Essays on Monetary Policy, Banking and Business Cycles

Inaugural-Dissertation

zur

Erlangung des Doktorgrades

der

Wirtschafts- und Sozialwissenschaftlichen Fakultät

der

Universität zu Köln

2017

vorgelegt von

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Tag der Promotion: 13.12.2017

To my parents and grandparents

Acknowledgements

I would like to express my sincere gratitude to my supervisors Helge Braun and Andreas Schabert who supported my work and helped me get results of better quality. Their ears were always open to me and I enjoyed every insightful discussions with them. Especially, I want to thank Andreas Schabert for his great patience with me and my questions, and for his great support in overcoming numerous obstacles I have been facing through my research. Without his guidance and persistent help this dissertation would not have been possible.

I am very grateful to Wouter den Haan for his support and time. I also want to thank Lawrence Christiano and Daisuku Ikeda for answering my questions. In addition, special thanks to Johannes Pfeifer: he was a great help and a valuable motivator! His generous support was priceless.

I also want to thank everyone from the office of the Center for Macroeconomic Research for their great assistance in all administrative matters.

Finally, I want to take this opportunity to express the profound gratitude to my beloved parents, grandparents, and my brother. I am also deeply grateful to my friends for supporting me and motivating me throughout writing this thesis. Thank you for your love!

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Chapter 1

Introduction

This thesis consists of three self-contained chapters that contribute to the research fields of business cycles, monetary policy, and banking regulation. All three topics are directly linked to the financial crisis of 2007 and the European debt crisis during 2012. Both crises have significant effects on the real economy, on the interplay between the fiscal and the monetary authority, and on the regulation of the banking sector.

The second chapter, therefore, analyzes the reaction of the German business cycle to both crises. It investigates their effects on the real economy by conducting a business cycle decomposition and explicitly looking at the importance of foreign demand and price shocks. Both are especially interesting for Germany as this country is an export-oriented economy. The crisis led to immense foreign demand shocks and foreign prices shocks. It is, however, neither empirically nor theoretically clear which of the two effects (demand or price) dominated the impacts of the financial and European debt crisis on the German economy. Francois and Woerz (2009) stress that a drop in relative prices is a sign for a potential loss in terms of competitiveness, whereas a drop in quantities simply shows that there is less use for the goods in demand.

The third chapter investigates the optimal monetary reaction to a temporarily shortsighted fiscal authority. It is characterized by its preference for financing government spending through higher debt rather than higher taxes. A problem that is explained by political uncertainty in that the politicians have a finite and time-varying horizon. This tendency to finance government spending predominantly by government debt leads to high public-debt-to-GDP ratios. During 2007, and especially during

2012, these high public-debt-to-GDP ratios cast serious doubt on the solvency of several southern European countries during the European debt crisis. A temporarily myopic fiscal authority is associated with this so-called debt bias, which can be an independent source of business cycle fluctuations (see Kumhof and Yakadina 2007). Therefore, the third chapter presents the optimal monetary policy reaction to a temporarily shortsighted fiscal authority that minimizes the distortion caused by this fiscal shortsightedness.

The forth chapter investigates the recent European implementation of the Basel III regulation package. The financial crisis of 2007 was the motivation for a stricter banking regulation in Europe: The regulation aimed at reducing the overall probability and consequences of a future banking crisis similar to the crisis seen in 2007. However, the European implementation of Basel III is quite special regarding European government bonds. Banks that invest in European government bonds do not have to hold any equity against them. All bonds issued by European governments are seen as riskless assets and investments in these bonds can be fully financed by debt. Therefore, the last chapter investigates how fully debt-financed government bonds influence the optimal design of an equity requirement constraint.

In all three chapters I use dynamic stochastic general equilibrium (DSGE) models which have become standard tools in the field of macroeconomics. Using a DSGE structure puts discipline on the reduced-form parameters of the state-space model, which are less likely to change in response to changes in the policy, making these models robust to the Lucas (1976) critique. Authors such as Smets and Wouters (2007) and Edge, Kiley, and Laforte (2010) proved the forecasting power of these models.

I will now present the three chapters in more detail: Chapter 2, beside specifying and estimating a parsimonious open economy DSGE model, provides a detailed historical decomposition of the German business cycle based on the estimation and investigates the relative importance of foreign demand and foreign price effects for the German economy. Concretely, it studies the effects of the financial crisis of 2007 and the European debt crisis during 2012 on the German business cycle. The tight connectivity of a globalized economic system accelerated the spill-over effects. Both crises naturally affected the German economy as it is highly integrated in the world economy.

Therefore, my thesis starts with an investigation of the reaction of the German business cycle to this immense economic turmoil. Since the German economy became more and more export-oriented over time, the severe drop in international trade during 2007 - 2009 came as a serious assault on the German export sector. Real exports dropped by about 18 percent between the first quarter of 2008 and the second quarter of 2009, while imports dropped by 12 percent. The dominant negative reaction of the export sector could be a sign that the crisis was mainly located at the foreign demand side. Import prices decreased by about 11 percent between the second quarter of 2008 and the third quarter of 2009, while export prices fell by only 3 percent. Consequently, the terms of trade, defined as export prices divided by import prices, rose during the same period. As Mann (1999) points out, a rise in the terms of trades could mean that the rest of the world is willing to pay higher prices for German exports goods. It means that German exports can purchase more imports, which in turn implies that the German income can support a higher standard of living. Thus, the terms of trade could be used as a measure of competitiveness of an economy. However, rising exports can lead to a rising trade surplus. Taken together, the crisis led to immense foreign demand shocks and foreign prices shocks. It is, however, neither empirically nor theoretically clear which of the two effects (demand or price) dominated the impacts of the financial and European debt crisis on the German economy. Francois and Woerz (2009) stress that a rise in relative prices is a sign for a potential gain in the competitiveness, whereas a drop in the quantities simply shows that there is less use for the demanded goods. Therefore, negative demand effects would signify that the demand dropped because the global economy cooled down. However, positive price effects would indicate that the German economy improved its competitiveness. Using a DSGE model and Bayesian estimation techniques I find that during the financial crisis of 2007 - 2009 the German economy was hit by a series of negative foreign demand shocks, while at the same time price shocks had positive impacts on the growth rate of the GDP. These positive price effects worked mainly through heavily falling import prices. The German export sector clearly profited from rising terms of trade, which could be indicative of the competitiveness of this sector. This effect could not be seen during the European debt crisis, where positive price effects were not present. In addition, I confirm the results of Ohanian (2010) who stresses that, in contrast to the U.S. economy, the German economy suffered from a reduction in its productivity. I also confirm the findings of Gerke et al. (2012) that the monetary policy was not expansive enough, and those of Drygalla (2016) who finds that the fiscal policy stimulated the German economy during the recession, albeit only to a small extent except when the output was already expanding again. For the European debt crisis one can not find stimulating effects.

Chapter 3 analyzes the optimal monetary policy reaction to a temporarily shortsighted fiscal authority. Understanding the interplay between fiscal and monetary policy is not only important in general, but significant especially before and during a crisis.

That governments prefer financing government spending mainly by debt can be seen by the fact that since 2006 the average debt-to-GDP ratio of the OECD countries has risen from 74.6 percent to 111 percent in 2015. The literature on political economy explains part of these findings by introducing a dimension of political uncertainty in that the politicians have a finite and time-varying horizon. According to Grossman and Huyck (1988), political myopia is the result of an expected finite planning horizon associated with the expected fiscal authority's probability to survive in power (see also Rieth 2011). In addition, Kumhof and Yakadina (2007) argue that such political uncertainty gives rise to positive and significant long-run debt level and to short-run debt bias. A temporarily myopic fiscal authority is associated with this so-called debt bias, which is related to political polarization or turnover (see Hatchondo, Martinez, and Roch 2015). The short-run debt bias is associated with negative shocks to the fiscal authority's discount factor. Such shocks give rise to populist tax cuts, which can be an independent source of business cycle fluctuations (see Kumhof and Yakadina 2007). Business cycle fluctuations clearly affect the welfare of the agents living in the economy. Therefore, a benevolent monetary authority wants to react optimally to political business cycles caused by a temporarily shortsighted fiscal authority. In this chapter I describe this optimal monetary policy reaction. This chapter is in line with the literature that investigates the interaction between the fiscal and monetary authorities. Adam (2011), for example, derives the optimal monetary and fiscal policy under commitment in dependency to the level of the fiscal authority debt. However, as the author stresses, ”the [...] paper focused exclusively on technology shocks. Other shocks, e.g., shocks to agent’s discount factors give rise to additional sources of budget risk, as they move the real interest rates at which the government can refinance its outstanding debt.” (Adam 2011, , p. 71) Thus, Adam (2011) does not investigates distortions caused by a fiscal authority. Niemann and Hagen (2008), Niemann (2011) and Niemann, Pichler, and Sorger (2013) describe the interactions of monetary and fiscal policy in a strategic game where none of them can commit to future actions. In their model, the fiscal authority is always impatient, always causing adverse welfare effects, which is a quite strong assumption. Rieth (2011) investigates an impatient fiscal authority. He examines the transition dynamics induced by a fiscal authority that permanently has a higher discount factor than private households. However, an optimal monetary reaction is not presented. Kumhof and Yakadina (2007), Juessen and Schabert (2013), and Hatchondo, Martinez, and Roch (2015) use a lower fiscal authority discount factor to model political uncertainty induced by a finite planning horizon. They investigate political business cycles caused by fluctuations in the planning horizon resulting from discount factor shocks. However, they do not investigate an optimal monetary policy response to these fluctuations. Thus, this chapter contributes to the literature by investigating the optimal monetary response to business cycles caused by shocks to the fiscal authority’s discount factor. Both authorities can fully commit to their behavior and are in the long-run fully benevolent. I use a parsimonious infinite-horizon economy with sticky prices, monopolistic competition, a distortionary labor income tax, and an exogenous shock to the fiscal authority’s discount factor. One aspect of the fiscal shortsightedness is its myopia. A temporarily myopic fiscal authority is characterized by a shift from tax-financed to debt-financed fiscal policy. The second aspect of fiscal shortsightedness is as follows: The fiscal authority does not internalize the reaction of a benevolent central bank to a temporarily myopic fiscal policy. Hence, my argument is similar to that made by Niemann (2011), who states that the implication of fiscal myopia is the failure to internalize the systematic response of future policies to variations in the future state of the economy. I derive the following results: A fiscal authority that is hit by a temporary discount factor shock increases the public spending and decreases the labor income tax financed by higher public debt. A lower labor income tax reduces the marginal cost for producers, thus leading them to lower their prices. Consequently, inflation falls, but its volatility and price dispersion increase. With the volatility of the tax rate and the inflation rate rising, the distortions in the economy increase. Therefore, the central bank's optimal response is to reduce these distortions. The central bank achieves this by reducing the money supply in order to reduce seigniorage revenues. Lower seigniorage revenues lower the fiscal authority's income. Therefore, the fiscal authority cannot lower the tax rate as much. This leads to higher tax revenues. Therefore, debt accumulation is smaller, and consequently, there are fewer price movements. Thus, the volatility of the inflation rate shrinks and price dispersion declines. As a result, the central bank can reduce the volatility of inflation and the labor income tax rate, thus reducing the welfare costs and increasing overall welfare compared to an economy where the central bank uses either a constant money growth rate or a standard policy as proposed by Taylor (1993).

Chapter 4 analyzes a different aspect of the financial crisis: Since the financial crisis of 2007, the regulation of the banking sector stands in the focus of the current political and academic debate. Therefore, this chapter investigates the design of an optimal equity requirement constraint.

Owing to the financial crisis, the Basel II banking regulations were adjusted. This reform is known as Basel III. However, the European equity requirement constraint favors government bonds strongly. Banks that invest in European government bonds do not have to hold any equity against them. All bonds issued by European governments are seen as riskless assets and investments in these bonds can be fully financed by debt. Therefore, I investigate in this chapter the effects of government bonds on the optimal design of an equity requirement constraint. More specifically, I investigate the impact of safe assets (here government bonds) on a long-run optimal equity requirement constraint. Recent papers have proved the optimality of introducing an equity requirement constraint using models with financial frictions. Authors such as Martinez-Miera and Suarez (2012), Bigio (2014), Nguyen (2014) and others focus on studying why an equity requirement constraint is useful and analyzing the effects of a stricter constraint on the economy. However, none of them analyze how the optimal design of an equity requirement constraint is influenced by the amount of safe assets. I analyze the long-run optimality and therefore the maximization of the steady-state value of the welfare. As the equity requirement regulation has a long-term perspective, and not a business-cycle perspective like the countercyclical capital buffers, I choose to focus on the model's stationary competitive equilibrium. The model is a simplified version of the model of Christiano and Ikeda (2014). I extend their model by introducing safe assets (e.g. government bonds). The model contains the following agents: A representative household composed of equal fraction of savers and bankers, good and bad firms, final goods producers, mutual funds, and a government. The private savers consume the final output goods and save by investing in riskless bonds issued by mutual funds. They own the banks and the firms. The mutual funds use the savers' deposits to give loans to a diversified set of banks. Free entry and perfect competitions among the mutual funds lead to zero profits. Banks borrow from mutual funds. They offer firms loans. The banks make loans to one firm each making their asset side risky. However, banks can increase the probability to find firms of the good type by exerting costly unobservable search effort. In addition, banks can invest in riskless government bonds. The following results are obtained: The higher the amount of government bonds, the stricter the equity requirement constraint must be. The reason is as follows: The key role of banks in this model is the identification of good debtors by exerting costly search effort. However, the model contains an agency problem between banks and their creditors: Hidden action. Therefore, the banks' effort is not observable. As shown by various authors (such as Spremann 1987), a hidden action problem leads to an effort level lower than the socially optimal one. Only if banks have a sufficiently high amount of equity, the incentives of exerting search effort are increased. Thus, an equity requirement constraint mitigates the distortions caused by the hidden action problem: A higher amount of equity leads to a higher amount of effort as shown by Christiano and Ikeda (2014). In this case, the classic skin-in-the-game argument is at play. Besides, the hidden effort problem, a binding limited liability constraint is present, which is why the Modigliani-Miller theorem does not apply here. Therefore, an increase in the banks' leverage reduces the bank's incentive to exert costly search effort. As this chapter shows, the limited liability constraint distorts the banks' choice of exerting costly search effort to find good debtors. The distortion is caused by the non-zero interest spread stemming from the binding limited liability constraint: As effort is non-observable, the banks' creditors demand state-dependent interest rates as the creditors of banks with poorly performing assets must participate in losses. If the bankers' creditors do not offer a contingent debt contract, there will be no compensation for the possibility that the banks receive a low return on its investment and simply default. Therefore, banks have to pay a higher interest rate to their creditors in case they have found a good debtor, as Christiano and Ikeda (2014) show. In addition, I demonstrate that a higher amount of government bonds reduces the interest rate spread charged by the banks' creditors: An increase in government bonds also increases the return of banks with poorly performing assets, leading to a weaker limited liability constraint. This reduces the interest spread paid by the banks and increases the incentive to exert costly effort. Thus, on the one hand government bonds positively affect the banks' effort. On the other hand, they are safe assets and so banks cannot influence the return of government bonds by increasing the search effort. Thus, the higher the amount of government bonds, the lower the incentive to search for good loans tends to be. In addition, following the European implementation of Basel III, government bonds can be fully financed with debt. Hence, the higher the amount of government bonds, the higher the amount of banks' debt is, increasing banks' leverage. As long as the limited liability is binding, increasing debt increases this distortion of the effort choice. To compensate this, a stricter equity requirement regulation is necessary. To sum up, there are two frictions in the model: A hidden action problem and a limited liability constraint. Therefore, one can make a second-best argument: To reach the first-best case, one needs two instruments, which are the amount of government bonds and the equity requirement regulation. In fact, the chapter shows that one can reach the first-best case by increasing both the amount of government bonds and the risk-weight on loans, i.e. a stricter equity requirement constraint.

Chapter 2

The Importance of Foreign Demand and Price Shocks for the German Business Cycle

2.1 Introduction

The financial crisis of 2007 - 2009 originated in the U.S. financial market and then spread rapidly around the world. The tight connectivity of a globalized economic system accelerated this spillover even more. Since sound financial markets are the foundation of a sound real economy, the problems in the banking system disturbed fast into the real economy. The resulting global recession led to a massive drop in international trade. Shortly, after that immense negative impact on the global economy, a second crisis emerged in 2009. Rising doubt about the solvency of several southern European governments led to a serve distrust in the sustainability of the euro. In addition, rising uncertainty as to how governments should stimulate investments in the short run, and formulate regulatory and economic policy in the long run, led firms to reduce their investments. Julio and Yook (2012) showed that political uncertainty leads firms to reduce investment expenditure. Both crises naturally affected the German economy due to its high integration in the world economy.

Since 1991 the German economy has become increasingly export-oriented. The net-export-to-GDP-ratio increased from minus 0.02 percent in the first quarter of 1991 to

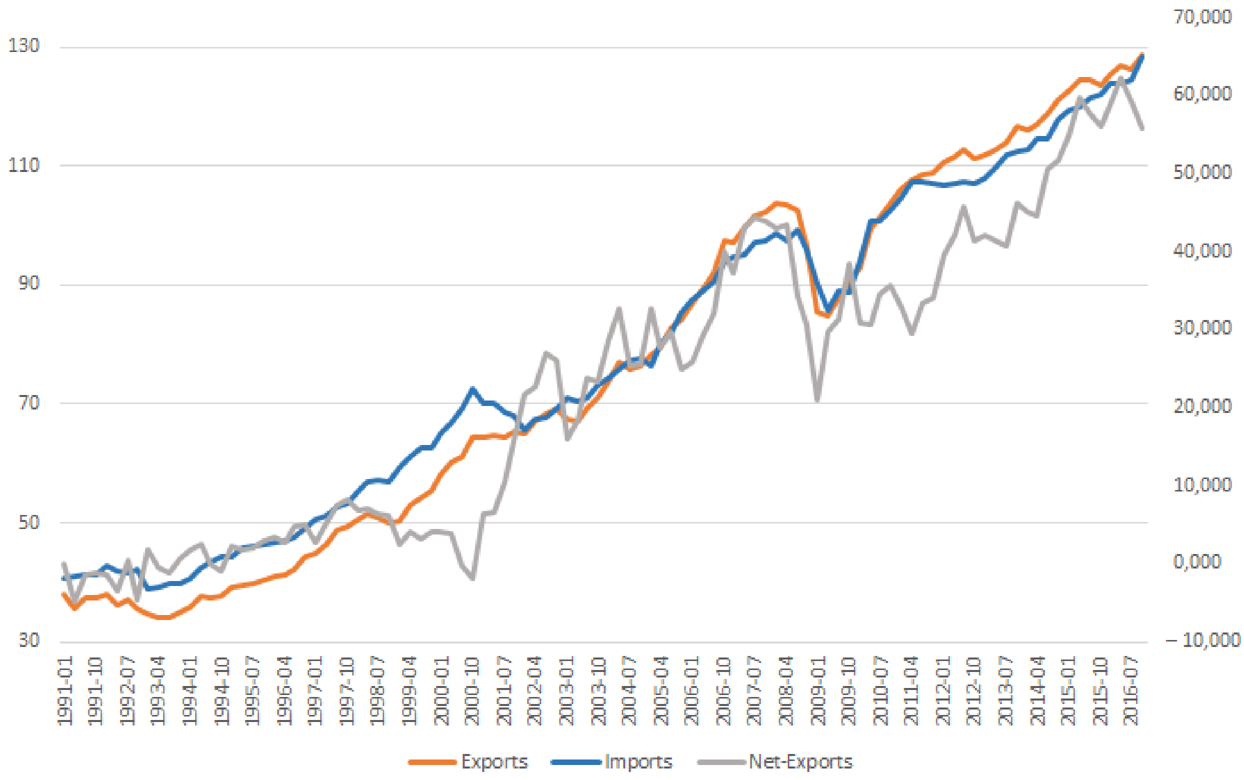
7.06 percent in the last quarter of 2016. In addition, the German export-to-GDP ratio constantly increased from 24 percent in 1991 to over 46 percent in 2016. Therefore, it is not surprising that Germany suffered heavily from the global drop in demand during 2007 - 2009 and from the drop in demand of the southern European countries during the European debt crisis. As a result, the recession of 2009 has enveloped to be the most severe one for Germany since World War II: Gross domestic product (GDP) dropped by about 5 percent in the first quarter of 2009. In addition, the European debt crisis led to negative quarterly GDP growth rate during 2012. At its high, the growth rate was about minus one percent. Since 1991, there have been only five quarters with a growth rate lower than that in 2012.

The severe drop in international trade during 2007 - 2009 hit the German export sector critically (see Figure 2.1): Real exports dropped from 103.75 index points in the first quarter of 2008 to 84.74 index points in the second quarter of 2009. This was a decrease of about 18 percent. At the same time, the German imports dropped from 97.56 index points (first quarter of 2008) to 85.71 index points (second quarter of 2009) - a decrease of about 12 percent. The dominant negative reaction of the exports could indicate that the crisis was mainly located at the foreign demand side. Consequently, this led to a decrease of the German export surplus: from about 43 billion euro (first quarter 2008) to about 21 billion euro (first quarter 2009). In addition, prices of exports and imports also reacted quite strongly to the international crisis (see Figure 2.2). Import prices decreased from 104.4 points (second quarter of 2008) to 92.5 index points (third quarter of 2009) - a reduction of about 11 percent. Export prices however, fell from 99.8 index points (second quarter 2008) to 96.8 index points (third quarter 2009) - a reduction of only 3 percent. Consequently, the terms of trade defined as export prices divided by import prices rose in the same period. As import prices include a high share of commodity prices, which have a high volatility, they fell much more strongly than export prices. As Hummels and Klenow (2005) show richer countries export higher quantities at modestly higher prices, along with higher quality. Thus, the smaller reaction of export prices could be interpreted as a sign for a higher quality of German export goods. Thus, these goods cannot be substituted easily and German exporters were not forced to decrease their prices as much. It is, however, neither empirically nor theoretically clear which of the two effects (demand or price) dominated the impacts of the financial and European debt crisis on the German economy. As Haddad, Harrison, and Hausman (2010) argue, one would expect that if the decline in trade was mostly driven by a negative demand shock, then both prices and quantities would be negatively affected. However, if supply side shocks were important, with a reduction in trade credit leading to a reduction in supply of traded goods independently of the negative demand shock, then one would have expected less downward pressure, and possibly upward pressure, on prices (see Haddad, Harrison, and Hausman 2010).

In this chapter, I investigate the effects of the foreign price and the foreign demand channel on German exports and imports and thus on the German GDP. I also analyze which of the two was more important in the context of the financial crisis of 2007 - 2009 and the European debt crisis. My work is partly motivated by the findings of Enders and Born (2016), who show that in Germany the trade channel was twice as important for the transmission of the crisis as the financial channel, as well as by the findings of Ohanian (2010), who suspects that the crisis in Germany worked mainly through a reduction in productivity. He investigates the crisis from a Neoclassical perspective. I instead see the crisis through the lens of a dynamic stochastic general equilibrium (DSGE) model that features both channels in order to assess their quantitative relevance. As Flotho (2009) argues, using a DSGE structure puts discipline on the reduced-form parameters of the state-space model, which are less likely to change in response to changes in the policy. Thus, these models are robust to the Lucas (1976) critique. As DSGE models can be rewritten in a reduced-form VARMA model, they stand in direct competition to VARMA models in general. However, Smets and Wouters (2007) and Edge, Kiley, and Laforte (2010) show that DSGE models are competitive with VARMAs in terms of forecasting power. Having a structural model and data for prices and quantities of exports and imports, a historical decomposition at the posterior mean of the estimated parameter is performed. I use this decomposition to investigate the importance of the different shocks included in the model. Moreover, I test how robust the results of the historical decomposition of the German business cycle are compared to the results found in the literature.

The following insight is obtained: During the financial crisis of 2007 - 2009, the German economy was hit by a series of negative foreign demand shocks. At the same time, however, foreign price shocks had a positive impact on the growth rate of the GDP, mainly because import prices fell much more than export prices. One can conclude that due to the rise in the relative prices and thereby a potential gain in the competition strength, the drop in the foreign demand for German goods was dampened, thus leading to a smaller decline in the German GDP. In comparison to the financial crisis of 2007 - 2009 the European debt crisis showed a different pattern: Foreign price shocks had negative implications. In addition, as Gadatsch, Hauzenberger, and Stähler (2016) also show, the fiscal policy's contribution to real GDP growth was negative in the last quarter of 2012. In both periods the monetary policy was not expansive enough leading to a negative impact of the monetary shock on the German GDP growth rate.

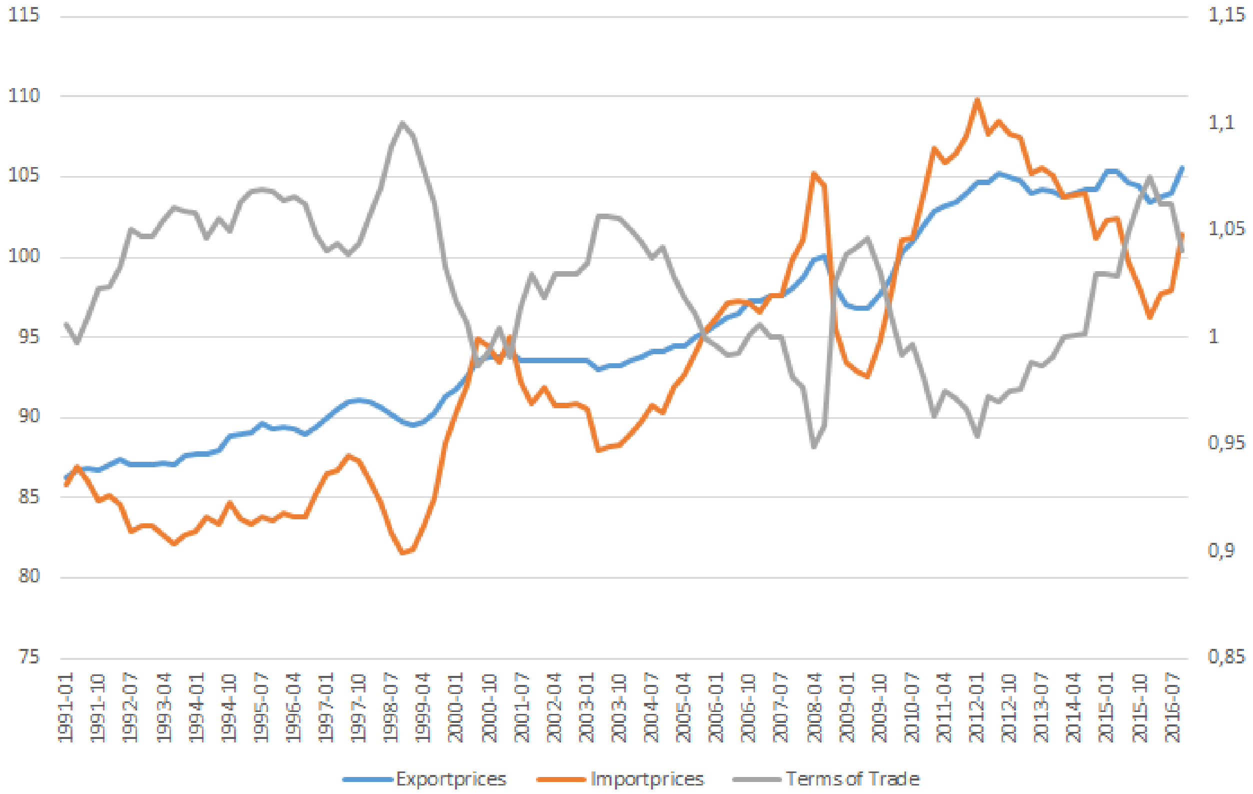
Figure 2.1: Real exports and imports



Notes: Real exports and imports (both chain indices: 2010=100), and the net-exports of Germany (right y-axis in billion Euro). Quarterly frequency.

Related to my research question, several authors investigate the importance of dif-

Figure 2.2: Real export and import prices, and the terms of trade



Notes: Real export and import prices (both chain indices: 2010=100), and the terms of trade of Germany (right y-axis). Quarterly frequency.

ferent shocks for the transmission of the 2007 - 2009 financial crisis. Enders and Born (2016) analyze the effects of the trade and the financial channel and assess which of the two was more important in the transmission of the crisis. They found that, calibrated to German data, the model predicts the trade channel to be twice as important for the transmission of the crisis as the financial channel. For the UK, the reverse holds. Drygalla (2016) studies the effects of fiscal policy in an estimated DSGE model for the case of the German stimulus packages during the Great Recession. Thus, he also conducts a historical decomposition of the German business cycle and finds that, over the entire time period considered, fiscal shocks had only marginal effects on output. Far greater had been the influence of foreign shocks which is not surprising given the export orientation of the Germany economy (see Drygalla 2016). Gadatsch, Hauzenberger, and Stähler (2016) also investigate the effects of fiscal policy during the global financial crisis starting in 2007. Their historical decomposition suggests that discretionary fiscal measures indeed pushed up quarter-on-quarter GDP growth during the crisis. In terms of annualized quarter-on-quarter growth rates, this positive effect implies a contribution of 1.2 pp for Germany and 0.12 pp for the rest of the euro area (see Gadatsch, Hauzenberger, and Stähler 2016). They also show that negative foreign shocks played a major role in the decline of German GDP in 2008. Ohanian (2010), who investigates the 2007 - 2009 economic crisis from a Neoclassical perspective, concludes that in contrast to the U.S. economy the main distortions of the German economy came from a drop in productivity while the employment rate was in fact higher than the level consistent with the marginal product of labor. This was partly driven by the short-time work program of the German government. Of course, if output falls and the input factors of the production function do not fall by the same amount, it only means that the productivity of the input factors must have decreased. Gerke et al. (2012) use a historical shock decompositions of real GDP growth since 2005 to perform a model comparison exercise. For Germany they find that the most driving factors underlying the recent financial crisis are shocks stemming from abroad, from the demand side, and from productivity changes.

Other authors look especially at the great trade collapse that occurred in late 2008. As Baldwin (2009) notes, this drop was sudden, severe, and synchronized - the steepest fall of world trade in recorded history and the deepest fall since the Great Depression. In particular, export-oriented countries suffered naturally heavily from this decline. Bénassy-Quéré et al. (2009) emphasize that a large part of the recent drop in the level of trade is linked to price rather than volume effects. Francois and Woerz (2009) stress that a drop in the relative price is a sign for a potential loss in the competitiveness, whereas a drop in quantity simply shows that there is less use for the demanded goods.

