can enhance the effectiveness of environmental policies while advancing gender equality. Policies to support females' participation in the workforce, such as flexible work arrangements, childcare support, would likely amplify the positive effects observed from our experiments.

Fifth, the interactions between environmental objectives, economic shifts, and gender dynamics call for a comprehensive policy framework. Such a framework should integrate environmental, economic, and social policies to maximize synergies and minimize trade-offs. For example, combining carbon taxes with subsidies for green technology and targeted support for displaced workers can help achieve environmental goals while promoting economic growth and gender equality.

These policy implications highlight the potential for environmental policies to contribute to sustainable development goals, including reducing emissions, fostering economic transformation towards green sectors, and advancing gender equality.

There are several avenues for future research. One would be to include capital markets to account for any heterogeneity in risk and investment behavior. While we can draw conclusions on the burden of climate policy based on the weight attached to different consumption goods, the inclusion of savings would enrich the policy propagation mechanism. Another avenue is to consider the role of heterogeneous labor mobility costs. How will climate policy affect income inequality if women face relatively higher costs of switching occupations?

References

Annicchiarico, B. and Di Dio, F. (2015). Environmental policy and macroeconomic dynamics in a new keynesian model. *Journal of Environmental Economics and Management*, 69:1–21.

Aragón, F. M., Rud, J. P., and Toews, G. (2018). Resource shocks, employment, and gender:

evidence from the collapse of the uk coal industry. *Labour Economics*, 52:54–67.

Arrow, K. J., Cropper, M. L., Eads, G. C., Hahn, R. W., Lave, L. B., Noll, R. G., Portney, P. R., Russell, M., Schmalensee, R., Smith, V. K., et al. (1996). Is there a role for benefit-cost analysis in environmental, health, and safety regulation? *Science*, 272(5259):221–222.

Benkhodja, M. T., Fromentin, V., and Ma, X. (2023). Macroeconomic effects of green subsidies. *Journal of Cleaner Production*, 410:137166.

Bord, R. J. and O'Connor, R. E. (1997). The gender gap in environmental attitudes: The case of perceived vulnerability to risk. *Social science quarterly*, pages 830–840.

Bravo, C. P., Cordts, A., Schulze, B., and Spiller, A. (2013). Assessing determinants of organic food consumption using data from the german national nutrition survey ii. *Food quality and Preference*, 28(1):60–70.

Carattini, S., Heutel, G., and Melkadze, G. (2021). Climate policy, financial frictions, and transition risk. *National Bureau of Economic Research*.

Casaló, L. V. and Escario, J.-J. (2018). Heterogeneity in the association between environmental attitudes and pro-environmental behavior: A multilevel regression approach. *Journal of Cleaner Production*, 175:155–163.

Chetty, R., Guren, A., Manoli, D., and Weber, A. (2011). Are micro and macro labor supply elasticities consistent? a review of evidence on the intensive and extensive margins. *American Economic Review*, 101(3):471–475.

Cremer, H., Gahvari, F., and Ladoux, N. (2003). Environmental taxes with heterogeneous consumers: an application to energy consumption in france. *Journal of Public Economics*, 87(12):2791–2815.

Dinkelman, T. and Ngai, L. R. (2022). Time use and gender in africa in times of structural transformation. *Journal of Economic Perspectives*, 36(1):57–80.

Douenne, T. and Fabre, A. (2020). French attitudes on climate change, carbon taxation and other climate policies. *Ecological Economics*, 169:106496.

Douenne, T., Hummel, A. J., and Pedroni, M. (2022). Optimal fiscal policy in a climate-economy model with heterogeneous households. *Available at SSRN 4018468.*

Fremstad, A. and Paul, M. (2019). The impact of a carbon tax on inequality. *Ecological Economics*, 163:88–97.

Fullerton, D. (2011). Six distributional effects of environmental policy. *Risk Analysis: An International Journal*, 31(6):923–929.

Goulder, L. H., Hafstead, M. A., Kim, G., and Long, X. (2019). Impacts of a carbon tax across us household income groups: What are the equity-efficiency trade-offs? *Journal of Public Economics*, 175:44–64.

