THE ECONOMIC AND ENVIRONMENTAL EFFECTS OF GREEN FINANCIAL POLICIES: A GENERAL EQUILIBRIUM APPROACH

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Özet

Merkez bankaları şimdiye kadar yeşil dönüşümü desteklemek için yeşil finansal varlıklar ve stres testleri gibi makro ihtiyati politika araçlarını teşvik etmeye odaklanmıştır. Bu nedenle, üzerinde mutabakata varılmış temel bir politika bulunmamakla birlikte merkez bankaları çeşitli araçları devreye sokmaktadır. Bu çalışmada, yeşil finansman politikalarını analiz etmek için reel iş çevrimleri modeline (RBC) dayalı bir DSGE modeli geliştirilmektedir. Modelin temel bileşenleri, "yeşil" ve "kirli" sektörlere ayrılmış üretim zinciri; yeşil politikaları desteklemek için zorunlu karşılık oranı, farklılaştırılmış faiz oranı ve teminat kredilendirme oranı araçlarını kullanabilen merkez bankası ve bankacılık sistemi aracılığıyla kirli sektörlere vergi uygulayan maliye politikasından oluşmaktadır. Çalışma sonuçlarına göre, üç merkez bankası politika aracının da yeşil firmaların üretimini olumlu desteklediği sonucuna ulaşılmıştır. Bu üç araç arasında en etkili araç, faiz oranı aracıdır. Ek olarak, düşük yoğunluklu vergi politikalarının kirlilik üzerindeki etkisinin çok sınırlı olduğu görülmektedir.

Anahtar Kelimeler: E-DSGE, yeşil finans, çevre kirliliği, merkez bankası, yeşil firma.

Abstract

Central banks have so far focused on promoting green financial assets and macroprudential policy instruments such as stress tests to support the green transition. For this purpose, although there is no basic policy set with consensus, central banks put into practice various tools. In this analysis, we develop a DSGE model for green financial policy analysis based on a real business cycle (RBC) model. The model's key ingredients are production chain disaggregated into 'green' and 'dirty' sectors; the central bank that can use the required reserve ratio, differentiated interest rate, and collateral lending ratio tools to support green policies; fiscal policy to impose taxes on the dirty sectors through the banking system. Under our central calibration, we find that all three central bank policy instruments positively support the production of green firms. Among these three tools, the most effective tool is the relending interest rate tool. Additionally, we find that the impact of low-intensity tax policies on pollution is very limited.

Keywords: E-DSGE, green finance, pollution, central bank, green firm.

Introduction

In recent years, green finance has become an essential topic for countries to ensure sustainable green economic growth, together with environmental policies aimed at reducing greenhouse gas emissions. The Paris Agreement, which was put on the agenda by the United Nations in 2015, considers keeping the global average temperature increase below two degrees in the long term as one of the agreed conditions to reduce the risks and effects of climate change (Paris Agreement, Article 2/1a). The Paris Agreement emphasizes the importance of the use of financial resources in this regard and stipulates the policies under the articles; "Developed country Parties shall provide financial resources to assist developing country Parties with respect to both mitigation and adaptation in continuation of their existing obligations, (Paris Agreement, Article 9/1)" and "As part of a global effort, developed country Parties should continue to take the lead in mobilizing climate finance from a wide variety of sources, instruments and channels, noting the significant role of public funds, through a variety of actions, including supporting country-driven strategies, and taking into account the needs and priorities of developing country Parties. Such mobilization of climate finance should represent a progression beyond previous efforts, (Paris Agreement Article 9/3)". Firms need to adapt their technologies to produce low-carbon emissions and invest in this direction to achieve the Agreement's goals related to climate change. However, the prices of green energy resources are still high, and it is not attractive for firms to invest in such projects due to the lower rate of return and higher investment risk compared to fossil fuels (Yoshino and Hesary, 2018). This situation poses a risk for the banks, and they are unwilling to give loans to these sectors. In this respect, the initiatives are taken by the private sector, and private banking alone in reaching the targets on climate change do not seem sufficient. For this reason, direct public support, central bank policies, and other regulatory institutions' initiatives come to the fore in providing the necessary financing conditions for achieving climate change targets.

There are two tools that policymakers have brought to the fore in the fight against climate change, primarily to reduce carbon emissions. The first one is the carbon tax, which is a price tool. A carbon tax is a tax on the amount of carbon dioxide produced by fossil fuels. Firms are subject to tax the per amount of carbon dioxide emissions in their production processes. The other is cap and trade, which is a quantity tool. In the cap-and-trade system, an upper limit is determined for the carbon emissions of the firms included in this system. Thus, certainty is ensured in the amount of carbon emission to be released into the atmosphere within a certain period. Firms purchase permits to emit carbon under this system or incur an abatement cost to reduce emissions. Since both tools cause a certain cost according to the amount of carbon emissions, both tools are driving forces for firms to reduce carbon emissions. However, these tools impose a significant cost burden on firms. In addition, in the models examining the optimal policy response under the cap-and-trade, it is concluded that the price effect[1] dominates the income effect[2] for the firms, especially during the expansion periods, and accordingly, the emission limits should be increased in these periods (Heutel, 2012). Considering the cost burden on firms, a sustainable green financial structure that includes all financial actors gains tremendous importance.

While the banking system, one of the critical drivers of the financial system, does not support green investments at the desired level due to the risks posed by green investments, its scorecard is not very good in financing fossil fuel investments that pollute the environment. According to the Banking on Climate Chaos 2022 report, in the six years since the Paris agreement, the world's 60 largest private banks financed fossil fuels with USD 4.6 trillion, with $742 billion in 2021 alone. 2021 fossil fuel financing numbers remained above 2016 levels, when the Paris Agreement was signed. Of particular significance is the revelation that the 60 banks profiled in the report funneled $185.5 billion just last year into the 100 companies doing the most to expand the fossil fuel sector. Moreover, according to the report, banks that joined the Net-Zero Banking Alliance (NZBA, part of the Glasgow Financial Alliance for Net Zero) in 2021 also significantly finance the largest oil and gas companies. Central banks, which act as the dominant institution in ensuring financial stability in the economies and creating sustainable financial conditions, have not undertaken sufficient responsibility for implementing policies on climate change until now. The performances of central banks on green transformation can be followed in the "The Green Central Banking Scorecard" report

[1] The opportunity cost of spending on abatement instead of investing in capital. During expansions, the return of capital is higher, and thus abatement is relatively costlier.
[2] Increase in income leads a higher demand for a clean environment.

published by Positive Money. The report examines whether central banks in G20 countries are implementing policies aligned with their climate commitments. In this context, central banks are evaluated according to the criteria of research and advocacy, monetary policies, financial policies, and leading by example to the sector. According to this evaluation, the central banks of the countries are given a grade from A to F. According to the 2021 report, the score of China, which ranks first on the list, corresponds to the "C" grade, which can be considered mediocre on the scorecard. In addition, the lack of green financial and fiscal policies gives rise to the score of all central banks decrease compared to the previous year. The report reveals that there are no effective policies that significantly reduce financial support for fossil fuels across G20 countries. In the report, it is stated that the issue of climate change is prominent in the discourse and research of central banks. Still, there is a general failure to put this discourse into practice and transform it into concrete policy practices.

Central banks have so far focused on promoting green financial assets and macroprudential policy instruments such as stress tests to support the green transition. For this purpose, although there is no basic policy set with consensus among central banks, there are different tools put into practice by different central banks. The most widely used tool is decarbonize corporate bond asset purchase programs. Central banks have extensively used asset purchase programs in their fight against the economic fallout of COVID-19. Nowadays, central banks have started to use this tool to contribute to the green transformation. Reserve requirements is another tool that is being used. Using this tool, central banks could differentiate requirements depending on how green a bank's lending is. Another policy option available to central banks is the differentiation of the interest rate on required reserves or loans to banks based on banking green credit performance. Also, such as credit limits and quotas, can be utilized to guide credit from unsustainable to sustainable sectors of the economy.

This thesis examines how the potential green financial policies affect macroeconomic and environmental issues in an economy. To address this, we develop a DSGE model for green financial policy analysis based on a real business cycle (RBC) model. There are two types of firms engaged in dirty and clean production within the structure of the model, and we include the banking system in the model to examine green policy tools. Within the scope of the model, the central bank can use the required reserve ratio, differentiated interest rate, and collateral lending ratio tools to support green policies. In addition, we include the fiscal policy in the system to impose taxes on the sectors that make dirty production through the banking system. Thus, we examine how financial policies affect the economy and the environment. In addition, we discuss how tax policy effectively reduces pollution and the costs it causes in a period of expansion due to productivity shocks. The study will contribute to the literature in terms of examining the effects of green financial policies on the economy and the environment, and the impact of different-intensity tax policies on macroeconomic and environmental variables. According to the study's results, all three central bank policy instruments positively support the production of green firms. Among these three tools, the most effective tool is the relending interest rate tool, which implies differentiated interest rate. On the other hand, the tool that causes the least cost to the economy in production is the collateral lending ratio tool. Productivity-based expansion remains a little more limited under high-intensity tax policies while the increase in pollution decreases. The impact of low-intensity tax policies on pollution is also very limited.

The remainder of this paper is structured as follows. Section 1 introduces the green financial policies of central banks. Section 2 situates the existing literature. Section 3 presents the model specification. In section 4, calibration of the model is justified. Section 5 presents the results of impulse response analysis for different policy tools. Section 6 will draw conclusions from the findings of the study.

1. Central Banks and Green Financial Policies

As a result of the development of technology and rapid industrialization, the increase in emissions of greenhouse gases, in general, has led to the problem of global warming, bringing global climate changes. Global climate change affects the economy in general through its effects on production activities, productivity, and the financial system through the financial risks it creates. The fact that these factors affect price stability and financial stability necessitated the central banks to follow the developments regarding global climate change. In fact, recent studies by developed country central banks and international financial institutions frequently examine global climate changes.