Haddad, Harrison, and Hausman (2010) decompose the great trade collapse into price and quantity effects. However, they do not use a DSGE model. Their findings suggest that the intensive rather than extensive margin mattered the most. On average, quantities declined and prices fell. Price declines were driven primarily by commodities (see Haddad, Harrison, and Hausman 2010). Haddad, Harrison, and Hausman (2010) point out that a decline in trade that is mostly driven by a negative demand shock leads both prices and quantities to fall. However, Haddad, Harrison, and Hausman (2010) stress that if the supply side is dominant, meaning a reduction in trade credit leading to a reduction in the supply of traded goods independently of the negative demand shock, then one would expect less downward pressure and possibly upward pressure on prices. In addition, they find that across all products, both prices and quantities fell significantly in the U.S. and the E.U. Thus, demand shocks have played a major role. The author find that Germany had above-average quantity effects compared to other countries, but a smaller (near zero) price effect. This indicates that these effects might have had different signs and acted as another motivation to investigate price and quantity effects and their impact on the German GDP.

In this context, my contribution to the literature is the following one. Besides specifying and estimating a parsimonious open economy DSGE model, I provide a detailed historical decomposition of the German business cycle based on the estimation and investigate the relative importance of foreign demand and foreign price effects for the German economy. I also compare the financial crisis of 2007 - 2009 and the European debt crisis and make a robustness check by comparing my results with the results found in the literature.

The rest of the chapter is structured as follows: Section 2.2 describes the model's design; Section 2.3 discusses the data and the estimation methodology; Section 2.4 presents and discusses the results of the historical decomposition; Section 2.5 concludes the work.

2.2 Model

I use a quantitative dynamic-optimizing business cycle model of a small open economy. The assumption of a small open economy allows me to treat the specific origin of the financial crisis and the European debt crisis as exogenous to the economy in question (see also Enders and Born (2016) for a similar approach). The model is a variant of Kollmann (2001). The DSGE model used in this chapter has a detailed export and import sector. The domestic country produces intermediate goods for the production of final goods, which are used in the country and exported abroad. The final goods sector uses domestic intermediate goods and imported foreign intermediate goods to produce final goods for both private and public consumption, as well as for private investments. The model's parameters are estimated using Bayesian techniques. As data I use different macroeconomic data and data for import and export prices provided by Bloomberg[1].

2.2.1 The representative household

The preferences of the representative household are described by the following period utility function:

$$u(C_t, L_t) = \exp\left(Z_t^C\right) \frac{(C_t - hC_{t-1})^{1-\psi}}{1-\psi} - \exp\left(Z_t^L\right) \chi \frac{L_t^{1+\gamma}}{1+\gamma},\ 0 < h < 1,\ \psi > 0,\ \gamma > 0,\ \chi \geq 0,$$

where C_t stands for the private consumption. h denotes the degree of the habit persistence[2]. L_t is the labor supply of the household. ψ measures the inverted intertemporal elasticity of substitution, and γ represents the elasticity of the labor supply. χ is a scaling parameter to adjust the steady-state of labor supply. Z_t^C and Z_t^L are exogenous preference shocks following each an AR(1) process:

$$Z_t^i = \rho_{Z^i} Z_{t-1}^i + \epsilon_{Z^i,t},\ i \in \{C, L\},$$

with $0 \leq \rho_{Z^i} \leq 1$. $\epsilon_{Z^i,t}$ are zero-mean, serially uncorrelated, normally distributed innovations with standard deviation σ_{Z^i}.

The representative household accumulates capital K_t in the following manner:

$$K_{t+1} = K_t(1 - \delta(u_t)) + I_t \exp\left(Z_t^I\right) - \Phi(I_t, I_{t-1})I_t, \tag{2.1}$$

where I_t stands for the investments at time t. Z_t^I is an exogenous shock following an AR(1) process (see Justiniano, Primiceri, and Tambalotti 2010):

$$Z_t^I = \rho_{Z^I} Z_{t-1}^I + \epsilon_{Z^I,t},$$

with $0 \leq \rho_{Z^I} \leq 1$. $\epsilon_{Z^I,t}$ are zero-mean, serially uncorrelated, normally distributed

[1] The names of the two time series in the Bloomberg terminal are as follows: *GRBUIMP Index* for German import prices and *GRBUEXP Index* for German export prices.

[2] See Ravn, Schmitt-Grohé, and Uribe (2006) for a discussion of the difference between external and internal habit formation.

innovations with standard deviation σ_{Z^I}. $\Phi(I_t, I_{t-1})$ is an investment adjustment cost function (see Christiano, Eichenbaum, and Evans 2005):

$$\Phi(I_t, I_{t-1}) = 0.5\Phi^I \left(\frac{I_t}{I_{t-1}} - 1\right)^2, \ \Phi^I > 0,$$

where Φ^I measures the level of the capital adjustment costs.

Households are assumed to own physical capital. Owners of physical capital can control the intensity with which the capital stock is utilized (see Schmitt-Grohé and Uribe 2012): u_t measures the capacity utilization in period t. The effective amount of capital services supplied to firms in period t is given by $u_t K_t$. I assume that increasing the intensity of capital utilization entails a cost in the form of a faster rate of depreciation. Hence, $\delta(u_t)$ is an increasing and convex function of the rate of capacity utilization:

$$\delta(u_t) = \delta_0 + \delta_1(u_t - 1) + \frac{\delta_2}{2}(u_t - 1)^2, \ 0 \leq \{\delta_0, \ \delta_1, \ \delta_2\},$$

δ_0 corresponds to the rate of depreciation of the capital stock in the deterministic steady-state in which u_t is unity. δ_1 governs the steady-state level of u_t. δ_2 defines the sensitivity of capacity utilization to variations in the rental rate of capital.

The household maximizes its life-time utility:

$$\max_{\{C_t, \, L_t, \, K_{t+1}, \, I_t, \, u_t, \, B_{t+1}, \, D_{t+1}\}} \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t u(C_t, L_t), \ 0 < \beta < 1, \tag{2.2}$$

where $\mathbb{E}_t$ denotes the mathematical expectation operator conditional upon information available in period t. β is the discount factor. B_t and D_t are riskless nominal foreign and domestic government bonds. The maximization problem is restricted by the following period budget constraint:

$$e_t B_{t+1} + D_{t+1} + P_t C_t + P_t I_t = W_t L_t + e_t B_t (1 + R^*_{t-1}) + D_t (1 + R^D_{t-1}) - T_t + P_t R^K_t K_t u_t + \Pi_t, \tag{2.3}$$

where e_t is the nominal exchange rate, expressed as the domestic currency price of foreign currency. B_{t-1} denotes nominal bonds which pay a nominal interest rate R^*_t in foreign currency. The domestic government bonds D_t pay a nominal interest rate R^D_t. W_t stands for the nominal wage. T_t are nominal tax payments. Capital services $u_t K_t$

pay a return R_t^K. The household is the owner of the firms and thus receives nominal dividends Π_t. P_t is the price of the final goods used for private and public consumption as well as for investments.

The household's optimization problem involves maximizing (2.2) given (2.1) and (2.3). The first-order conditions associated with this optimization problem are:

$$\lambda_t P_t = \exp\left(Z_t^C\right)(C_t - hC_{t-1})^{-\psi} - \beta h \exp\left(Z_{t+1}^C\right)(C_{t+1} - hC_t)^{-\psi},$$

$$W_t \lambda_t = \chi \exp\left(Z_t^L\right) L_t^\gamma,$$

$$\mu_t + \mathbb{E}_t\left(\beta\left(\lambda_{t+1} P_{t+1} R_{t+1}^K u_{t+1} - \mu_{t+1}(1 - \delta(u_{t+1}))\right)\right) = 0,$$

$$\mu_t\left(\Phi(I_t, I_{t-1}) + \Phi^I \frac{I_t}{I_{t-1}}\left(\frac{I_t}{I_{t-1}} - 1\right) - e^{Z_t^I}\right) - \lambda_t P_t = \beta \mathbb{E}_t\left(\mu_{t+1}\Phi^I\left(\frac{I_{t+1}}{I_t} - 1\right)\left(\frac{I_{t+1}}{I_t}\right)^2\right),$$

$$\lambda_t P_t R_t^K K_t + \mu_t K_t\left(\delta_1 + \delta_2(u_t - 1)\right) = 0,$$

$$\lambda_t e_t = \beta \mathbb{E}_t\left(\lambda_{t+1} e_{t+1}(1 + R_t^*)\right), \tag{2.4}$$

$$\lambda_t = \beta \mathbb{E}_t\left(\lambda_{t+1}(1 + R_t^D)\right), \tag{2.5}$$

where λ_t and μ_t are Lagrange multipliers of the period budget constraint and of the capital accumulation equation. Setting (2.4) and (2.5) equal, the uncovered interest rate parity between the domestic and the foreign government bond interest rates is obtained.

To avoid the non-stationary problem, R_t^* is debt-elastic (see Schmitt-Grohé and Uribe 2003):

$$R_t^* = R^{*,ss} + \kappa\left(e^{-e_t B_{t+1}} - 1\right), \ \kappa > 0,$$

where $R^{*,ss}$ is the steady-state value of the foreign interest rate. κ is strictly positive and measures the elasticity of the interest rate with respect to the current foreign level of debt denominated in domestic currency. See Hristov (2016) for a similar approach.

2.2.2 The production sector

There are two types of firms producing two different goods - intermediate goods and final goods. All producers of each type have identical technologies and enjoy the same demand. Final goods producers act under perfect competitions. In contrast, there is monopolistic competition in the intermediate goods market. Final goods producers need domestic and foreign intermediate goods to produce the final goods for private and public consumption as wells as for private investments. Intermediate goods are tradable whereas final goods are not.

Domestic final goods production

The final goods producers are in a perfect competition to each other. Therefore, the price of the final goods is equal to the marginal cost of production. Final goods used for consumption and investment are sold exclusively in the home country. They are not tradable. Final goods are produced with domestic and foreign intermediate goods. Final goods producers use the aggregated intermediate goods to produce final goods Z_t. They use a constant elasticity of substitution production function of the following form:

$$Z_t = \exp\left(AZ_t\right)\left((\alpha^d)^{\frac{1}{\vartheta}}(Q_t^d)^{\frac{\vartheta-1}{\vartheta}} + (1-\alpha^d)^{\frac{1}{\vartheta}}(Q_t^m)^{\frac{\vartheta-1}{\vartheta}}\right)^{\frac{\vartheta}{\vartheta-1}},\ 0 < \alpha^d < 1,\ \vartheta > 0,$$

where α^d measures the importance of the foreign intermediate goods. A higher α^d means a higher home bias. ϑ is the domestic demand elasticity. AZ_t is exogenous and measures how productive the final goods producers are. It follows an AR(1) process:

$$AZ_t = \rho_{AZ} AZ_{t-1} + \epsilon_{AZ,t},\ 0 \leq \rho_{AZ} \leq 1,$$

where the zero-mean, serially uncorrelated innovations ϵ_{AZ} are normally distributed with standard deviation σ_{AZ}.

The quantity index of domestic intermediate goods Q_t^i with $i \in \{d,\ m\}$ is given by:

$$Q_t^i = \left(\int_0^1 (q_t^i(s))^{\frac{1-\nu}{\nu}} ds\right)^{\frac{\nu}{1-\nu}},\ \nu > 1. \tag{2.6}$$

ν is the elasticity of domestic demand for the differentiated domestic intermediate goods. $q_t^d(s)$ and $q_t^m(s)$ are quantities of the domestic and imported type s intermediate goods. Let $p_t^d(s)$ and $p_t^m(s)$ be the prices of these goods. Cost minimization of the final goods producers implies for their demand:

$$q_t^i(s) = \left(\frac{p_t^i(s)}{\mathcal{P}_t^i} \right)^{-\nu} Q_t^i, \tag{2.7}$$

where the price index $\mathcal{P}_t^i$ is defined by:

$$\mathcal{P}_t^i = \left(\int_0^1 (p_t^i(s))^{1-\nu} ds \right)^{\frac{1}{1-\nu}},$$

and

$$Q_t^d = \alpha^d \left(\frac{\mathcal{P}_t^d}{P_t} \right)^{-\vartheta} Z_t,$$

$$Q_t^m = (1-\alpha^d) \left(\frac{\mathcal{P}_t^m}{P_t} \right)^{-\vartheta} Z_t.$$

Perfect competition in the final goods market implies that the good's price P_t is equal to the marginal production cost:

$$P_t = \left(\alpha^d (\mathcal{P}_t^d)^{1-\vartheta} + (1-\alpha^d)(\mathcal{P}_t^m)^{1-\vartheta} \right)^{\frac{1}{1-\vartheta}}.$$

Domestic intermediate goods production

Each intermediate goods producer produces a differentiated intermediate good $y_t(s)$ indexed by $s \in [0,1]$. Consequently, the elasticity of substitution between the intermediate goods is not infinite. For the production of individual intermediate goods intermediate goods producers need capital $u_t(s)K_t(s)$ and labor $L_t(s)$ from the representative household. They use the following production function:

$$y_t(s) = \exp(A_t) \left(u_t(s) K_t(s) \right)^{\alpha} L_t(s)^{1-\alpha}, \; 0 < \alpha < 1, \tag{2.8}$$

where A_t is exogenous and measures the productivity of the intermediate goods sector. It follows an AR(1) process:

$$A_t = \rho_A A_{t-1} + \epsilon_{A,t},\ 0 \leq \rho_A \leq 1,$$

where the zero-mean, serially uncorrelated innovations ϵ_A are normally distributed with standard deviation σ_A.

The domestic intermediate goods producers satisfy two demands: The domestic demand for intermediate goods used in the domestic final goods production $q_t^d(s)$ and the foreign demand for domestic intermediate goods used in the production of the foreign final goods $q_t^x(s)$. Thus, the total demand is given by:

$$y_t(s) = q_t^d(s) + q_t^x(s). \tag{2.9}$$

The foreign demand for domestic intermediate goods is equivalently to Equation (2.6) given by:

$$q_t^x(s) = \left(\frac{p_t^x(s)}{\mathcal{P}_t^x}\right)^{-\nu} Q_t^x, \tag{2.10}$$

where $p_t^x(s)$ is the price for the domestic intermediate goods denominated in the foreign currency. The price index $\mathcal{P}_t^x$ for exported domestic intermediate goods is given by:

$$\mathcal{P}_t^x = \left(\int_0^1 (p_t^x(s))^{1-\nu} ds\right)^{\frac{1}{1-\nu}}.$$

And the quantity index of the exported domestic intermediate goods Q_t^x is given by:

$$Q_t^x = \left(\int_0^1 (q_t^x(s))^{\frac{1-\nu}{\nu}} ds\right)^{\frac{\nu}{1-\nu}}.$$

Firms in the intermediate goods sector can change their prices every period. However, they face quadratic price adjustment costs á la Rotemberg (1982). They maximize the net present value of all period t profits discounted with the household's stochastic discount factor:

$$\max_{\{u_t(s)K_t(s),\, L_t(s),\, p_t^d(s),\, p_t^x(s)\}} \mathbb{E}_t \sum_{j=0}^{\infty} SDF_{t,t+j} \Pi_t(s),$$

where $SDF_{t,t+j}$ is the stochastic discount factor defined as:

$$SDF_{t,t+j} = \beta^j \frac{\lambda_{t+j} P_{t+j}}{\lambda_t P_t}.$$

The period t real profit is $\Pi_t(s)$. It is given by:

$$\begin{aligned}\Pi_t(s) =& \frac{p_t^d(s)}{P_t} q_t^d(s) + \frac{e_t p_t^x(s)}{P_t} q_t^x(s) \\ &- \frac{W_t}{P_t} L_t(s) - R_t^K u_t(s) K_t(s) \\ &- \frac{1}{2}\Phi^{P^d} \left(\frac{p_t^d(s)}{p_{t-1}^d(s)} - 1\right)^2 q_t^d(s) - \frac{1}{2}\Phi^{P^x} \left(\frac{p_t^x(s)}{p_{t-1}^x(s)} - 1\right)^2 q_t^x(s),\end{aligned}$$

where $\Phi^{P^d} > 0$ and $\Phi^{P^x} > 0$ measure the degree of the price adjustment costs. The firms' first-order conditions given the demand functions (2.7) and (2.10) as well as the production function (2.8) and the total demand (2.9) are as follows:

$$R_t^K = \xi_t \exp(A_t)\, \alpha (u_t(s) K_t(s))^{\alpha-1} L_t(s)^{1-\alpha},$$

$$\frac{W_t}{P_t} = \xi_t \exp(A_t)\, (1-\alpha)(u_t(s) K_t(s))^{\alpha} L_t(s)^{-\alpha},$$

$$\begin{aligned}&\left(\frac{p_t^d(s)}{\mathcal{P}_t^d}\right)^{-\nu} \left((1-\nu)\frac{1}{P_t} + \xi_t \nu \frac{1}{p_t^d(s)} - \Phi^{P^d}\left(\frac{p_t^d(s)}{p_{t-1}^d(s)} - 1\right)\frac{1}{p_{t-1}^d(s)} + \frac{1}{2}\Phi^{P^d}\left(\frac{p_t^d(s)}{p_{t-1}^d(s)} - 1\right)^2 \nu \frac{1}{p_t^d(s)}\right) \\ &= -(Q_t^d)^{-1} \mathbb{E}_t \left(SDF_{t,t+1} \Phi^{P^d} \left(\frac{p_{t+1}^d(s)}{p_t^d(s)} - 1\right) \frac{p_{t+1}^d(s)}{p_t^d(s)^2} \left(\frac{p_{t+1}^d(s)}{\mathcal{P}_{t+1}^d}\right)^{-\nu} Q_{t+1}^d\right),\end{aligned}$$

$$\begin{aligned}&\left(\frac{p_t^x(s)}{\mathcal{P}_t^x}\right)^{-\nu} \left(e_t(1-\nu)\frac{1}{P_t} + \xi_t \nu \frac{1}{p_t^x(s)} - \Phi^{P^x}\left(\frac{p_t^x(s)}{p_{t-1}^x(s)} - 1\right)\frac{1}{p_{t-1}^x(s)} + \frac{1}{2}\Phi^{P^x}\left(\frac{p_t^x(s)}{p_{t-1}^x(s)} - 1\right)^2 \nu \frac{1}{p_t^x(s)}\right) \\ &= -(Q_t^x)^{-1} \mathbb{E}_t \left(SDF_{t,t+1} \Phi^{P^x} \left(\frac{p_{t+1}^x(s)}{p_t^x(s)} - 1\right) \frac{p_{t+1}^x(s)}{p_t^x(s)^2} \left(\frac{p_{t+1}^x(s)}{\mathcal{P}_{t+1}^x}\right)^{-\nu} Q_{t+1}^x\right),\end{aligned}$$

where ξ_t is the Lagrange multiplier of the production function (2.8). The total demand (2.9) has already been inserted.

Foreign intermediate goods are sold domestically by importers. They have monopolistic power and set the import price as a markup over the foreign price level (see Mark 2001, p. 228):

$$p_t^m(s) = e_t \frac{\nu}{\nu - 1} \exp(P_t^*),$$

where P_t^* is the foreign price index. It is assumed to follow an AR(1) process:

$$P_t^* = \rho_{P^*} P_{t-1}^* + \epsilon_{P^*,t},\ 0 \leq \rho_{P^*} \leq 1,$$

where the zero-mean, serially uncorrelated innovations ϵ_{P^*} are normally distributed with standard deviation σ_{P^*}.

The foreign country

The foreign demand for domestic intermediate goods is given by:

$$Q_t^x = \left(\frac{\mathcal{P}_t^x}{\exp\left(P_t^*\right)}\right)^{-\eta} \exp\left(Z_t^*\right),\ \eta > 0,$$

where η is the foreign demand elasticity. Z_t^* is the foreign demand following an AR(1) process:

$$Z_t^* = \rho_{Z^*} Z_{t-1}^* + \epsilon_{Z^*,t},\ 0 \leq \rho_{Z^*} \leq 1,$$

where the zero-mean, serially uncorrelated innovations ϵ_{Z^*} are normally distributed with standard deviation σ_{Z^*}.

2.2.3 The government

The government consumes G_t and finances its consumption by issuing government bonds D_t and a lump-sum tax T_t. Thus, its period budget constraint is given by:

$$P_t G_t + (1 + R_{t-1}^D) D_t = D_{t+1} + T_t.$$

G_t follows a simple linear rule:

$$G_t = G^{ss} Y^{ss} (1 - \rho_G) + \rho_G G_{t-1} + \rho_Y \left(\frac{Y_t}{Y_{t-1}} - 1\right) \epsilon_{G,t},\ 0 \leq \rho_G \leq 1,\ 0 < G^{ss} < 1,\ \rho_Y \in \mathbb{R},$$

where the zero-mean, serially uncorrelated innovations ϵ_G are normally distributed with standard deviation σ_G. G^{ss} is the steady-state public-spending-to-GDP-ratio.

The central bank sets the nominal interest rate by following a standard Taylor rule similar to Born, Peter, and Pfeifer (2013):

$$\frac{1+R_t^D}{1+R^{D,ss}} = \left(\frac{1+R_{t-1}^D}{1+R^{D,ss}}\right)^{\rho_R} \left[\left(\frac{\pi_t}{\pi^{ss}}\right)^{\nu_1} \left(\frac{Y_t}{Y_{t-1}}\right)^{\nu_2}\right]^{1-\rho_R} \exp(\epsilon_{Z^M,t}),$$

with $0 \leq \rho_R \leq 1$, $\nu_1 > 0$, and $\nu_2 > 0$. $\epsilon_{Z^M,t}$ are zero-mean, serially uncorrelated, normally distributed innovations with standard deviation σ_{Z^M}. $\pi_t = \frac{P_t}{P_{t-1}}$ is the gross inflation rate.

2.2.4 Market clearing conditions

The standard market-clearing conditions are applicable to final goods:

$$Z_t = C_t + I_t + G_t.$$

The nominal GDP $P_t Y_t$ is measured by:

$$P_t Y_t = P_t Z_t + e_t \mathcal{P}_t^x Q_t^x - \mathcal{P}_t^m Q_t^m.$$

For the current account it holds:

$$e_t B_{t+1} = e_t \mathcal{P}_t^x Q_t^x - \mathcal{P}_t^m Q_t^m + e_t B_t (1 + R_{t-1}^*).$$

2.3 Estimation

In this section, I describe how the model is estimated. First I describe the data and their transformations. I then go on to describe the calibration of the non-estimated parameters, and the prior choices, and finally I discuss the estimated posterior distributions and their corresponding means.

2.3.1 The data

I use eleven quarterly macroeconomic time series. These are time series for the GDP, private and public consumption, private investments, labor hours worked, exports and imports, export and import prices, CPI inflation, and the interest rate set by the monetary authority. All series start in the first quarter of 1991 and range until the last quarter of 2016. All data except export and import prices and the interest rate are data from the German statistical bureau and are seasonally adjusted at the source. They are chained indices where the year 2010 equals 100. Export and import price indices are delivered by Bloomberg[3]. For the interest rate I use a shadow interest rate calculated by Wu and Xia (2017). Because this model is linear, it potentially allows nominal interest rates to go negative and faces difficulties in the zero lower bound environment, which is present in the euro area since the end of 2012. To account for unconventional monetary policy and the non-linear behavior of the main interest rates, the shadow rate can be an appropriated tool (see Wu and Xia 2016).

To estimate a dynamic stochastic general equilibrium model, one has to specify observation equations. This means that the data used for estimation has to be coherent to the data produced by the model (see Pfeifer 2017). Thus, as the model's variables are all stationary, the data have to be transformed so that they, too, become stationary. To that end, I use the following transformations:

- The time series of the GDP, private and public consumption, private investments, exports, imports, and labor hours worked are non-stationary. All data are divided by the total number of population to get per capita units. After taking the logarithm, the first differences are calculated. The resulting quarterly growth rates are demeaned. This gives stationary time series with zero mean.

- The terms of trade are calculated by dividing the export prices by the import prices. This time series is logarithmized. The first differences are calculated and the resulting quarterly growth rates are demeaned. I use the terms of trade as a measurement of the competitiveness of the German economy. As Mann (1999) points out, a rise in the terms of trade could mean that the rest of the world is willing to pay higher prices for German exports goods. It means that German exports can purchase more imports, implying that the average German income can support a higher standard of living. An improvement in the terms of trade is thus associated with a higher standard of living. However, rising exports can lead to a rising trade surplus. If a trade surplus is unsustainable, then an improvement

[3]Code: GRBUIMP Index, GRBUEXP Index

of the terms of trade is not a good measure of competitiveness anymore (see Mann 1999).

- The interest rate is quoted as the net interest rate in percentage points and in an annualized form. In contrast, the model is written in quarterly frequency and considers gross interest rates (see Pfeifer 2017). Therefore, the interest rate has to be transformed in the following way:

$$R_t^{D,obs} = \left(1 + \frac{R_t^{D,data}}{100}\right)^{\frac{1}{4}},$$

  where $R_t^{D,data}$ is the shadow interest rate calculated by Wu and Xia (2017) and $R_t^{D,obs}$ the time series used in the estimation. Since $R_t^{D,obs}$ has a clear falling trend, the series is logarithmized and first differences are calculated. Finally, the time series is demeaned as well.

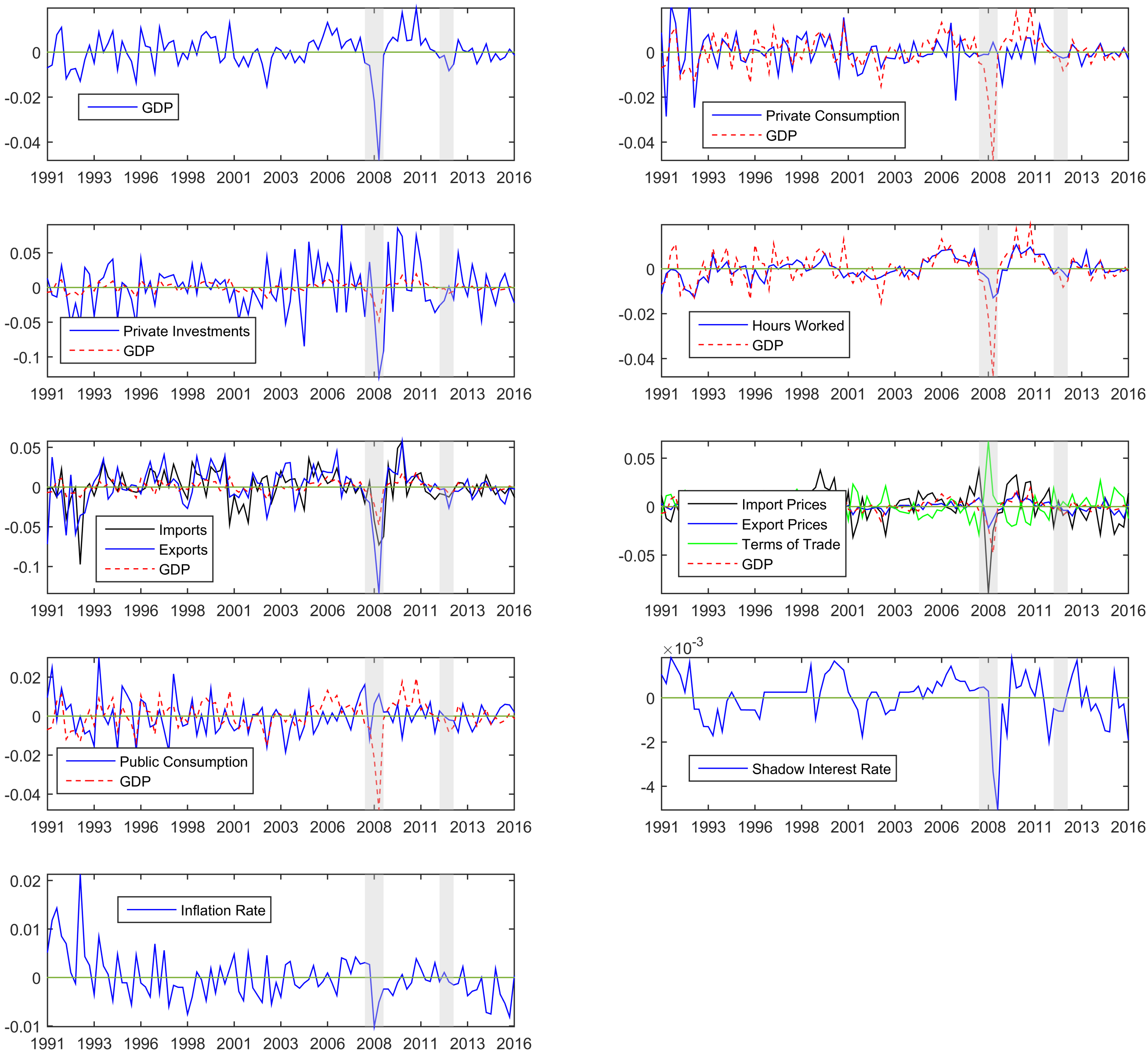
Figure 2.3 presents all the transformed time series. A detailed description of the data can be found in the Appendix 2.A.1. The main findings are as follows:

- The demeaned GDP growth rate was significantly low during the Great Recession. In the first quarter of 2009, the quarterly demeaned growth rate was minus 4.91 percent. The European debt crisis also had a negative impact on the GDP growth rate: Between the second quarter of 2012 and the first quarter of 2013, the quarterly growth rates were all negative - the maximum being minus 0.8 percent.

- Private investments react strongly to the financial crisis. In the first quarter of 2009, the demeaned growth rate was minus 13 percent. Moreover, during the European debt crisis private investments fell significantly. Between the second quarter of 2011 and the first quarter of 2013, real private investments decreased by 13 percent.

- During the financial crisis, exports fell much more than imports. In the first quarter of 2009, the demeaned growth rate of real exports was about minus 15 percent, whereas of the rate of real imports was about minus 7 percent. The same pattern can be found during the European debt crisis around the year 2012.

Figure 2.3: Demeaned quarterly growth rates



Notes: This figure shows the demeaned quarterly growth rates for the GDP, private and public consumption, private investments, hours worked, exports, imports, export prices, import prices, the CPI, terms of trade and the shadow interest rate of the European Central Bank. The two shaded areas mark the both crises which are analyzed.

- The demeaned quarterly growth rate of the terms of trade increased during the financial crisis by more than 5 percent in the first quarter of 2009. This was mainly driven by the fact that import prices fall stronger than export prices. In contrast, until the first quarter of 2012, the terms of trade showed a series of negative quarterly growth rates, because import prices rose more than export prices. However, since the first quarter the terms of trade increased mainly because import prices fell again.

2.3.2 Calibration, prior selection, estimation settings, and estimation results

The model is estimated using Bayesian estimation techniques with the software package *Dynare 4.6.0*[4] (see Adjemian et al. 2011) and solved with a first-order perturbation.