Gruber, J. (2013). A tax-based estimate of the elasticity of intertemporal substitution. *The Quarterly Journal of Finance*, 3(01):1350001.

Heutel, G. (2012). How should environmental policy respond to business cycles? optimal policy under persistent productivity shocks. *Review of Economic Dynamics*, 15(2):244–264.

Kahn, M. E. and Mansur, E. T. (2013). Do local energy prices and regulation affect the geographic concentration of employment? *Journal of Public Economics*, 101:105–114.

Känzig, D. R. (2023). The unequal economic consequences of carbon pricing. Technical report, National Bureau of Economic Research.

Kitao, S. and Mikoshiba, M. (2020). Females, the elderly, and also males: Demographic aging and macroeconomy in japan. *Journal of the Japanese and International Economies*, 56:101064.

Lee, H., Ryu, D., and Son, J. (2024). Life-cycle decisions and general equilibrium in the heterogeneous-agent olg economy. *Applied Economics*, pages 1–20.

Li, J., Zhang, J., Zhang, D., and Ji, Q. (2019). Does gender inequality affect household green consumption behaviour in china? *Energy Policy*, 135:111071.

Migheli, M. (2021). Green purchasing: the effect of parenthood and gender. *Environment, Development and Sustainability*, 23(7):10576–10600.

Ngai, L. R. and Petrongolo, B. (2017). Gender gaps and the rise of the service economy. *American Economic Journal: Macroeconomics*, 9(4):1–44.

OECD (2021). *Gender and the Environment*.

Rhodes, E., Axsen, J., and Jaccard, M. (2017). Exploring citizen support for different types of climate policy. *Ecological Economics*, 137:56–69.

Ruggles, S. (2015). Patriarchy, power, and pay: The transformation of american families, 1800–2015. *Demography*, 52(6):1797–1823.

Sánchez, M., López-Mosquera, N., and Lera-López, F. (2016). Improving pro-environmental behaviours in spain. the role of attitudes and socio-demographic and political factors. *Journal of Environmental Policy & Planning*, 18(1):47–66.

Somuncu, T. (2023). Environmental regulations, imperfect mobility, and the gender adaptation gap.

Stern, P. C., Dietz, T., Abel, T., Guagnano, G. A., and Kalof, L. (1999). A value-belief-norm theory of support for social movements: The case of environmentalism. *Human ecology review*, pages 81–97.

Ureña, F., Bernabéu, R., and Olmeda, M. (2008). Women, men and organic food: differences in their attitudes and willingness to pay. a spanish case study. *international Journal of consumer Studies*, 32(1):18–26.

Wang, H. (2022). Study on the impact of female labor force participation on carbon emissions based on the fixed effect model and fgls estimation. In *2022 International Conference on mathematical statistics and economic analysis (MSEA 2022)*, pages 1097–1102. Atlantis Press.

Williams III, R. C., Gordon, H., Burtraw, D., Carbone, J. C., and Morgenstern, R. D. (2015). The initial incidence of a carbon tax across income groups. *National Tax Journal*, 68(1):195–213.

Xiao, C. and McCright, A. M. (2015). Gender differences in environmental concern: Revisiting the institutional trust hypothesis in the usa. *Environment and Behavior*, 47(1):17–37.

Yip, C. M. (2018). On the labor market consequences of environmental taxes. *Journal of Environmental Economics and Management*, 89:136–152.

A Key mechanisms

For the demand side, from the first order conditions of female and male consumption, we have:

$$\frac{C_{f,g,t}}{C_{f,b,t}} = \left(\frac{1}{1-\mu_{f,c}} - 1\right) P_{g,t}^{-\epsilon_{f,c}} \quad \text{(A.1)}$$

$$\frac{C_{m,g,t}}{C_{m,b,t}} = \left(\frac{1}{1-\mu_{m,c}} - 1\right) P_{g,t}^{-\epsilon_{m,c}} \quad \text{(A.2)}$$

That is, the consumption of green goods relative to brown goods depends on the relative price. The cheaper the relative price of green goods, the higher the relative demand for green goods from both female and male consumers. Also, the green consumption of female and male consumers depends on two parameters: the proportion of green goods in consumers' consumption panel $\mu_{i,c}, i = \{f, m\}$; and the elasticity of substitution between green and brown goods $\epsilon_{i,c}, i = \{f, m\}$. From equation A.2 above, we derive the following theorems:

Theorem 1 The relative consumption of green goods is increasing with the proportion of green goods at steady state $\mu_{i,c}, i = \{f, m\}$.