The idea that developments related to global climate change should be included in the monetary policy strategy was first stated by the Bank of England in 2015. In this context, global climate change has been defined as the "tragedy of the horizon." It was emphasized that central banks should take role today to eliminate the problems that may arise in the financial system due to climate change (Carney, 2015). It is thought that global climate changes affect financial stability mainly through three main channels: physical risks, transition risks, and liability risks. Physical risks refer to the adverse effects of the increased default risk on the financial sector balance sheets during the elimination of physical damage caused by natural events caused by climate change. It has been shown that the credit risk due to physical risks may increase from around 10 percent for banks operating in the Eurozone to 30 percent in 2050 (Alogoskoufis et al. 2021).

Transition risks refer to the risks posed to financial stability by reallocating resources during adaptation to global climate change policy (Paris Agreement) or technology changes and the possibility that some sectors will become inoperable or face severe costs.[3] Transition risks may remain at a more limited level compared to physical risks (de Guindos, 2021). A similar finding in a study by the International Monetary Fund (IMF) predicts that the short-term cost of the transition to a carbon-neutral economy can be more than compensated in the long term (IMF, 2020).

Finally, liability risk refers to the risk arising from the claims of compensation for losses by persons or businesses exposed to physical risk or transition risk. It is the duty of central

[3] CBRT, Inflation Report, 2021/4

banks and regulatory institutions to manage these risks caused by global climate change and to observe financial stability. However, the difficulties in pricing the risk may also affect financial stability and policies in this direction. While global climate changes bring risks to the financial system, it also creates new potential to meet the financing needed to manage these risks. Environmentalist financial instruments developed in this context are called "green bonds."

In the discussions in the literature and policy circles, it is stated that including green bonds in the central bank balance sheets can alleviate the risks discussed above. The effects of global climate changes on price stability are due to adverse shocks caused by climate change, causing an increase in prices by affecting economic activity. In addition, weather events caused by global climate change negatively affect the agricultural sector and cause an increase in food prices. In addition, the possibility of global climate change reducing labor productivity in the long run is also mentioned (Somanathan et al., 2015). In 2017, a Network for Greening the Financial System (NGFS) was established to consider the effects of global climate change on price stability and financial stability in setting monetary policy. NGFS focused its work on six main themes.[4] These;

- Integrating climate-related risks into a financially sustainable system and micro-controlling,
- To include sustainability factors in portfolio management,
- Closing data gaps,
- Build an intellectual capacity that promotes technical assistance and knowledge sharing,
- To make statements about climate and environment in international coordination,
- Contributing to taxonomy development efforts are determined.

In this context; making financial risk divergence measurements of green bonds and other financial instruments, evaluating methods for micro-level measurement of climate and environmental financial risks, developing and updating audit practices, developing climate scenarios, measuring the macro-financial effects of climate-related risks, encouraging central banks to provide sustainable principles in investments, promoting

[4] NFGS Annual Report, 2020

green finance, providing a standard view of central banks on the difficulties caused by climate change in the implementation of monetary policy stand out as the working subjects of the NGFS.

Considering that the effects of global climate change on economic activity, as well as the financial risks that may be caused by climate change, will be reflected on the balance sheets of central banks, it is essential to change the authorities and policies of central banks in a way that takes into account global climate change. To date, central banks have been involved in policies related to climate change, mainly in the form of holding green bonds on their balance sheets. The inclusion of green bonds in the balance sheets of the central bank has been implemented by the European Central Bank (ECB) since 2016. Finally, the ECB submitted an action plan in July 2021 to incorporate climate change considerations into its monetary policy strategy. In this direction, the ECB states that issues related to climate change will be included more in monetary policy management and will expand its analytical capacity in macroeconomic modeling, statistics, and monetary policy related to climate change. Also, ECB announced that it would include climate change issues in monetary policy operations in risk assessment, corporate sector asset purchases, and collateral framework and would implement the action plan in line with European Union policies.[5]

The Bank of England is another central bank that places climate change-related issues within its monetary policy management. In 2021, the mandate of the Bank of England Monetary Policy Board was changed to be “in line with the government's strategy for strong, sustainable and balanced growth, while also being consistent with environmental sustainability and zero carbon emissions.” Accordingly, the Bank of England in May 2021, announced that it will start buying green bonds to support its goal of reducing carbon emissions to zero as of 2050.[6]

The Dutch Central Bank (DeNederlandscheBank) established the "Sustainable Finance Platform,” operating since 2016. The platform continues its activities to promote sustainable finance awareness and increase cooperation. In addition, the Dutch Central

[5] ECB Detailed Roadmap of Climate Change Related Actions (July 2021)

[6] Results of the 2021 Climate Biennial Exploratory Scenario (CBES)

Bank published its sustainable finance strategy document in July 2021.[7] Within the scope of this finance strategy, it has revealed the five fundamental pillars of the green finance policies that will be implemented for five years. These:

- A financial system resilient to sustainability risks,
- More sustainable monetary tasks and payments,
- Informed debate on creating a sustainable economy,
- Robust sustainability data and statistics,
- Sustainable organizations are determined.

Financial stability, control, and resolution come to the fore under resilient financial system policy. Accordingly, the central bank will incorporate sustainable risks into its audit methodology, create forward-looking toolkits to monitor macroprudential sustainability risks, including stress tests and scenario analyses, and monitor access to financial products and services. The monetary tasks and payment systems policy set consists of monetary policies that are more compatible with climate targets and sub-policies, reducing the environmental impact of payment systems. Informed debate on creating a sustainable economic policy focuses on bringing sustainability themes to the agenda, using economic models that include environmental effects, and providing access to sufficient statistics and high-quality data, especially on carbon emissions. The sustainable organization consists of policies for reserve and investment management in line with international climate targets and the Paris Agreement, making it sustainable in a climate-neutral manner in its internal operations, and transparently reporting risks.

Similarly, the Central Bank of Japan implemented its green policy strategy within the scope of climate change in 2021.[8] In this context, it was announced that financial institutions providing green financing and making green investments were allowed to receive funds from the Bank of Japan in return for their investments or loans. In addition, financial institutions would be supported in identifying and managing their climate-related risks. In addition, it was stated that new analytical tools would be used to analyze

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[7] Sustainable Finance Strategy 2021-2025, DeNederlandscheBank

[8] The Bank of Japan's Strategy on Climate Change, 2021 July

better the effects of climate change on economic activity, prices, and the financial system. Fed focuses on green finance policy under the Financial Stability Climate Committee and Supervision Climate Committee established in 2021. These initiatives by the Central Banks give important clues that green financing policies in central banking will become an important part of monetary policy and financial stability policies in the coming period.

However, there is not yet a policy tool that central banks have agreed on and put into practice according to a certain rule, as in inflation targeting. The debate on alternative policy instruments continues, and some central banks have partial implementations.

With these alternative policy tools, it is possible to allocate loans to green investments and implement climate-friendly practices by impacting investment decisions. While some of these are variations of traditional monetary policy instruments, such as differentiated rediscount rates and required reserve ratios that affect the money multiplier and encourage green credit, others can be classified as non-traditional policy instruments (Volz, 2017).

Differentiated required reserve ratios are one of the policy instruments by which central banks can directly affect credit distribution. The required reserve ratio is the share of deposits banks should keep in reserve and therefore not lend as a loan. Required reserves significantly impact economic activity and money stock, directly affecting banks' ability to create credit. As the central bank lowers this ratio, the banks' ability to lend increases, and on the contrary, the banks' ability to lend decreases. While determining the differentiated reserve requirement ratio, the geographical regions of the loans can be considered, as well as the portfolios of private banks. Epstein (2007) states that asset-based reserve requirements have been widely used to support the desired sector. According to Campiglio (2016), providing lower required reserve ratios on green assets will be a way to favor green investments over traditional investments. However, many developed countries have removed reserve requirements from their central bank monetary policy instruments. The required reserve ratio is a monetary policy tool currently used by the central banks of developing countries (Dikau and Collins, 2017).

Central Banks can differentiate loans given to the private sector by placing certain conditions and constraints on the capital requirements of private banks. Changing the risk weights of the banks' assets and regulating the bank's capital adequacy minimum ratio will directly affect the banks' ability to create credit and credit composition. Campiglio

(2016) recommends adjusting Basel III risk-weighted capital ratios so that low-carbon investments exert a lower pressure than other investments.[9] Similarly, this policy can be implemented by applying credit quotas to banks according to the sector type. In this way, banks have to allocate some of their loans to a particular sector. To implement this policy, the central bank can set an upper quota for the sectors it does not want to be supported and a minimum quota for the green sectors it intends to support. Although this tool is not used much in developing countries with high growth needs, it is used from time to time in developed countries, especially for the housing sector, to reduce market risks.

Another discussed tool includes carbon certificates in banks' reserves (Ma, 2015). This way, it is possible to distribute carbon certificates to low-carbon projects, making them exchangeable with privileges and reducing capital costs for carbon projects. Rozenberg et al. (2011) propose to improve the market for carbon certificates by making carbon certificates acceptable as part of banks' reserves.

Finally, there are green macroprudential policy tools that central banks can resort to. Carbon stress tests can identify and quantify financial institutions' exposure to carbon-intensive assets. According to the problems to be determined, risk weights and upper limits can be changed, and additional capital supports can be provided. In addition, by differentiating leverage ratios by sector, assigning carbon-intensive assets higher risk weights considering that future environmental policies might reduce their value is another risk-mitigating response measure (Schoenmaker and Tilburg, 2016).

[9] Basel III is the third of the Basel agreements that set international standards on issues such as banks' stress testing, liquidity requirement and capital adequacy, as well as non-risk-based leverage ratios.

2. Literature Review

The literature on Environmental Dynamic Stochastic General Equilibrium Models (E-DSGE) is relatively new and has a history of about a decade. E-DSGE models that focus on green finance, on the other hand, have a shorter history as green finance has just started to take place in the country's economic policies. This section will review the literature on E-DSGE models that consider environmental factors and green finance. We will also introduce the literature on DSGE-based general equilibrium models that consider stochastic factors.

In their study, Fischer and Springborn (2011) examined the effects of emission intensity targets, emission limits, and taxes on economic activity through the real business cycle model they built. The upper limit of emissions reduces the impact of the productivity shock on all variables in the economy. Again, according to the study's results, the emission tax leads to similar results to the emission limit, with more volatility. However, emission intensity targets generate more labor, capital, and output than any other policy that can be implemented.