Calibration and prior selection

Most of the model's parameters are estimated using Bayesian estimation techniques. Seven are set by hand. In particular, the depreciation rates for private capital is set to $\delta = 0.025$, implying an annual depreciation of 10 percent. The discount factor β is set to 0.994 in order to match the inverse of the average quarterly gross real interest rate over the sample period. The G^{ss} is the steady-state of the public spending and equals the empirical mean of the public-spending-to-GDP ratio. The parameter δ_1 governs the steady-state level of u_t. I set this parameter at a value consistent with a unit steady-state value of u_t (see Schmitt-Grohé and Uribe 2012). The share of private capital in the production function is set to 0.32 so as to match the steady-state share of labor income to GDP to its sample average of 68 percent (see Drygalla 2016). α^d is set in such a way that the steady-state import-to-GDP-ratio equals the empirical mean of 29.83 percent. In addition, like Hristov (2016), I set labor to a steady-state value of 0.2. Table 2.1 summarizes the chosen parameter values.

The priors for the estimated parameters can be found in Table 2.2. Priors are chosen following standard approaches in the literature. Some means are set to reflect their empirical counterparts or values already found in the literature.

[4] I use the latest available version on 15.08.2017.

Table 2.1: Calibrated parameter values and steady-state values

Parameter	Value
β	0.9940
α	0.3200
δ	0.0250
G^{ss}	0.1883
u	1.0000
$P^m Q^m / Y$	0.2983
L	0.2000

In order to find the mode of the likelihood function, I use a covariance matrix adaptation evolution strategy algorithm of Hansen and Kern (2004), which is an evolutionary algorithm for difficult non-linear non-convex optimization. To guarantee convergence of the Markov chain the number of replications for the Metropolis-Hastings algorithm is set to 2,500,000. I also follow Schmitt-Grohé and Uribe (2012) and use a measurement error to solve the problem that, up to the first-order, the resource constraint of the model economy postulates a linear restriction among the observables. As the government sector is very simplified, I account for this by assuming a measurement error on the time series of the government spending. I do not assume an error in the observation equation for the GDP like Schmitt-Grohé and Uribe (2012), because the main goal of this chapter is a historical decomposition of the German GDP. Thus, assuming a measurement error on the observation equation of the GDP would lead to a deviation of the model's time series of the GDP from the empirically observed time series. As I intend to decompose the observed GDP, I abstract from a measurement error in the observation equation of this time series.

Bayesian estimation results

Results for the posterior distribution of the estimated parameters and shocks variances are documented in Table 2.2. The plots of the posterior distributions can be found in the Appendix 2.A.2. Mean and highest posterior density intervals are taken from the posterior distributions, which are based on a Markov chain with 2,500,000 draws, where the first 10 percent are used for burn-in. The acceptance ratio of the chain is about 30.19 percent. This is near the optimal acceptance rate of 23.4 percent proposed by Roberts, Gelman, and Gilks (1997) and commonly chosen acceptance ratios.

Table 2.2: Priors and posteriors for Germany. Results from the Metropolis-Hastings algorithm (2,500,000 draws).

	Prior			Posterior			
	Dist.	*Mean*	*Stdev.*	*Mean*	*Stdev.*	5%	95%
h	beta	0.500	0.1000	0.319	0.0801	0.1881	0.4469
γ	gamm	2.000	0.5000	4.578	0.5771	3.6172	5.5026
ψ	gamm	1.500	0.2000	1.561	0.1936	1.2429	1.8760
η	gamm	1.200	0.1000	0.694	0.0173	0.6690	0.7183
ϑ	gamm	0.500	0.1000	0.224	0.0193	0.1927	0.2563
ν	norm	5.000	5.0000	5.142	0.4831	4.3551	5.8968
Φ	gamm	2.000	1.5000	0.159	0.0810	0.0535	0.2706
Φ^d	gamm	50.000	10.0000	35.220	9.3153	20.1309	49.8546
Φ^x	gamm	50.000	10.0000	74.873	11.4787	55.9339	93.3906
δ_2	gamm	0.050	0.0200	0.006	0.0024	0.0022	0.0096
ρ_G	beta	0.750	0.1000	0.886	0.0362	0.8281	0.9464
ρ_{π^*}	beta	0.750	0.1000	0.627	0.0491	0.5467	0.7076
ρ_{Z^I}	beta	0.750	0.1000	0.731	0.0854	0.5959	0.8657
ρ_A	beta	0.750	0.1000	0.993	0.0033	0.9881	0.9982
ρ_{AZ}	beta	0.750	0.1000	0.967	0.0106	0.9504	0.9836
ρ_{Z^L}	beta	0.750	0.1000	0.995	0.0024	0.9915	0.9986
ρ_{Z^*}	beta	0.750	0.1000	0.817	0.0259	0.7743	0.8590
ρ_{Z^C}	beta	0.750	0.1000	0.790	0.0670	0.6868	0.8973
ρ_R	beta	0.750	0.1000	0.819	0.0265	0.7775	0.8620
ν_1	norm	1.700	0.1000	1.597	0.1095	1.4149	1.7761
ν_2	gamm	0.120	0.0500	0.066	0.0203	0.0331	0.0976
ν_3	gamm	0.120	0.0500	0.122	0.0210	0.0872	0.1554
ρ_y	norm	0.000	0.5000	0.175	0.0580	0.0807	0.2706
κ	gamm	0.050	0.0250	0.004	0.0010	0.0019	0.0052
ϵ_{π^*}	invg	0.010	2.0000	0.040	0.0059	0.0300	0.0486
ϵ_{Z^L}	invg	0.010	2.0000	0.028	0.0033	0.0225	0.0332
ϵ_A	invg	0.010	2.0000	0.005	0.0005	0.0039	0.0056
ϵ_{AZ}	invg	0.010	2.0000	0.002	0.0002	0.0017	0.0025
ϵ_G	invg	0.010	2.0000	0.005	0.0004	0.0039	0.0051
ϵ_{Z^*}	invg	0.010	2.0000	0.021	0.0015	0.0186	0.0235
ϵ_{Z^C}	invg	0.010	2.0000	0.021	0.0039	0.0151	0.0273
ϵ_{Z^I}	invg	0.010	2.0000	0.008	0.0022	0.0049	0.0110
ϵ_{Z^M}	invg	0.010	2.0000	0.002	0.0002	0.0016	0.0023
$\epsilon_{G_{obs}}$	invg	0.001	0.0100	0.011	0.0008	0.0098	0.0124

Note: *beta* stands for the Beta distribution; *norm* for the Normal distribution; *gamma* for the Gamma distribution; *invg* for the Inverse Gamma distribution.

Table 2.3 shows the Geweke (1991) convergence tests based on means of draws 250,000 to 1,375,000 vs 1,375,000 to 2,500,000. Accordingly, all parameters converge. A look at the trace plots also confirms convergence: No drifts are present.

Next, I discuss the estimated parameter values and compare them to values found in the literature:

- h measures the degree of habit persistence of private households. The posterior mean of 0.319 is line with Drygalla (2016).

- γ measures the inverse Frisch elasticity. While the real business cycle literature often models a relatively high Frisch elasticity of two (see Prescott 1986) or more (see King, Plosser, and Rebelo 1988), recent papers of Bayesian DSGE model estimation found far smaller values for the Frisch elasticity in a New Keynesian model framework. For example, Justiniano and Primiceri (2008) argue for values between 0.25 and 0.5. These findings are in line with some micro-data based studies like Pistaferri (2003) or Kliem and Uhlig (2016). Thus, the prior has a high standard deviation accounting for the parameter uncertainty. The estimated posterior mean of γ is 4.578, leading to a Frisch elasticity of about 0.21. This is in line with values commonly chosen in the DSGE literature.

- ψ is the intertemporal elasticity of substitution. The posterior mean of 1.134 is near the estimate of Drygalla (2016) for the German economy.

- η and ϑ measure the demand elasticity. Their posterior means are 0.694 and 0.224 respectively. Empirical estimations find strongly varying values for η and ϑ. Heathcote and Perri (2002) estimate values slightly below one[5]. Hooper and Marquez (1993) find average values for the German price elasticity of about 1.06 for exports and 0.5 for imports. The posterior means of η and ϑ are lower than these findings but are similar to the values chosen by Kollmann (2001).

- The steady-state value for the markup of the price over marginal cost of the price of the imported goods is estimated to be $\frac{1}{\nu-1} = 0.1944$. This is consistent with the findings of Martins, Scarpetta, and Pilat (1996) for the G3 countries (see also Kollmann 2001), who finds values for the markup of 22 percent.

[5]See also Coeurdacier (2009) for a discussion

Table 2.3: Geweke Convergence Tests, based on means of draws 250,000 to 1,375,000 vs 1,375,000 to 2,500,000. p-values are for χ^2-test for equality of means.

	Posterior		p-values			
Parameter	*Mean*	*Stdev.*	*No Taper*	4% *Taper*	8% *Taper*	15% *Taper*
ϵ_{π^*}	0.0395	0.0059	0.0000	0.8154	0.8061	0.7946
ϵ_{Z^L}	0.0280	0.0033	0.0000	0.5571	0.5876	0.6000
ϵ_A	0.0048	0.0005	0.0000	0.7703	0.7935	0.8006
ϵ_{AZ}	0.0021	0.0002	0.0000	0.4156	0.4080	0.4233
ϵ_G	0.0045	0.0004	0.0000	0.3120	0.3388	0.3175
ϵ_{Z^*}	0.0211	0.0015	0.0000	0.5192	0.5469	0.5694
ϵ_{Z^C}	0.0213	0.0039	0.0000	0.2548	0.1545	0.1007
ϵ_{Z^I}	0.0078	0.0022	0.0000	0.8875	0.8809	0.8851
ϵ_{Z^M}	0.0020	0.0002	0.4391	0.9804	0.9815	0.9815
$\epsilon_{G_{obs}}$	0.0111	0.0008	0.0000	0.6921	0.6898	0.7343
h	0.3170	0.0796	0.0000	0.2779	0.2046	0.1758
γ	4.5863	0.5783	0.0000	0.1876	0.2222	0.2603
ψ	1.5612	0.1938	0.0000	0.4627	0.4388	0.4413
η	0.6943	0.0173	0.0000	0.4848	0.4672	0.4131
ϑ	0.2245	0.0193	0.0000	0.6213	0.6224	0.6313
ν	5.1413	0.4799	0.0000	0.8178	0.8281	0.8340
Φ	0.1569	0.0791	0.0000	0.8332	0.8237	0.8285
Φ^d	35.0754	9.2852	0.0000	0.6586	0.6353	0.6125
Φ^x	75.0422	11.5118	0.0000	0.6058	0.6036	0.6273
δ_2	0.0059	0.0024	0.0000	0.8030	0.8104	0.8186
ρ_G	0.8862	0.0361	0.0000	0.0951	0.1048	0.0873
ρ_{π^*}	0.6258	0.0493	0.0000	0.3107	0.2248	0.2031
ρ_{Z^I}	0.7318	0.0846	0.0000	0.8445	0.8417	0.8453
ρ_A	0.9931	0.0033	0.2785	0.9737	0.9754	0.9762
ρ_{AZ}	0.9666	0.0105	0.0000	0.5417	0.5739	0.5882
ρ_{Z^L}	0.9949	0.0024	0.0030	0.8526	0.8448	0.8440
ρ_{Z^*}	0.8168	0.0258	0.0000	0.6194	0.6639	0.6987
ρ_{Z^C}	0.7913	0.0664	0.0000	0.4428	0.4050	0.3956
ρ_R	0.8186	0.0265	0.0000	0.8297	0.8351	0.8342
ν_1	1.5954	0.1095	0.9448	0.9982	0.9979	0.9979
ν_2	0.0658	0.0202	0.0000	0.2901	0.2792	0.2588
ν_3	0.1218	0.0209	0.0000	0.8936	0.8970	0.8952
ρ_y	0.1753	0.0578	0.0000	0.0858	0.1020	0.0694
κ	0.0036	0.0010	0.0433	0.9427	0.9427	0.9437

- Φ measures the investment adjustment costs and partly controls the variance of investments in the model. The posterior mean is 0.159. The relative volatility of the investments' growth rate to the GDP's growth rate in the model is $\frac{\sigma_{\Delta I}}{\sigma_{\Delta Y}} = 4.65$. This is near the empirical counterpart of $\frac{\sigma_{\Delta I_{obs}}}{\sigma_{\Delta Y_{obs}}} = 4.05$.

- Φ^{Pd} and Φ^{Px} are in line with the findings of Keen and Wang (2007), who give advice for realistic values for the price adjustment cost parameter. Given that the markup of 19.4 percent and given that the discount factor is 0.994 one can, according to Keen and Wang (2007), calculate the percentage of reoptimizing firms. The posterior means for Φ^{Pd} and Φ^{Px} are 35.22 and 74.87, leading to a share of reoptimizing firms of 28.7 percent and 20.7 percent respectively. This is in line with the findings of Drygalla (2016).

- The posterior mean for δ_2, which measures the sensitivity of capacity utilization to variations in the rental rate of capital, equals 0.006 and is smaller than the estimate of Schmitt-Grohé and Uribe (2012) for U.S. data.

- All of the nine exogenous variables exhibit a high degree of persistence, with the respective AR(1) parameters ranging from 0.627 to 0.995.

- The estimated parameters of the monetary policy rule show a high persistence of 0.819. This is not surprising considering that the data shows extended periods without any change in the time series values. Additionally, the reaction parameters show that the central bank acts countercyclically by increasing the interest rate whenever the inflation rate ($\nu_1 = 1.597$) and the output ($\nu_2 = 0.006$) deviate positively from their long-run value or whenever the output growth rate ($\nu_3 = 0.122$) is positive.

- κ measures the elasticity of the interest rate with respect to the current foreign level of debt. It is quite small and in line with the value found in Schmitt-Grohé and Uribe (2003).

- The standard deviations of the shock processes range between 0.002 for the monetary policy and 0.040 for the foreign inflation shock.

- The posterior mean for κ is equal to 0.004. This is small and similar to value in Schmitt-Grohé and Uribe (2003).

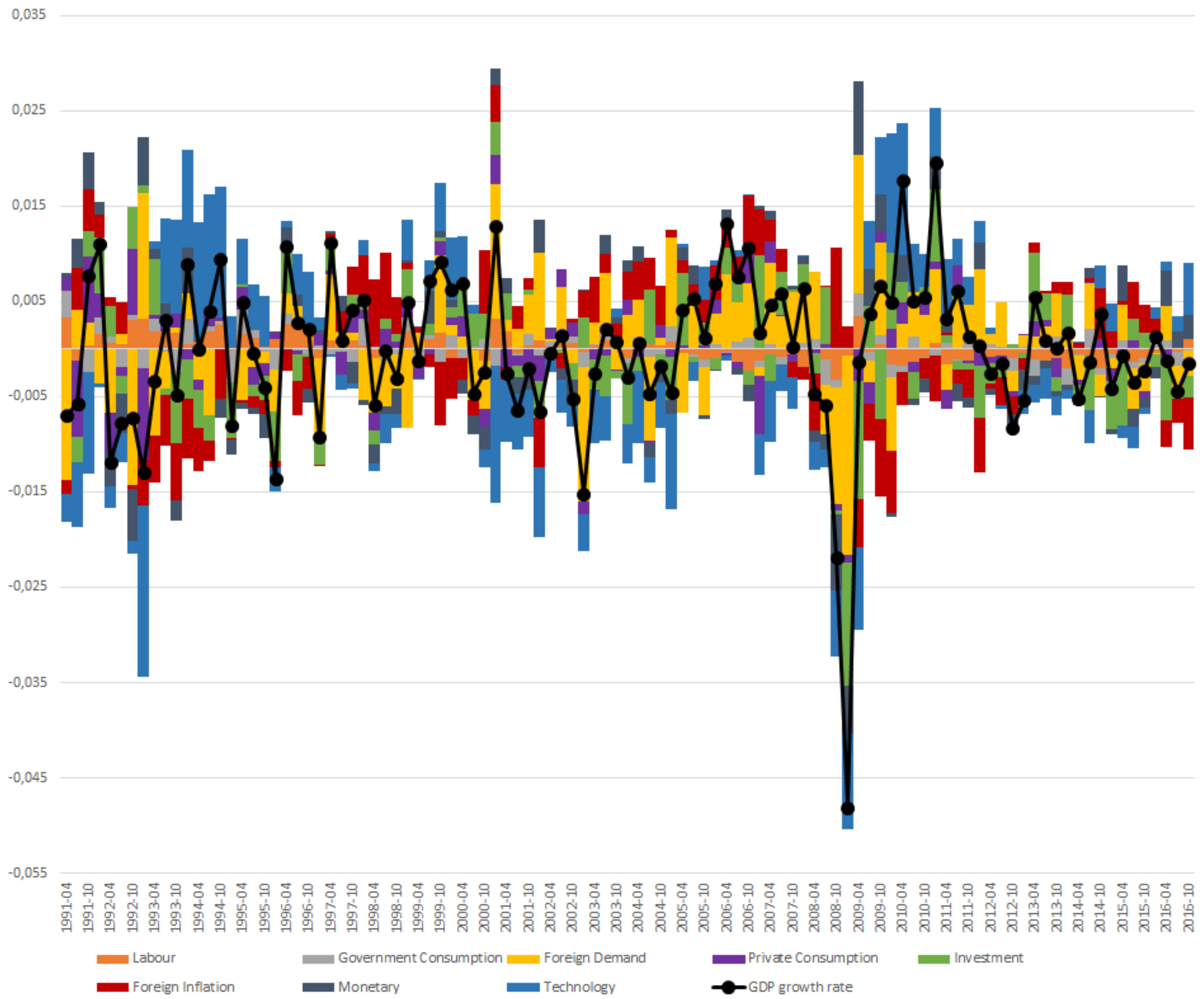
Appendix 2.A.2 compares the prior and posterior distributions of all estimated parameters. All posterior distributions show well-behaved shapes. Tests prove the identification of all estimated parameters in the model. I use the identification toolbox for *Dynare* developed by Ratto and Iskrev (2011).

2.4 Decomposition

Based on the estimation in the previous section and on the derived smoothed shocks using the Kalman smoother, one can investigate which shocks mainly caused the negative German quarterly GDP growth rates during 2008 - 2009 and then again during 2012. In the first period, the financial crisis spread out worldwide, while in the second period the European debt crisis reached its peak. Figures 2.4, 2.5, and 2.6 show the historical decomposition of the German quarterly GDP growth rate from 1999 until 2016. There are nine shocks in the model. The two technology shocks of the intermediate and final goods sector are added to one shock simply named technology shock. The colored bars correspond to the contribution of the respective smoothed shocks to the deviation of the endogenous variables from their steady-state values.

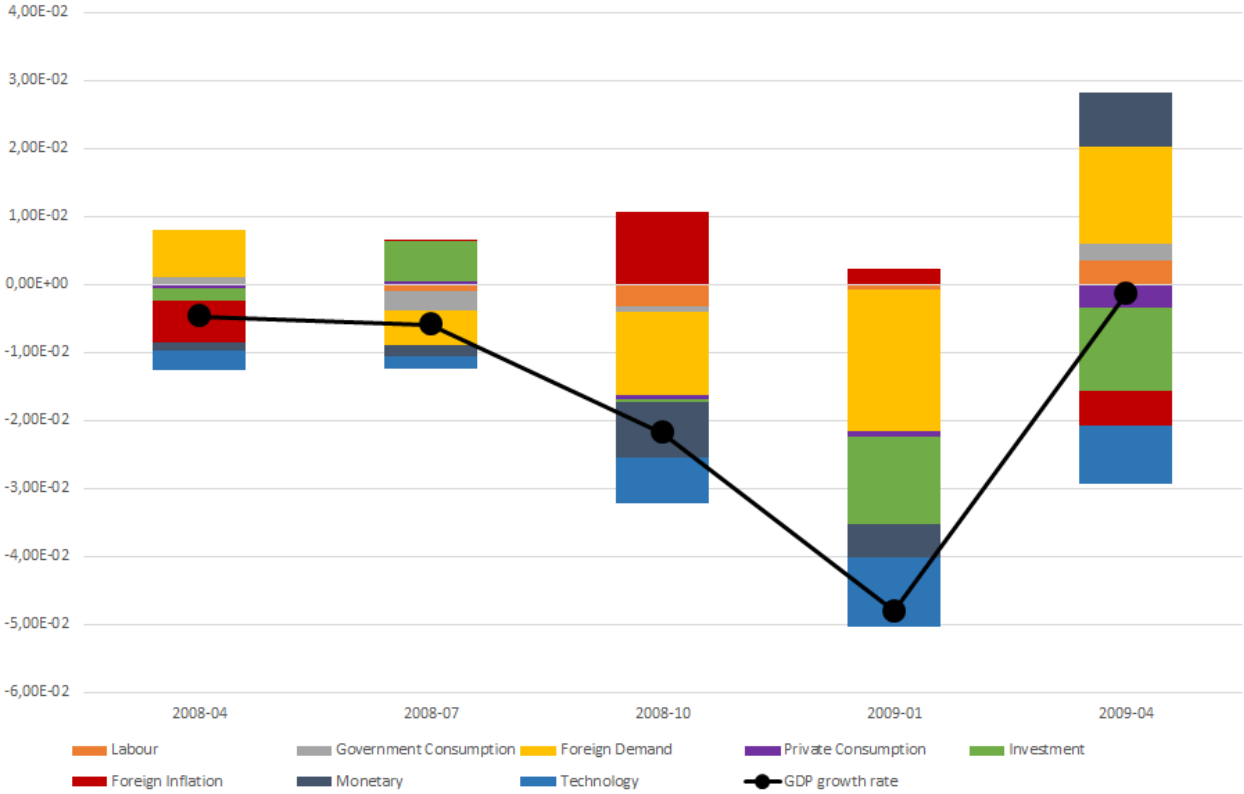
I start the discussion with the historical shock decomposition of 2008 - 2009. In the interpretation of the shock contribution regarding the government spending shocks, one must keep in mind that I assume an observational error on the time series of government spending. Thus, the estimated innovations of the government spending shocks depend on the empirical time series plus the estimated observation error. Figures 2.4 and 2.5 show that over five quarters (2008q2 - 2009q2) the German GDP had negative quarterly growth rates. In the second quarter of 2008, when the financial crisis that had originated in the U.S. economy spread over the world, the German export-oriented economy, which is fully integrated in the financial and non-financial economy of the world, began to feel the global economic cooling. Real GDP dropped by 0.48 percent on quarterly basis. According to the model this drop can be explained by a negative shock stemming mainly from the foreign inflation, the productivity shock, and the private

Figure 2.4: Historical decomposition of the demeaned German GDP quarterly growth rate



Notes: Historical decomposition of the demeaned German GDP quarterly growth rate (black solid line). Contributions of the nine model shocks at the posterior mean of the estimated parameters. The coloured bars correspond to the contribution of the respective smoothed shocks to the deviation of the smoothed endogenous variable from its steady-state.

Figure 2.5: Historical decomposition of the demeaned German GDP quarterly growth rate around the year 2009



Notes: Historical decomposition of the demeaned German GDP quarterly growth rate (black solid line) around the year 2009. Contributions of the nine model shocks at the posterior mean of the estimated parameters. The coloured bars correspond to the contribution of the respective smoothed shocks to the deviation of the smoothed endogenous variable from its steady-state.

investments shock. A negative shock on the capital accumulation equation through the investment shock reduces the transformation rate of investment goods into productive capital goods (see Equation (2.1)). Firms had obviously reduced their investments due to increasing uncertainty about the future demand. This uncertainty also reduced the labor demand translating into a reduction in the number of hours worked by minus 0.38 percent on quarterly basis. This is a negative shock to the labor market. However, private consumption shrank slightly, with a small negative effect on the German GDP growth rate. As exports do not fall as much as predicted by the model, the foreign demand shock is estimated to have a positive effect on the GDP growth rate.

Shocks from abroad were dominated by a negative foreign price shock. Import prices rose stronger than export prices leading to falling terms-of-trade and therefore to more expensive imports. In total, this shock accounts for about 48 percent of all negative shocks, which is in line with findings for example by Gadatsch, Hauzenberger, and Stähler (2016) and Haddad, Harrison, and Hausman (2010). These results show that the fall in the GDP growth rate in the second quarter of 2008 was mainly driven by an increasing uncertainty on the firm side and a drop in the relative prices of the export and import sectors.

In the third quarter of 2008 the German GDP fell further. The quarterly growth rate was demeaned minus 0.59 percent. In contrast to the preceding quarter, there were positive impulses from the private investment side as private investments rose by demeaned 3.68 percent, compensating the majority of negative shocks. Negative impulses came from the labor market, from abroad, from the government spending side, and from the monetary policy. The government reduced its spending from the second to the third quarter by nearly one percent, which reduced overall demand leading to a further decline of the GDP. Interestingly, the German government spending had a negative impact on the GDP quarterly growth rate. This negative impact is a hint that government spending was actually too small to stimulate German economy. According to the results of Drygalla (2016), fiscal policy had a negative impact in the third and fourth quarters of 2008, while stimulating the German economy since the first quarter of 2009 albeit only to a small extent and in the strongest manner when output was already expanding again.

The importance of the foreign shocks switched. In the third quarter of 2008 the impact of the negative foreign demand shock dominated the foreign price shock, which was slightly positive. It is quite interesting how differently German export and imports reacted to the slowdown of the global economy. While import prices fell, imports rose also driven by a stable private consumption. In contrast, exports fell while export prices rose. Thus, the foreign demand shock was bigger than the foreign price shock. In total it accounted for about 42 percent of all negative shocks. These negative foreign demand shocks were an indicator for the upcoming cooling of the global trade.

An indicator that firms got worried about the future economic development of Germany can be found in the hours worked. They decreased by about 0.64 percent between the first and third quarter - a reduction of 94 million hours. The labor shock explains 8.8 percent of the GDP drop in the third quarter of 2008. However, as the reduction in hours worked does not fully explain the decline in the GDP, the rest of the GDP reduction is explained by a negative productivity shock. This is in line with the findings of Ohanian (2010). Ohanian (2010) stresses that in contrast to the U.S. economy the German economy suffered from reduced productivity.

Ohanian's findings can be supported by the decomposition of the fourth quarter of 2008. In this quarter things changed dramatically as the crisis became more severe. The demeaned quarterly GDP growth rate dropped to minus 2.1 percent. Such a decrease had been rarely seen before. It is mainly explained by a drop in productivity and a combination of negative foreign demand, labor, and monetary policy shocks. Positive effects were coming from the foreign prices.

The negative effect of the monetary policy is a hint that the central bank did not decrease the interest rate aggressively enough. The interest rate was not low enough according to given inflation and output growth rates, leading to an estimated negative impact of the central bank. A finding also confirmed by Gerke et al. (2012).

In addition, as hours worked dropped by 0.58 percent on a quarterly basis, but GDP dropped by more than 2 percent the majority of the decrease is associated by a decline in productivity. This is in line with the argumentation of Ohanian (2010) and the findings of Gadatsch, Hauzenberger, and Stähler (2016).

The shocks from abroad worked in opposite directions. There was a negative impact of the foreign demand shock, because global demand lowered real exports by demeaned 7.1 percent on a quarterly basis. However, the terms of trade improved by demeaned 6.7 percent, as import prices decreased far more than export prices. This is a strong hint that the German export sector profited from falling import prices, of which a high share are commodity prices, making production cheaper. This increase of the terms of trade is a sign for a potential gain in the competition strength. The same argumentation can be found in Francois and Woerz (2009).

In the first quarter of 2009 the German economy dropped heavily. The demeaned quarterly growth rate was about minus 4.9 percent. Part of this decline is explained by a reduction in productivity. The other part is mainly explained by negative impacts stemming from investment, foreign demand, and the monetary policy shocks. Private investments reacted strongly to the increasing risk in the markets, with a demeaned negative growth of 12.9 percent on a quarterly basis, leading to a strong negative impact on the GDP.

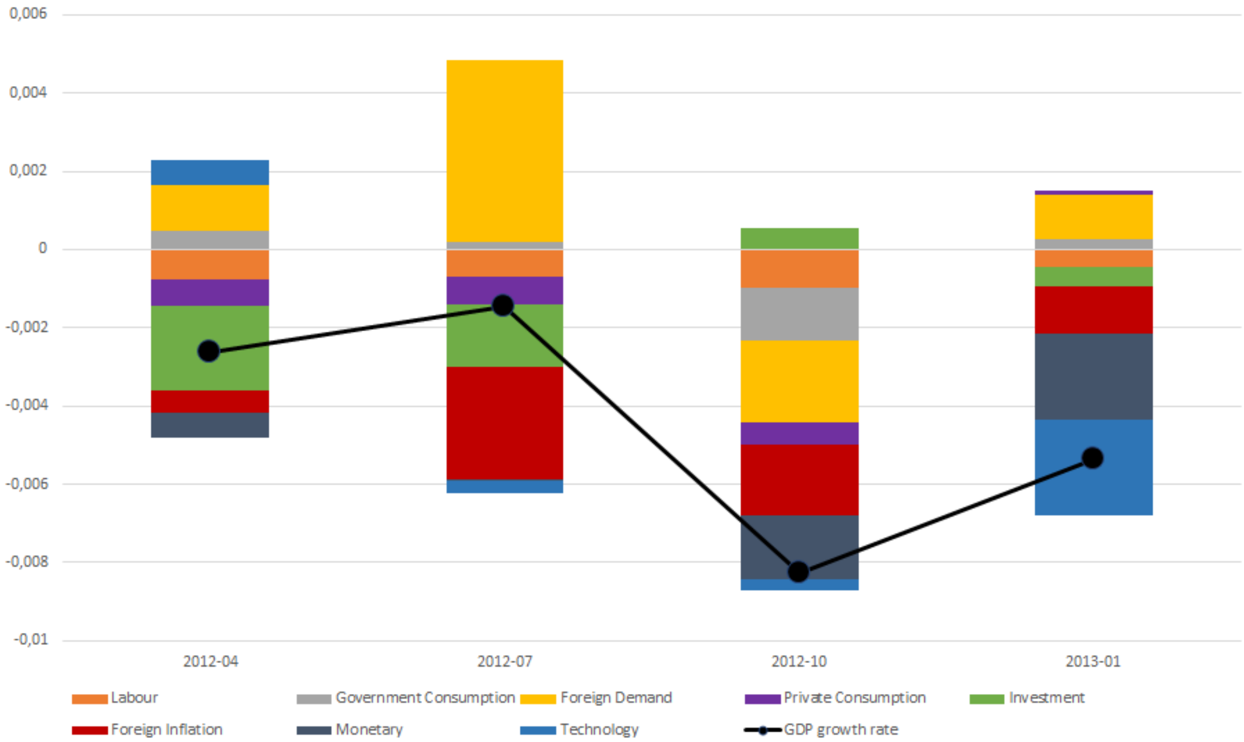
As Baldwin (2009) reports, the collapse of global trade was massive: While during the crisis years of 1982 and 2001 the drops were relatively mild, growth from the previous year quarter reached minus 5 percent at the most. The decrease in the third and fourth quarter 2008 was much worse. The OECD reported for both periods that world trade flows had been 15 percent below their previous year levels (see Baldwin 2009, p. 1). This severe reduction in global demand is mirrored by the strong negative impact of the foreign demand shock in Figures 2.4 and 2.5. However, positive operating price effects reduced this negative demand effect. In fact, the terms of trade improved further by demeaned 1.2 percent, as export prices fell less than import prices.