From this theorem, we can suppose that by the survey from OECD, if female consumers are more ecological oriented, then we should have $\mu_{f,c} > \mu_{m,c}$, which naturally lead to a higher consumption of green goods from female consumers at time t.

Theorem 2 When the relative price of green goods $P_{g,t} > 1$, the relative consumption of green goods is decreasing with the elasticity of substitution $\epsilon_{i,c}, i = \{f, m\}$. If the relative price of green goods $P_{g,t} < 1$, the relative consumption of green goods is increasing with the elasticity of substitution $\epsilon_{i,c}, i = \{f, m\}$.

From theorem 2, we can get that today as ecological transition just starts, and the production of green goods is more costly as firms need to make more efforts to reduce pollution, green goods are therefore relatively more expensive than the brown goods, i.e. $P_{g,t} > 1$. In this case, we can assume that female consumers, compared to male consumers, are less attracted by the less expensive brown goods. They prefer to pay more money to buy environment-friendly goods rather the polluting goods, even they are cheaper. Therefore, for female consumers, green goods are less substitutable by brown goods, i.e. $\epsilon_{f,c} < \epsilon_{m,c}$.

The two parameters $\mu_{i,c}$ and $\epsilon_{i,c}$,$i = \{f, m\}$ capture the different preference of green goods from female and male consumers.

It is true that the consumption of green goods also depends on income level. In general, high-income consumers are more comfortable to buy green goods because they are not only environment-friendly but also healthier. In this paper, we focus mainly on gender differences and abstract the income heterogeneity.

In terms of the goods supply side, from first order conditions of green and brown firms, i.e. equation (3.15) divided by (3.22), and (3.16) by (3.23), we can derive the following relation:

$$P_{g,t} = \frac{A_{b,t}[1 - \psi_1 {\eta_t}^{\psi_2} - \tau_{e,t}\varphi(1 - \eta_t)]\mu_{f,b,h}^{\frac{1}{\epsilon_{b,h}}} H_{b,t}^{\frac{1}{\epsilon_{b,h}}} H_{f,b,t}^{-\frac{1}{\epsilon_{b,h}}}}{A_{g,t}\mu_{f,g,h}^{\frac{1}{\epsilon_{g,h}}} H_{g,t}^{\frac{1}{\epsilon_{g,h}}} H_{f,g,t}^{-\frac{1}{\epsilon_{g,h}}}} \tag{A.3}$$

$$P_{g,t} = \frac{A_{b,t}[1 - \psi_1 {\eta_t}^{\psi_2} - \tau_{e,t}\varphi(1 - \eta_t)](1 - \mu_{f,b,h})^{\frac{1}{\epsilon_{b,h}}} H_{b,t}^{\frac{1}{\epsilon_{b,h}}} H_{m,b,t}^{-\frac{1}{\epsilon_{b,h}}}}{A_{g,t}(1 - \mu_{f,g,h})^{\frac{1}{\epsilon_{g,h}}} H_{g,t}^{\frac{1}{\epsilon_{g,h}}} H_{m,g,t}^{-\frac{1}{\epsilon_{g,h}}}} \tag{A.4}$$