Heutel (2012) examined the optimal environmental policy to be applied against the fluctuations caused by the productivity shocks on the economy, in the case of pollution externalities, based on a DSGE model he built using the USA data. The study concludes that an environmental policy that allows carbon emissions to be cyclical, increasing during expansions and decreasing during recessions, is optimal. In addition, a decentralized economic model in which the government chooses a tax rate and firms, and households respond to this situation is also examined. According to the results in this model, it is concluded that the optimal tax rate or emission quota is still cyclical and that the tax rate or emission quota should be reduced during recession periods.

Acemoglu et al. (2012) developed a model structure in which the final product is produced from clean and dirty intermediate products. According to the study's results, if the inputs are sufficiently substitutable, sustainable growth can be achieved with temporary taxes and support for the innovation of clean inputs. The optimal policy for the transition to a clean economy includes both carbon taxes and research and development support for clean products, provided that excessive use is avoided. The longer it is delayed for environmental policy to intervene, the more the costs will rise due to slow growth and a more prolonged transition phase. Acemoglu et al. (2016) also examined the appropriate policy framework for transitioning to a green economy using a similar model. In this context, it is stated that relying on emission taxes alone will not be sufficient and that production and innovation in clean technologies can be encouraged.

Golosov et al. (2014) analyzed the effects of climate change externalities due to fossil energy use through the DSGE model. Within the scope of the study, a formula for marginal externality damage was developed. Accordingly, the damage incurred is proportional to the GDP and is closely related to three factors: discounting, expected damage elasticity, and carbon corrosion in the atmosphere. Optimal emissions tax as an environmental policy is equal to the marginal externality and is related to expectations and possible solutions to uncertainties about future losses.

Annicchiarico and Di Dio (2015) examined the effects of different environmental policies on the dynamics of the economy through the New Keynesian model, which takes nominal and real rigidities into account. According to the results of the study, the cap affects reducing macroeconomic fluctuations. Staggered price adjustments significantly affect the performance of environmental policy put in place. Total welfare tends to be higher with a tax on emissions as long as prices are sticky.

In her study, Punzi (2018), the effect of monetary and financial shocks on economic activity is examined by estimating an E-DSGE model in which heterogeneous firms and the banking system are included. According to the study, only financial shocks to green firms can increase this sector's total production and loan volume. On the other hand, although the total factor productivity shock and loosening monetary policies cause a temporary increase in total output in the short run, green firms are negatively affected by productivity shocks and loosening monetary policies eventually.

In another study, Chan (2020) examines the effectiveness of fiscal and monetary policy tools in reducing air pollution using the E-DSGE model. Monetary, fiscal, and carbon tax policies cause reductions in emission reduction costs, income tax revenues, and general price level. In addition, according to the study’s results, it is only a fiscal policy tool that provides an increase in household welfare simultaneously with the protection of emission levels in an economic expansion due to a total factor productivity shock.

Benmir and Roman (2020) examined monetary and macroprudential policies aimed at reducing carbon emissions by using a DSGE model with financial frictions. According to the study's results, carbon emission reduction policies cause two main inefficiencies: risk premium and deterioration in total welfare. However, it has been concluded that macroprudential policies in favor of loans given to the green sector increase green capital and production with a minor welfare loss.

Pan (2020) examined the effect of green finance policies in China through the DSGE model. The study discusses relending advantages, interest support, and required reserve ratio as monetary policy tools. Accordingly, in addition to being effective tools in promoting green credit, all three policy instruments positively affect the transition to a green economy and the environment. Moreover, the costs of the policies are limited compared to their benefits.

Gallagher (2021) developed a DSGE model in which dirty and clean firms and a climate module are included. In addition, a monetary policy authority within the model can apply quantitative easing to the public and private sectors. The study concluded that a central bank, which considers carbon cost, should prefer to buy the bonds of companies that produce relatively greener.

Douenne, Hummel, and Pedroni (2022) examined optimal fiscal policy under a climate model with heterogeneous units. Accordingly, tax distortions have a negligible effect on the optimal tax. Optimal carbon taxation produces relatively adverse but progressive welfare effects in the 21st century, significant positive but regressive in the post-period.

3. Model Specification

The model consists of four basic blocks. The first block consists of households that consume and supply labor. In the second block, two distinct types of firms are engaged in dirty and clean production. The third block is about the financial structure of the economy. In this block, the activity of the banking sector in the economy is examined. Fourth, the monetary and fiscal policy block examines the government's role in the economy. In the subsections, the behavior of each unit in the economy will be discussed detail. We rely on the methods of Pan (2020) and Punzi (2018) studies in building the general equilibrium structure of the model.

3.1. Households

Households exist in the structure of the model, indexed in the continuous range j ∈ (0,1), and try to maximize their utility by taking into account the consumption, leisure, and deposit balance. While households want to maximize their intertemporal utility, they decide how much they will consume, how much deposit they will keep, how they will distribute their investment among dirty and clean firms, and the labor they will supply. The utility preference function of the representative household can be written as:

$$E_t^j \sum_{k=0}^{\infty} \beta^k \left\{ ln(C_{j,t}) - \frac{\left(L_{j,t}^g\right)^{1+\sigma_1}}{1+\sigma_1} - \frac{\left(L_{j,t}^d\right)^{1+\sigma_2}}{1+\sigma_2} \right\} \qquad (2.1)$$

In function 2.1, $C_{j,t}$, corresponds to consumption level, $L_{j,t}^g$ and $L_{j,t}^d$ correspond to the household's labor supply for clean and dirty firms, respectively. σ_1 and σ_2 are the inverse Frisch elasticity of labor. The inverse Frisch elasticity measures the percentage change in working hours caused by a 1 percent change in wages under a given marginal utility.[10]

The budget constraint equation of the household in any period t is following [11]:

$$C_t + D_t + I_t = W_t^g L_t^g + W_t^d L_t^d + R_t^K K_t^g + R_t^K K_t^d + R_{t-1}^s D_{t-1} \qquad (2.2)$$

The left side of the equation is the household's expenditures, taxes, and investments, and the right side is the source. C_t, corresponds to household expenditures, D_t, corresponds

[10] Heer and Mausner, 2006

[11] In equations of the model, interest rates and capital return rates are used as (1+ interest rate/return rate).

to households' deposits, I_t their investments in the real sector. R_t^K, is the rate of return on physical capital, R_{t-1}^s, is the interest rate paid by the bank on deposits. $W_t^g L_t^g$ and $W_t^d L_t^d$, are the wage earned by the household based on the time spent working in clean and dirty firms.

Finally, K_t^gve K_t^d, correspond to the capital stock of green producing and non-green producing firms, respectively. The capital formation process is stated in the following equation:

$$K_{t+1} = (1-\delta)K_t + I_t \tag{2.3}$$

The net capital stock of depreciation (δ), in each period depends on the capital stock of the previous period and the investment amount.

When the household solves the problem of maximizing its utility by using the utility function and the budget constraint equation, first-order conditions for consumption, labor supply, investment, and deposits are following:

$$\frac{1}{C_t} = \lambda \tag{2.4}$$

$$\left(L_t^g\right)^{\sigma_1} = \frac{W_t^g}{C_t} \tag{2.5}$$

$$\left(L_t^d\right)^{\sigma_2} = \frac{W_t^d}{C_t} \tag{2.6}$$

$$\frac{C_{t+1}}{C_t} = \beta(1-\delta+R_{t+1}^K) \tag{2.7}$$

$$\frac{C_{t+1}}{C_t} = \beta R_t^D \tag{2.8}$$

The Lagrange multiplier (λ) in the equation of 2.4 expresses the additional benefit provided to the household by a unit change in the budget. Equations 2.5 and 2.6 describe the labor supply provided by the household for green and non-green production firms. Equations 2.7 and 2.8 can be characterized as Euler's equation, which shows the consumption-saving path of the household. Equality states the condition that the household should be indifferent between consuming one unit today or saving and consuming in the future.[12]

3.2. Firms

Within the structure of the model, there are two types of representative firms operating in a perfectly competitive market and producing final goods. While one of the firms produces green products with a minimum level of pollution, the other firm produces non-green products that cause high pollution. Firms provide their payments for the use of labor and capital within the structure of the model by borrowing from the bank. Therefore, lending enters the production process as working capital. The overall price level for the market is normalized to 1. Accordingly, the profit equation of a representative clean and dirty firm in any period can be shown as:

$$\Pi_t^{g,d} = Y_t^{g,d} - \left[(R_t^{g,d} - 1)B_t^{g,d} + W_t^{g,d}L_t^{g,d} + R_t^K K_t^{g,d}\right] \quad (2.9)$$

Assuming the debt used by the firm through the bank is used as working capital ($B_t^{g,d} = W_t^{g,d}L_t^{g,d} + R_t^K K_t^{g,d}$), the profit equation turns into the following equation:

$$\Pi_t^{g,d} = Y_t^{g,d} - R_t^{g,d}B_t^{g,d} \quad (2.10)$$

In the above equations, $\Pi_t^{g,d}$, denotes profit for firms, $R_t^{g,d}$, denotes firms' borrowing interest and $Y_t^{g,d}$ denotes firms' output. Firms produce under the standard Cobb-Douglas constant returns to scale production function:

$$Y_t^{g,d} = A_t\left(K_t^{g,d}\right)^{\alpha}\left(L_t^{g,d}\right)^{1-\alpha} \quad (2.11)$$

The coefficient α in equation 2.11 corresponds to the production elasticity of capital, in other words, the share of the capital in production under constant returns to scale production function. A_t, stands for total factor productivity and has an autoregressive (AR (1)) process of total factor productivity shock:

$$logA_t = (1 - \rho_A)logA_{ss} + \rho_A logA_{t-1} + \xi_{t,A} \quad (2.12)$$

[12] Junior, 2015

A_{ss} in the equation stands for productivity at steady-state, and ρ_A represents the autoregression parameter with an absolute value less than one. The shock parameter $\xi_{t,A}$, follows the normal distribution process with σ_A variance and zero mean (N (0, σ_A)).