The second quarter of 2009 showed first signs of economic improvement. Even if the demeaned quarterly GDP growth rate was still minus 0.14 percent, compared to the growth rate of the previous quarter this was clearly a turning point. Positive impulses came mainly from abroad as real German exports stabilized. In addition, the monetary policy had positive effects. This is mainly because the world trade began to rise again, as seen by the increase in the total imports of the OECD countries by 1.27 percent on quarterly basis between the first and the second quarter of 2009. In addition, the expansive monetary policy had positive impacts on the financial system improving lending conditions for firms and reducing the overall uncertainty. In addition, private consumption fell by 1.5 percent having a negative impact on the German GDP. In all, the German GDP was lifted up by a series of positive demand shocks also stemming from the government side. This time negative effects were coming from the productivity side, the foreign inflation and the private investments.

To sum up, the crisis period in Germany, lasting from the third quarter of 2008 to the second quarter of 2009, is characterized by a series of negative foreign demand, negative investment shocks, a decline in total productivity, and a monetary policy that was not expansive enough. However, on the plus side, positive impulses of the foreign price shock stabilized the German economy and prevented the GDP from falling even more. In particular, the reaction of the German export prices in relation to the German import prices clearly signifies the competitiveness of the German export sector and prevented the German economy from experiencing a far deeper recession. In total the trade channel (here measured as the absolute sum of the foreign price and foreign demand shocks) is on average three times larger than the investment shocks. This is similar to the results found by Enders and Born (2016), who report that calibrated to German data, their model predicts the trade channel to be twice as important for the transmission of the crisis as the financial channel.

Next, I discuss the historical decomposition of the German GDP quarterly growth rates around the year 2012. The European debt crisis began in 2009, reaching its peak between 2011 and the end of 2013. It led investors to question the solvency of European governments, especially of several southern countries. Rising uncertainty in the markets had negative spillover effects on the economic situation in the euro area. Several euro area member states were unable to fulfill their obligations, leading to massive uncertainty regarding the stability of the euro. The crisis had significant adverse economic and labor market effects: The unemployment rate in the euro area reached 12 percent in 2013. Consequently, the crisis had negative effects on economic growth, not only of the crisis states, but of the entire euro area as well. In 2016 Germany was the leading EU economy, accounting for over a fifth (21.1 percent) of the euro area GDP. In addition, as it has a dominant export sector, the German economy was negatively hit by the ongoing turmoil in the euro area, too. The export

Figure 2.6: Historical decomposition of the demeaned German GDP quarterly growth rate around the year 2012



Notes: Historical decomposition of the demeaned German GDP quarterly growth rate (black solid line) around the year 2012. Contributions of the nine model shocks at the posterior mean of the estimated parameters. The coloured bars correspond to the contribution of the respective smoothed shocks to the deviation of the smoothed endogenous variable from its steady-state.

orientation of Germany led to an immense trade-surplus and increasing dependency on foreign demand. Between 1991 and 2016 the German current account balances rose from minus 1.42 percent to 8.34 percent of the GDP. This surplus simply means that Germany is lending money to other countries to finance their consumption of German exports (see Lane 2012). The current account imbalances reallocate resources from high-income to low-income countries, leading to an income convergence. However, if these capital inflows are used to finance rather unproductive sectors (such as the real estate sector seen for example in Spain or Ireland) and delay adjustment to structural shocks, then the accumulation of external imbalances builds up massive macroeconomic risk (see Lane 2012).

In Figures 2.4 and 2.6 one can see that in Germany between the second quarter of 2012 and the first quarter of 2013 the demeaned quarterly growth rates were negative. In the last quarter of 2012 the German demeaned growth rate was the lowest at about minus 0.8 percent, followed by an equally low growth rate of minus 0.5 percent in the first quarter of 2013.

Compared to that of the financial crisis of the years 2007 - 2009 the decomposition of the European debt crisis shows a different picture. First of all, the labor market shocks and private consumption shocks had a greater contribution than before. Private sector consumption shock led to a reduction in the German GDP growth rate. During the second quarter of 2012 and the first quarter of 2013, all demeaned quarterly growth rates of the private consumption were negative. Clearly, German households consumed under the trend level as the rising uncertainty surrounding the economic outlook led to reduced consumption.

In all four quarters (2012q2 - 2013q1), the labor market shock had a negative impact on the quarterly GDP growth rate. During this period, the hours worked were reduced by minus 0.23 percent, combined with a decline in productivity of the German economy which was the strongest in the first quarter of 2013. In that quarter, the productivity shock accounted for over 36 percent of all negative shocks.

Besides reducing the hours worked, firms also reduced the real investments by 3.02 percent. Therefore, negative private investment shocks were present. In fact, the increasing uncertainty regarding the stability of the European economy and of the euro area led German firms to shrink their production by reducing the input factors and their investments into productive capital, fearing a prolonging downturn of future demand. As several southern European countries were fighting their high public debt by running fiscal austerity programs, the overall demand for imports of German goods dropped as well. As Broyer, Petersen, and Schneider (2012) point out, German exports to the euro area should have risen by 20.6 percent since 2010. However, the increase came in at only 7.7 percent. According to the authors this difference of 12.9 percentage points is attributed to the European debt crisis. Therefore, once again the drop in the GDP in the third quarter of 2012 was caused by a negative foreign demand shock. This time, however, compared to the first quarter of 2009, the third quarter of 2012 was mainly characterized by a drop in real exports. Real exports fell by minus 1.4 percent between the third and fourth quarters of 2012, whereas real imports nearly stayed flat.

Moreover, export and import prices changed most between the second and third quarters of 2012. As real import prices rose more than real export prices the terms of trade fell. Therefore, this time the foreign inflation shock had negative effects over all quarters. From the third quarter of 2009, the terms of trade started falling constantly, mainly because import prices rose more than export prices.

Interestingly, the effect of the government spending shock turned out to be negative in the last quarter of 2012, also confirmed by the results of Gadatsch, Hauzenberger, and Stähler (2016). This could be the effect of the reduction in the gross public investments by nearly minus 2.9 percent between the third and the final quarters of 2012, and a sign that the German fiscal policy was not expansive enough. The same holds true for the monetary policy. In the last quarter of 2012 and the first quarter of 2013, the monetary policy shock had a negative impact on the German GDP growth rate. This is because the shadow interest rate did not fall as much as one would expect given the inflation rate and the GDP growth rate.

2.5 Conclusion

The financial crisis of 2007 - 2009 and the European debt crisis of 2012 had an impact through various channels on the German economy. As the German economy is highly integrated in the world trade and has a strong export-oriented economy I explore in this chapter the importance of the foreign demand versus the foreign price shocks for the German business cycle. A drop in relative prices would be a sign for a potential loss in the competition strength, whereas a drop in quantities would simply show that there is less use for the demanded goods.

Using a DSGE model and Bayesian estimation techniques I find that during the financial crisis of 2007 - 2009 the German economy was hit by a series of negative foreign demand shocks, while at the same time price shocks had positive impacts on the growth rate of the GDP. These positive price effects worked mainly through heavily falling import prices. The German export sector clearly profited from rising terms of trade, which could be a sign for the competitiveness of this sector. This effect could not be seen during the European debt crisis, where positive price effects were not present.

In addition, I can confirm the results of Ohanian (2010) who stresses that in contrast to the U.S. economy the German economy suffered from reduced productivity. I can also confirm the findings of Gerke et al. (2012) that monetary policy was not expansive enough and the findings of Drygalla (2016) who finds that the fiscal policy stimulated the German economy during the recession, albeit only to a small extent and strongest when output was already expanding again. For the European debt crisis one cannot find stimulating effects.

2.A Appendix

2.A.1 Data

There are several important characteristics of the demeaned time series:

- The big drop in the GDP in the first quarter of 2009 after several smaller negative growth rates was of historical size. A negative quarterly growth rate of nearly 5 percent has never been seen since 1991. The most negative quarterly growth rate only reached 1.6 percent in the first quarter of 2003. However, the economy recovers fast. The first positive growth rate can already be found in the third quarter of 2009 followed by two high positive quarterly growth rates of 1.7 percent in the second quarter of 2010 and 1.5 percent in the first quarter of 2011. Compared to the influence of the financial crisis the European debt crisis did not have such a negative impact on the German economy. However, the quarterly GDP growth rate was about minus 0.8 percent in the last quarter of 2012; Till 1991 the quarterly growth rate was only five times lower. Even if the quarterly growth rate did not fall as much as in 2009, one can be aware of four negative demeaned growth rates in a row since the second quarter of 2012.

- In contrast to the time series of the GDP growth rates, the private consumption shows a quite different pattern. As the first rumor about a potential house price bubble in the U.S. spread around the world, private consumption reacted to the increased uncertainty leading to a drop of about minus 2.2 percent in the first quarter of 2007. As the crisis became more serve, a second decrease happened in the third quarter of 2009: The demeaned quarterly growth rate was of about minus 1.5 percent. In general, the reaction of the private consumption to the financial crisis and the European government debt crisis was smaller than the reaction of the GDP. Interestingly, despite the huge negative growth rate of the GDP in the first quarter of 2009, the private consumption had a positive quarterly growth rate of about 0.3 percent at the same time. One can be generally aware of a lagged and smoothed response of private consumption.

  During the European debt crisis a different pattern of the private consumption was present. Since the second quarter of 2012 until the first quarter of 2013 the demeaned quarterly growth rate were negative.

- In front of the financial crisis growth rates start climbing from minus 4.7 percent in the second quarter of 2001 to 8.9 percent in the first quarter of 2007. However, the financial crisis hit private investments massively. In the first quarter of 2009 the private investment growth rate was minus 13 percent after about minus 4 percent in the last quarter of 2008. In fact there were many positive quarterly growth rates of the private investments before the breakout of the financial crisis. In addition, the volatility of the growth rates is much bigger than the volatility of the GDP growth rates. Given that, the influence of private investment shocks on the GDP growth rates should be expected to be quite big.

  As the first rumor regarding the credibility of the Greek government spread out, investment started decreasing. Since the second quarter of 2011 investment fell constantly till the first quarter of 2013 by about 13 percent.

- On the other hand the production factor labor showed a less strong reaction. Although hours worked declined, the growth rate was only about minus 1.4 percent in the first quarter of 2009. In fact, this can be partly explained by the German labor law, which does not allow fast dismissals, leading to a less responsive behavior of the hours worked. Thereby, this stabilized the private consumption as households were less exposed to losing their employment. However, a relatively stable number of hours worked while GDP growth rates dropped strongly can only be explained by a decline in productivity and/or capital reduction. This is also what Ohanian (2010) diagnosed for the recession distortions for Germany. Gerke et al. (2012) found a similar result.

  During the European debt crisis, one can see similar to the GDP a reduction in the hours worked. The biggest reduction was present in the first quarter of 2013: A drop of 0.38 percent per quarter.

- With respect to the trade sector, exports and imports show a quite correlated behavior. Preceding the Great Recession, net-exports showed a period of quite strong increases from the last quarter of 2000 until the second quarter of 2008.

However, the fall in net-exports (see Figure 2.1) since the second quarter of 2008 was mainly driven by a drop in exports. The fall was nearly 19 percent between the second quarter of 2008 and the first quarter of 2009, whereas imports fell by only 13 percent during the same period. The most negative growth rate can be found in the first quarter of 2009. The negative growth rate of real exports was about 15 percent, and that of real imports of about 7 percent. This is not surprising as the export-oriented German economy is naturally quite dependent on global demand, which was strongly negatively affected by the financial crisis caused by the collapse of the U.S. house price bubble. Moreover, one can be aware of a relatively stable private consumption which also partly stabilized the import sector. Interestingly, since the end of 2010, exports and imports growth rates had showed a smaller volatility much like the volatility of the GDP growth rate.

In contrast, the European debt crisis had not such a negative impact on exports or imports of Germany. During 2012, exports and imports were quite stable. Exports, however, dropped in the last quarter of 2012 by about 1.4 percent on a quarterly basis. At the same time, imports rose constantly.

- The import and export prices showed a different pattern. Before the massive drop in the GDP growth rate in the first quarter of 2009 the terms of trade constantly fell, meaning that Germany was able to export relatively cheaper than to import. Import prices fell much stronger than export prices. Import prices fell in the first quarter of 2009 by nearly 10 percent, whereas export prices fell only by nearly 5 percent. Since 2012 import prices have constantly fallen while export prices remained nearly unchanged, leading to a rise in the terms of trade. At the same time the export-import ratio declined. There was also a period of many negative growth rates since the beginning of 2013. In general, import prices fluctuated more than export prices. This is not only because import prices include very volatile commodity prices but also because Germany exports high-quality goods not easy to substitute, leading to stable export prices.

- Public consumption showed more stable growth rates. Both crises have only a small to nearly no effect on public consumption. However, since the second quarter of 2007 there are more positive growth rates of the public consumption than before. This led to an increase in the average growth rate from 0.17 percent per quarter to 0.22 percent per quarter. Since 2012 one can also observe that the growth rates are less volatile.

- The shadow interest rate showed two strong drops: The first associated with the financial crisis located in the U.S. in the third quarter of 2008 and the second with the public debt crisis in the euro area in the first quarter of 2012. These drops simply reflect the stimulating monetary policy the European Central Bank had used to mitigate the negative impacts of these crises. Starting 2009, the time series of the growth rates was more volatile, reflecting the higher activity of the European Central Bank. They used unconventional monetary policy leading to a strong negative shadow interest rate of about minus 4.5 percent per year in the fourth quarter of 2016.

- The demeaned quarterly inflation rate dropped significantly during the financial crisis. Between the last quarter of 2008 and the first quarter of 2010 the inflation rate was always negative. During the European debt crisis the inflation rate was also negative or only slightly positive. Interestingly, since the last quarter of 2013 the inflation rate was mainly negative. This time in a comparable size to the inflation rate during the financial crisis. As Reinhart and Rogoff (2010) argue, periods after a financial crisis are associated with very slow growth and deflation.

2.A.2 Plots

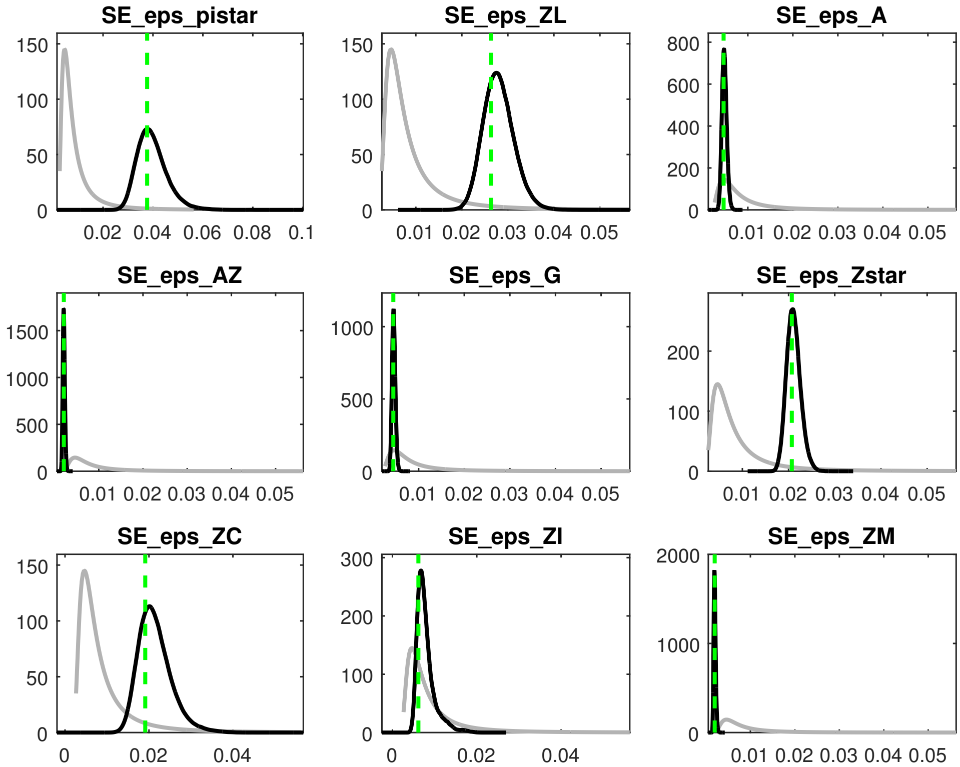


Figure 2.7: Priors and posteriors

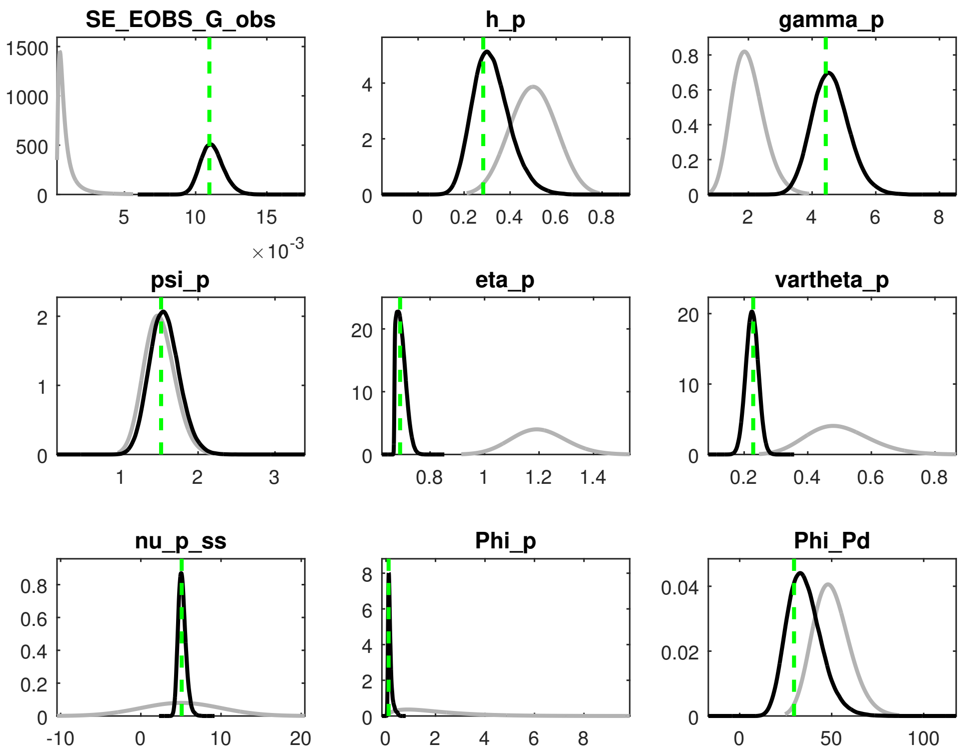


Figure 2.8: Priors and posteriors (cont.)

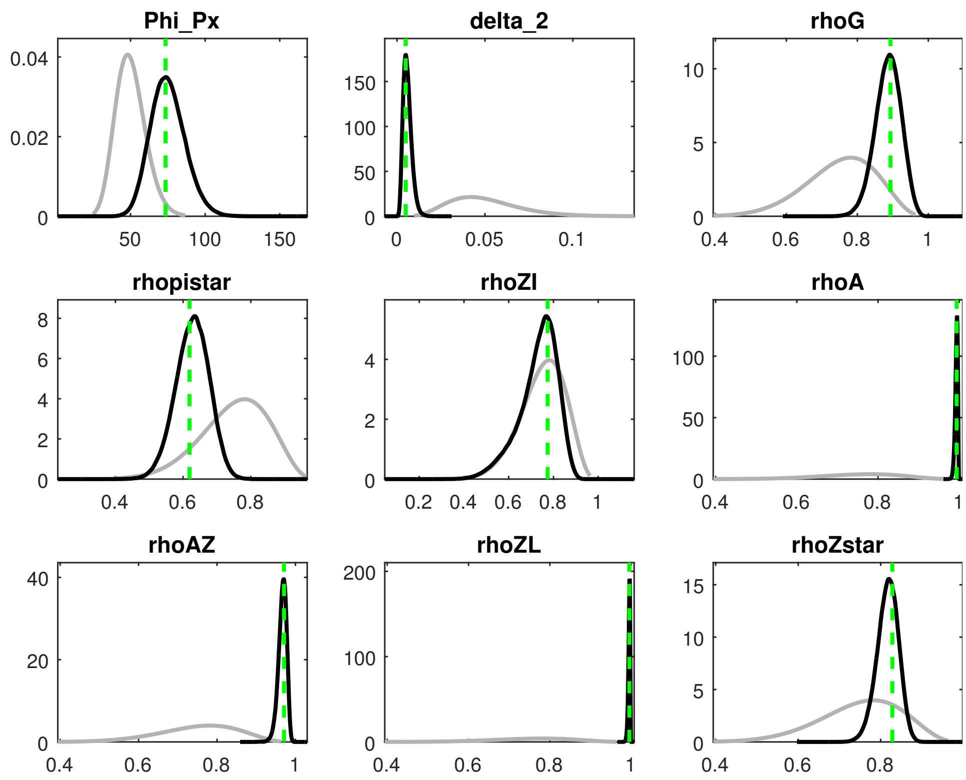


Figure 2.9: Priors and posteriors (cont.)

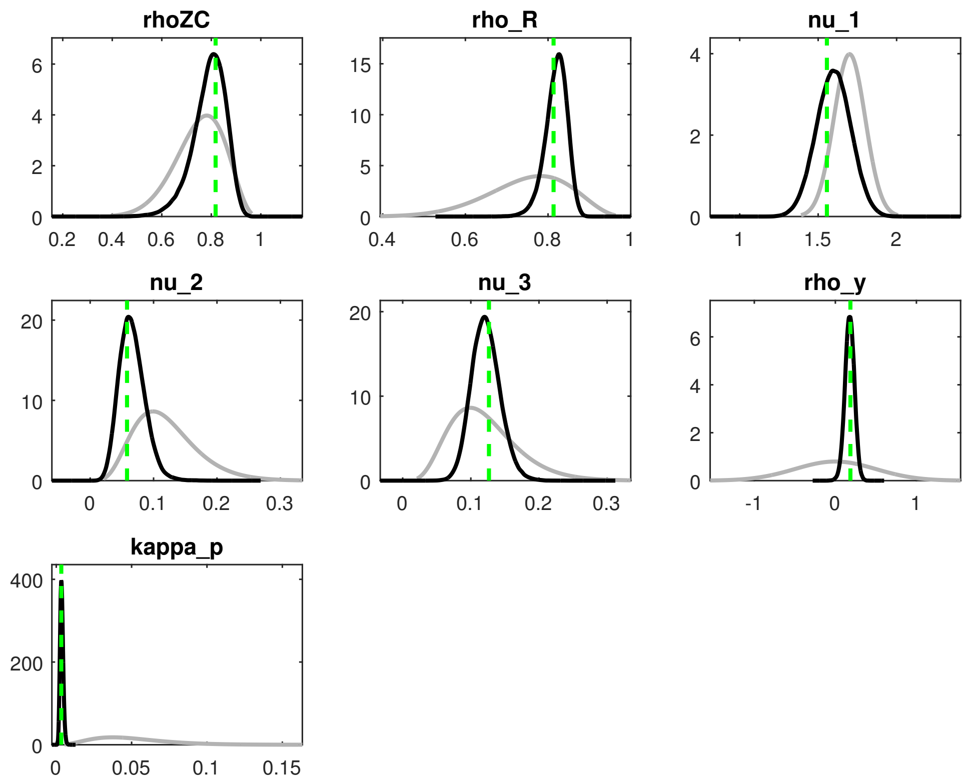


Figure 2.10: Priors and posteriors (cont.)

Chapter 3

Optimal Monetary Policy Reaction to a Temporarily Shortsighted Fiscal Authority

3.1 Introduction

In almost every country fiscal authorities increase public spending financed mainly by raising public debt. The unpopular pay-back and reduction of this debt by increasing taxes and decreasing public consumption does often not happen to the extent necessary, increasing debt even further. Thus, since 2006 the average debt-to-GDP ratio of the OECD countries has risen from 74.6 percent to 111 percent in 2015. It comes to a rollover of public debt - a convenient tool used by incumbent politicians. Of course, this cannot happen systematically as this would lead investors to stop buying government bonds for fear of a Ponzi scheme.

The literature on political economy explains part of these findings by introducing a dimension of political uncertainty in that the politicians have a finite and time-varying horizon. Kumhof and Yakadina (2007) use this assumption to explain why the fiscal authority cares more about the welfare of households in the near future. This is a typical example of fiscal myopia. According to Grossman and Huyck (1988), political myopia is the result of an expected finite planning horizon associated with the expected fiscal authority's probability to survive in power (see also Rieth 2011). In addition, Kumhof and Yakadina (2007) argue that such political uncertainty gives rise to positive and significant long-run debt level and to short-run debt bias. The short-run debt bias is associated with negative shocks to the fiscal authority's discount factor. Such shocks give rise to populist tax cuts, which can be an independent source of business cycle fluctuations (see Kumhof and Yakadina 2007). In contrast, a permanent high debt can be associated with a permanent myopia of the fiscal authority, i.e. it has always a lower discount factor than the private sector. A permanent myopic fiscal authority leads to a permanent accumulation of public debt. Thus, one can distinguish between two effects discussed in the literature - a permanently myopic fiscal authority leading to high public debt accumulation and temporarily myopic fiscal authority associated with the so-called debt bias related to political polarization or turnover (see Hatchondo, Martinez, and Roch 2015). The effects of polarization on fiscal dynamics are discussed in Azzimonti (2011). As this temporary deviation form the benevolent planner's behavior causes business cycle fluctuations, as shown by Kumhof and Yakadina (2007), it is natural to ask how a monetary authority should react to temporary fiscal myopia.

Therefore, instead of focusing on long-run distortions stemming from a permanently shortsighted fiscal authority, I concentrate on a temporarily shortsighted fiscal authority. The shortsighted behavior is caused by a temporary discount factor shock. Consequently, the fiscal authority is fully benevolent in the long-run, which also guarantees the non-existence of a Ponzi scheme. In addition, I assume that, as Niemann (2011) observes, the fiscal authority fails to fully internalize the consequences of its current myopia. Niemann (2011) argues that an important implication of fiscal myopia is the failure to internalize the systematic response of future policies to variations in the future state of the economy. I follow this argument by assuming that the fiscal authority is unable to internalize the monetary policy response to its temporary shortsightedness. Thus, the fiscal authority is not only myopic but also shortsighted. Consequently, the aim of the chapter is to answer the following question: What is the optimal monetary response to a temporarily shortsighted fiscal authority?

Using a standard New Keynesian model along the lines of Schmitt-Grohé and Uribe (2007), I introduce a fiscal authority's discount factor shock. I thus follow Eggertsson and Woodford (2003), who use a discount factor shock to model myopic households.

One aspect of the fiscal shortsightedness is its myopia. A temporarily shortsighted fiscal authority is characterized by a shift from tax-financed to debt-financed fiscal policy. This means that it is willing to reduce taxes and/or to increase public spending temporarily at the cost of higher future debt. In fact, the fiscal authority underestimates the welfare costs generated by the future increase in distortionary taxes, which are needed to service the higher debt, since its discount factor differs temporarily from the discount factor of the private households. However, these welfare costs are only present temporarily as the fiscal authority is only temporarily myopic. Thus, the fiscal authority's behavior is generally welfare maximizing. In the long-run, there are no distortions. One can interpret these discount factor shocks as political preference shocks, which lead the fiscal authority to prefer higher consumption today. These political preference shocks can be caused, for example, by elections. Malley, Philippopoulos, and Woitek (2007) model elections explicitly and their impact on fiscal policy. Niemann (2011) argues that the fiscal myopia is taken as a primitive of the model. Therefore, it is important to understand that such myopia can arise endogenously in a political-economic context such as electoral concerns among politicians. With the decline in political uncertainty, the fiscal authority gets back to the long-run consistent and benevolent policy. In contrast to the fiscal authority, the central bank always has the same discount factor as the private households and thus shares the same objective function. Therefore, the central bank maximizes households' utility by reacting optimally to the distortions in the economy. The distortions are caused by the temporarily shortsighted behavior of the fiscal authority. By changing the distortionary labor income tax rate, the fiscal authority induces changes in firms' marginal costs, leading to price movements. The overall higher volatility of the economic variables causes welfare to decline. Fiscal myopia is only one of the two aspects of the fiscal shortsightedness in this model.

The second aspect of fiscal shortsightedness is the following: The fiscal authority does not internalize the reaction of a benevolent central bank to a temporarily shortsighted fiscal policy. Therefore, the fiscal authority maximizes households' lifetime utility assuming that the central bank follows the long-run consistent monetary policy rule, i.e. a constant real money growth rate. Hence, my argument is similar to that made by Niemann (2011), who says that an implication of fiscal myopia is the failure to internalize the systematic response of future policies to variations in the future state of the economy. I extend this argument further by assuming that the fiscal authority fails to internalize the optimal response of the monetary policy.

I derive the following results: a fiscal authority that is hit by a temporary discount factor shock increases the public spending and decreases the labor income tax financed by higher public debt. A lower labor income tax reduces the marginal cost for producers, thus leading them to lower their prices. Consequently, inflation falls, but its volatility and price dispersion increase. With the volatility of the tax rate and the inflation rate rising, the distortions in the economy increase. Therefore, the central bank's optimal response is to reduce these distortions. The central bank achieves this by reducing the money supply in order to reduce seigniorage revenues. Lower seigniorage revenues lower the fiscal authority's income. Therefore, the fiscal authority cannot lower the tax rate as much as under a long-run consistent monetary policy, i.e. under a constant money growth rate. This leads to higher tax revenues. Therefore, debt accumulation is smaller, and consequently, there are fewer price movements. Thus, the volatility of the inflation rate shrinks and price dispersion declines. Consequently, the central bank can reduce the volatility of inflation and the labor income tax rate, thereby reducing the welfare costs and increasing overall welfare compared to an economy where the central bank uses either the long-run consistent or a standard rule-based policy as proposed by Taylor (1993).

This chapter is in line with the literature that investigates the interaction between the fiscal and monetary authorities. Adam (2011), for example, derives the optimal monetary and fiscal policy under commitment in dependency to the level of the fiscal authority debt. However, as the author stresses, "the [...] paper focused exclusively on technology shocks. Other shocks, e.g., shocks to agent's discount factors give rise to additional sources of budget risk, as they move the real interest rates at which the government can refinance its outstanding debt." (Adam 2011, , p. 71) Thus, he does not investigates distortions caused by a fiscal authority. Niemann and Hagen (2008), Niemann (2011) and Niemann, Pichler, and Sorger (2013) describe the interactions of monetary and fiscal policy in a strategic game where none of them can commit to future actions. In their model, the fiscal authority is always impatient, always causing adverse welfare effects, which is a quite strong assumption. Rieth (2011) investigates an impatient fiscal authority. He looks at the transition dynamics induced by a fiscal authority that permanently has a higher discount factor than private households. However, an optimal monetary reaction is not presented. Kumhof and Yakadina (2007), Juessen and Schabert (2013), and Hatchondo, Martinez, and Roch (2015) use a lower fiscal authority discount factor to model political uncertainty induced by a finite planning horizon. They investigate political business cycles caused by fluctuations in the planning horizon resulting from discount factor shocks, but also do not investigate an optimal monetary policy response to these fluctuations. Thus, this chapter contributes to the literature by investigating the optimal monetary response to business cycles caused by shocks to the fiscal authority's discount factor.