In a simplified case, in which we assume that the elasticities of substitution between female and male workers are identical in green and brown sectors, i.e. $\epsilon_{g,h} = \epsilon_{b,h} = \epsilon_h$, we get:

$$\frac{H_{f,g,t}}{H_{f,b,t}} = P_{g,t}^{\epsilon_h}\left(\frac{A_{g,t}}{A_{b,t}[1 - \psi_1 {\eta_t}^{\psi_2} - \tau_{e,t}\varphi(1 - \eta_t)]}\right)^{\epsilon_h} \frac{\mu_{f,g,h}}{\mu_{f,b,h}} \frac{H_{g,t}}{H_{b,t}} \tag{A.5}$$

$$\frac{H_{m,g,t}}{H_{m,b,t}} = P_{g,t}^{\epsilon_h}\left(\frac{A_{g,t}}{A_{b,t}[1 - \psi_1 {\eta_t}^{\psi_2} - \tau_{e,t}\varphi(1 - \eta_t)]}\right)^{\epsilon_h} \frac{1 - \mu_{f,g,h}}{1 - \mu_{f,b,h}} \frac{H_{g,t}}{H_{b,t}} \tag{A.6}$$

from which we derive:

$$\frac{H_{f,g,t}}{H_{f,b,t}} / \frac{H_{m,g,t}}{H_{m,b,t}} = \frac{\mu_{f,g,h}}{\mu_{f,b,h}} / \frac{1 - \mu_{f,g,h}}{1 - \mu_{f,b,h}} \tag{A.7}$$

Theorem 3 If $\mu_{f,g,h} > \mu_{f,b,h}$, then we have $\frac{\mu_{f,g,h}}{\mu_{f,b,h}} > \frac{1-\mu_{f,g,h}}{1-\mu_{f,b,h}}$, and we get $\frac{H_{f,g,t}}{H_{f,b,t}} > \frac{H_{m,g,t}}{H_{m,b,t}}$. In other words, if $\mu_{f,g,h} > \mu_{f,b,h}$, then female workers have a larger possibility to work in green sector compared to male workers.

Theorem 4 In a simple case, if $\epsilon_{gh} = \epsilon_{bh} = \epsilon$, and $W_{f,g} = W_{f,b}$, then we have:

$$\frac{H_{g,t}}{H_{b,t}} / \frac{H_{f,g}}{H_{f,b}} = \frac{\mu_{f,b,h}}{\mu_{f,g,h}} \left(\frac{A_b[1 - \psi_1 \eta^{\psi_2} - \tau_e \varphi(1-\eta)]}{P_g A_g} \right)^{\epsilon} \tag{A.8}$$

If the RHS decreases with the productivity of green sector A_g, then the structural change toward green sector among female workers is more prominent than among the male workers.

B FOCs

Endogeneous variables:

$\{C_{f,t}, C_{m,t}, H_{f,t}, H_{m,t}, H_{f,g,t}, H_{f,b,t}, H_{m,g,t}, H_{m,b,t}, C_{f,b,t}, C_{m,b,t}, C_{f,g,t}, C_{m,g,t}, P_{g,t},$
$\lambda_{f,t}, \lambda_{m,t}, H_{g,t}, H_{b,t}, A_{g,t}, a_{b,t}, A_{b,t}, T_t, T_{f,t}, T_{m,t}, W_{f,g,t}, W_{m,g,t}, W_{f,b,t}, W_{m,b,t}, Y_{g,t}, Y_{b,t}, x_t, d(x_t),$
$e_t, e_t^{row}, Z_t, \eta_t\}$

Exogeneous shocks:

$\{\epsilon_{ag,t}, \epsilon_{ab,t}, \epsilon_{lcs,t}, \epsilon_{\tau_e,t}, \epsilon_{Z,t}, \epsilon_{\omega,t}\}$

$$C_{f,t} = \left(\mu_{f,c}^{1/\epsilon_{f,c}} C_{f,g,t}^{\left(\epsilon_{f,c}-1\right)/\epsilon_{f,c}} + (1-\mu_{f,c})^{1/\epsilon_{f,c}} C_{f,b,t}^{\left(\epsilon_{f,c}-1\right)/\epsilon_{f,c}}\right)^{\epsilon_{f,c}/\left(\epsilon_{f,c}-1\right)} \quad \text{(B.1)}$$

$$C_{m,t} = \left(\mu_{m,c}^{1/\epsilon_{m,c}} C_{m,g,t}^{(\epsilon_{m,c}-1)/\epsilon_{m,c}} + (1-\mu_{m,c})^{1/\epsilon_{m,c}} C_{m,b,t}^{(\epsilon_{m,c}-1)/\epsilon_{m,c}}\right)^{\epsilon_{m,c}/(\epsilon_{m,c}-1)} \quad \text{(B.2)}$$