Firms produce in a way that maximizes their profits regarding the resource and borrowing constraints:

$$\max_{L_t^{g,d} K_t^{g,d}} \Pi_t^{g,d} = Y_t^{g,d} - R_t^{g,d} B_t^{g,d} \tag{2.13}$$

$$s.t. \begin{cases} Y_t^{g,d} = A_t \left(K_t^{g,d}\right)^{\alpha} \left(L_t^{g,d}\right)^{1-\alpha} \\ B_t^{g,d} = W_t^{g,d} L_t^{g,d} + R_t^K K_t^{g,d} \end{cases} \tag{2.14}$$

For the firm that has solved the profit problem above, the first-order conditions are as follows:

$$K_t^{g,d} = \alpha \frac{Y_t^{g,d}}{R_t^{g,d} R_t^K} \tag{2.15}$$

$$L_t^{g,d} = (1-\alpha) \frac{Y_t^{g,d}}{R_t^{g,d} W_t^{g,d}} \tag{2.16}$$

Equations 2.15 and 2.16 correspond to the capital and labor demands of the firms, respectively. Companies pollute the environment during their production processes, green ones less and non-green ones more. The pollution amount target for green finance policy is directly dependent on the amount of production, and we identify it with the following function:

$$\boldsymbol{E_t = k\left(Y_t^g\right)^{\varepsilon_1}\left(Y_t^d\right)^{\varepsilon_2}} \tag{2.17}$$

In the above equation, E_t shows the total amount of pollution, ε_1 ve ε_2 show the pollution elasticity of firms concerning production, and the elasticity of the green firm is relatively minor compared to that of the non-green firm. The k, in the equation corresponds to the pollution adaptation coefficient.

3.3. Financial Sector

Within the structure of the model, we include the financial sector in the model with the banking system. The representative bank collects household deposits and provides loans to green and non-green firms. However, banks place reserves in the central bank depending on the required reserve ratio. We embed the green monetary policy into the model based on the incentives and advantages the central bank provides to the banks. It is possible to collect these advantages and incentives under two headings. First, banks gain the advantage of reducing the required reserve ratio, which determines the amount they have to keep at the central bank, depending on the proportion of the loan they provide to green firms. Secondly, banks can borrow from the central bank at a lower interest rate than the policy rate, up to a certain limit, depending on the amount of green credit they provide. In addition, we include the taxation of non-green firms in the model through the banking system. Banks are taxed on loans they give to non-green firms. Under the assumption that banks will reflect this tax on the interest rates to be applied directly, non-green firms are indirectly exposed to pollution tax. Under these conditions, the profit equation of the bank operating in the market can be written as follows:

$$\Pi_t^b = \left(R_t^g - 1\right)B_t^g + \left(R_t^d - 1\right)B_t^d - \tau B_t^d - (R_t^s - 1)D_t - \left(R_t^{rl} - 1\right)U_t \quad (2.18)$$

Π_t^b, in the equation represents the bank's profit. B_t^g and B_t^d correspond to loans to green and non-green firms, respectively. D_t is the deposits of households keep in banks. U_t, represents the amount of green borrowing the bank can hold at a lower interest rate from the central bank, and τ represents the tax imposed on loans to non-green firms. R_t^g and R_t^d represent the interest rate on loans to green and non-green firms, respectively, R_t^s is the interest on deposits paid to households, and finally, R_t^{rl} refers to the advantageous green borrowing interest rate provided by the central bank to the banks.

The bank's asset and liability position should be in balance. The bank’s assets consist of the loans given to green and non-green firms and the amount of reserves held in the central bank. There are household deposits and green borrowing from the central bank on the liabilities side. The balance sheet of the bank can be determined as the following equation:

$$B_t + (rr - X_t)D_t = D_t + U_t \quad (2.19)$$

In equation 2.19, B_t is the total loan amount, rr is the required reserve ratio, and X_t is the coefficient representing the decrease in the required reserve ratio due to the bank's green loan. The second part on the left side of the equation expresses the required reserve amount the bank should keep in the central bank after decreasing the required reserve ratio. We use the following equation for the reduction in the required reserve ratio:

$$X_t = \frac{B_t^g}{B_t} N_t \quad (2.20)$$

As it can be understood from equation 2.20, the decrease in the required reserve ratio is related to the proportion of the green loan amount to the total loan. Therefore, the green credit the bank gives proportionally more, the greater the reduction in the required reserve ratio. In other words, the required reserve amount that the bank should keep in the central bank decreases. In this case, the bank can reuse the reserves as loans for profit rather than keeping them at the central bank. N_t is the required reserve ratio reduction elasticity of the green loan rate.

We formulate the green borrowing facility with a lower interest rate, which is another advantage provided by the central bank to the banks, as follows:

$$U_t \leq B_t^g M_t \quad (2.21)$$

According to the equation, the upper limit of the bank's green borrowing with favorable interest is proportional to the amount of green loan it gives. The M_t coefficient in the equation can be defined as the central bank's collateral rate requirement in terms of green loan assets for relending.

A profit-maximizing bank solves the following problem under the balance sheet and incentive constraints:

$$\max_{B_t^i, B_t^g, D_t, U_t} \quad \Pi_t^b = (R_t^g - 1)B_t^g + (R_t^d - 1)B_t^d - \tau_t B_t^d - (R_t^s - 1)D_t - (R_t^{rl} - 1)U_t \quad (2.22)$$

$$s.t. \begin{cases} B_t = B_t^g + B_t^d \\ B_t + (rr - X_t)D_t = D_t + U_t \\ X_t = \frac{B_t^g}{B_t} N_t \\ U_t \leq B_t^g M_t \end{cases} \quad (2.23)$$

The first-order conditions for the bank are as follows:

$$R_t^g = \Psi_t + \frac{\Psi_t D_t N_t B_t^g}{\left(B_t^g + B_t^d\right)^2} - \frac{\Psi_t D_t N_t}{B_t^g + B_t^d} - \Omega_t M_t \quad (2.24)$$

$$R_t^d = \Psi_t + \frac{\Psi_t D_t N_t B_t^g}{\left(B_t^g + B_t^d\right)^2} + \tau \quad (2.25)$$

$$R_t^{rl} = \Psi_t - \Omega_t \quad (2.26)$$

$$R_t^s = (rr - X_t) - \Psi_t(rr - X_t - 1) \tag{2.27}$$

Equations 2.24 and 2.25 state the bank's green and non-green loan supply conditions, respectively. Equation 2.26 represents the bank's green borrowing demand, and equation 2.27 represents the bank's deposit demand conditions. The Lagrange coefficient Ψ_t corresponds to the profit provided by an additional unit of credit, and Ω_t corresponds to the gain provided by an additional unit of green borrowing from the central bank.

3.4. Central Bank and Fiscal Policy

Within the model's scope, we did not consider the central bank's behavior regarding policies such as inflation targeting. The central bank is embedded in the model with three policy tools through the advantages and incentives it provides to the banking system. These policy tools are the green lending rate (R_t^{rl}), the collateral rate requirement, (M_t) and N_t, which is the required reserve ratio reducing elasticity of the green loan ratio. Using these tools, the central bank influences bank and firm behavior to encourage green production. These three policy instruments have first-order autoregressive shock processes:

$$logN_t = (1 - \rho_n)logN_{ss} + \rho_n logN_{t-1} + \xi_{t,n} \tag{2.28}$$

$$logR_t^{rl} = \left(1 - \rho_{r^{rl}}\right)logR_{ss}^{rl} + \rho_{r^{rl}} logR_{t-1}^{rl} - \xi_{t,r^{rl}} \tag{2.29}$$

$$logM_t = (1 - \rho_m)logM_{ss} + \rho_m logM_{t-1} + \xi_{t,m} \tag{2.30}$$

In the equations, N_{ss}, R_{ss}^{rl}, M_{ss} represent the steady state values of the relevant variables. ρ_n , $\rho_{r^{rl}}$ and ρ_m have absolute values less than one and are autoregressive (AR (1)) parameters of the relevant variables. $\xi_{t,n}$, $\xi_{t,r^{rl}}$ and $\xi_{t,m}$ represent shocks and have normal distributions (N (0, $\sigma_{n,m,r^{rl}}$)). The minus sign before the shock in the second equation indicates that the policy shock works in a way that lowers the interest rate for green financing.

In addition, the pegged policy instrument equations for all three policy instruments are as follows, depending on the preference of the central bank to stick to a policy consistently and use it continuously for a certain period:

$$\hat{n}_t = \phi_n \hat{e}_t \tag{2.31}$$

$$\hat{r}_t^{rl} = -\phi_{r^{rl}}\hat{e}_t \tag{2.32}$$

$$\widehat{m}_t = \phi_m \hat{e}_t \tag{2.33}$$

$\hat{n}_t$, $\hat{r}_t^{rl}$ ve $\widehat{m}_t$ in the equations represent the percentage deviation of the related monetary policy instrument from the steady-state value. $\hat{e}_t$, corresponds to the percent deviation of the pollution from the stable equilibrium value. The central bank responds with certain elasticities (ϕ_n, $\phi_{r^{rl}}$, ϕ_m) to the deviation of pollution from its steady-state value.

We introduce fiscal policy into the model through a single policy instrument. The financial authority provides its expenditures from the taxes collected by the banks due to their non-green loans. We do not consider other policies of the financial authority within the scope of the model. Accordingly, the equilibrium state of the fiscal authority is identified in the following equation:

$$G_t = \tau_t B_t^j \tag{2.34}$$

We will discuss how economic agents respond to different tax rates by assigning different values to the tax rate within the model. τ_t, the tax policy instrument of the fiscal authority, follows an autoregressive process:

$$log\tau_t = (1-\rho_\tau)log\tau_{ss} + \rho_\tau log\tau_{t-1} + \xi_{t,\tau} \tag{2.35}$$

The pegged policy tool equation for fiscal policy can be written as follows:

$$\hat{\tau}_t = \phi_\tau \hat{e}_t \tag{2.36}$$

The fiscal authority responds to the deviations from the steady state, depending on its pollution targets, by using the elasticity parameter ϕ_τ. We will have the opportunity to examine the effects of the fiscal authority's policies on economic activity through tax shocks.