The rest of the chapter is organized as follows: Section 3.2 describes the economic model; Section 3.3 presents the fiscal and the monetary policy; Section 3.4 shows the model's parametrization; Section 3.5 examines the dynamics according to a discount factor shock and presents the optimal monetary response; Section 3.6 concludes the chapter.

3.2 The model

I use a parsimonious infinite-horizon economy with sticky prices, monopolistic competition, and a distortionary labor income tax. Households demand money to fulfill a cash-in-advance constraint. The fiscal authority finances its consumption by levying a distortionary labor income tax, receiving seigniorage from the central bank, and issuing one-period, nominal, risk-free non-state-contingent bonds.

In each period, households supply labor to firms and consume a set of differentiated goods. Each differentiated good is produced by a single firm in a monopolistically competitive environment. Prices are assumed to be sticky á la Calvo (1983). Households can invest in riskless government bonds. The fiscal authority levies a distortionary labor income tax. Taxes and bonds are used to finance public consumption. Moreover, households face a cash-in-advance constraint, as they need money to buy goods.

Money is supplied by a central bank.

3.2.1 Households

The economy is populated by a continuum of identical households of mass one. Each household has preferences defined over private consumption C_t, labor effort N_t, and public spending G_t. Households maximize the sum of discounted period utility with respect to their period-by-period budget constraints:

$$\max_{\{C_t,N_t,B_t,M_t\}} \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t U(C_t, G_t, N_t),\ 0 < \beta < 1,$$

where $\mathbb{E}_t$ denotes the mathematical expectation operator conditional on information available at time t. β is the discount factor and U is a strictly concave period utility function strictly increasing in its first and second arguments, strictly decreasing in its third argument. For the period utility function, I assume the following functional form

$$U(C_t, G_t, N_t) = \frac{(C_t(1-N_t)^{\gamma})^{1-\sigma}}{1-\sigma} + \frac{G_t^{1-\psi^G}}{1-\psi^G},\ \sigma > 0,\ \gamma > 0,\ \psi^G > 0.$$

The consumption good is a composite good containing a continuum of differentiated goods, $C_t(i)$:

$$C_t = \left(\int_0^1 C_t(i)^{1-\frac{1}{\epsilon}} di\right)^{\frac{1}{(1-1/\epsilon)}},\ \epsilon > 1, \tag{3.1}$$

where ϵ measures the intratemporal elasticity of substitution across different varieties of consumption goods. The level of $C_t(i)$ is given by

$$C_t(i) = \left(\frac{P_t(i)}{P_t}\right)^{-\epsilon} C_t,$$

which is the solution of minimizing the total expenditure, $\int_0^1 P_t(i)C_t(i)di$, for any given level of C_t, subject to Equation (3.1). $P_t(i)$ denotes the nominal price of a good of variety i at time t. P_t denotes a nominal price index given by

$$P_t = \left(\int_0^1 P_t(i)^{1-\epsilon} di\right)^{\frac{1}{1-\epsilon}}.$$

The households' period-by-period budget constraint is provided by

$$C_tP_t + \left(\frac{B_t}{1+i_t}\right) + \frac{\Phi}{2}B_t^2 + M_t = B_{t-1} + M_{t-1} + (1-\tau_t^W)W_tN_t + T_t, \tag{3.2}$$

where W_t is the nominal wage for a given amount of labor. B_t are non-state contingent, riskless, nominal bonds issued by the fiscal authority. i_t is the nominal interest rate. T_t are nominal dividends from ownership of firms. M_t are nominal money holdings. τ_t^W denotes a tax on labor income. P_t is the price for the consumption good. Φ measures the size of the transaction costs that must be paid to a financial intermediary when households enter the capital market, maintaining either a short or a long position in real fiscal authority bonds. The transaction costs imply that an increase in the level of fiscal authority debt leads to an increase in the interest rate of fiscal authority bonds. The transaction costs ensure the existence of a well-defined steady-state. This being just a tool to ensure a well-defined steady-state, I set Φ very small, so that the results are not biased by the value of Φ. Kumhof and Yakadina (2007) also use this kind of transaction costs.

In addition, households have to buy products with money, meaning they face a cash-in-advance constraint:

$$M_t \geq \nu^m C_tP_t,\ \nu^M > 0, \tag{3.3}$$

where ν^M measures the fraction of consumption held in money. Like Schmitt-Grohé and Uribe (2007), I use $\lambda_t\mu_t$ as the Lagrange multiplier of the cash-in-advance constraint and λ_t as the Lagrange multiplier of the households' budget constraints. The first-order conditions of the households' problem with respect to C_t, N_t, M_t, and B_t are:

$$U_{C,t} = \lambda_t(1-\mu_t\nu^M), \tag{3.4}$$

$$-U_{N,t} = (1-\tau_t^W)w_t\lambda_t, \tag{3.5}$$

$$\lambda_t(1+\mu_t) - \beta E_t\lambda_{t+1}\frac{1}{\pi_{t+1}} = 0, \tag{3.6}$$

$$\lambda_t \left(\frac{1}{1+i_t} + \Phi b_t \right) = \beta E_t \lambda_{t+1} \frac{1}{\pi_{t+1}}, \tag{3.7}$$

where $\pi_t \equiv \frac{P_t}{P_{t-1}}$ is the gross inflation rate, w_t is the real wage, and b_t are the real bonds.

3.2.2 Firms

Each good's variety i is produced by a single firm in a monopolistically competitive environment. Each firm i uses labor services $N_t(i)$ as the single input factor. The production technology is given by

$$Y_t(i) = N_t(i)^{1-\alpha},\ 0 < \alpha < 1,$$

where $Y_t(i)$ is the output of good i. For the firms' price setting behavior, I assume price setting á la Calvo (1983). Prices are sticky, as in each period a fraction $\theta \in [0, 1)$ of randomly picked firms is not allowed to change the nominal price of the good it produces. The remaining $(1-\theta)$ firms choose prices optimally. Firms choose their price P_t^* which maximizes their profit:

$$\max_{P_t^*} \sum_{k=0}^{\infty} \theta^k E_t \left(Q_{t,t+k} (P_t^* Y_{t+k|t} - \Psi_{t+k}(Y_{t+k|t})) \right), \tag{3.8}$$

where $Q_{t,t+k} \equiv \left(\beta^k \frac{\lambda_{t+k}}{\lambda_t} \frac{1}{\pi_{t+k}} - \Phi b_t \right)$ denotes the stochastic discount factor and Ψ_t the cost function.[1] The maximization of the (3.8) subject to the demand equation

$$Y_{t+k|t} = \left(\frac{P_t^*}{P_{t+k}} \right)^{-\epsilon} Y_{t+k}, \tag{3.9}$$

where $Y_{t+k|t}$ denotes output in period $t+k$ for a firm that has last reset its price in period t and P_t is the aggregate price index[2], leads to the following first-order condition of firms' optimization problem:

$$\sum_{k=0}^{\infty} \theta^k E_t \left(Q_{t,t+k} Y_{t+k|t} \left(P_t^* - \frac{\epsilon}{\epsilon - 1} MC_{t+k|t} P_{t+k} \right) \right) = 0,$$

[1] The definition of $Q_{t,t+k}$ follows directly from the households' first-order condition (3.7).

[2] It is given by: $(P_t)^{1-\epsilon} = \theta \left(P_{t-1}\right)^{1-\epsilon} + (1-\theta) \left(P_t^*\right)^{1-\epsilon}$.

where one used that $MC_{t+k|t} = \psi_{t+k|t}/P_{t+k}$ and $\psi_{t+k|t} = \Psi'_{t+k}(Y_{t+k|t})$. Rewriting this equation yields (by dividing by P_{t+k}):

$$\sum_{k=0}^{\infty} \theta^k E_t \left(Q_{t,t+k} \left(\frac{P_t^*}{P_{t+k}} \right)^{-1-\epsilon} Y_{t+k} \left(\frac{P_t^*}{P_{t+k}} - \frac{\epsilon}{\epsilon - 1} MC_{t+k|t} \right) \right) = 0. \tag{3.10}$$

Following Schmitt-Grohé and Uribe (2007), I write (3.10) in a recursive representation. I define

$$x_{1,t} \equiv E_t \sum_{k=0}^{\infty} \theta^k Q_{t,t+k} \left(\frac{P_t^*}{P_{t+k}} \right)^{-1-\epsilon} Y_{t+k} MC_{t+k|t}.$$

Solving forward and using the demand Equation (3.9) leads to:

$$x_{1,t} = (\tilde{P}_t^*)^{-1-\epsilon} Y_t MC_t + \theta E_t \left(\beta \frac{\lambda_{t+1}}{\lambda_t} \frac{1}{\pi_{t+1}} - \Phi b_t \right) \pi_{t+1}^{\epsilon} \left(\frac{\tilde{P}_t^*}{\tilde{P}_{t+1}^*} \right)^{-1-\epsilon} x_{1,t+1}, \tag{3.11}$$

where $\tilde{P}_t^* \equiv \frac{P_t^*}{P_t}$ denotes the relative price of any good whose price was adjusted in period t in terms of the composite good. Define in addition

$$x_{2,t} \equiv E_t \sum_{k=0}^{\infty} \theta^k Q_{t,t+k} \left(\frac{P_t^*}{P_{t+k}} \right)^{-\epsilon-1} Y_{t+k} \frac{P_t^*}{P_t}.$$

Solving forward and using the demand Equation (3.9) leads to:

$$x_{2,t} = Y_t (\tilde{P}_t^*)^{-\epsilon} + \theta E_t \left(\beta \frac{\lambda_{t+1}}{\lambda_t} \frac{1}{\pi_{t+1}} - \Phi b_t \right) \pi_{t+1}^{\epsilon-1} \left(\frac{\tilde{P}_t^*}{\tilde{P}_{t+1}^*} \right)^{-\epsilon} x_{2,t+1}. \tag{3.12}$$

Thus,

$$\frac{\epsilon}{\epsilon - 1} x_{1,t} = x_{2,t}. \tag{3.13}$$

3.2.3 The public sector

The fiscal authority chooses the public consumption G_t, the labor income tax rate τ_t^W, and the fiscal authority debt B_t. It has access to a distortionary labor income tax, issues one-period non-state-contingent bonds, and receives seigniorage revenues from the central bank. The fiscal authority's period-by-period budget constraint is then given by

$$G_t P_t + B_{t-1} + M_{t-1} = \frac{B_t}{(1 + i_t)} + \tau_t^W N_t W_t + M_t. \tag{3.14}$$

The central bank has one instrument, the monetary base.[3] Thus, the central bank's task is to satisfy the households' money demand and to transfer seigniorage revenues to the fiscal authority. I define real seigniorage revenues Ψ_t as follows

$$\Psi_t = m_t - \frac{m_{t-1}}{\pi_t}.$$

A more detailed description of the fiscal authority's and the central bank's behavior can be found in Section 3.3.

3.2.4 The equilibrium

I restrict my analysis to symmetric equilibria, where all households and firms behave in an identical way. There will be no arbitrage opportunities and the markets will be clear. The goods market clearing condition is

$$Y_t = G_t + C_t. \tag{3.15}$$

Firms can differ with regard to their prices, which may lead to dispersed prices. Thus, market clearing of the goods market implies:

$$N_t^{1-\alpha} = \int_0^1 \left(\frac{P_t(i)}{P_t}\right)^{-\epsilon} Y_t \, di.$$

This can be rewritten as

$$\frac{N_t^{1-\alpha}}{Y_t} = \underbrace{\int_0^1 \left(\frac{P_t(i)}{P_t}\right)^{-\epsilon} di}_{\equiv S_t} \Leftrightarrow Y_t = \frac{N_t^{1-\alpha}}{S_t}. \tag{3.16}$$

S_t measures the price dispersion induced by the assumed nature of price stickiness (see Schmitt-Grohé and Uribe 2007). Rewriting S_t yields

$$S_t = \int_0^1 \left(\frac{P_t(i)}{P_t}\right)^{-\epsilon} di,$$

[3] See McCallum (1999) for the similarity between an interest and a monetary base rule.

$$\Leftrightarrow S_t = (1-\theta)\left(\frac{P_t^*}{P_t}\right)^{-\epsilon} + (1-\theta)\theta\left(\frac{P_{t-1}^*}{P_t}\right)^{-\epsilon} + ...,$$

$$\Leftrightarrow S_t = (1-\theta)\sum_{j=0}^{\infty}\theta^j\left(\frac{P_{t-j}^*}{P_t}\right)^{-\epsilon}.$$

Alternatively, by using that $\frac{P_t^*}{P_t} \equiv \tilde{P}_t^*$:

$$S_t = (1-\theta)(\tilde{P}_t^*)^{-\epsilon} + \theta\pi_t^{\epsilon}S_{t-1}. \tag{3.17}$$

Thus, for the real marginal cost it holds:

$$MC_t = \frac{w_t}{(1-\alpha)N_t^{-\alpha}S_t^{-1}}. \tag{3.18}$$

Lastly, the aggregate price index can be rewritten to describe the inflation rate:

$$1 = \theta\pi_t^{-1+\epsilon} + (1-\theta)\left(\tilde{P}_t^*\right)^{1-\epsilon}. \tag{3.19}$$

Definition 1. *For the given fiscal policy* $\{b_t, G_t, \tau_t^W\}$ *and monetary policy* $\{m_t\}$*, satisfying the fiscal authority budget constraint* (3.14)*, a competitive equilibrium is a set of sequences* $\{C_t, N_t, Y_t, w_t, \tilde{P}_t^*, \pi_t, i_t, x_{1,t}, x_{2,t}, S_t, MC_t, \lambda_t, \mu_t\}_{t=0}^{\infty}$*, satisfying (*3.3*)-(*3.7*), (*3.11*), (*3.12*), (*3.13*), (*3.15*), (*3.16*), (*3.17*), (*3.18*), (*3.19*) and the transversality condition for an initial value for the real fiscal authority debt.*

3.3 The behavior of the public sector

I expand the standard New Keynesian model presented above with a temporarily shortsighted fiscal authority. One aspect of this fiscal shortsightedness is fiscal myopia. Temporary fiscal myopia is modelled by a shock χ_t to the fiscal authority's discount factor in line with Primiceri, Schaumburg, and Tambalotti (2006). The government maximizes households' utiltiy:

$$E_0\sum_{t=0}^{\infty}\chi_t\beta^tU(C_t, N_t, G_t)$$

The fiscal authority maximizes households' lifetime utility using $\left(\beta^G\right)^t = \chi_t \beta^t$ as its discount factor. As χ_t follows an AR(1) process with mean one, the fiscal authority's discount factor β^G equals the households' discount factor β in the long-run. Thus, in the absence of political uncertainty, the fiscal authority is fully benevolent. However, if a positive shock hits χ_t, the fiscal authority weights current utility temporarily higher than the households' do, leading the fiscal authority to increase its consumption. This makes the issuance of new debt relatively attractive for the fiscal authority, since it is willing to pay a higher interest rate than that demanded by the households, resulting in a debt bias (see Rieth 2011). The fiscal authority finances the increase in public consumption by increasing its debt and lowering the labor income tax, supporting a temporary consumption boom similar to that shown by Kumhof and Yakadina (2007). This fiscal myopia is only one of the two aspects of fiscal shortsightedness in this model. The second aspect of fiscal shortsightedness is the following one: The fiscal authority does not internalize the reaction of a benevolent central bank to a temporarily myopic fiscal policy. Therefore, the fiscal authority maximizes households' lifetime utility based on the assumption that the central bank follows the long-run consistent monetary policy rule, i.e. a constant real money growth rate. Hence, my argument is similar to that of Niemann (2011), who says that an implication of fiscal myopia is the failure to internalize the systematic response of future policies to variations in the future state of the economy. I take this argument further by assuming that the fiscal authority fails to internalize the optimal response of the monetary policy. The optimal monetary policy is described in detail in Section 3.5.

On the contrary, the central bank's discount factor β^M is always equal to the households' discount factor β. Thus, the central bank always maximizes the households' lifetime utility and is fully benevolent.

Sections (3.3.1) and (3.3.2) describe the fiscal and monetary authority's optimization problem in greater detail.

3.3.1 The fiscal authority's optimization problem

The fiscal authority maximizes the net present value of households' lifetime utility given the long-run consistent central bank behavior described by $\frac{m_t}{m_{t-1}}\pi_t = \pi^{SS}$. π^{SS} is the steady-state value of the gross inflation rate. The complete optimization problem and the corresponding first-order conditions are described in the Appendix 3.A.3. It is important to note that, using this representation of the optimization problem of the fiscal authority, I incorporate both aspects of the fiscal authority's shortsightedness: The fiscal authority does not internalize the central bank's optimal reaction and it can have a different discount factor than the households.

I begin by solving the model under a temporarily shortsighted fiscal authority given a constant money growth rate consistent with the long-run monetary policy. The behavior of the fiscal authority is derived using the primal approach to the Ramsey problem. First, one derives a sequence of implementability constraints by substituting prices i_t and w_t and the tax rate τ_t^W in the households' budget constraint (3.2) using the households' first-order conditions (3.5) and (3.7) and the definition of the firms' marginal costs (3.18) and iterating forward. Using the transversality condition as well as the definition of firms' profits, one ends up with:[4]

$$\frac{\lambda_t}{\pi_t} b_{t-1} = E_t \sum_{j=0}^{\infty} \beta^j \lambda_{t+j} \Big[C_{t+j} - E_t \Phi b_{t+j}^2 + E_t \frac{\Phi}{2} b_{t+j}^2 + m_{t+j} - m_{t+j-1} \frac{1}{\pi_{t+j}} + \frac{U_{N,t+j}}{\lambda_{t+j}} N_{t+j} - N_{t+j}^{1-\alpha} S_{t+j}^{-1} + MC_{t+j} (1-\alpha) N_{t+j}^{-\alpha} S_{t+j}^{-1} N_{t+j} \Big]. \tag{3.20}$$

The transversality condition (3.20), along with the equilibrium conditions and the assumed behavior of the monetary authority, form the constraints of the fiscal authority's optimization problem. Based on the corresponding first-order conditions of this optimization problem, I can approximate the fiscal authority's policy by linear functions. Since the model is solved using a linear approximation, one can use a linear approximation of the fiscal authority's behavior without any significant loss of accuracy. This approximation is found by using linear regressions of the fiscal authority's instruments (the fiscal authority's real debt b_t and public spending G_t).[5] To minimize the loss of information, I choose a high number of simulated periods and use all observable

[4]The complete derivation can be found in the Appendix 3.A.1. The implementability constraint for the fiscal authority is also the same for the central bank. The optimization problem of the central bank is explained in Section 3.3.2.

[5]I do not have to regress the labor income tax, since, given the debt and public spending, taxes are completely determined.

predetermined variables as regressors. I use the following regression equations:

$$
\begin{aligned}
b_t - b^{ss} =& \phi_{bb}(b_{t-1} - b^{ss}) + \phi_{b\chi}(\chi_{t-1} - \chi^{ss}) + \phi_{bS}(S_{t-1} - S^{ss}) \\
&+ \phi_{bm}(m_{t-1} - m^{ss}) + \phi_{b\lambda}(\lambda_{t-1} - \lambda^{ss}) + \phi_{b\tilde{P}^*}(\tilde{P}^*_{t-1} - \tilde{P}^{*ss}) + \phi_{b\epsilon^\chi}\epsilon^\chi_t,
\end{aligned}
\tag{3.21}
$$

$$
\begin{aligned}
G_t - G^{ss} =& \phi_{Gb}(b_{t-1} - b^{ss}) + \phi_{G\chi}(\chi_{t-1} - \chi^{ss}) + \phi_{GS}(S_{t-1} - S^{ss}) \\
&+ \phi_{Gm}(m_{t-1} - m^{ss}) + \phi_{G\lambda}(\lambda_{t-1} - \lambda^{ss}) + \phi_{G\tilde{P}^*}(\tilde{P}^*_{t-1} - \tilde{P}^{*ss}) + \phi_{b\epsilon^\chi}\epsilon^\chi_t,
\end{aligned}
\tag{3.22}
$$

where $(\cdot)^{ss}$ stands for the corresponding steady-state value. Only predetermined variables (namely the lagged price dispersion S_{t-1}, lagged government bonds b_{t-1}, lagged real money holdings m_{t-1}, the lagged Lagrange multiplier of the households' optimization problem λ_{t-1}, lagged optimal firms' price $\tilde{P}^*_{t-1}$, as well as the exogenous lagged discount factor shock χ_{t-1} and its corresponding innovation ϵ^χ_t) are used as explanatory variables mimicking the standard state space representation.

Next, I solve the model and simulate the economy for 50,000 periods. I then run the two regressions (3.21) and (3.22). For the given parameters (see Section 3.4) Table 3.1 reports the estimation results.

Table 3.1: Estimated parameters for the linear approximation of the fiscal policy solving the model with a Taylor approximation of order one and simulating the model for 50,000 periods.

Parameter	ϕ_{bb}	$\phi_{b\chi}$	ϕ_{bS}	ϕ_{bm}	$\phi_{b\tilde{P}^*}$	$\phi_{b\lambda}$	$\phi_{b\epsilon^\chi}$
Value	0.8653	0.2337	22.283	-431.028	-6.40e-03	-0.3232	0.0310
Parameter	ϕ_{Gb}	$\phi_{G\chi}$	ϕ_{GS}	ϕ_{Gm}	$\phi_{G\tilde{P}^*}$	$\phi_{G\lambda}$	$\phi_{G\epsilon^\chi}$
Value	-0.0085	0.0074	-0.1644	11.845	-2.18e-04	0.0091	0.0223

The estimation results give insight into the fiscal authority's behavior. The fiscal authority's bonds have a high autocorrelation. As expected, the government bonds and the public consumption increase in the fiscal authority's weight χ_t on the current period's outcomes. In addition, the coefficient ϕ_{bm} measuring the effect of real money holdings on real fiscal authority bonds is negative, indicating that higher seigniorage revenues render debt financed fiscal policy less necessary.

The policy functions (3.21) and (3.22) describe the behavior of a temporarily shortsighted fiscal authority. Therefore, I can isolate the inefficiency caused by a temporarily shortsighted fiscal authority. In the next step, I solve the central bank's optimization problem by taking these policy function as given. Thus, the central bank acts optimally by considering the fiscal authority's shortsighted policy described by Equations (3.21) and (3.22). A detailed description of the monetary policy can be found in the following section.

3.3.2 The central bank's optimization problem

The central bank's optimization is described by the maximization of the households' lifetime utility given the equilibrium conditions and the behavior of the temporarily shortsighted fiscal authority. As the central bank's discount factor β^M is always equal to the households' discount factor β, the central bank is fully benevolent. The first-order conditions of this optimization problem describe the optimal monetary policy under full commitment, considering the behavior of the temporarily shortsighted fiscal authority. The transversality condition (3.20), the equilibrium conditions, and the behavior of the fiscal authority described by (3.21) and (3.22) are the constraints of the central bank's optimization problem. The mathematical description of this optimization problem as well as the derivation of the corresponding first-order conditions can be found in the Appendix 3.A.2.

3.4 Parametrization

This section describes the parametrization of the model. All parameters are chosen to match quarterly data. The discount factor shock χ_t follows a stationary AR(1) process

$$\chi_t = \chi_{t-1}^{\rho^\chi} \exp\left(\epsilon_t^\chi\right),$$

where ϵ_t^χ is white noise with a mean of zero. For the discount factor shock, the persistence value ρ^χ is set to a modest value of 0.6. The standard deviation of the innovations is $\sigma^{\chi} = 0.01$.[6]

Since the period utility function has the same functional form as in Schmitt-Grohé and Uribe (2007), the values I assign to the preference parameters are similar to those used by these authors: $\sigma = 2$, so that the intertemporal elasticity of consumption, holding the hours worked as constant, is 0.5; γ is set to 1.7, given that in the deterministic steady-state households allocate on average about 20 percent of their time to work, as it is the case in the U.S. economy according to Prescott (1986). I choose the elasticity with respect to public spending ψ^G to be 1.1367, matching the fact that in the deterministic steady-state, public spending is 20 percent of GDP, which is in line with postwar U.S. data.

The households' discount factor β is 0.9902, which is consistent with an annual real rate of interest of 4 percent (see Prescott 1986). I follow Schmitt-Grohé and Uribe (2007) in setting the price elasticity ϵ to be 5. The fraction of firms that can change their price in any given quarter measured by θ is 0.8. This value implies that on average firms change their price every five quarters.

The production function is Cobb-Douglas with $(1-\alpha)$ as the cost share of labor. It is set to 0.7 in line with the empirical findings that in the U.S. economy wages represent about 70 percent of total production costs.

Since monetary aggregate M1 is about 17 percent of annual GDP during the period 1960 - 1999, I set the steady-state ratio of M to Y to be 0.68. Lastly I set the transaction costs parameter Φ to be 0.01. This value is quite arbitrary, as higher values of Φ only lead to a faster convergence of the bonds after a discount factor shock. I set it to this small number just to exclude the existence of a unit root and to prevent that the results are biased by the transaction costs. Table 3.2 summarizes the chosen parameter values.

[6]In a robustness analysis, I have varied the values for the persistence and the standard deviation of the discount factor shock. The results presented below do not change qualitatively.

Table 3.2: Model's parametrization matching quarterly data.

Parameter	Value	Parameter	Value
β	0.9902	ψ^G	1.1367
σ	2.0000	γ	1.7000
Φ	0.0100	θ	0.8000
ϵ	5.0000	ρ^χ	0.6000
G/Y	0.2000	σ^χ	0.0100
m/Y	0.6800	α	0.3000

3.5 The optimal central bank reaction to a temporarily shortsighted fiscal authority

This section describes the optimal monetary response to a temporary increase of χ_t by analyzing impulse response functions.[7] The fiscal authority becomes more impatient, since it now prefers higher current utility than before the discount factor shock has occurred. It simply discounts the future more.

I present three different monetary policies: the optimal monetary behavior derived in Section 3.3.2 and two other monetary policy regimes to compare how much the optimal monetary policy differs from the long-run consistent monetary policy and a standard New Keynesian monetary policy. To summarize:

1. The long-run consistent monetary policy sets the real money growth rate constant:
$$\frac{m_t}{m_{t-1}}\pi_t = \pi^{SS}. \tag{3.23}$$

2. The "standard" New Keynesian monetary policy is the optimal response to a fiscal authority consumption shock in a standard New Keynesian model abstracted from a discount factor shock. This rule has a similar interpretation as the well-known policy rule proposed by Taylor (1993). The derivation of this policy is described in more detail below.

The rationale for this comparison is as follows: The first rule describes a monetary authority that does not take into account the fiscal authority's behavior. Instead,

[7] All results are calculated using *Dynare 4.4.2* for MatLab. The software package is available at http://www.dynare.org.

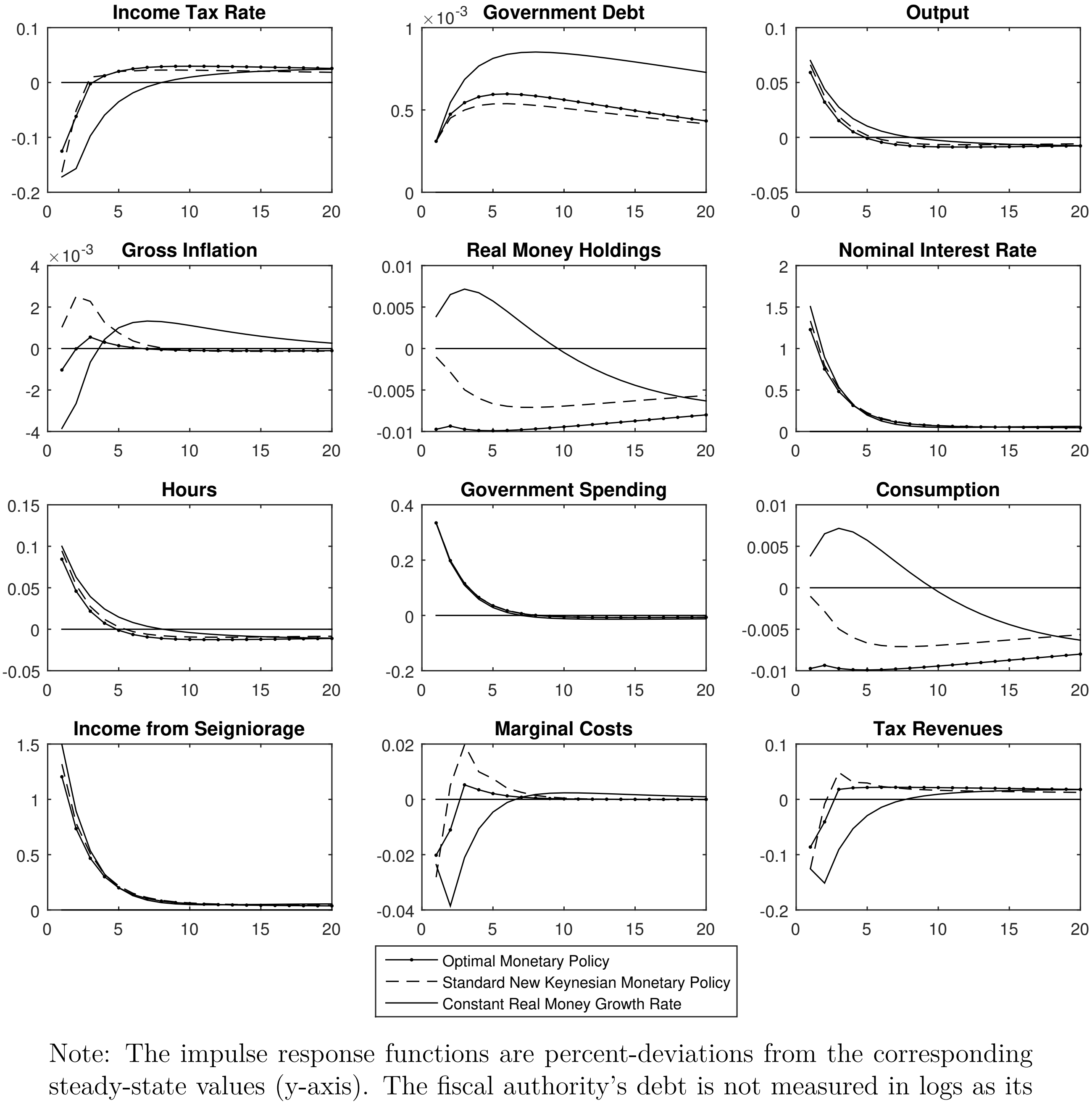
it passively follows a given rule, which is, however, consistent in the long-run. The second policy considers the fiscal authority's behavior and is derived using the Ramsey approach. However, this policy describes the behavior of a monetary authority in a standard New Keynesian model, where a discount factor shock is not present. By comparing this policy with the optimal one, I ask whether and how much the central bank has to adjust its standard policy to temporary fiscal shortsightedness.