$$H_{f,t} = H_{f,g,t} + H_{f,b,t} \quad \text{(B.3)}$$

$$H_{m,t} = H_{m,g,t} + H_{m,b,t} \quad \text{(B.4)}$$

$$C_{f,b,t} + P_{g,t} C_{f,g,t} \leq (1-\omega) \sum_{j=g,b} W_{f,j,t} H_{f,j,t} + T_{f,t} - \frac{\phi_f}{2} \left(\frac{H_{f,g,t}}{H_{f,b,t}} - \frac{H_{f,g,t-1}}{H_{f,b,t-1}}\right)^2 \quad \text{(B.5)}$$

$$C_{m,b,t} + P_{g,t} C_{m,g,t} \leq (1-\omega) \sum_{j=g,b} W_{m,j,t} H_{m,j,t} + T_{m,t} - \frac{\phi_m}{2} \left(\frac{H_{m,g,t}}{H_{m,b,t}} - \frac{H_{m,g,t-1}}{H_{m,b,t-1}}\right)^2 \quad \text{(B.6)}$$

$$P_{g,t} \lambda_{f,t} = \mu_{f,c}^{1/\epsilon_{f,c}} C_{f,t}^{1/\epsilon_{f,c}-\gamma} C_{f,g,t}^{-1/\epsilon_{f,c}} \quad \text{(B.7)}$$

$$P_{g,t} \lambda_{m,t} = \mu_{m,c}^{1/\epsilon_{m,c}} C_{m,t}^{1/\epsilon_{m,c}-\gamma} C_{m,g,t}^{-1/\epsilon_{m,c}} \quad \text{(B.8)}$$

$$\lambda_{f,t} = (1-\mu_{f,c})^{1/\epsilon_{f,c}} C_{f,t}^{1/\epsilon_{f,c}-\gamma} C_{f,b,t}^{-1/\epsilon_{f,c}} \quad \text{(B.9)}$$

$$\lambda_{m,t} = (1-\mu_{m,c})^{1/\epsilon_{m,c}} C_{m,t}^{1/\epsilon_{m,c}-\gamma} C_{m,b,t}^{-1/\epsilon_{m,c}} \quad \text{(B.10)}$$

$$\lambda_{f,t}(1-\omega) W_{f,g,t} = \chi H_{f,t}^{\sigma} + \phi_f [\lambda_t (\frac{H_{f,g,t}}{H_{f,b,t}} - \frac{H_{f,g,t-1}}{H_{f,b,t-1}}) - \beta \lambda_{t+1} (\frac{H_{f,g,t+1}}{H_{f,b,t+1}} - \frac{H_{f,g,t}}{H_{f,b,t}})] \frac{1}{H_{f,b,t}} \quad \text{(B.11)}$$

$$\lambda_{f,t}(1-\omega) W_{f,b,t} = \chi H_{f,t}^{\sigma} - \phi_f [\lambda_t (\frac{H_{f,g,t}}{H_{f,b,t}} - \frac{H_{f,g,t-1}}{H_{f,b,t-1}}) - \beta \lambda_{t+1} (\frac{H_{f,g,t+1}}{H_{f,b,t+1}} - \frac{H_{f,g,t}}{H_{f,b,t}})] \frac{H_{f,g,t}}{H_{f,b,t}^2} \quad \text{(B.12)}$$

$$\lambda_{m,t}(1-\omega) W_{m,g,t} = \chi H_{m,t}^{\sigma} + \phi_m [\lambda_t (\frac{H_{m,g,t}}{H_{m,b,t}} - \frac{H_{m,g,t-1}}{H_{m,b,t-1}}) - \beta \lambda_{t+1} (\frac{H_{m,g,t+1}}{H_{m,b,t+1}} - \frac{H_{m,g,t}}{H_{m,b,t}})] \frac{1}{H_{m,b,t}} \quad \text{(B.13)}$$