3.5. Aggregate Equilibrium

In terms of the solution of the model, the labor market, capital market, product market and banking market should be in equilibrium. Besides, all of the production is used in consumption and investment decisions. In this regard, for market clearing conditions the following equations can be stated:

$$K_t = K_t^g + K_t^d \tag{2.37}$$

$$L_t = L_t^g + L_t^d \tag{2.38}$$

$$B_t = B_t^g + B_t^d \; , \;\; B_t + (rr - X_t)D_t = D_t + U_t \tag{2.39}$$

$$Y_t = Y_t^g + Y_t^d \tag{2.40}$$

$$Y_t = C_t + I_t + G_{\;t} \tag{2.41}$$

4. Calibration

This section will examine the model's parameterization in line with the existing literature.[13] The share of capital in production is set to 0.45. The inverse Frisch elasticities $\sigma_{1,2}$ for labor supplies to both firms are set to 1 and the depreciation rate is equal to 0.025. The intertemporal discount factor β is equal to 0.99, implying that the annual steady-state interest rate is 4%. The total factor productivity is equal to 1, considering there is no technological progress at the steady state. The productivity shock persistence parameter is assigned as 0.95 considering the study of Smets and Wouters (2007). For the firms engaged in green production, the elasticity of pollution due to production is set to 0.05, and for non-green firms, this elasticity value is set to 0.95. The pollution coefficient is calibrated as 1. Policy instruments that central banks have reached a consensus on implementation as a policy instrument are not common yet. For this reason, Punzi (2018) and Pan (2020) studies are followed in selecting the parameters related to the policy tools used by the central bank within the framework of green finance. These calibrated values are given in Table 4.1.

Table 4.1. List of Calibrated Parameters

Parameter	Definition	Value
α	Share of capital in production	0.45
δ	Capital depreciation rate	0.025
β	Discount factor	0.99
A	Total factor productivity	1
k	Pollution coefficient	1
ε_1	Pollution elasticity of green firms	0.05
ε_2	Pollution elasticity of non-green firms	0.95
$\frac{B_t^g}{B_t}$	Proportion of green loan to total loan	0.1
τ	Tax rate for non-green loan	0.05 R_t^j
R^{rl}	Green relending interest rate	1.03
Parameter	**Definition**	**Value**

[13] Smets and Wouters (2007), Gali (2008), Jerman and Quadrini (2012), Heutel (2012), Torres (2013), Dio Dio (2015), Pan (2020) studies are used for parametrization.

M	Collateral rate requirement	0.5
N	Required reserve ratio reduction elasticity	0.1
rr	Required reserve ratio	0.15
$\sigma_{1,2}$	The inverse of the Frisch elasticity of labor supply	1
ρ_A	Persistence of productivity shock	0.95
ρ_n	Persistence of reduction elasticity shock	0.9
$\rho_{r^{rl}}$	Persistence relending interest rate shock	0.9
ρ_m	Persistence of collateral rate requirement shock	0.9
ρ_τ	Persistence of tax shock	0.9

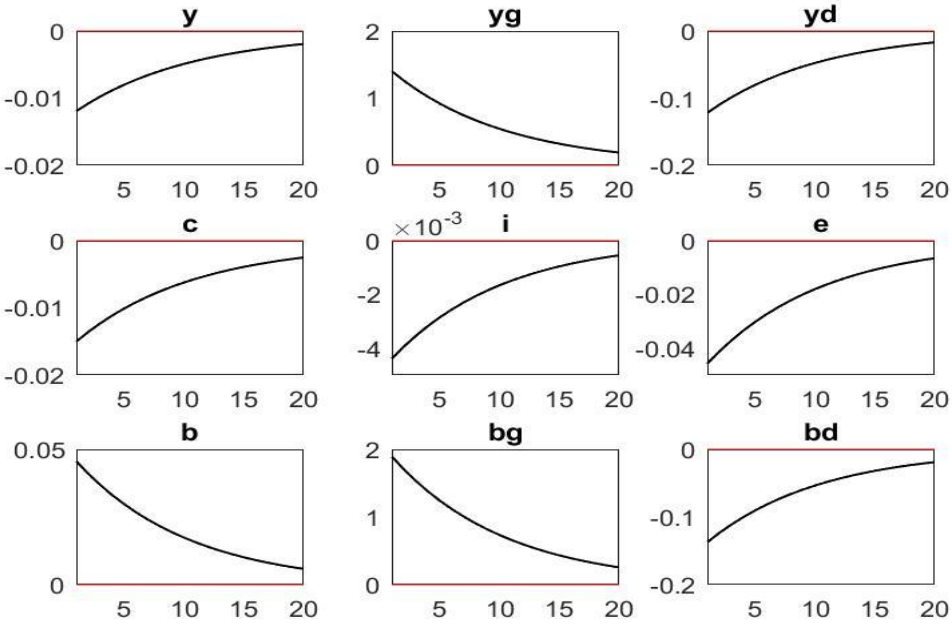
5. Analysis of Results

First, we solved the steady state of the model built in Chapter 3. Then, following the Uhlig (1999) method, we linearized the equations and solved the model using Matlab and Dynare package programs. Thus, we will examine how macroeconomic variables respond to monetary and fiscal policy shocks and the dynamic properties of the model with the impulse-response analyzes. Through these analyses, it is monitored how the variables react to external shocks. The responses of the variables help to understand the transmission mechanisms within the model.

5.1. Relending Interest Rate Shock

In Figure 5.1, we examine the effect of the green relending interest rate shock on key macroeconomic variables. The responses of the variables to the shock are in the form of a percentage point deviation from their steady-state values. Initially, there is a 2-percentage point increase in loans given to green firms. On the other hand, there is an approximately 0.17 percentage point drop in loans given to non-green firms. The main reason behind this situation is that it becomes more profitable for the bank to increase green loans after the interest relending shock. For this reason, the bank has directed its loans towards green loans to some extent. The total output of firms engaged in green production, which has access to more credit facilities and therefore more working capital, increases by approximately 1.4 percentage points. On the other hand, the output of non-green firms decreased by about 0.12 percent due to decreased credit access. Although the interest relending shock causes a significant increase in the production of green firms, it has a limited effect on the production structure of non-green firms. Accordingly, total production decreased by only about 0.01 percentage points in the first stage. The decrease in total production is negligible. Consumption and investment also move with total output. The pollution in the economy due to the shock initially decreased to a moderate level, resulting in a partial recovery. Over time, the decrease in pollution started to disappear with the waning of the shock.

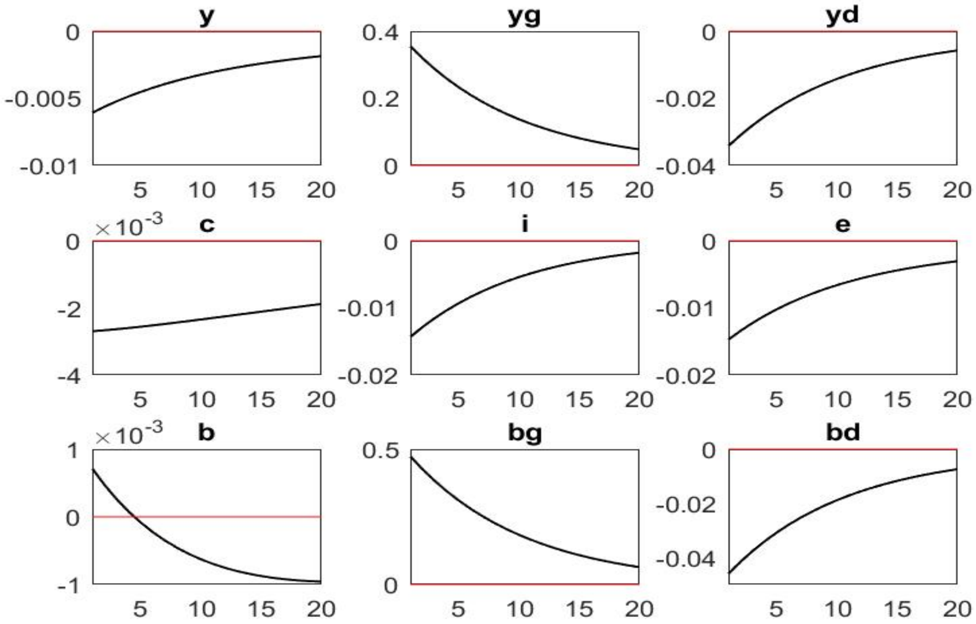
Figure 5.1. Relending Interest Rate Shock



5.2. Required Reserve Ratio Shock

Another policy tool the central bank can use is changing the required reserve ratio. While using this policy tool, we consider the elasticity of the proportion of green loans to the total loan. Figure 5.2 shows the effects of the required reserve ratio shock on macroeconomic variables. After the shock, the amount of loans given to green production firms initially increased by 0.5 percent. The decrease in loans given to non-green firms is negligible (0.04%). The green firms' output initially increases by approximately 0.35 percentage points depending on the increase in working capital. Due to the moderate decrease in loans, the total production level of non-green firms is not affected much and shows a limited decline. Due to the high share of non-green firms in the economy, the total output follows a similar process to the behavior of non-green firms, with an extremely limited decrease (0.006%). In a sense, this policy tool does not negatively affect total output, while it positively contributes to the production level of green firms. The pollution, on the other hand, showed a gradual decrease at the beginning due to the limited reduction in the production of non-green firms, and returned to its previous level over time as the shock subsided.