I start the analysis by investigating the reaction of a number of endogenous variables of interest to a temporary increase in χ_t, where the central bank sets the real money growth rate constant (see Figure 3.1). The fiscal authority becomes temporarily shortsighted and increases its consumption by about 0.3 percent of its steady-state value. For a myopic fiscal authority, the issuance of new debt becomes relatively more attractive since it is willing to pay a higher interest rate than that demanded by the households. This in turn induces a debt bias. Thus, the fiscal authority finances its higher spending by increasing its debt and by additionally reducing the labor income tax, generating a consumption boom, as illustrated by Kumhof and Yakadina (2007). However, since debt has to be repaid, the income tax rate increases slowly and stays over its steady-state value at maximum 0.024 percent after 32 quarters. Higher public debt also leads to an increase in the nominal interest rate. As the labor income tax rate falls, households supply more labor. The impact causes marginal costs to fall, as they are a negative function of the tax rate.[8] This induces firms to lower prices. With declining inflation, the central bank increases today's money supply to keep the real money growth rate constant. Equation (3.23) shows a negative link between today's money stock and today's inflation given past money supply. As the cash-in-advance constraint holds, higher real money holdings go tandem with higher private consumption. Overall, these effects lead the output to rise above its steady-state value by about 0.07 percent. Thus, it can be concluded that the monetary authority under the first policy regime supports the fiscal authority's shortsightedness by increasing the money supply and thus the fiscal authority's seigniorage revenues.

By considering the optimal monetary policy (see Figure 3.1), one can detect clear differences in the central bank's behavior compared the long-run consistent monetary

[8]The negative relation can be seen by inserting the real wage in Equation (3.18) into the intratemporal labor decision (3.5).

Figure 3.1: Impulse responses to a temporary increase in the fiscal authority's discount factor



Note: The impulse response functions are percent-deviations from the corresponding steady-state values (y-axis). The fiscal authority's debt is not measured in logs as its steady-state is near zero. The x-axis is measured in quarters. A first-order approximation is used.

policy. As before, the fiscal authority increases its spending by almost 0.3 percent, but finances it with less debt accumulation and a higher labor income tax rate than in the case of the long-run consistent monetary policy. Instead of the tax rate decreasing by about 0.17 percent, it falls only about 0.125 percent. This change is induced by a conservative monetary authority, which does not support the temporary fiscal shortsightedness. The central bank's goal is to maximize households' welfare, which is why it tries to minimize all welfare costs induced by a shortsighted fiscal authority. In the presence of nominal rigidities, inflation volatility entails welfare costs because it generates price dispersion. The income tax rate's volatility also causes welfare costs due to the distorting tax. Thus, the central bank attempts to lower both volatilities. To achieve this, the central bank uses money supply actively to reduce the volatility of the inflation and of the tax rate. In fact, it lowers money supply, thereby reducing the fiscal authority's income from seigniorage. This leads the fiscal authority to reduce its tax cut, since forgone seigniorage revenues have to be financed. Consequently, tax revenues do not decrease as much as before, leading to a faster reduction in the fiscal authority's debt. However, since the fiscal authority is temporarily shortsighted, it does not reduce public spending in reaction to the lower seigniorage revenues. The initial amount of debt is its optimal response to a lower discount factor, and although seigniorage revenues decline, the fiscal authority does not lower its spending significantly. Instead, it only reduces the tax cut. As the shortsighted fiscal authority prefers a high present utility, reducing public spending would actually reduce its utility. Therefore, its optimal response to the money supply reduction is mainly a reduction in the tax rate cut. As the tax rate's response is weaker than in the case of the long-run consistent monetary policy, marginal costs do not fall as much as before. This dampens the reaction of the inflation rate, since firms, which can adjust their prices in the current period, do not reduce their prices as much as before. In addition, reducing the money supply does also reduce private consumption, as households are limited in their consumption by the cash-in-advance constraint.

Table 3.3: Standard deviation (in percentage points) of corresponding variables in the models with the long-run consistent monetary policy, the optimal monetary policy and the standard monetary policy (second-order approximation).

Variable	Constant Money Growth Rate	Optimal Monetary Policy	Standard Monetary Policy
Income Tax Rate	0.1103	0.0760	0.0754
Inflation	0.0060	0.0014	0.0039

To conclude, the central bank can reduce both the volatility of the inflation rate and the labor income tax rate (see Table 3.3), thereby reducing the welfare costs of a temporarily shortsighted fiscal authority. This increases as expected the overall welfare compared to a long-run consistent monetary policy.

To calculate the welfare gains I solve the model by using a second-order approximation. Faia and Monacelli (2007) point out that one cannot rely on first-order approximation methods to evaluate welfare. In this model, distortions exert an effect both in the short-run and in the steady-state, while stochastic volatility has an effect on both the first and second moments of the variables that are critical for welfare. Therefore, higher-order approximation is necessary.[9]

The following results are obtained: Households living in an economy with a long-run consistent monetary policy must be provided with an increase in their consumption by 0.021 percent as a compensation in order to make them equal with households living in an economy with an optimal monetary policy. In other words, this consumption compensation is the percentage increase in consumption that would yield the same welfare level as implied by the optimal policy. This number seems to be small, but one can notice, using figures for total personal consumption expenditures in the U.S. in 2013, that the welfare costs are about 2.34 billion U.S.-dollars per year.

This leads to the conclusion that, if the central bank takes fiscal policy into account, it tries to reduce the fiscal authority's real debt accumulation. To achieve this goal, the central bank has to reduce the monetary supply, which reduces the volatility of the inflation and the tax rate, too. In addition, the smaller decline in the inflation rate reduces the real debt even further.

Lastly, one could wonder if the optimal monetary reaction is simply a standard reaction of an uninformed central bank or if the central bank has to modify its policy when the fiscal authority gets temporarily shortsighted. Therefore, I use the model described above but modify it slightly so that it becomes a standard New Keynesian model without any kind of fiscal shortsightedness. Instead, I replace the endogenous public spending by exogenous public spending, which is modelled using an AR(1) process. Having this standard model I can find the optimal standard New Keynesian

[9] See also Kim and Kim (2003) and Kim and Kim (2005) for an analysis of the inaccuracy of welfare calculations based on linear approximations.

monetary policy reaction to an increase in public spending. I derive this optimal central bank reaction by solving a standard Ramsey planner problem where public spending is an exogenous variable. After that I approximate the optimal standard central bank policy by running a linear regression. This is similar to the derivation of linear rules for the fiscal authority's instruments in Section 3.3.1. This time, however, I do it for the central bank instrument - the real money supply. The following regression (3.24) has the dependent variable $m_t\pi_t$, and since $Y_t = G_t + C_t$, and $m_t = \nu^m C_t$ the regression (3.24) can be rewritten as a simple money growth rate rule. Therefore, it has a similar interpretation to the standard monetary rule proposed by Taylor (1993). Concretely, the linear regression has the following form:

$$\begin{aligned} m_t\pi_t - (m^{ss}\pi^{ss}) =& \phi_{gmb}(b_{t-1} - b^{ss}) + \phi_{gmS}(S_{t-1} - S^{ss}) + \phi_{gmY}(Y_{t-1} - Y^{ss}) \\ &+ \phi_{gm\pi}(\pi_{t-1} - \pi^{ss}) + \phi_{gmG}(G_{t-1} - G^{ss}) + \phi_{gmi}(i_{t-1} - i^{ss}), \end{aligned} \tag{3.24}$$

The estimated parameter values are shown in Table 3.4.

Table 3.4: Estimated parameters for the central bank policy after solving a standard New-Keynesian model with a first-order approximation and simulating the model for 50,000 periods.

Parameter	ϕ_{gmb}	ϕ_{gmS}	ϕ_{gmY}	$\phi_{gm\pi}$	ϕ_{gmG}	ϕ_{gmi}
Value	-0.0115	-57.553	0.5273	0.0308	-0.5098	6.94e-01

I use this linear monetary policy rule along with the two linear fiscal authority policy rules (3.21) and (3.22) to describe the standard New Keynesian monetary policy. Figure 3.1 presents the reaction of this type of central bank to a temporarily shortsighted fiscal authority. The standard central bank policy lies between the constant real money growth rate policy and the optimal policy, indicating that the standard central bank policy cannot mimic the optimal policy completely. The volatility of the labor income tax rate is nearly the same as under the optimal monetary policy; however, the volatility of the inflation rate is nearly three times larger. Consequently, the mean of the economy's welfare is lower than under the optimal policy. Interestingly, in contrast to the constant real money growth rate rule, the standard New Keynesian monetary policy implies a reduction in the money supply similar to the optimal monetary policy. However, this reduction is smaller compared with the optimal monetary policy. Therefore, the central bank has to modify its standard behavior in case of a temporarily shortsighted fiscal authority by decreasing money supply more than it would normally do.

3.6 Conclusion

In this chapter, I evaluate the stabilizing properties of an optimal monetary policy under a temporarily shortsighted fiscal authority. Both the central bank and the fiscal authority act under full commitment and the fiscal authority is only temporarily shortsighted. One aspect of the fiscal shortsightedness is fiscal myopia. The other is that the fiscal authority does not internalize the reaction of a benevolent central bank to a temporarily shortsighted fiscal policy.

The findings are as follows: If the fiscal authority is hit by a temporary shock evoking fiscal shortsightedness, the fiscal authority increases public spending, and decreases labor income tax financed by accumulation of public debt. A lower labor income tax lowers the marginal cost of the producers, leading them to lower their prices. Thus, inflation falls; however, the volatility of inflation and the price dispersion increase. As the volatility of the tax rate and of the inflation rate rise, the distortions in the economy increase, too. Therefore, the central bank's optimal response is to reduce these distortions by decreasing the money supply in order to reduce seigniorage revenues. Lower seigniorage revenues decrease the fiscal authority's seigniorage income. Consequently, the fiscal authority cannot lower the tax rate as much as under the long-run consistent, i.e. a constant real money growth rate rule, or under a standard New Keynesian monetary policy (similar to the one proposed by Taylor (1993)). Higher tax revenues lead to less debt accumulation and to less movements in goods' prices. Thus, the volatility of the inflation rate shrinks and price dispersion declines. Therefore, the central bank can lower the volatility of inflation and the labor income tax rate, thereby reducing welfare costs and increasing overall welfare.

However, the model studied in this chapter leaves out several features that are important for understanding business fluctuations. Incorporating nominal wage stickiness, real frictions such as habit formation, capital adjustment costs, and variable capacity utilization would enrich the model and improve its realism. I leave it to future research to integrate these feature, and to check how introducing these elements would influence my results.

In addition, an interesting extension would be to ask the same question in the context of a monetary union. One could expand the model to a two-country model in order to derive the optimal monetary response to a temporarily shortsighted behavior of only one of the two fiscal authorities. The central bank would try to stabilize the overall inflation rate of the monetary union.

In addition, as public spending is unproductive in my model, an interesting future research direction would be to investigate if the results are robust when introducing productive public spending.

3.A Appendix

3.A.1 Derivation of the implementability constraint

This appendix shows in detail how to derive the sequence of implementability constraints. We start with the households' period-by-period budget constraint

$$C_t + \left(\frac{b_t}{1+i_t}\right) + \frac{\Phi}{2}b_t^2 + m_t = \frac{b_{t-1}}{\pi_t} + m_{t-1}\frac{1}{\pi_t} + (1-\tau_t^W)w_t N_t + t_t. \tag{3.25}$$

By using the households' FOCs to substitute out $\frac{1}{1+i_t}$ and $(1-\tau_t^W)w_t$ and by using the definition of real firms' profits $t_t = N_t^{1-\alpha}S_t^{-1} - MC_t(1-\alpha)N_t^{-\alpha}S_t^{-1}N_t$ one can rewrite (3.25) as follows:

$$\begin{aligned} &C_t + b_t E_t\left(\beta\frac{\lambda_{t+1}}{\lambda_t}\frac{1}{\pi_{t+1}} - \Phi b_t\right) + \frac{\Phi}{2}b_t^2 + m_t = \\ &b_{t-1}\frac{1}{\pi_t} + m_{t-1}\frac{1}{\pi_t} - \frac{U_{N,t}}{\lambda_t}N_t + N_t^{1-\alpha}S_t^{-1} - MC_t(1-\alpha)N_t^{-\alpha}S_t^{-1}N_t. \end{aligned} \tag{3.26}$$

Rewrite (3.26) as

$$\begin{aligned} b_{t-1}\frac{1}{\pi_t} =& C_t + b_t E_t\left(\beta\frac{\lambda_{t+1}}{\lambda_t}\frac{1}{\pi_{t+1}} - \Phi b_t\right) + \frac{\Phi}{2}b_t^2 + m_t \\ &- m_{t-1}\frac{1}{\pi_t} + \frac{U_{N,t}}{\lambda_t}N_t - N_t^{1-\alpha}S_t^{-1} + MC_t(1-\alpha)N_t^{-\alpha}S_t^{-1}N_t. \end{aligned} \tag{3.27}$$

For convenience, define

$$z_t \equiv C_t - \Phi b_t^2 + \frac{\Phi}{2}b_t^2 + m_t - m_{t-1}\frac{1}{\pi_t} + \frac{U_{N,t}}{\lambda_t}N_t - N_t^{1-\alpha}S_t^{-1} + MC_t(1-\alpha)N_t^{-\alpha}S_t^{-1}N_t. \tag{3.28}$$

Using this definition one can rewrite (3.27) as

$$b_{t-1} = z_t\pi_t + \pi_t\beta E_t\left(\frac{\lambda_{t+1}}{\lambda_t}\frac{1}{\pi_{t+1}}b_t\right). \tag{3.29}$$

Then iterate forward (3.29)

$$b_{t-1} = z_t\pi_t + \beta\pi_t E_t\left(\frac{\lambda_{t+1}}{\lambda_t}z_{t+1}\right) + \beta^2\pi_t E_t\left(\frac{\lambda_{t+2}}{\lambda_t}z_{t+2}\right) + \ldots + \beta^{j+1}\pi_t E_t\left(\frac{\lambda_{t+j+1}}{\lambda_t}\frac{1}{\pi_{t+j+1}}b_{t+j}\right). \tag{3.30}$$

Letting $j \to \infty$ and using the transversality condition yields the sequence of implementability constraints

$$\lambda_t b_{t-1} \frac{1}{\pi_t} = E_t \sum_{j=0}^{\infty} \beta^j \lambda_{t+j} z_{t+j}. \tag{3.31}$$

Or by using the definition of z_t

$$\begin{aligned}\lambda_t b_t \frac{1}{\pi_t} = E_t \sum_{j=0}^{\infty} \beta^j \lambda_{t+j} \Big[C_{t+j} - \Phi b_{t+j}^2 + \frac{\Phi}{2} b_{t+j}^2 + m_{t+j} - m_{t+j-1} \frac{1}{\pi_{t+j}} + \frac{U_{N,t+j}}{\lambda_{t+j}} N_{t+j} \\ - N_{t+j}^{1-\alpha} S_{t+j}^{-1} + MC_{t+j}(1-\alpha) N_{t+j}^{-\alpha} S_{t+j}^{-1} N_{t+j} \Big].\end{aligned} \tag{3.32}$$

3.A.2 The central bank's optimization problem

Setting up the central bank's as well as the fiscal authority's optimization problem one has to be aware of the infinite double sum, thus one rewrites it recursively following Aiyagari et al. (2002).[10] The central bank's optimization problem is described by

[10] One solves the double sum by defining a new Lagrangian multiplier $\lambda_t^{0,j} = \lambda_{t-1}^{0,j} + \chi_t \omega_t,\ j = \{f, m\}$, where ω_t is the Lagrangian multiplier of (3.20) and $\lambda_{-1}^{0,j}$ is assumed to be zero. In addition one uses the law of iterated expectations. In the case of the central bank, χ_t equals one. The complete derivation can be found in Appendix 3.A.4.

$$
\begin{aligned}
\max_{\{C_t,N_t,\tilde{P}_t^*,S_t,x_{1,t},x_{2,t},\pi_t,MC_t,m_t,\lambda_t,\mu_t,b_t,G_t\}} J_t^m = E_0 \sum_{t=0}^{\infty} \beta^t \Big[& U(C_t,N_t,G_t) + \lambda_t^{0,m}\Big(\lambda_t C_t \\
& + m_t\lambda_t - m_{t-1}\frac{1}{\pi_t}\lambda_t + U_{N,t}N_t \\
& - \lambda_t \frac{N_t^{1-\alpha}}{S_t} + \lambda_t MC_t(1-\alpha)S_t^{-1}N_t^{1-\alpha} \\
& - \frac{\Phi}{2}b_t^2\lambda_t\Big) + \left(\lambda_{t-1}^{0,m} - \lambda_t^{0,m}\right)\frac{\lambda_t}{\pi_t}b_{t-1} \\
& + \lambda_t^{1,m}\left(\frac{N_t^{1-\alpha}}{S_t} - C_t - G_t\right) \\
& + \lambda_t^{2,m}\left(\frac{\epsilon}{\epsilon-1}x_{1,t} - x_{2,t}\right) + \lambda_t^{3,m}\Bigg(x_{1,t} \\
& \quad - (\tilde{P}_t^*)^{-1-\epsilon}\frac{N_t^{1-\alpha}}{S_t}MC_t - \theta E_t\Bigg(\frac{\beta\lambda_{t+1}}{\lambda_t}\frac{1}{\pi_{t+1}} \\
& \quad - \Phi b_t\Bigg)\pi_{t+1}^{\epsilon}\left(\frac{\tilde{P}_t^*}{\tilde{P}_{t+1}^*}\right)^{-1-\epsilon} x_{1,t+1}\Bigg) \\
& + \lambda_t^{4,m}\Bigg(x_{2,t} - \frac{N_t^{1-\alpha}}{S_t}(\tilde{P}_t^*)^{-\epsilon} - \theta E_t\Bigg(\frac{\beta\lambda_{t+1}}{\lambda_t}\frac{1}{\pi_{t+1}} \\
& \quad - \Phi b_t\Bigg)\pi_{t+1}^{\epsilon-1}\left(\frac{\tilde{P}_t^*}{\tilde{P}_{t+1}^*}\right)^{-\epsilon} x_{2,t+1}\Bigg) \\
& + \lambda_t^{5,m}\left(1 - \theta\pi_t^{-1+\epsilon} - (1-\theta)\left(\tilde{P}_t^*\right)^{1-\epsilon}\right) \\
& + \lambda_t^{6,m}\left(S_t - (1-\theta)(\tilde{P}_t^*)^{-\epsilon} - \theta\pi_t^{\epsilon}S_{t-1}\right) \\
& + \lambda_t^{7,m}\left(U_{C,t} - \lambda_t(1-\mu_t\nu^M)\right) \\
& + \lambda_t^{8,m}\left(\lambda_t(1+\mu_t) - \lambda_{t+1}\beta\frac{1}{\pi_{t+1}}\right) \\
& + \lambda_t^{9,m}\left(-m_t + \nu^M C_t\right) + \lambda_t^{10,m}\Big(b_t - b^{ss} \\
& - \phi_{bb}(b_{t-1} - b^{ss}) - \phi_{b\chi}(\chi_{t-1} - \chi^{ss}) \\
& - \phi_{bS}(S_{t-1} - S^{ss}) - \phi_{bm}(m_{t-1} - m^{ss}) \\
& - \phi_{b\lambda}(\lambda_{t-1} - \lambda^{ss}) - \phi_{b\tilde{P}^*}(\tilde{P}_{t-1}^* - \tilde{P}^{*ss}) \\
& - \phi_{b\epsilon^\chi}\epsilon_t^\chi\Big) + \lambda_t^{11,m}\Big(G_t - G^{ss} - \phi_{Gb}(b_{t-1} - b^{ss}) \\
& - \phi_{G\chi}(\chi_{t-1} - \chi^{ss}) - \phi_{GS}(S_{t-1} - S^{ss}) \\
& - \phi_{Gm}(m_{t-1} - m^{ss}) - \phi_{G\lambda}(\lambda_{t-1} - \lambda^{ss}) \\
& - \phi_{G\tilde{P}^*}(\tilde{P}_{t-1}^* - \tilde{P}^{*ss}) - \phi_{b\epsilon^\chi}\epsilon_t^\chi\Big)\Big],
\end{aligned}
\tag{3.33}
$$

where the last two conditions are the linear policy functions describing the fiscal authority's behavior. The first order conditions of the central bank's optimization problem are:

$$\frac{\partial J_t^m}{\partial C_t} = U_{C,t} + \lambda_t^{0,m}\lambda_t + \lambda_t^{1,m}(-1) + \lambda_t^{7,m}U_{CC,t} + \lambda_t^{9,m}\nu^M = 0, \tag{3.34}$$

$$\begin{aligned}\frac{\partial J_t^m}{\partial N_t} &= U_{N,t} + \lambda_t^{0,m}\Big(U_{NN,t}N_t + U_{N,t} - \lambda_t(1-\alpha)N_t^{-\alpha}S_t^{-1} + \lambda_t MC_t(1-\alpha)^2 S_t^{-1}N_t^{-\alpha}\Big)\\ &\quad + \lambda_t^{1,m}(1-\alpha)N_t^{-\alpha}S_t^{-1} - \lambda_t^{3,m}(1-\alpha)S_t^{-1}N_t^{-\alpha}MC_t(\tilde{P}_t^*)^{-1-\epsilon}\\ &\quad + \lambda_t^{4,m}(-1)(1-\alpha)N_t^{-\alpha}S_t^{-1}(\tilde{P}_t^*)^{-\epsilon}\\ &= 0,\end{aligned} \tag{3.35}$$

$$\begin{aligned}\frac{\partial J_t^m}{\partial \tilde{P}_t^*} &= -\lambda_t^{3,m}\theta E_t\left(\frac{\beta\lambda_{t+1}}{\lambda_t}\frac{1}{\pi_{t+1}} - \Phi b_t\right)(\pi_{t+1})^{\epsilon}(-\epsilon-1)\left(\frac{\tilde{P}_t^*}{\tilde{P}_{t+1}^*}\right)^{-\epsilon-2}\frac{1}{\tilde{P}_{t+1}^*}x_{1,t+1}\\ &+ \lambda_t^{4,m}(-1)\theta E_t\left(\frac{\beta\lambda_{t+1}}{\lambda_t}\frac{1}{\pi_{t+1}} - \Phi b_t\right)(\pi_{t+1})^{\epsilon-1}(-\epsilon)\left(\frac{\tilde{P}_t^*}{\tilde{P}_{t+1}^*}\right)^{-\epsilon-1}\frac{1}{\tilde{P}_{t+1}^*}x_{2,t+1}\\ &+ \lambda_t^{5,m}(-1)(1-\theta)(1-\epsilon)(\tilde{P}_t^*)^{-\epsilon} + \lambda_t^{6,m}(-1)(1-\theta)(-\epsilon)(\tilde{P}_t^*)^{-\epsilon-1}\\ &+ \lambda_t^{3,m}(-1)(-1-\epsilon)(\tilde{P}_t^*)^{-\epsilon-2}N_t^{1-\alpha}S_t^{-1}MC_t + \lambda_t^{4,m}(-1)N_t^{1-\alpha}S_t^{-1}(-\epsilon)(\tilde{P}_t^*)^{-\epsilon-1}\\ &+ (\beta)^{-1}\Bigg(\lambda_{t-1}^{3,m}(-1)\theta\left(\frac{\beta\lambda_t}{\lambda_{t-1}}\frac{1}{\pi_t} - \Phi b_{t-1}\right)\pi_t^{\epsilon}(-\epsilon-1)\left(\frac{\tilde{P}_{t-1}^*}{\tilde{P}_t^*}\right)^{-\epsilon-2}\tilde{P}_{t-1}^*(\tilde{P}_t^*)^{-2}(-1)x_{1,t}\\ &+ \lambda_{t-1}^{4,m}(-1)\theta\left(\frac{\beta\lambda_t}{\lambda_{t-1}}\frac{1}{\pi_t} - \Phi b_{t-1}\right)\pi_t^{\epsilon-1}(-\epsilon)\left(\frac{\tilde{P}_{t-1}^*}{\tilde{P}_t^*}\right)^{-\epsilon-1}\tilde{P}_{t-1}^*(\tilde{P}_t^*)^{-2}(-1)x_{2,t}\Bigg)\\ &+ \beta E_t\lambda_{t+1}^{11,m}(-\phi_{G\tilde{P}^*}) + \beta E_t\lambda_{t+1}^{10,m}(-\phi_{b\tilde{P}^*}) = 0,\end{aligned} \tag{3.36}$$

$$\begin{aligned}\frac{\partial J_t^m}{\partial S_t} &= \lambda_t^{1,m}N_t^{1-\alpha}(-1)S_t^{-2} + \lambda_t^{6,m} + \lambda_t^{0,m}\Big(-N_t^{1-\alpha}S_t^{-2}\lambda_t(-1)\\ &\quad - \lambda_t MC_t(1-\alpha)S_t^{-2}N_t^{1-\alpha}\Big) + \lambda_t^{3,m}(-1)(\tilde{P}_t^*)^{-1-\epsilon}N_t^{1-\alpha}(-1)S_t^{-2}MC_t\\ &\quad + \lambda_t^{4,m}(-1)(\tilde{P}_t^*)^{-\epsilon}N_t^{1-\alpha}(-1)S_t^{-2}\\ &\quad + (\beta)E_t\lambda_{t+1}^{6,m}(-1)\theta\pi_{t+1}^{\epsilon} + \beta E_t(-\lambda_{t+1}^{10,m}\phi_{bS} - E_t\lambda_{t+1}^{11,m}\phi_{GS}) = 0,\end{aligned} \tag{3.37}$$

$$\frac{\partial J_t^m}{\partial x_{1,t}} = \lambda_t^{2,m}\frac{\epsilon}{(\epsilon-1)} + \lambda_t^{3,m} + (\beta)^{-1}\lambda_{t-1}^{3,m}(-1)\theta\left(\beta\frac{\lambda_t}{\lambda_{t-1}}\frac{1}{\pi_t} - \Phi b_{t-1}\right)\pi_t^{\epsilon}\left(\frac{\tilde{P}_{t-1}^*}{\tilde{P}_t^*}\right)^{-\epsilon-1} = 0, \tag{3.38}$$

$$\frac{\partial J_t^m}{\partial x_{2,t}} = \lambda_t^{2,m}(-1) + \lambda_t^{4,m} + (\beta)^{-1}\lambda_{t-1}^{4,m}(-1)\theta\left(\beta\frac{\lambda_t}{\lambda_{t-1}}\frac{1}{\pi_t} - \Phi b_{t-1}\right)\pi_t^{\epsilon-1}\left(\frac{\tilde{P}_{t-1}^*}{\tilde{P}_t^*}\right)^{-\epsilon} = 0, \tag{3.39}$$

$$\begin{aligned}\frac{\partial J_t^m}{\partial \pi_t} &= \lambda_t^{5,m}(-\theta)(\epsilon-1)\pi_t^{\epsilon-2} + \lambda_t^{6,m}(-\theta)\epsilon\pi_t^{\epsilon-1}S_{t-1} \\ &\quad + (\beta)^{-1}\lambda_{t-1}^{3,m}(-\theta)\left(\beta\frac{\lambda_t}{\lambda_{t-1}}\frac{1}{\pi_t} - \Phi b_{t-1}\right)\pi_t^{\epsilon-1}\epsilon\left(\frac{\tilde{P}_{t-1}^*}{\tilde{P}_t^*}\right)^{-\epsilon-1} x_{1,t} \\ &\quad + (\beta)^{-1}\lambda_{t-1}^{4,m}(-\theta)\left(\beta\frac{\lambda_t}{\lambda_{t-1}}\frac{1}{\pi_t} - \Phi b_{t-1}\right)\pi_t^{\epsilon-2}(\epsilon-1)\left(\frac{\tilde{P}_{t-1}^*}{\tilde{P}_t^*}\right)^{-\epsilon} x_{2,t} \\ &\quad + \lambda_t^{0,m}\lambda_t(-1)m_{t-1}\frac{1}{\pi_t^2}(-1) + \beta^{-1}\lambda_{t-1}^{8,m}\lambda_t\beta\frac{1}{\pi_t^2} + (\lambda_{t-1}^{0,m} - \lambda_t^{0,m})\frac{\lambda_t b_{t-1}}{\pi_t^2}(-1) \\ &\quad + \beta^{-1}\lambda_{t-1}^{3,m}(-\theta)\beta\frac{\lambda_t}{\lambda_{t-1}}\frac{1}{\pi_t^2}(-1)\pi_t^{\epsilon}\left(\frac{\tilde{P}_{t-1}^*}{\tilde{P}_t^*}\right)^{-\epsilon-1} x_{1,t} \\ &\quad + \beta^{-1}\lambda_{t-1}^{4,m}(-\theta)\beta\frac{\lambda_t}{\lambda_{t-1}}\frac{1}{\pi_t^2}(-1)\pi_t^{\epsilon-1}\left(\frac{\tilde{P}_{t-1}^*}{\tilde{P}_t^*}\right)^{-\epsilon} x_{2,t} \\ &= 0,\end{aligned} \tag{3.40}$$

$$\frac{\partial J_t^m}{\partial MC_t} = \lambda_t^{0,m}(1-\alpha)\lambda_t - \lambda_t^{3,m}(\tilde{P}_t^*)^{-1-\epsilon} = 0, \tag{3.41}$$

$$\begin{aligned}\frac{\partial J_t^m}{\partial \lambda_t} &= \lambda_t^{0,m}\left(C_t + m_t - m_{t-1}\frac{1}{\pi_t} - N_t^{1-\alpha}S_t^{-1} + MC_t(1-\alpha)S_t^{-1}N_t^{1-\alpha} - \frac{\Phi}{2}b_t^2\right) \\ &\quad + \left(\lambda_{t-1}^{0,m} - \lambda_t^{0,m}\right)\frac{b_{t-1}}{\pi_t} + \lambda_t^{3,m}(-\theta)\beta E_t\frac{\lambda_{t+1}}{(\lambda_t)^2}(-1)\pi_{t+1}^{\epsilon}\left(\frac{\tilde{P}_t^*}{\tilde{P}_{t+1}^*}\right)^{-1-\epsilon} x_{1,t+1} \\ &\quad + \lambda_t^{4,m}(-\theta)\beta E_t\frac{\lambda_{t+1}}{(\lambda_t)^2}(-1)\pi_{t+1}^{\epsilon-1}\left(\frac{\tilde{P}_t^*}{\tilde{P}_{t+1}^*}\right)^{-\epsilon} x_{2,t+1} \\ &\quad + \lambda_t^{7,m}(-1)(1-\mu_t\nu^M) + \lambda_t^{8,m}(1+\mu_t) + (\beta)^{-1}\left(\lambda_{t-1}^{3,m}(-\theta)\beta\frac{1}{\lambda_{t-1}}\pi_t^{\epsilon}\left(\frac{\tilde{P}_{t-1}^*}{\tilde{P}_t^*}\right)^{-1-\epsilon} x_{1,t}\right. \\ &\quad \left. + \lambda_{t-1}^{4,m}(-\theta)\beta\frac{1}{\lambda_{t-1}}\pi_t^{\epsilon-1}\left(\frac{\tilde{P}_{t-1}^*}{\tilde{P}_t^*}\right)^{-\epsilon} x_{2,t} + \lambda_{t-1}^{8,m}(-1)\beta\frac{1}{\pi_t}\right) \\ &\quad + \beta E_t\lambda_{t+1}^{11,m}(-\phi_{G\lambda}) + \beta E_t\lambda_{t+1}^{10,m}(-\phi_{b\lambda}) = 0,\end{aligned} \tag{3.42}$$

$$\frac{\partial J_t^m}{\partial \mu_t} = \lambda_t^{7,m}\lambda_t \nu^M + \lambda_t^{8,m}\lambda_t = 0, \tag{3.43}$$

$$\frac{\partial J_t^m}{\partial m_t} = \lambda_t^{0,m}\lambda_t + \lambda_t^{9,m}(-1) + \beta\lambda_{t+1}^{0,m}(-1)\frac{1}{\pi_{t+1}}\lambda_{t+1} + \beta E_t(-\lambda_{t+1}^{10,m}\phi_{bm} - \lambda_{t+1}^{11,m}\phi_{Gm}) = 0, \tag{3.44}$$

$$\begin{aligned}\frac{\partial J_t^m}{\partial b_t} &= \lambda_t^{0,m}\lambda_t(-\Phi)b_t + (\beta)E_t\left(\lambda_t^{0,m} - \lambda_{t+1}^{0,m}\right)\frac{\lambda_{t+1}}{\pi_{t+1}} + \lambda_t^{3,m}E_t(-\theta)(-\Phi)\pi_{t+1}^{\epsilon}\left(\frac{\tilde{P}_t^*}{\tilde{P}_{t+1}^*}\right)^{-1-\epsilon} x_{1,t+1} \\ &+ \lambda_t^{4,m}E_t(-\theta)(-\Phi)\pi_{t+1}^{\epsilon-1}\left(\frac{\tilde{P}_t^*}{\tilde{P}_{t+1}^*}\right)^{-\epsilon} x_{2,t+1} + \beta E_t(-\lambda_{t+1}^{10,m}\phi_{bb} - \lambda_{t+1}^{11,m}\phi_{Gb}) + \lambda_t^{10,m} = 0,\end{aligned} \tag{3.45}$$

$$\frac{\partial J_t^m}{\partial G_t} = U_{G,t} + \lambda_t^{1,m}(-1) + \lambda_t^{11,m} = 0. \tag{3.46}$$