$$\lambda_{m,t}(1-\omega) W_{m,b,t} = \chi H_{m,t}^{\sigma} - \phi_m [\lambda_t (\frac{H_{m,g,t}}{H_{m,b,t}} - \frac{H_{m,g,t-1}}{H_{m,b,t-1}}) - \beta \lambda_{t+1} (\frac{H_{m,g,t+1}}{H_{m,b,t+1}} - \frac{H_{m,g,t}}{H_{m,b,t}})] \frac{H_{m,g,t}}{H_{m,b,t}^2} \quad \text{(B.14)}$$

$$H_{g,t} = \left(\mu_{f,g,h}^{1/\epsilon_{g,h}} H_{f,g,t}^{\left(\epsilon_{g,h}-1\right)/\epsilon_{g,h}} + (1-\mu_{f,g,h})^{1/\epsilon_{g,h}} H_{m,g,t}^{\left(\epsilon_{g,h}-1\right)/\epsilon_{g,h}}\right)^{\epsilon_{g,h}/\left(\epsilon_{g,h}-1\right)} \quad \text{(B.15)}$$

$$H_{b,t} = \left(\mu_{f,b,h}^{1/\epsilon_{b,h}} H_{f,b,t}^{\left(\epsilon_{b,h}-1\right)/\epsilon_{b,h}} + (1-\mu_{f,b,h})^{1/\epsilon_{b,h}} H_{m,b,t}^{\left(\epsilon_{b,h}-1\right)/\epsilon_{b,h}}\right)^{\epsilon_{b,h}/\left(\epsilon_{b,h}-1\right)} \quad \text{(B.16)}$$

$$T_t = T_{f,t} + T_{m,t} \quad \text{(B.17)}$$

$$Y_{g,t} = A_{g,t} H_{g,t} \quad \text{(B.18)}$$

$$\log(A_{g,t}) = (1-\rho_{A_g}) \log(A_g) + \rho_{A_g} \log(A_{g,t-1}) + \epsilon_{A_{g,t}} \quad \text{(B.19)}$$

$$W_{f,g,t} - \epsilon_{lcs,t} = P_{g,t} A_{g,t} \mu_{f,g,h}^{\frac{1}{\epsilon_{g,h}}} H_{g,t}^{\frac{1}{\epsilon_{g,h}}} H_{f,g,t}^{-\frac{1}{\epsilon_{g,h}}} \quad \text{(B.20)}$$

$$W_{m,g,t} - \epsilon_{lcs,t} = P_{g,t} A_{g,t} (1-\mu_{f,g,h})^{\frac{1}{\epsilon_{g,h}}} H_{g,t}^{\frac{1}{\epsilon_{g,h}}} H_{m,g,t}^{-\frac{1}{\epsilon_{g,h}}} \quad \text{(B.21)}$$

$$
\begin{aligned}
Y_{b,t} &= A_{b,t}H_{b,t} && \text{(B.22)}\\
A_{b,t} &= (1-d(x_{t-1}))a_{b,t} && \text{(B.23)}\\
\log(a_{b,t}) &= (1-\rho_{a_b})\log(a_b)+\rho_{a_b}\log(a_{b,t-1})+\epsilon_{a_{b,t}} && \text{(B.24)}\\
d(x_t) &= d_0+d_1x_t+d_2x_t^2 && \text{(B.25)}\\
x_t &= (1-\delta_x)x_{t-1}+e_t+e_t^{row} && \text{(B.26)}\\
e_t &= \varphi(1-\eta_t)Y_{b,t} && \text{(B.27)}\\
e_t^{row} &= 36e_t && \text{(B.28)}\\
Z_t &= \psi_1{\eta_t}^{\psi_2}Y_{b,t} && \text{(B.29)}\\
W_{f,b,t} &= A_{b,t}[1-\psi_1{\eta_t}^{\psi_2}-(\tau_{e,t}+\epsilon_{\tau_e,t})\varphi(1-\eta_t)]\mu_{f,b,h}^{\frac{1}{\epsilon_{b,h}}}H_{b,t}^{\frac{1}{\epsilon_{b,h}}}H_{f,b,t}^{-\frac{1}{\epsilon_{b,h}}} && \text{(B.30)}\\
W_{m,b,t} &= A_{b,t}[1-\psi_1{\eta_t}^{\psi_2}-(\tau_{e,t}+\epsilon_{\tau_e,t})\varphi(1-\eta_t)](1-\mu_{f,b,h})^{\frac{1}{\epsilon_{b,h}}}H_{b,t}^{\frac{1}{\epsilon_{b,h}}}H_{m,b,t}^{-\frac{1}{\epsilon_{b,h}}} && \text{(B.31)}\\
\eta_t &= [\frac{(\tau_{e,t}+\epsilon_{\tau_e,t})\varphi}{\psi_1\psi_2(1-\epsilon_{Z,t})}]^{\frac{1}{\psi_2-1}} && \text{(B.32)}\\
T_t &+ \epsilon_{lcs,t}\sum_{i=f,m}H_{i,g,t}=(\tau_{e,t}+\epsilon_{\tau_e,t})e_t+\omega\sum_{i=f,m;j=g,b}W_{i,j,t}H_{i,j,t} && \text{(B.33)}\\
T_{f,t} &= T_t/2 && \text{(B.34)}\\
Y_{g,t} &= C_{g,t} && \text{(B.35)}
\end{aligned}
$$