Figure 5.2. Required Reserve Ratio Shock

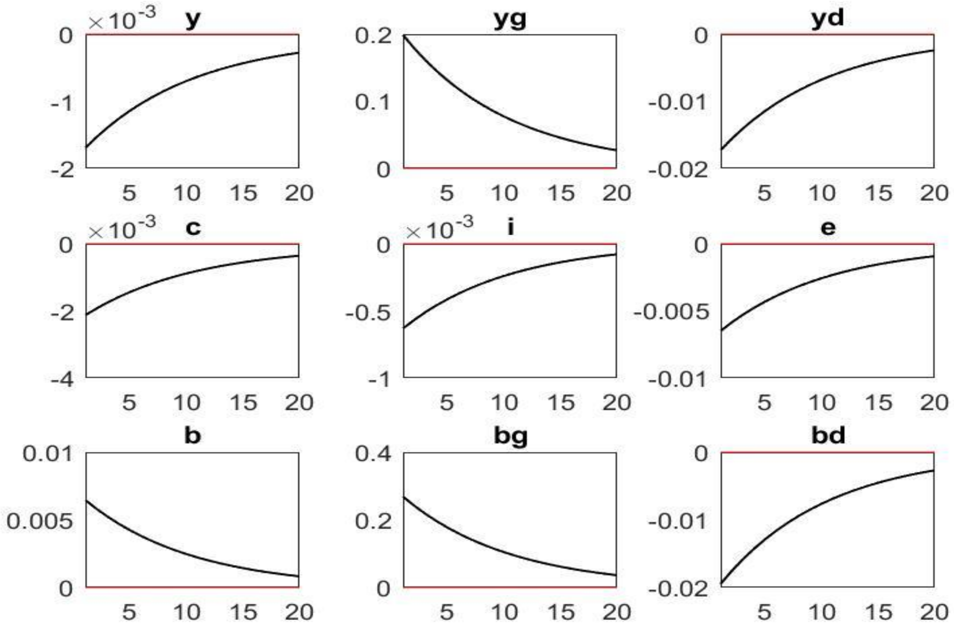


As a whole, it can be stated that this policy tool has an effective structure because the costs it causes in terms of production in the whole economy are pretty low, but it contributes positively to green production firms and the reduction of pollution. However, although it is not as effective as relending interest rate in terms of affecting the production performance of green firms, it creates less cost than the interest relending tool in terms of the total production cost to the economy. It also lags behind the interest relending policy tool in its pollution reduction performance.

5.3. Collateral Lending Ratio Shock

Another policy tool that the central bank can use is collateral lending. A positive shock to the collateral lending ratio increases the bank's upper limit to borrow from the central bank at a lower interest rate. In Figure 5.3, we see the macroeconomic effects of such a shock.

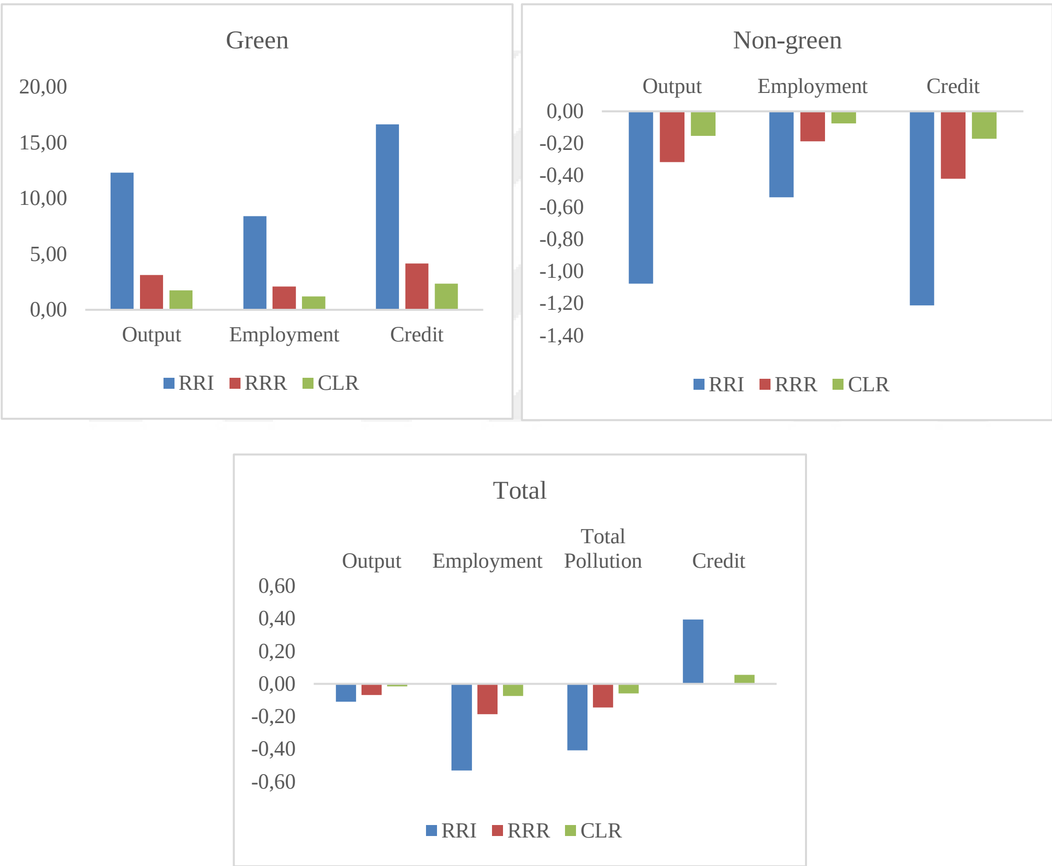
Figure 5.3. Collateral Lending Ratio Shock



Like other policy instruments, the total amount of credit reached by green firms is increased, hence their production accordingly (0.2%). Non-green firms are affected by the shock to a very limited extent. Similarly, the reduction in total output is negligible. Consumption and investment follow a similar process to output. The level of pollution initially decreased, albeit by a small amount. The impact of the collateral lending shock lags behind the effect of the other two policy instruments, the green relending interest rate, and required reserve ratio shocks. Among these three policy instruments, the collateral lending tool has the minor effectiveness in supporting green firms and pollution. Still, it is the instrument that has the least cost to the economy in terms of production.

It is possible to see the total impact of these three policy instruments on important macroeconomic variables over twenty periods. Figure 5.4 shows these effects as a whole. When the figures are discussed together, it is seen that the relending interest rate is the most effective policy tool in the fight against pollution. On the other hand, the highest cost to be incurred in production and employment arises because of this policy tool. In addition, the relending interest rate is the most powerful policy tool that facilitates access to credit by the green firms and reduces the opportunity of the non-green firms to reach credit. Increasing the chance for green firms to access credit will contribute to the faster growth of the clean sectors. It will also encourage non-green firms to adapt to increase their access to credit in their production processes. Required reserve ratio and collateral lending instruments also give similar results in terms of both benefits and costs, with more limited effects. Acemeoglu et al. (2016) emphasize that in addition to relying on emission taxes, the production of clean technologies can be encouraged in the transition to a clean economy. In this respect, considering the positive effects of these monetary policy tools, especially the relending interest rate, in terms of the growth of green firms and improving their production capacities, and the limited costs they cause in total production, they are in line with the policy framework of Acemoğlu et al. (2016) study.

Figure 5.4. Aggregate Effect of Policy Tools Shocks (20 periods, %)

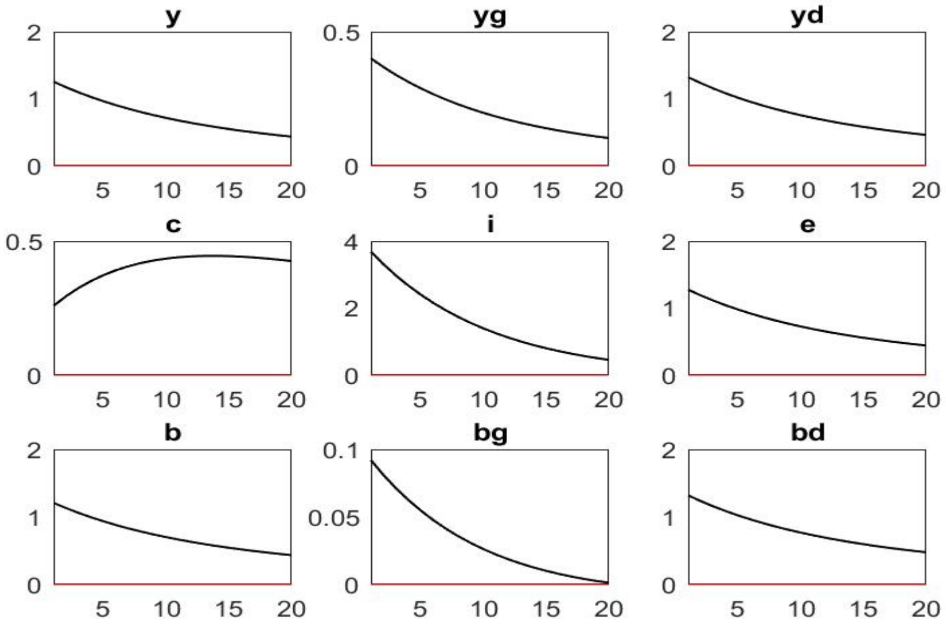


* RRR: Required Reserve Ratio, RRI: Relending Interest Rate, CLR: Collateral Lending Rate

5.4. Total Factor Productivity Shock

First, the effect of the total factor productivity shock on macroeconomic variables is analyzed under the baseline scenario where the tax rate is determined as 5 percent. These effects are shown in figure 5.5.