3.A.3 The fiscal authority's optimization problem

The fiscal authority's optimization problem is described by

$$\begin{aligned}&\max_{\{C_t,N_t,\tilde{P}_t^*,S_t,x_{1,t},x_{2,t},\pi_t,MC_t,\lambda_t,\mu_t,b_t,G_t,m_t\}} J_t^f = \\ &= E_0\sum_{t=0}^{\infty}\chi_t\beta^t\Big[U(C_t,N_t,G_t) + \frac{\lambda_t^{0,f}}{\chi_t}\Big(\lambda_t C_t + m_t\lambda_t - m_{t-1}\frac{1}{\pi_t}\lambda_t + U_{N,t}N_t - \lambda_t\frac{N_t^{1-\alpha}}{S_t} \\ &+ \lambda_t MC_t(1-\alpha)S_t^{-1}N_t^{1-\alpha} - \frac{\Phi}{2}b_t^2\lambda_t\Big) \\ &+ \left(\frac{\lambda_{t-1}^{0,f} - \lambda_t^{0,f}}{\chi_t}\right)\frac{\lambda_t}{\pi_t}b_{t-1}\end{aligned} \tag{3.47}$$

$$
\begin{aligned}
&+\lambda_t^{1,f}\left(\frac{N_t^{1-\alpha}}{S_t}-C_t-G_t\right)\\
&+\lambda_t^{2,f}\left(\frac{\epsilon}{\epsilon-1}x_{1,t}-x_{2,t}\right)\\
&+\lambda_t^{3,f}\left(x_{1,t}-(\tilde{P}_t^*)^{-1-\epsilon}\frac{N_t^{1-\alpha}}{S_t}MC_t-\theta E_t\left(\frac{\beta\lambda_{t+1}}{\lambda_t}\frac{1}{\pi_{t+1}}-\Phi b_t\right)\pi_{t+1}^{\epsilon}\left(\frac{\tilde{P}_t^*}{\tilde{P}_{t+1}^*}\right)^{-1-\epsilon}x_{1,t+1}\right)\\
&+\lambda_t^{4,f}\left(x_{2,t}-\frac{N_t^{1-\alpha}}{S_t}(\tilde{P}_t^*)^{-\epsilon}-\theta E_t\left(\frac{\beta\lambda_{t+1}}{\lambda_t}\frac{1}{\pi_{t+1}}-\Phi b_t\right)\pi_{t+1}^{\epsilon-1}\left(\frac{\tilde{P}_t^*}{\tilde{P}_{t+1}^*}\right)^{-\epsilon}x_{2,t+1}\right)\\
&+\lambda_t^{5,f}\left(1-\theta\pi_t^{-1+\epsilon}-(1-\theta)\left(\tilde{P}_t^*\right)^{1-\epsilon}\right)\\
&+\lambda_t^{6,f}\left(S_t-(1-\theta)(\tilde{P}_t^*)^{-\epsilon}-\theta\pi_t^{\epsilon}S_{t-1}\right)\\
&+\lambda_t^{7,f}\left(U_{C,t}-\lambda_t(1-\mu_t\nu^M)\right)\\
&+\lambda_t^{8,f}\left(\lambda_t(1+\mu_t)-\lambda_{t+1}\beta\frac{1}{\pi_{t+1}}\right)\\
&+\lambda_t^{9,f}\left(-m_t+\nu^M C_t\right)\\
&+\lambda_t^{10,f}\left(\frac{m_t}{m_{t-1}}\pi_t-\pi_{SS}\right)\Bigg],
\end{aligned}
\tag{3.48}
$$

The first order conditions of the fiscal authority's optimization problem are:[11]

$$
\frac{\partial J_t^f}{\partial C_t}=U_{C,t}+\frac{\lambda_t^{0,f}}{\chi_t}\lambda_t+\lambda_t^{1,f}(-1)+\lambda_t^{7,f}U_{CC,t}+\lambda_t^{9,f}\nu^M=0, \tag{3.49}
$$

$$
\begin{aligned}
\frac{\partial J_t^f}{\partial N_t}&=U_{N,t}+\frac{\lambda_t^{0,f}}{\chi_t}\left(U_{NN,t}N_t+U_{N,t}-\lambda_t(1-\alpha)N_t^{-\alpha}S_t^{-1}+\lambda_t MC_t(1-\alpha)^2S_t^{-1}N_t^{-\alpha}\right)\\
&+\lambda_t^{1,f}(1-\alpha)N_t^{-\alpha}S_t^{-1}-\lambda_t^{3,f}(1-\alpha)S_t^{-1}N_t^{-\alpha}MC_t(\tilde{P}_t^*)^{-1-\epsilon}\\
&+\lambda_t^{4,f}(-1)(1-\alpha)N_t^{-\alpha}S_t^{-1}(\tilde{P}_t^*)^{-\epsilon}=0,
\end{aligned}
\tag{3.50}
$$

[11] $U_{.}$ stands for the first derivative of the utility function with respect to the corresponding variable. $U_{..}$ stands for the second derivative of the utility function with respect to the corresponding variable.

$$\begin{aligned}
\frac{\partial J_t^f}{\partial \tilde{P}_t^*} &= -\lambda_t^{3,f}\theta E_t\left(\frac{\beta\lambda_{t+1}}{\lambda_t}\frac{1}{\pi_{t+1}}-\Phi b_t\right)(\pi_{t+1})^{\epsilon}(-\epsilon-1)\left(\frac{\tilde{P}_t^*}{\tilde{P}_{t+1}^*}\right)^{-\epsilon-2}\frac{1}{\tilde{P}_{t+1}^*}x_{1,t+1}\\
&+\lambda_t^{4,f}(-1)\theta E_t\left(\frac{\beta\lambda_{t+1}}{\lambda_t}\frac{1}{\pi_{t+1}}-\Phi b_t\right)(\pi_{t+1})^{\epsilon-1}(-\epsilon)\left(\frac{\tilde{P}_t^*}{\tilde{P}_{t+1}^*}\right)^{-\epsilon-1}\frac{1}{\tilde{P}_{t+1}^*}x_{2,t+1}\\
&+\lambda_t^{5,f}(-1)(1-\theta)(1-\epsilon)(\tilde{P}_t^*)^{-\epsilon}+\lambda_t^{6,f}(-1)(1-\theta)(-\epsilon)(\tilde{P}_t^*)^{-\epsilon-1}\\
&+\lambda_t^{3,f}(-1)(-1-\epsilon)(\tilde{P}_t^*)^{-\epsilon-2}N_t^{1-\alpha}S_t^{-1}MC_t+\lambda_t^{4,f}(-1)N_t^{1-\alpha}S_t^{\alpha-1}(-\epsilon)(\tilde{P}_t^*)^{-\epsilon-1}\\
&+\frac{\chi_{t-1}}{\chi_t}(\beta)^{-1}\Bigg(\lambda_{t-1}^{3,f}(-1)\theta\left(\frac{\beta\lambda_t}{\lambda_{t-1}}\frac{1}{\pi_t}-\Phi b_{t-1}\right)\pi_t^{\epsilon}(-\epsilon-1)\left(\frac{\tilde{P}_{t-1}^*}{\tilde{P}_t^*}\right)^{-\epsilon-2}\tilde{P}_{t-1}^*(\tilde{P}_t^*)^{-2}(-1)x_{1,t}\\
&+\lambda_{t-1}^{4,f}(-1)\theta\left(\frac{\beta\lambda_t}{\lambda_{t-1}}\frac{1}{\pi_t}-\Phi b_{t-1}\right)\pi_t^{\epsilon-1}(-\epsilon)\left(\frac{\tilde{P}_{t-1}^*}{\tilde{P}_t^*}\right)^{-\epsilon-1}\tilde{P}_{t-1}^*(\tilde{P}_t^*)^{-2}(-1)x_{2,t}\Bigg)=0,
\end{aligned} \tag{3.51}$$

$$\begin{aligned}
\frac{\partial J_t^f}{\partial S_t} &= \lambda_t^{1,f}N_t^{1-\alpha}(-1)S_t^{-2}+\lambda_t^{6,f}+\frac{\lambda_t^{0,f}}{\chi_t}\Big(-N_t^{1-\alpha}S_t^{-2}\lambda_t(-1)\\
&-\lambda_t MC_t(1-\alpha)S_t^{-2}N_t^{1-\alpha}\Big)+\lambda_t^{3,f}(-1)(\tilde{P}_t^*)^{-1-\epsilon}N_t^{1-\alpha}(-1)S_t^{-2}MC_t\\
&+\lambda_t^{4,f}(-1)(\tilde{P}_t^*)^{-\epsilon}N_t^{1-\alpha}(-1)S_t^{-2}+\frac{\chi_{t+1}}{\chi_t}(\beta)E_t\lambda_{t+1}^{6,f}(-1)\theta\pi_{t+1}^{\epsilon}\\
&=0,
\end{aligned} \tag{3.52}$$

$$\frac{\partial J_t^f}{\partial x_{1,t}} = \lambda_t^{2,f}\frac{\epsilon}{(\epsilon-1)}+\lambda_t^{3,f}+\frac{\chi_{t-1}}{\chi_t}(\beta)^{-1}\lambda_{t-1}^{3,f}(-1)\theta\left(\beta\frac{\lambda_t}{\lambda_{t-1}}\frac{1}{\pi_t}-\Phi b_{t-1}\right)\pi_t^{\epsilon}\left(\frac{\tilde{P}_{t-1}^*}{\tilde{P}_t^*}\right)^{-\epsilon-1}=0, \tag{3.53}$$

$$\frac{\partial J_t^f}{\partial x_{2,t}} = \lambda_t^{2,f}(-1)+\lambda_t^{4,f}+\frac{\chi_{t-1}}{\chi_t}(\beta)^{-1}\lambda_{t-1}^{4,f}(-1)\theta\left(\beta\frac{\lambda_t}{\lambda_{t-1}}\frac{1}{\pi_t}-\Phi b_{t-1}\right)\pi_t^{\epsilon-1}\left(\frac{\tilde{P}_{t-1}^*}{\tilde{P}_t^*}\right)^{-\epsilon}=0, \tag{3.54}$$

$$
\begin{aligned}
\frac{\partial J_t^f}{\partial \pi_t} &= \lambda_t^{5,f}(-\theta)(\epsilon-1)\pi_t^{\epsilon-2} + \lambda_t^{6,f}(-\theta)\epsilon\pi_t^{\epsilon-1}S_{t-1} \\
&+ \frac{\chi_{t-1}}{\chi_t}(\beta)^{-1}\lambda_{t-1}^{3,f}(-\theta)\left(\beta\frac{\lambda_t}{\lambda_{t-1}}\frac{1}{\pi_t} - \Phi b_{t-1}\right)\pi_t^{\epsilon-1}\epsilon\left(\frac{\tilde{P}_{t-1}^*}{\tilde{P}_t^*}\right)^{-\epsilon-1} x_{1,t} \\
&+ \frac{\chi_{t-1}}{\chi_t}(\beta)^{-1}\lambda_{t-1}^{4,f}(-\theta)\left(\beta\frac{\lambda_t}{\lambda_{t-1}}\frac{1}{\pi_t} - \Phi b_{t-1}\right)\pi_t^{\epsilon-2}(\epsilon-1)\left(\frac{\tilde{P}_{t-1}^*}{\tilde{P}_t^*}\right)^{-\epsilon} x_{2,t} \\
&+ \frac{\lambda_t^{0,f}}{\chi_t}\lambda_t(-1)m_{t-1}\frac{1}{\pi_t^2}(-1) + \frac{\chi_{t-1}}{\chi_t}\beta^{-1}\lambda_{t-1}^{8,f}\lambda_t\beta\frac{1}{\pi_t^2} + \lambda_t^{10,f}\frac{m_t}{m_{t-1}} \\
&+ \frac{\lambda_{t-1}^{0,f} - \lambda_t^{0,f}}{\chi_t}\frac{\lambda_t b_{t-1}}{\pi_t^2}(-1) \\
&+ \frac{\chi_{t-1}}{\chi_t}\beta^{-1}\lambda_{t-1}^{3,f}(-\theta)\beta\frac{\lambda_t}{\lambda_{t-1}}\frac{1}{\pi_t^2}(-1)\pi_t^{\epsilon}\left(\frac{\tilde{P}_{t-1}^*}{\tilde{P}_t^*}\right)^{-\epsilon-1} x_{1,t} \\
&+ \frac{\chi_{t-1}}{\chi_t}\beta^{-1}\lambda_{t-1}^{4,f}(-\theta)\beta\frac{\lambda_t}{\lambda_{t-1}}\frac{1}{\pi_t^2}(-1)\pi_t^{\epsilon-1}\left(\frac{\tilde{P}_{t-1}^*}{\tilde{P}_t^*}\right)^{-\epsilon} x_{2,t} = 0,
\end{aligned} \tag{3.55}
$$

$$
\frac{\partial J_t^f}{\partial MC_t} = \frac{\lambda_t^{0,f}}{\chi_t}(1-\alpha)\lambda_t - \lambda_t^{3,f}(\tilde{P}_t^*)^{-1-\epsilon} = 0, \tag{3.56}
$$

$$
\begin{aligned}
\frac{\partial J_t^f}{\partial \lambda_t} &= \frac{\lambda_t^{0,f}}{\chi_t}\left(C_t + m_t - m_{t-1}\frac{1}{\pi_t} - N_t^{1-\alpha}S_t^{-1} + MC_t(1-\alpha)S_t^{-1}N_t^{1-\alpha} - \frac{\Phi}{2}b_t^2\right) \\
&+ \left(\frac{\lambda_{t-1}^{0,f} - \lambda_t^{0,f}}{\chi_t}\right)\frac{b_{t-1}}{\pi_t} + \lambda_t^{3,f}(-\theta)\beta E_t\frac{\lambda_{t+1}}{(\lambda_t)^2}(-1)\pi_{t+1}^{\epsilon}\left(\frac{\tilde{P}_t^*}{\tilde{P}_{t+1}^*}\right)^{-1-\epsilon} x_{1,t+1} \\
&+ \lambda_t^{4,f}(-\theta)\beta E_t\frac{\lambda_{t+1}}{(\lambda_t)^2}(-1)\pi_{t+1}^{\epsilon-1}\left(\frac{\tilde{P}_t^*}{\tilde{P}_{t+1}^*}\right)^{-\epsilon} x_{2,t+1} \\
&+ \lambda_t^{7,f}(-1)(1-\mu_t\nu^M) + \lambda_t^{8,f}(1+\mu_t) + \frac{\chi_{t-1}}{\chi_t}(\beta)^{-1}\left(\lambda_{t-1}^{3,f}(-\theta)\beta\frac{1}{\lambda_{t-1}}\pi_t^{\epsilon}\left(\frac{\tilde{P}_{t-1}^*}{\tilde{P}_t^*}\right)^{-1-\epsilon} x_{1,t}\right. \\
&\left.+ \lambda_{t-1}^{4,f}(-\theta)\beta\frac{1}{\lambda_{t-1}}\pi_t^{\epsilon-1}\left(\frac{\tilde{P}_{t-1}^*}{\tilde{P}_t^*}\right)^{-\epsilon} x_{2,t} + \lambda_{t-1}^{8,f}(-1)\beta\frac{1}{\pi_t}\right) = 0,
\end{aligned} \tag{3.57}
$$

$$
\frac{\partial J_t^f}{\partial \mu_t} = \lambda_t^{7,f}\lambda_t\nu^M + \lambda_t^{8,f}\lambda_t = 0, \tag{3.58}
$$

$$
\begin{aligned}
\frac{\partial J_t^f}{\partial b_t} &= \frac{\lambda_t^{0,f}}{\chi_t}\lambda_t(-\Phi)b_t + \frac{\chi_{t+1}}{\chi_t}\beta E_t\left(\frac{\lambda_t^{0,f}-\lambda_{t+1}^{0,f}}{\chi_{t+1}}\right)\lambda_{t+1}\frac{1}{\pi_{t+1}} \\
&\quad + \lambda_t^{3,f}(-\theta)(-\Phi)E_t\pi_{t+1}^{\epsilon}\left(\frac{\tilde{P}_t^*}{\tilde{P}_{t+1}^*}\right)^{-1-\epsilon}x_{1,t+1} \\
&\quad + \lambda_t^{4,f}(-\theta)(-\Phi)E_t\pi_{t+1}^{\epsilon-1}\left(\frac{\tilde{P}_t^*}{\tilde{P}_{t+1}^*}\right)^{-\epsilon}x_{2,t+1} = 0,
\end{aligned}
\tag{3.59}
$$

$$
\frac{\partial J_t^f}{\partial G_t} = U_{G,t} - \lambda_t^{1,f} = 0, \tag{3.60}
$$

$$
\frac{\partial J_t^f}{\partial m_t} = \frac{\lambda^{0,f}}{\chi_t}\lambda_t + \lambda_t^{9,f}(-1) + \lambda_t^{10,f}\frac{\pi_t}{m_{t-1}} + \frac{\chi_{t+1}}{\chi_t}\beta E_t\left(-\frac{\lambda_{t+1}^{0,f}}{\chi_{t+1}}\frac{1}{\pi_{t+1}}\lambda_{t+1} + \lambda_{t+1}^{10,f}\pi_{t+1}\frac{m_{t+1}}{m_t^2}(-1)\right) = 0. \tag{3.61}
$$

3.A.4 Derivation of the infinite double sum

This appendix shows how the infinite double sum of the fiscal authority's optimization problem

$$
E_0\sum_{t=0}^{\infty}\chi_t\beta^t\omega_t E_t\sum_{j=0}^{\infty}\beta^j z_{t+j} \tag{3.62}
$$

where ω_t is the Lagrange multiplier of Equation (3.20). Equation (3.62) can be rewritten as[12]

$$
E_0\sum_{t=0}^{\infty}\chi_t\beta^t\frac{\lambda_t^{0,k}}{\chi_t}z_t,\ k=\{f,m\}, \tag{3.63}
$$

where ω_t is the Lagrange multiplier of the implementability constraint (3.20) and

$$
\begin{aligned}
z_{t+j} \equiv{}& \lambda_{t+j}\Big(C_{t+j} - \Phi b_{t+j}^2 + \frac{\Phi}{2}b_{t+j}^2 + m_{t+j} - m_{t+j-1}\frac{1}{\pi_{t+j}} + \frac{U_{N,t+j}}{\lambda_{t+j}}N_{t+j} \\
&- N_{t+j}^{1-\alpha}S_{t+j}^{-1} + MC_{t+j}(1-\alpha)N_{t+j}^{-\alpha}S_{t+j}^{-1}N_{t+j}\Big).
\end{aligned}
\tag{3.64}
$$

[12]The derivation follows closely Rieth (2011).

Write out the sum on the left hand side and make use of the law of iterated expectations

$$
\begin{aligned}
LHS =& E_0[\chi_0\omega_0 z_0 + \chi_0\omega_0\beta z_1 + \chi_0\omega_0\beta^2 z_2 + ... \\
& + \chi_1\omega_1\beta z_1 + \chi_1\omega_1\beta^2 z_2 + \chi_1\omega_1\beta^3 z_3 + ... \\
& + \chi_2\omega_2\beta^2 z_2 + \chi_3\omega_3\beta^3 z_3 + \chi_4\omega_4\beta^4 z_4 + ...] \\
=& E_0[\chi_0\omega_0 z_0 + \beta(\chi_0\omega_0 + \chi_1\omega_1) z_1 \\
& + \beta^2(\chi_0\omega_0 + \chi_1\omega_1 + \chi_2\omega_2) z_2 + ...].
\end{aligned} \tag{3.65}
$$

Now, define the round brackets recursively through the sequence of $\lambda_t^{0,k} = \lambda_{t-1}^{0,k} + \chi_t\omega_t$, with $\lambda_{-1}^{0,k} = 0$. Then the LHS can be written as

$$
\begin{aligned}
LHS =& E_0 \sum_{t=0}^{\infty} \chi_t \beta^t \frac{\lambda_t^{0,k}}{\chi_t} z_t \\
=& RHS,
\end{aligned} \tag{3.66}
$$

whereby for $k = m$: $\chi_t = 1, \forall t$.

Chapter 4

The Effect of Government Bonds on a Long-run Optimal Equity Requirement Constraint

4.1 Introduction

Since the financial crisis of 2007, the regulation of the banking sector stands in the focus of the current political and academic debate. The regulation of the financial sector is motivated by banks' economic importance. Thus, the stability and soundness of the banking system are the main goals of these regulations. The accumulation of extraordinary risk in banks' balance sheets over the previous years is one of the reasons to introduce stricter banking regulations. In fact, the negative economic consequences of the financial crisis of 2007, caused a growing consensus about the necessity of microprudential and macroprudential regulations (see BIS 2010). The aim is to reduce the negative effects of a banking crisis on the economy.

The first steps have involved adjusting the Basel II banking regulations. This reform is known as Basel III (see BIS 2010). The aim of this stricter regulation package is to reduce the overall probability and consequences of a future banking crisis. One of the arguments in favor of the reform of the Basel II regulation is the skin-in-the-game argument mentioned by authors such as Harris, Opp, and Opp (2014). It says that if banks are forced to hold more equity, the incentive to act more responsibly and in a risk-averse manner increases. In addition, in case of a failure of one or more banks, there is more equity, which could be used to pay out the banks' creditors.

On the whole, the implications of the crisis beginning in 2007 underline the importance of a higher equity ratio in the banks' balance sheets. If banks have to significantly hold more equity, they can better absorb severe, surprising reductions in their asset value. This capacity is important since severe losses require banks to recapitalize or deleverage. However, deleveraging could have serious implications for the real economy, as an asset price shock has a negative spillover effect on the banks' credit supply. Since firms' financing depends partly on bank credit, this reduction amplifies the initial shock by reducing the firms' investment capacity as Iacoviello (2015) shows. He finds that financial shocks account for two-thirds of the output collapse during the Great Recession in the U.S. To minimize these negative spillover effects, the Basel Committee on Banking Supervision revised the Basel II requirements and set a higher minimal equity level up to 10.5 percent of risk-weighted assets in order to improve the banks' hedging of their assets. Some authors, however, argue that these weights are still too low (see Admati et al. 2013). Moreover, Basel III introduces a stricter equity requirement constraint that forces banks to hold more core capital including ordinary shares and profits. It also introduces a leverage ratio and a liquidity coverage ratio constraint, which should ensure that banks hold enough liquidity during critical times. Banks also must accumulate specific countercyclical capital buffers (see BIS 2010).

The recent European implementation of the Basel III regulation package is the motivation for this research project.[1] The European equity requirement constraint favors government bonds strongly. Banks that invest in European government bonds do not have to hold any equity against them. All bonds issued by European governments are seen as riskless assets. Consequently, their risk-weight, which measures how much of the total investment volume has to be financed with equity, is set to zero. Therefore, I investigate in this chapter the effects of government bonds on the optimal design of this equity requirement constraint. I analyze the long-run optimality and thus the maximization of the welfare's steady-state value. As the equity requirement regulation has a long-term perspective, and not a business cycle perspective like the countercyclical

[1]See http://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:32013R0462; last accessed August 24, 2017.

capital buffers, I choose to focus on the model's stationary competitive equilibrium.

The following is observed: The higher the amount of government bonds, the stricter the equity requirement constraint must be. This has the following reason: The key role of banks in this model is the identification of good debtors by exerting costly search effort. However, the model contains an agency problem between banks and their creditors: Hidden action. Therefore, the banks' effort is not observable. As shown by various authors such as Spremann (1987), a hidden action problem leads to an effort level lower than the socially optimal one. Only if banks have a sufficiently high amount of equity, the incentives of exerting search effort are increased. Thus, an equity requirement constraint mitigates the distortions caused by the hidden action problem: A higher amount of equity leads to a higher amount of effort as shown by Christiano and Ikeda (2014). Consequently, the classic skin-in-the-game argument applies. Apart from the hidden effort problem, a binding limited liability constraint is present. Both lead to the fact that the Modigliani-Miller theorem does not apply here. Thus, an increase in the banks' leverage reduces the bank's incentive to exert costly search effort. As this chapter shows, the limited liability constraint distorts the banks' choice of exerting costly search effort to find good debtors. The distortion is caused by the non-zero interest spread stemming from the binding limited liability constraint: As effort is non-observable, the banks' creditors demand state-dependent interest rates as the creditors of banks with poorly performing assets must share in losses. If the bankers' creditors do not offer a contingent debt contract, there will be no compensation for the possibility that the bank receives a low return on its investment and simply defaults. Therefore, banks have to pay a higher interest rate to their creditors in case they have found a good debtor as Christiano and Ikeda (2014) show. In addition, I can show that a higher amount of government bonds reduces the interest rate spread charged by the banks' creditors: An increase in government bonds increases the return also of banks with poorly performing assets, leading to a less tight limited liability constraint. This reduces the interest spread paid by the banks and increases the incentive to exert costly effort. Therefore, government bonds have a positive effect on the banks' effort. Moreover, they are safe assets and thus banks cannot influence the return of government bonds by increasing the search effort. Thus, the higher the amount of government bonds, the lower the incentive to search for good loans tends to be. In addition, following the European implementation of Basel III, government bonds can be fully financed with debt. Thus, the higher the amount of government bonds, the higher the amount of banks' debt is, increasing the banks' leverage. As long as the limited liability is binding, increasing debt increases this distortion of the effort choice. To compensate for this, a stricter equity requirement regulation is necessary.

To sum up, there are two frictions in the model: A hidden action problem and a limited liability constraint. Therefore, a second-best argument would be the following: To reach the first-best case, one needs two instruments. These are the government bonds and the equity requirement regulation. In fact, the chapter shows that one can reach the first-best case by increasing both the amount of government bonds and the risk-weight on loans, i.e. a stricter equity requirement constraint.

Recent papers have proved the optimality of introducing an equity requirement constraint using models with financial frictions (see Christiano and Ikeda 2014). Macroeconomic models with financial frictions are better understood thanks to the contributions of Bernanke and Gertler (1989) and Kiyotaki and Moore (1997). Bernanke, Gertler, and Gilchrist (1999) and Christiano, Motto, and Rostagno (2014) have built New Keynesian models with credit market imperfections. They find that even small temporary shocks can exert persistent effects on the economy amplified by financial frictions. Many of the ideas in this chapter build on macroeconomic modeling that treats banks as intermediaries between savers and borrowers. Recent contributions include Brunnermeier and Sannikov (2014), Angeloni and Faia (2013), Gerali et al. (2010), Iacoviello (2015), Kiley and Sim (2011), Kollmann, Enders, and Müller (2011), Meh and Moran (2010), Williamson (2012), and Heuvel (2008). I mainly follow Christiano and Ikeda (2014), who have developed a business cycle model with a financial sector in a general equilibrium setting. This model introduces a banking sector into an otherwise standard medium-sized DSGE model such as Christiano, Eichenbaum, and Evans (2005) and Smets and Wouters (2007).

Several studies focus on identifying reasons why an equity requirement constraint is useful. In addition, many authors investigate the economic effects of introducing these constraints. Heuvel (2008) is one of the first to use a general equilibrium growth model with liquidity demand of private households to analyze the effects of an equity requirement constraint on the overall welfare. He finds that an equity requirement reduces the deposit and that the current requirement is too high. Others such as Christiano and Ikeda (2014) study leverage constraints in a New Keynesian model where banks have an unobservable effort choice. In their paper, a leverage constraint is welfare enhancing as it increases banks' equity and consequently the incentive to increase costly search effort. This enhances the banking system efficiency. Authors such as Martinez-Miera and Suarez (2012) analyze the effects of equity requirements on the banks' endogenous systemic risk taking. Bigio (2014) looks at risky financial intermediation under asymmetric information and analyzes how equity requirements change the overall risk level. Nguyen (2014) derives the optimal equity requirement in the case of no aggregate uncertainty. In all these papers, a stricter constraint reduces the riskiness of the banking system but at the costs of less lending leading to a lower output level. However, Begenau (2015) finds that, with preferences for liquidity, the trade-off of a higher equity requirement with regard to banks' lending activities is reversed: Since households value bank debt more when it is relatively scarce, they are willing to accept an even higher discount on the interest rate on bank debt. This in turn lowers the overall funding costs of bank assets, leading to more, not less, lending in the economy (see Begenau 2015). All these papers focus on finding reasons why an equity requirement constraint is useful and analyze the effects of a stricter constraint on the economy. However, none of them analyze how the optimal design an equity requirement constraint is influenced by the amount of safe assets. The present chapter seeks to close this gap.