C Resource Constraint

We first add the budget constraint of female and male consumers equation B.5 and B.6, together with the government budget constraint equation B.33, we get:

$$
\begin{aligned}
& C_{m,b,t} + P_{g,t}C_{m,g,t} + C_{f,b,t} + P_{g,t}C_{f,g,t} \\
& +T_t + \epsilon_{lcs,t} \textstyle\sum_{i=f,m} H_{i,g,t} \\
= \quad & (\tau_{e,t} + \epsilon_{\tau_e,t})e_t + \omega \textstyle\sum_{i=f,m;j=g,b} W_{i,j,t}H_{i,j,t} + \\
& (1-\omega) \textstyle\sum_{i=f,m;j=g,b} W_{i,j,t}H_{i,j,t} \\
& +T_{f,t} + T_{m,t} - \textstyle\sum_{i=f,m} \frac{\phi_i}{2}\left(\frac{H_{i,g,t}}{H_{i,b,t}} - \frac{H_{i,g,t-1}}{H_{i,b,t-1}}\right)^2 \\
<=> \quad & (C_{m,b,t} + C_{f,b,t}) + P_{g,t}\left(C_{m,g,t} + C_{f,g,t}\right) + \epsilon_{lcs,t} \textstyle\sum_{i=f,m} H_{i,g,t} \\
= \quad & (\tau_{e,t} + \epsilon_{\tau_e,t})e_t + \textstyle\sum_{i=f,m;j=g,b} W_{i,j,t}H_{i,j,t} - \\
& \textstyle\sum_{i=f,m} \frac{\phi_i}{2}\left(\frac{H_{i,g,t}}{H_{i,b,t}} - \frac{H_{i,g,t-1}}{H_{i,b,t-1}}\right)^2
\end{aligned}
\tag{C.1}
$$

From the zero profit assumption in both the green and brown sectors, we have $Y_{g,t} = (1-\epsilon_{lcs,t}) \sum_{i=f,m} W_{i,g,t}H_{i,g,t}$ and $Y_{b,t} = \sum_{i=f,m} W_{i,b,t}H_{i,b,t} + Z_t + (\tau_{e,t} + \epsilon_{\tau_e,t})e_t$. Replacing the RHS of the equation C.1, we get :

$$
\begin{aligned}
(C_{m,b,t} + C_{f,b,t}) + P_{g,t}\left(C_{m,g,t} + C_{f,g,t}\right) + Z_t \quad + \quad & \textstyle\sum_{i=f,m} \frac{\phi_i}{2}\left(\frac{H_{i,g,t}}{H_{i,b,t}} - \frac{H_{i,g,t-1}}{H_{i,b,t-1}}\right)^2 \\
= \quad & P_{g,t}Y_{g,t} + Y_{b,t}
\end{aligned}
\tag{C.2}
$$

which is the resource constraint.