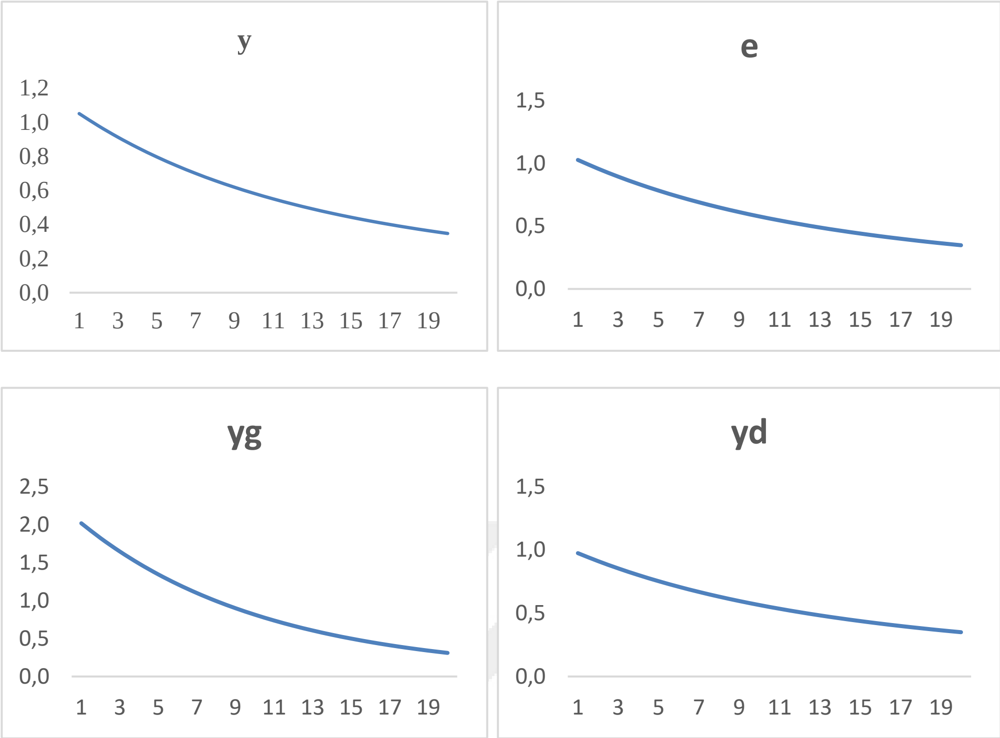
Figure 5.5. Total Factor Productivity Shock, (τ_t =0.05)



The effect of the total factor productivity shock on macroeconomic variables is realized through the classical transmission mechanism. Depending on the increase in the marginal productivity of labor and capital, the demand of the firms for these factors of production increases and the production of both firm types and, therefore the total production rises. While the output of non-green firms initially increased by approximately 1.3 percent, the production of green firms showed a more moderate increase of 0.4 percent. Depending on the rise in wages and capital return rates, significant increases are observed initially in consumption and investment. As a result of the total factor productivity shock, pollution also showed an initial hike of about 1.3 percent.

Figure 5.6 shows the effect of a total factor productivity shock on macroeconomic variables with a tax shock initially raises the tax rate to 15 percent for non-green loans.

Figure 5.6. Total Factor Productivity and Tax Shock

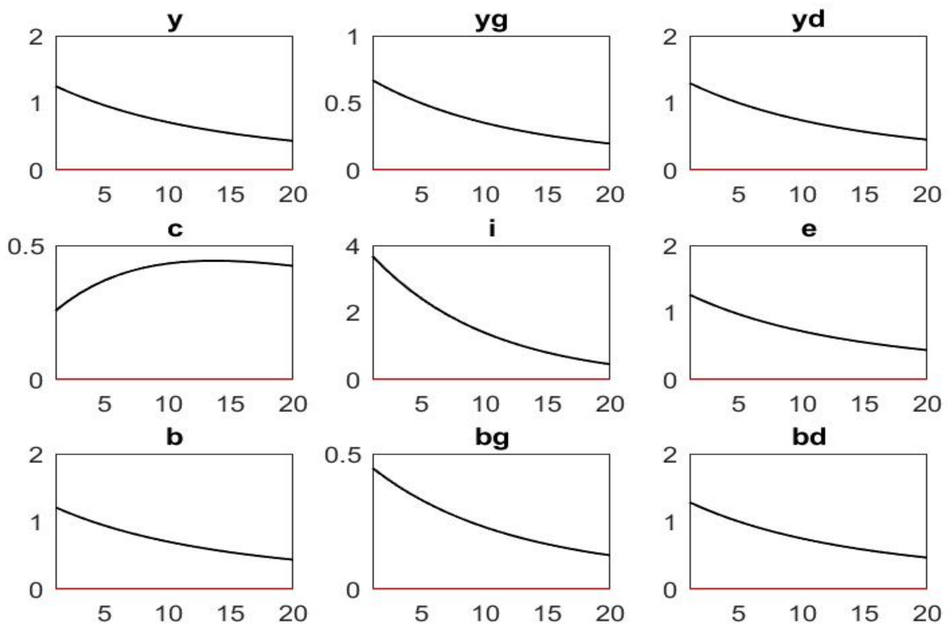


Firstly, with the introduction of the tax shock, the pollution rate initially showed an improvement compared to the base scenario, where the tax rate is 5 percent, and decreased from 1.3 percent to 1 percent. A similar status is seen in the total output. There is a 0.3 percentage point drop in the growth rate of total output. Since the tax rate directly affects the loans given to non-green firms, there is a decrease in the production levels of these firms. On the other hand, when the tax shock came into use along with the total factor productivity shock, the production performances of the green firms increased even more. The production growth rate, initially about 0.4 percent, has improved remarkably and reached a growth rate of 2 percent. In a sense, the effect of further pollution caused by the expansion in the economy due to the total factor productivity shock is partially compensated by the hike in the tax rate. In addition, the high tax rate also reduces the growth rates of macroeconomic variables, causing a partial decrease in volatility. These results align with the Heutel (2012) and Chan (2020) studies about the effects of tax rates on macroeconomic variables and emissions in expansion periods.

5.5. Pegged Policy Analysis

We investigate the different intensity reactions of the central bank and the financial authority to the pollution in the economy, through pegged policy tools, under two different scenarios. In the low-intensity scenario, the central bank and the fiscal authority respond to deviations in pollution with a relatively low-elasticity reaction function. ($\phi_{n,m,\tau,r} = 0.1$). In the high-intensity scenario, the central bank and fiscal authority react to deviations in pollution of two to one ($\phi_{n,m,\tau,r} = 2$). In order to measure the impact of policies, we give a productivity shock to the model and investigate the response of macroeconomic variables under policy sets of different intensities. Figure 5.7 and Figure 5.8 show the responses of macroeconomic variables to productivity shock under low and high intensity policies, respectively.

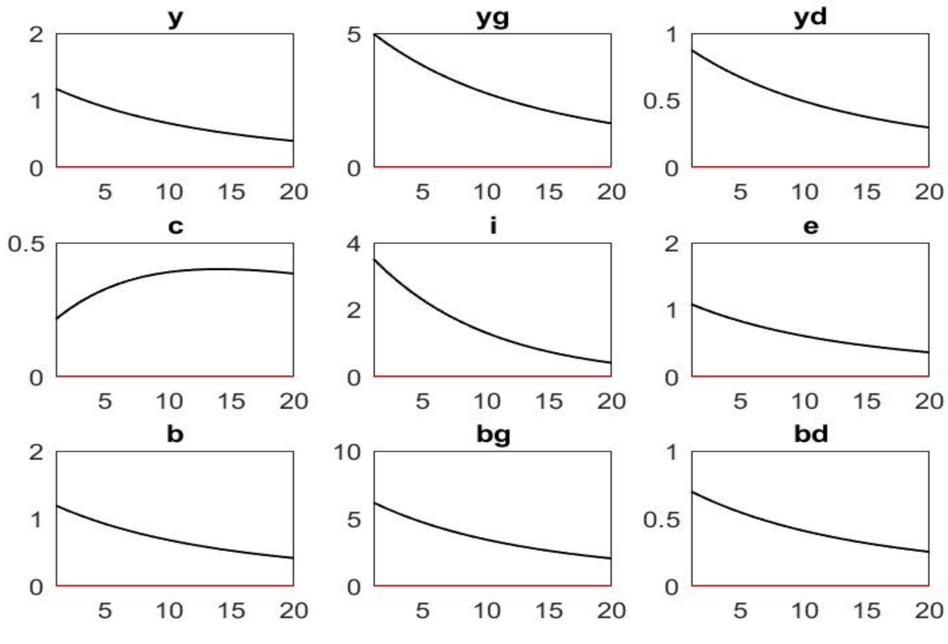
Figure 5.7. Productivity Shock Under Weak Policy Intensity



Under the low-intensity policy set, the output level in the economy increases after the productivity shock. It is seen that the non-green firms are not sufficiently affected by the policies, and that they can even borrow more easily compared to the green firms, with a more than 1 percent initial loan growth. Accordingly, the production growth of non-green firms during the period is above the green firms. As a result, pollution rises by over 1.27 percent initially, then decreases with the diminishing of the productivity shock.

Under the high-intensity policy set, it is seen that firms engaged in green production have a very advantageous position. Initially, production levels show a very high performance compared to the low-intensity policy set and increase by about 5 percent. During the period, green firms show a better production performance than non-green firms. Opportunities for green firms to reach credit have also improved considerably under the intense policy set, and access to the credit by non-green firms is lowered significantly. Under the low-intensity policy set, production initially increases 1.25 percent due to the shock, while total production increases 1.2 percent under the high-intensity policy set. Therefore, there is no significant loss in total production under the high-intensity policy. The growth rate of pollution under the high-intensity policy set initially decreased by about 0.17 percentage points compared to the low-intensity policy set and became 1.1 percent. However, at the end of twenty periods, it cannot return to its steady-state level.

Figure 5.8. Productivity Shock Under Strong Policy Intensity



Conclusion

Within the scope of the study, we introduced the banking system in the DSGE model and investigated the effect of alternative policy tools of the Central bank and financial authority on the performance of green and non-green firms. In this context, we included the central bank's relending interest rate, required reserve ratio and collateral lending ratio tools in the model as the central bank's tools to support green firms. We placed the financial authority in the model through the taxation of non-green loans, hence the firms, that use the loans as working capital. We investigate the impact of these policy instruments on both types of firms and the economy.

According to the study’s result, all three policy instruments (required reserve ratio, relending interest rate, collateral lending ratio) that central banks use, increase green firms' access to credit, thus positively affecting their production. The most effective among these three policy tools is the relending interest rate tool. The relending interest rate shock initially increases the green firm's production performance by approximately 1.2 percent, while increasing its access to credit by 2 percent. The effectiveness of the required reserve ratio tool comes after the relending interest rate tool. The collateral lending ratio tool is the least effective of these three monetary policy instruments. When we examine the impact of the shocks of these three policy tools for twenty periods, the relending interest tool increases the growth performance of the green firm by more than 10 percent in total throughout the period, the access to credit by more than 15 percent and employment by around 8 percent. The relending interest rate policy tool is prominent in supporting green firms for the green economy transition period. The performance of other tools during the period is significant.

These three monetary policy tools affect non-green firms negatively. The policy tool that most reduces the growth performance and opportunities of accessing credit of non-green firms is the relending interest rate policy tool. The overall effect of a relending interest rate shock on the non-green firm's output and credit growth is approximately 1.2 percent and 1 percent reductions, respectively. On the other hand, it causes a decrease of roughly

0.5 percent in employment. The impact of the other two policy instruments remains more limited.

Parallel to the impact of these three policy tools on green and non-green firms, the pollution reduction is most likely when the interest relending policy tool is implemented. The policy tool that creates the least cost to the economy in terms of production and employment is the collateral lending policy tool.

The fiscal authority's low-intensity tax policy is ineffective in reducing pollution when the economy expands due to a productivity shock. On the other hand, when the high-intensity tax policy is applied, the growth performance of the non-green firm decreases partially. In contrast, the growth performance of the green firm increases dramatically from 0.6 percent to 5 percent. Intensive tax policy also initially reduces the pollution growth by about 0.2 percent. Considering the relatively limited cost effect of the intensive tax policy, tax policy is one of the tools that can be implemented in the transition to a green economy, along with monetary policy tools.

Within the scope of the study, we did not consider the frictions caused by sunk loans in the banking system and the investment adjustment and capital utilization cost. This friction and costs directly affect banks' lending behavior and firms' investment behavior. Future work can be extended by considering these frictions and costs. Besides, we did not consider banks' risk weighting according to the sector. On the other hand, the transmission mechanism of policy rate shocks on firms can be analyzed by including these policy tools directly into the central bank inflation targeting reaction function.

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Appendices

Variable and Parameter Definitions

Variable/Parameter	Definition
A_t	Total factor productivity
$B_t^{g,d}$	Green and non-green firm borrowing
B_t	Total borrowing of firms
$C_{j,t}$	Household consumption
D_t	Household deposits
E_t	Pollution
G_t	Government expenditure
I_t	Investment
K_t^g	Capital stock, green sector
K_t^d	Capital stock, non-green sector
K_t	Total capital stock
$L_{j,t}^g$	Household labor supply, green firm
$L_{j,t}^d$	Household labor supply, non-green firm
$L_t^{g,d}$	Green and non-green firm labor demand
L_t	Household total labor supply
R_t^s	Deposit interest rate
$R_t^{g,d}$	Bank lending interest rate for green and non-green firm
R_t^K	Rate of return on physical capital
R_t^{rl}	Green relending interest rate
U_t	Green borrowing amount of bank from the central bank
W_t^g	Wages, green sector
W_t^d	Wages, non-green sector
$Y_t^{g,d}$	Green and non-green firm output
Y_t	Total output
$\Pi_t^{g,d}$	Green and non-green firm profit
Π_t^b	Bank profit
β	Discount factor
σ_1	Inverse Frisch elasticity, green firm
σ_2	Inverse Frisch elasticity, non-green firm
δ	Depreciation rate
λ	Lagrange multiplier for the household budget constraint
α	Capital share
ρ_A	Persistence of productivity shock
ρ_n	Persistence of reduction elasticity shock
$\rho_{r^{rl}}$	Persistence relending interest rate shock
ρ_m	Persistence of collateral rate requirement shock
ρ_τ	Persistence of tax shock
k	Pollution adaptation coefficient
ε_1	Pollution elasticity, green firm

Variable/Parameter	Definition
ε_2	Pollution elasticity, non-green firm
τ	Tax rate
rr	Required reserve ratio
X_t	Required reserve ratio decreasing coefficient
N_t	Required reserve ratio reduction elasticity
M_t	Central bank collateral rate requirement
Ψ_t	Lagrange multiplier for bank balance sheet constraint
Ω_t	Lagrange multiplier for bank green relending constraint
$\xi_{t,A}$	Total factor productivity shock
$\xi_{t,n}$	Required reserve ratio shock
$\xi_{t,r^{rl}}$	Relending interest rate shock
$\xi_{t,m}$	Collateral lending ratio shock
$\xi_{t,\tau}$	Tax shock
$\phi_{n,r^{rl},m}$	Central bank response elasticities to pollution
ϕ_τ	Government response elasticity to pollution

Set of Equations in the Model

Households:

$$E_t^j \sum_{k=0}^{\infty} \beta^k \left\{ ln(C_{j,t}) - \frac{\left(L_{j,t}^g\right)^{1+\sigma_1}}{1+\sigma_1} - \frac{\left(L_{j,t}^d\right)^{1+\sigma_2}}{1+\sigma_2} \right\} \tag{2.1}$$

$$C_t + D_t + I_t = W_t^g L_t^g + W_t^d L_t^d + R_t^K K_t^g + R_t^K K_t^d + R_{t-1}^D D_{t-1} \tag{2.2}$$

$$K_{t+1} = (1-\delta)K_t + I_t \tag{2.3}$$

$$\frac{1}{C_t} = \lambda \tag{2.4}$$

$$\left(L_t^g\right)^{\sigma_1} = \frac{W_t^g}{C_t} \tag{2.5}$$

$$\left(L_t^d\right)^{\sigma_2} = \frac{W_t^d}{C_t} \tag{2.6}$$

$$\frac{C_{t+1}}{C_t} = \beta(1-\delta+R_{t+1}^K) \tag{2.7}$$

$$\frac{C_{t+1}}{C_t} = \beta R_t^D \tag{2.8}$$

Firms:

$$\Pi_t^{g,d} = Y_t^{g,d} - \left[(R_t^{g,d}-1)B_t^{g,d} + W_t^{g,d}L_t^{g,d} + R_t^K K_t^{g,d}\right] \tag{2.9}$$

$$\Pi_t^{g,d} = Y_t^{g,d} - R_t^{g,d}B_t^{g,d} \tag{2.10}$$

$$Y_t^{g,d} = A_t\left(K_t^{g,d}\right)^{\alpha}\left(L_t^{g,d}\right)^{1-\alpha} \tag{2.11}$$

$$logA_t = (1-\rho_A)logA_{ss} + \rho_A logA_{t-1} + \xi_{t,A} \tag{2.12}$$

$$\max_{L_t^{g,d} K_t^{g,d}} \ \Pi_t^{g,d} = Y_t^{g,d} - R_t^{g,d}B_t^{g,d} \tag{2.13}$$

$$s.t. \begin{cases} Y_t^{g,d} = A_t\left(K_t^{g,d}\right)^{\alpha}\left(L_t^{g,d}\right)^{1-\alpha} \\ B_t^{g,d} = W_t^{g,d}L_t^{g,d} + R_t^K K_t^{g,d} \end{cases} \tag{2.14}$$

$$K_t^{g,d} = \alpha \frac{Y_t^{g,d}}{R_t^{g,d}R_t^K} \tag{2.15}$$

$$L_t^{g,d} = (1-\alpha)\frac{Y_t^{g,d}}{R_t^{g,d}W_t^{g,d}} \tag{2.16}$$

Pollution:

$$\boldsymbol{E_t = k\left(Y_t^g\right)^{\varepsilon_1}\left(Y_t^d\right)^{\varepsilon_2}} \tag{2.17}$$

Financial Sector:

$$\Pi_t^b = \left(R_t^g - 1\right)B_t^g + \left(R_t^d - 1\right)B_t^d - \tau B_t^d - (R_t^s - 1)D_t - \left(R_t^{rl} - 1\right)U_t \tag{2.18}$$

$$B_t + (rr - X_t)D_t = D_t + U_t \tag{2.19}$$

$$X_t = \frac{B_t^g}{B_t}N_t \tag{2.20}$$

$$U_t \leq B_t^g M_t \tag{2.21}$$

$$\max_{B_t^i, B_t^g, D_t, U_t} \Pi_t^b = \left(R_t^g - 1\right)B_t^g + \left(R_t^d - 1\right)B_t^d - \tau_t B_t^d - (R_t^s - 1)D_t - \left(R_t^{rl} - 1\right)U_t \tag{2.22}$$

$$s.t.\begin{cases} B_t = B_t^g + B_t^d \\ B_t + (rr - X_t)D_t = D_t + U_t \\ X_t = \frac{B_t^g}{B_t}N_t \\ U_t \leq B_t^g M_t \end{cases} \tag{2.23}$$

$$R_t^g = \Psi_t + \frac{\Psi_t D_t N_t B_t^g}{\left(B_t^g + B_t^d\right)^2} - \frac{\Psi_t D_t N_t}{B_t^g + B_t^d} - \Omega_t M_t \tag{2.24}$$

$$R_t^d = \Psi_t + \frac{\Psi_t D_t N_t B_t^g}{\left(B_t^g + B_t^d\right)^2} + \tau \tag{2.25}$$

$$R_t^{rl} = \Psi_t - \Omega_t \tag{2.26}$$

$$R_t^s = (rr - X_t) - \Psi_t(rr - X_t - 1) \tag{2.27}$$

Central Bank and Fiscal Policy:

$$logN_t = (1-\rho_n)logN_{ss} + \rho_n logN_{t-1} + \xi_{t,n} \tag{2.28}$$

$$logR_t^{rl} = \left(1 - \rho_{r^{rl}}\right)logR_{ss}^{rl} + \rho_{r^{rl}} logR_{t-1}^{rl} - \xi_{t,r^{rl}} \tag{2.29}$$

$$logM_t = (1 - \rho_m)logM_{ss} + \rho_m logM_{t-1} + \xi_{t,m} \quad (2.30)$$

$$\hat{n}_t = \phi_n \hat{e}_t \quad (2.31)$$

$$\hat{r}_t^{rl} = -\phi_{r^{rl}} \hat{e}_t \quad (2.32)$$

$$\widehat{m}_t = \phi_m \hat{e}_t \quad (2.33)$$

$$G_{\ t} = \tau_t B_t^j \quad (2.34)$$

$$log\tau_t = (1 - \rho_\tau)log\tau_{ss} + \rho_\tau log\tau_{t-1} + \xi_{t,\tau} \quad (2.35)$$

$$\hat{\tau}_t = \phi_\tau \hat{e}_t \quad (2.36)$$

Aggregate Equilibrium:

$$K_t = K_t^g + K_t^d \quad (2.37)$$

$$L_t = L_t^g + L_t^d \quad (2.38)$$

$$B_t = B_t^g + B_t^d \ , \ \ B_t + (rr - X_t)D_t = D_t + U_t \quad (2.39)$$

$$Y_t = Y_t^g + Y_t^d \quad (2.40)$$

$$Y_t = C_t + I_t \quad (2.41)$$