The rest of this chapter is organized as follows. Section 4.2 describes the economic model; Section 4.3 shows the calibration strategy; Section 4.4 presents the first-best case of the model; Section 4.5 shows the main results of the chapter and describes the effects of government bonds on the optimal design of the equity requirement constraint; Section 4.6 concludes.

4.2 The model

The model is a simplified version of the model of Christiano and Ikeda (2014). I extend their model by introducing safe assets (e.g. government bonds). In contrast to Christiano and Ikeda (2014), banks are not only able to give credit to firms but also to buy government bonds. The description of the model follows Christiano and Ikeda (2014).[2]

4.2.1 The general setup

The model contains the following agents: A representative household composed of equal sized fraction of savers and bankers, good and bad firms, final goods producers, mutual funds, and a government. The private savers consume the final output goods and save by investing in riskless bonds issued by mutual funds. They own the banks and the firms. The mutual funds use the savers' deposits to provide loans to a diversified set of banks. Free entry and perfect competitions among the mutual funds lead to zero profits. Banks borrow from the mutual funds. They offer firms loans. The banks make loans to one firm each making their asset side risky as they do not know the type of the firm and thus do not know whether their return will be high or low. However, banks can increase the probability to find firms of the good type by exerting costly unobservable search effort. In addition, banks can invest in riskless government bonds. Each firm has access to a constant return to scale investment technology. There are two types of firms - a good firm and a bad firm. Good firms earn higher returns than bad firms. The sole source of funds available to a firm is the funds received from banks. The firm uses these funds to acquire raw capital and convert it into effective capital used in the production of final goods. The final goods producers use the effective capital to produce final goods for private and public consumption and investments. The government finances its public unproductive consumption by government bonds and a lump-sum tax.

[2] Additionally, parts of the model descriptions borrow from the lecture notes on "Advanced Macroeconomics" (Spring, 2014) of Tony Yates and the presentation of Christiano and Ikeda at the "Macro Financial Modeling" at the NYU Stern in March, 2015.

4.2.2 The contract between the banks and the mutual funds

Private households deposit funds with mutual funds, whereupon mutual funds make loans to a diversified set of banks. There is a contract between the mutual funds and the banks. This contract defines the amount of the mutual funds' loans, the interest payments, and the exerted search effort. However, by assumption the effort choice of the banks is unobservable, implying a hidden effort problem: Neither the private household, nor the mutual funds can monitor the banks' exerted effort. To find the optimal contract between mutual funds and banks, both interact in a competitive market for deposit-loan contracts, which define the amount of deposits/loans d_t, the state-contingent interest rates $R^d_{g,t+1}$ and $R^d_{b,t+1}$, and the effort level e_t.[3] As effort is not observable, a bank always chooses its privately optimal effort level ex post, whatever the specified e_t in the contract. Following Christiano and Ikeda (2014), I assume that banks choose the most preferred contract from a set of contracts. As banks' effort is not observed by their creditors (the mutual funds), a debt contract between banks and mutual funds cannot be made contingent on the banks' search effort. Therefore, the contract can only be second-best.

After the contract is settled, the banks decide how much they invest in riskless government bonds and risky firm loans. The return of government bonds is independent of the exerted search effort. However, the return of firm loans depends on the amount of search effort exerted by the banks. The role of the banks is to exert costly unobservable search effort to increase the probability of identifying a good borrower. Since the chosen effort only affects the probability to find a good firm, the level of the returns do not reveal the banks' chosen effort.

Thus, the key point of the model is that effort is non-observable. Consequently, the mutual funds are forced to implement a debt contract that is contingent upon whether the banks have found a good or a bad firm. If they do not offer a contingent debt contract, there will be no compensation for the possibility that the bank receives a low return on its investment and simply defaults.[4] Therefore, banks have to pay

[3]For mutual funds, the contract is a deposit contract. However, for banks the mutual fund deposits are liabilities, which is why this contract is a loan contract for them.

[4]See the description of Tony Yates: https://tonyyateshomepage.files.wordpress.com/2015/04/lazy-banker-assignment-solutions1.pdf, last accessed August 24, 2017

a higher interest rate to the mutual funds in case they have found a good debtor: $R^d_{g,t+1} > R^d_{b,t+1}$. However, this reduces the incentive of exerting any search effort, as the profit from increasing effort by one extra unit gets smaller. Thus, there is an incentive problem: Banks are motivated to reduce their effort since they do not receive the full profit from increasing effort. Consequently, banks search less for good debtors, and the share of good firms is reduced. If in contrast, funding costs are independent of whether the returns are high or low, the banks capture all the returns of any extra marginal effort.[5] Nevertheless, such a contract requires banks' net worth to be high enough so that they can pay back their creditors in case the firm turns out to be a bad one. If net worth is low, they cannot fulfill their obligations and the contract has to be modified in such a way that the depositors are compensated by higher returns in case the bank has found a good creditor (see Christiano and Ikeda 2014).

4.2.3 Two constraints and the government bonds

There are two binding constraints that need to be taken into account when designing the contract. These constraints are: A limited liability constraint and an equity requirement constraint.

As in Christiano and Ikeda (2014), it is assumed that a bank's only source of funds for repaying the mutual funds is the return on its investments in loans and government bonds. There is no external equity. These constraints guarantee that the bank can pay out the mutual funds, whether the firm is a good one or a bad one. In fact, if the net worth of banks N_t is high enough, this limited liability constraint is not binding and the mutual funds do not have to worry if the bank has found a good or a bad firm. Thus, it can set $R^d_{g,t+1}$ equal to $R^d_{b,t+1}$ and the socially optimal level of effort is obtained. However, if the net worth of banks is too low, the limited liability constraint is binding. This means that the creditors of banks with poorly performing assets must share in losses (see Christiano and Ikeda 2014), inducing a positive spread between both interest rates $R^d_{g,t+1}$ and $R^d_{b,t+1}$. This reduces the incentive to exert effort as banks' return in case of finding a good firm falls. Therefore, an equity (net worth)

[5] See the description of Tony Yates: https://tonyyateshomepage.files.wordpress.com/2015/04/macroeconomics-and-financial-frictions-lazy-banker-model.pdf, last accessed August 24, 2017.

constraint that raises the equity held by the banks is welfare-improving, as it lowers this interest spread and increases the exerted effort. In other words, when banks have to increase equity in relation to the banks' debt due to a stricter equity requirement regulation, they are relatively more invested with their own funds in the projects they finance. Therefore, they have a higher incentive to increase the probability of finding good debtors by raising their search effort than when where their equity is lower.

Another source of inefficiency in the unobserved effort case is the presence of a market interest in the incentive constraint creating an externality.[6] This is based on the following: The private cost of the banks of higher deposits d_t is just the interest rate paid on deposits that equals the market interest rate due to the zero profits of mutual funds. However, the social cost of a higher d_t is higher. It comprises the market interest rate plus the distortion of the banks' effort choice due to the binding limited liability constraint. A binding limited liability constraint has the effect that $R^d_{b,t+1}$ decreases ceteris paribus with higher deposits. This increases $R^d_{g,t+1}$, thereby reducing the incentive of exerting costly effort. Thus, as the private cost of a higher d_t are lower than the social cost, banks' deposits may be too high, in which case a constraint is welfare-enhancing (see Christiano and Ikeda 2014).

Besides, a binding limited liability constraint, there is a binding equity requirement constraint. The equity requirement constraint forces banks to hold a specific amount of equity relative to the amount of risky assets in their balance sheet. Following the European implementation of Basel III, government bonds have a risk-weight of zero, meaning that banks can finance their investments in government bonds fully by deposits. This has a direct implication for the model's equilibrium: If government bonds rise, deposits rise equally. The higher amount of deposits increases the banks' leverage. As the limited liability constraint is binding, the Modigliani-Miller theorem does not apply here and the increase in the leverage reduces the bank's incentive to exert costly search effort. However, as a higher amount of government bonds also increases the profits of those banks that have found a bad firm, the limited liability constraint gets less tight reducing the interest spread, and as explained above, increasing the incen-

[6]This is not mentioned in the original paper, but in a presentation held by Christiano and Ikeda at the "Macro Financial Modeling" at the NYU Stern in March, 2015. https://bfi.uchicago.edu/sites/default/files/file_uploads/Stern_handout.pdf, last accessed August 24, 2017.

tive to exert effort. Thus, government bonds have reverse effects on the incentives of banks. In Section 4.5.1 I will analyze how government bonds affect the optimal equity regulation.

4.2.4 The representative household

The representative household is composed of equal sized fraction of savers and bankers. Its utility function is the equally-weighted average across the utility of all savers and bankers. Banks' behaviour is described in Section 4.2.5.

The savers maximize the infinite sum of discounted period-utility[7]

$$\max_{\{C_t,\, B_t^M\}} E_0 \sum_{t=0}^{\infty} \beta^t \log(C_t),\ 0 < \beta < 1,$$

where C_t is private consumption, and B_t^M are riskless bonds issued by mutual funds. E_t denotes the mathematical expectation operator conditional upon information available in period t. The maximization problem is restricted by a period budget constraint:

$$C_t + B_t^M = R_{t-1}^M B_{t-1}^M + \Pi_t - T_t, \tag{4.1}$$

where R_t^M is the gross payoff of the non-state contingent one-period bond B_t^M, which is issued by mutual funds. Π_t are dividends from ownership of firms and banks. T_t is a lump-sum tax.

The corresponding first-order conditions to the savers' maximization problem are:

$$\lambda_t = \frac{1}{C_t},$$

$$-\lambda_t + E_t\left(\lambda_{t+1}\, \beta\, R_t^M\right) = 0,$$

where λ_t is the Lagrange multiplier associated with the budget constraint (4.1).

[7]As the model should be as simple as possible in order to analyze the pure effect of the government bonds on the banking system I abstract from a labor decision.

4.2.5 The financial market

The discussion begins in period t after goods production for that period has occurred (see Christiano and Ikeda 2014). The financial market consists of three sub-markets summarized by the following diagrams:

1. The deposit market:

$$\text{savers} \xrightleftharpoons[\mathrm{R_t^M}]{\mathrm{B_t^M}} \text{mutual funds} \xrightleftharpoons[\mathrm{R^b_{d,t+1}, R^g_{d,t+1}}]{\mathrm{d_t}} \text{banks}$$

2. The loan market:

$$\text{banks} \xrightleftharpoons[\mathrm{R^b_{t+1}, R^g_{t+1}}]{\mathrm{L_t}} \text{firms}$$

3. The bond market:

$$\text{banks} \xrightleftharpoons[\mathrm{R_t^G}]{\mathrm{B_t^G}} \text{government}$$

Mutual funds take deposits B_t^M from the savers and make loans d_t to a diversified set of banks (see Christiano and Ikeda 2014). There is a mass of banks with net worth N_t in a competitive market. Banks acquire deposits d_t from mutual funds. Then they lend their net worth and debt to firms in the form of loans L_t and to the government in the form of government bonds B_t^G.

Firms need loans from banks to finance the buying of raw capital, which they convert into effective capital necessary for the output production. Each firm has access to a constant returns to scale investment technology. Firms are competitive and earn zero profit. The bank from which a firm receives its loan gets the return earned by this firm on its projects. There are good and bad firms. Good firms are better than bad firms in converting raw to effective capital and thus earn a higher return than bad firms. The gross rate of return on their period t investment is denoted by R^g_{t+1} and R^b_{t+1}. It holds that R^g_{t+1} is strictly bigger than R^b_{t+1} in all periods. A key function of banks is to identify good firms. To do this, banks exert costly search effort e_t. This effort is not observable to mutual funds. The bank identifies a good firm with probability $p(e_t)$ and a bad firm with probability $1 - p(e_t)$. The probability function $p(e_t)$ has the following form:

$$p(e_t) = \min\{1, \bar{a} + \bar{b}e_t\}, \bar{a}, \bar{b} > 0, \tag{4.2}$$

where $\bar{a}$ and $\bar{b}$ will be chosen so that $p(e_t)$ is strictly bigger than zero and smaller than one. Since $\bar{b}$ is positive, an increase in the banks' search effort e_t leads to a higher probability of finding good firms. Thus, the higher the search effort of the bank, the higher the share of good firms is in the economy increasing the accumulation of effective capital.

Mutual funds are the banks' creditors. They are competitive and perfectly diversified across banks. Free market entry drives their profits down to zero:

$$\left(p(e_t)R^d_{g,t+1} + (1 - p(e_t))R^d_{b,t+1}\right) - R^M_t = 0,$$

or by using balance sheet identity $d_t = B^M_t$:

$$\left(p(e_t)R^d_{g,t+1} + (1 - p(e_t))R^d_{b,t+1}\right) d_t - R^M_t d_t = 0. \tag{4.3}$$

Similar to Christiano and Ikeda (2014) the zero-profit condition hold in each period $t + 1$ state of nature. $R^d_{g,t+1}$ and $R^d_{b,t+1}$ denote the gross return received from a good bank and a bad bank respectively. A good bank is a bank whose debtor is a good firm. A bad bank is a bank whose debtor is a bad firm. B^M_t are the deposits from savers that mutual funds lend to the banks in the form of deposits d_t. The first part of Equation (4.3) represents the expected amount banks pay back to mutual funds: With probability $p(e_t)$, the bank is a good bank and can pay an interest rate of $R^d_{g,t+1}$. With probability $1 - p(e_t)$, the bank is a bad bank and pays back an interest rate of $R^d_{b,t+1}$. Both interest rates are part of the deposit-loan contract between mutual funds and banks. The first part of Equation (4.3) therefore represents the mutual funds' revenues, whereas the last part of Equation (4.3) denotes the mutual funds' financing costs.

As mentioned above the banks' search effort e_t is not observable by mutual funds. Thus, a bank always chooses e_t ex post to maximize its expected profit. This is a classical hidden action problem. It is solved by backward induction (see for example Kräkel 2015):

1. The agent chooses its optimal effort level.

2. Given the optimal effort level of the agent, the principal chooses an optimal contract.

In this case, the agent is the bank and the principal is the mutual fund, the depositor. However, in this model, the bank is the one that chooses the optimal contract from a set of feasible contracts. The contract defines the combination of $\{d_t, e_t, R^b_{g,t+1}, R^d_{b,t+1}\}$ given the optimally chosen effort level $e_t^{*,ex\ post}$. $e_t^{*,ex\ post}$ is the profit-maximizing effort level that a bank chooses after the contract is signed. The effort is unobservable by the mutual fund and thus is not negotiable. The contract is restricted by several constraints:

1. The participation constraint of the mutual fund: In this model, it is the zero-profit condition (4.3) due to free entry and perfect competition among mutual funds.

2. The incentive constraint of the bank: In this model, it is the optimal ex post chosen effort level $e_t^{*,ex\ post}$, whatever $\{d_t, R^b_{g,t+1}, R^d_{b,t+1}, e_t\}$ is set in the contract. Since e_t is unobservable, mutual funds know that whatever value for e_t is written into the contract, e_t will always be set according to the incentive constraint.

3. A limited liability constraint for the bank: It is assumed that the banks' only source of funds for repaying mutual funds is the earnings on its investments in loans and government bonds. There is no external equity (see Christiano and Ikeda 2014).

4. The balance sheet constraint of the bank.

5. A mandatory equity requirement constraint that demands a minimum level of equity relative to the bank's assets.

Each bank has a net worth N_t. It is assumed that the inflow or outflow of equity into the banks is exogenous and is not subject to the control of the bank. The only control banks have over N_t is their control over deposits (and their investment decision) and the resulting impact on their earnings (see Christiano and Ikeda 2014). This is in line with a number of models presented, for example, in Freixas and Rochet (2008). Equity is accumulated by using part of the banks' profit. The law of motion for N_t is then given by:

$$N_t = \gamma \Pi^B_{t-1} + \tilde{T},\ 0 < \gamma < 1,\ \tilde{T} > 0, \tag{4.4}$$

where γ measures the amount of the profit Π^B_{t-1} banks use to accumulate equity. $\tilde{T}$ is an exogenous influx of new equity. Profits are the only endogenous source to increase net worth, as similar to Christiano and Ikeda (2014) I assume that there is no outside equity available. The profit Π^B_{t-1} of the banks is defined as:

$$\Pi^B_{t-1} = B^G_{t-1}R^G_{t-1} + (N_{t-1} + d_{t-1} - B^G_{t-1})(p(e_{t-1})R^g_t + (1-p(e_{t-1}))R^b_t) - (p(e_{t-1})R^d_{g,t} + (1-p(e_{t-1}))R^d_{b,t})d_{t-1}, \tag{4.5}$$

where R^G_t is the interest on government bonds. In addition, the bank's balance sheet needs to be balanced:

$$L_t + B^G_t = N_t + d_t. \tag{4.6}$$

Equation (4.6) shows that the amount of liabilities has to be equal to the amount of assets.

Following the described procedure for solving hidden action problems, I derive the ex post effort choice of the bank. The bank maximizes its ex ante reward from a loan contract

$$\max_{e_t} E_t \lambda_{t+1} \left[B^G_t R^G_t + \Big(L_t(p(e_t)R^g_{t+1} + (1-p(e_t))R^b_{t+1}) - (p(e_t)R^d_{g,t+1} + (1-p(e_t))R^d_{b,t+1})d_t \Big) \right] - \frac{1}{2}e^2_t \tag{4.7}$$

λ_{t+1} is the value of marginal consumption from funds remitted by the banks to the households. $\frac{1}{2}e^2_t$ measures the utility costs of exerting effort. Here the effort cost are pure utility cost and cause no resource costs. I thereby follow the modeling strategy of Christiano and Ikeda (2014). In addition, the effort cost are fixed costs and consequently there are economies of scale effects. The relative costs fall if the balance sheet grows. Here I follow Christiano and Ikeda (2014), however, one could also extend the model by introducing effort cost that are proportional to the amount of loans.

Considering the probability function (4.2), the first-order condition of the maximization problem (4.7) is given by:

$$e_t = E_t \lambda_{t+1} (L_t p'(e_t)(R^g_{t+1} - R^b_{t+1}) - d_t p'(e_t)(R^d_{g,t+1} - R^d_{b,t+1})). \tag{4.8}$$

Equation (4.8) describes the ex post optimal effort choice of the banks when effort is unobservable. Based on Equation (4.6), Equation (4.8) can be written as:

$$e_t = E_t \lambda_{t+1} ((N_t + d_t - B^G_t) p'(e_t)(R^g_{t+1} - R^b_{t+1}) - d_t p'(e_t)(R^d_{g,t+1} - R^d_{b,t+1})). \tag{4.9}$$

Mutual funds understand that the bank will always choose e_t according to (4.9). Equation (4.9) shows that the banks' search effort increases when the equity N_t increases. This is the skin-in-the-game argument mentioned, among others, by Harris, Opp, and Opp (2014). The more the banks are invested with their funds, the higher their incentive to exert search effort is. Additionally, if the spread $R^d_{g,t+1} - R^d_{b,t+1}$ is positive and rises, effort falls, since the banks' profit from one unit of extra effort decreases. Equation (4.9) also shows the negative effect of government bonds on the banks' optimal level of search effort. A higher amount of government bonds leads ceteris paribus to a lower banks' effort. Since the amount of riskless assets in the banks' balance sheet increases the amount of riskless effort-independent returns increases, too. This reduces the incentive to exert search effort. However, as I will show later, the government bonds also have a positive effect on the banks' search effort.

Next, I describe the optimal deposit-loan contract. The bank chooses the most preferred contract from the set of contracts to maximize its utility of the expected profit minus the utility costs of the exerted search effort. This means the optimization problem is defined by the bank's choice of the optimal contract $\{d_t, e_t, R^b_{g,t+1}, R^d_{b,t+1}\}$ given the ex post chosen effort level and given the abovementioned constraints.

Before describing this optimization problem, I present these constraints in more detail. By assumption, there is no external equity. Therefore, a limited liability constraint holds. As in Christiano and Ikeda (2014) it is assumed that the banks' only source of funds for repaying mutual funds is the earnings on its investments. A feasible contract has to take into account that

$$B_t^G R_t^G + L_t R_{t+1}^g - R_{g,t+1}^d d_t \geq 0, \tag{4.10}$$

$$B_t^G R_t^G + L_t R_{t+1}^b - R_{b,t+1}^d d_t \geq 0. \tag{4.11}$$

In other words, what the banks get from their investments in firms and government bonds has to be greater than or equal to what the banks promise to pay out to mutual funds. Mutual funds are only interested in contracts that are feasible, so the above inequalities represent restrictions on the set of contracts that both parties are willing to consider. In practice, only the second inequality is binding. Christiano and Ikeda (2014) show that either both Equations (4.10) and (4.11) do not bind, or only Equation (4.11) binds. So only the limited liability constraint in the bad state is relevant. Intuitively, if banks earn enough to pay back mutual funds in the bad state, then they will have enough earned if their debtor turns out to be one of the good type. Therefore, only economies, in which constraint (4.11) is binding, are investigated. This means that the mutual fund shares in losses if its debtor is a bad bank - a bank that has found a bad firm. That means $R_{b,t+1}^d$ is low, and $R_{g,t+1}^d$ has to be high. However, the higher the spread $R_{g,t+1}^d - R_{b,t+1}^d$ is, the lower is the incentive to exert search effort (see Equation (4.9)). Thus, a binding limited liability constraint has a negative effect on the search effort of the banks, since in the case $R_{g,t+1}^d > R_{b,t+1}^d$ the bank has to compensate the mutual fund for low returns from bad debtors with high returns $R_{g,t+1}^d$ in the good case reducing the profit from increasing the share of good debtors by increasing the effort level. Therefore, the bigger this interest spread, the bigger are the distortions caused on the effort choice through the term $d_t p'(e_t)(R_{g,t+1}^d - R_{b,t+1}^d)$[8](see Equation (4.9)).

One can rewrite Equation (4.11) using the balance sheet constraint (4.6):

$$B_t^G (R_t^G - R_{t+1}^b) + (N_t + d_t) R_{t+1}^b \geq R_{b,t+1}^d d_t \tag{4.12}$$

[8] If the limited liability constraint is not binding a possible equilibrium would be that $R_{g,t+1}^d = R_{b,t+1}^d$ and the term mentioned would be zero. There would be no distortion of the banks' effort choice. In Section 4.4 one can find a more detailed comparison of an economy where the limited liability constraint is not binding with an economy where it is binding. The economy, where the limited liability constraint is not binding, will be the economy, where effort is observable. This will be the first-best case.

As long as $R_t^G > R_{t+1}^b$, an increase in the government bonds tends to lead to a ceteris paribus higher $R_{b,t+1}^d$. A higher $R_{b,t+1}^d$ reduces $R_{g,t+1}^d$ due to the zero-profit condition (4.3) of mutual funds and the spread $R_{g,t+1}^d - R_{b,t+1}^d$ falls, which increases the incentive to exert search effort (see Equation (4.9)). Thus, government bonds can also have a positive effect on the search effort of the bank, since a higher amount of government bonds reduces the negative effect of a binding limited liability constraint on e_t.

In addition, a regulation of the bank's debt is present:

$$\Gamma^{BG} B_t^G + \Gamma^L L_t \geq d_t,\ 0 \leq \{\Gamma^{BG}, \Gamma^L\} \leq 1, \tag{4.13}$$

where Γ^L (Γ^{BG}) measures how much of the investment in loans (government bonds) can be financed by debt. The lower this weight the less debt banks can have and the smaller is their leverage. Thus, the lower Γ^L and Γ^{BG} are, the stricter is the leverage constraint. In Europe Γ^{BG} is set to one. All bonds issued by European governments are seen as riskless assets by the European implementation of the Basel III regulation package and can be fully financed by debt. This means that an increase in government bonds leads to a one-for-one increase in d_t.

One can slightly rewrites Equation (4.13):

$$\Gamma^{N,BG} B_t^G + \Gamma^{N,L} L_t \leq N_t,\ 0 \leq \{\Gamma^{N,BG}, \Gamma^{N,L}\} \leq 1, \tag{4.14}$$

with $\Gamma^{N,BG} = 1 - \Gamma^{BG}$ and $\Gamma^{N,L} = 1 - \Gamma^L$. Thus, the debt constraint can also be interpreted as an equity requirement constraint. The higher $\Gamma^{N,BG}$ and $\Gamma^{N,L}$ are the stricter is the constraint and the more equity banks are forced to hold.

Both banks and mutual funds are only interested in feasible contracts. Therefore, the contract has to take into account the limited liability constraint (4.11), the ex post chosen effort level (4.9), and the zero-profit condition (4.3) of the mutual fund, the balance sheet identity (4.6), and the leverage constraint (4.13). The bank faces the following maximization problem when choosing the optimal deposit-loan contract:

$$\max_{\{e_t,\, R^d_{g,t+1},\, R^d_{b,t+1},\, d_t\}} E_t \sum_{t=0}^{\infty} \beta^t \Big[\lambda_{t+1}\Big[B^G_t R^G_t + L_t(p(e_t)R^g_{t+1} + (1-p(e_t))R^b_{t+1}) -$$
$$(p(e_t)R^d_{g,t+1} + (1-p(e_t))R^d_{b,t+1})d_t\Big] - \frac{1}{2}e_t^2$$
$$+ \mu_{t+1}[p(e_t)R^d_{g,t+1}d_t + (1-p(e_t))R^d_{b,t+1}d_t - R^M_t d_t]$$
$$+ \eta_t\Big[e_t - \lambda_{t+1}((N_t + d_t - B^G_t)p'(e_t)(R^g_{t+1} - R^b_{t+1}) - d_t p'(e_t)(R^d_{g,t+1} - R^d_{b,t+1}))\Big]$$
$$+ \nu_{t+1}[B^G_t R^G_t + (N_t + d_t - B^G_t)R^b_{t+1} - R^d_{b,t+1}d_t]$$
$$+ \chi_t[(1-\Gamma^{N,BG})B^G_t + (1-\Gamma^{N,L})(N_t + d_t - B^G_t) - d_t]\Big],$$

where μ_{t+1}, ν_{t+1} and χ_t have to be non-negative and as shown in the Appendix 4.A.2 η_t has to be negative. The Lagrange multiplier η_t on (4.9) is not contingent on the realizations of the period $t+1$ state, since the constraint is on the effort level exerted by the bank in period t (see Christiano and Ikeda 2014). Note that the zero-profit condition and the limited liability constraint have to be satisfied in each period $t+1$ state of nature, which is indicated by the fact that the multipliers, μ_{t+1} an ν_{t+1}, are contingent upon the realization of period $t+1$ uncertainty (see Christiano and Ikeda 2014). The corresponding first-order conditions for the solution of this maximization problem can be found in Appendix 4.A.1.

After the deposit-loan contract is settled, the bank makes its investment decision. It can decide how much of its liabilities $N_t + d_t$ it invests in riskless government bonds and in risky loans. The bank chooses the amount of loans and the amount of government bonds given the deposit-loan contract $\{d_t, e_t, R^b_{g,t+1}, R^d_{b,t+1}\}$ and given the balance sheet identity (4.6). This leads to the following optimization problem:

$$\max_{B^G_t} E_0 \sum_{t=0}^{\infty} \beta^t \lambda_{t+1}\Big[B^G_t R^G_t + (N_t + d_t - B^G_t)(p(e_t)R^g_{t+1} + (1-p(e_t))R^b_{t+1}) - R^M_t d_t - \frac{1}{2}e_t^2\Big], \tag{4.15}$$

where the balance sheet identity (4.6) and the zero-profit condition (4.3) are already inserted. One gets the following equilibrium condition:

$$R^G_t = p_t R^g_{t+1} + (1-p_t)R^b_{t+1}. \tag{4.16}$$

This equation says that, if the investments in government bonds and loans should be strictly positive, the returns of both investment have to be equal in each period $t+1$ state of nature.

4.2.6 Capital production

Each firm has access to a constant returns-to-scale investment technology. The technology requires an investment at the end of goods production in period t and produces output during production in $t+1$ (see Christiano and Ikeda 2014). The sole source of funds available to a firm is the funds received from its bank. A firm uses these funds to acquire raw capital, $\tilde{K}_{t+1}$. Good (bad) firms convert one unit of raw capital into $\exp(g)$ ($\exp(b)$) units of effective capital $\bar{K}_{t+1}$ used for producing an output good. g is strictly bigger than b. Consequently, good firms are better than bad firms in converting raw capital into effective capital. Once this conversion is accomplished, firms rent their homogeneous effective capital on the $t+1$ capital market. Thus, in period $t+1$ the quantity of effective capital is given by:

$$\bar{K}_{t+1} = \left(p(e_t)\exp(g) + (1-p(e_t))\exp(b)\right)\tilde{K}_{t+1}. \tag{4.17}$$

As explained, the firms rent the services of effective capital in a competitive capital market. The equilibrium rental rate in this market is R^{K}_{t+1}. Its value is determined in the final good sector. Firms' effective capital, $\bar{K}_{t+1}$, depreciates at the rate δ while it is being used by firms to produce output. After production firms sell used effective capital to capital producers, which produce new raw capital, which they sell back to the firms. The rates of return of good and bad firms are given by

$$R^{g}_{t+1} = \exp(g)R^{\bar{K}}_{t+1}, \tag{4.18}$$

$$R^{b}_{t+1} = \exp(b)R^{\bar{K}}_{t+1}, \tag{4.19}$$

where

$$R^{\bar{K}}_{t} = r^{\bar{K}}_{t} + (1-\delta).$$

$R_t^{\bar{K}}$ is the return on capital. R_{t+1}^g and R_{t+1}^b are the firms' type-specific returns on effective capital. One can see that the factors $\exp(g)$ and $\exp(b)$ scale the capital return up or down, depending on the type of the firm. $r_t^{\bar{K}}$ is the return on effective capital, which is paid by the firms for using effective capital for the production of the final output good.

There is a large number of identical capital producers. The representative capital producer purchases effective capital in t and investment goods I_t to produce new, raw capital. Thus, it holds:

$$\tilde{K}_{t+1} = I_t + \bar{K}_t \ (1 - \delta) \,. \tag{4.20}$$

Equations (4.17) and (4.20) show, that if e_t is low in period t, then the stock of effective capital is low in period $t + 1$. A reduction in the search effort has a persistent effect, because effective capital is the input factor for the production of new raw capital. This effect of banks' effort on the quantity of effective capital reflects their role in allocating capital between good and bad firms. Thus, $p(e_t) \exp(g) + (1 - p(e_t)) \exp(b)$ is a measure for the allocative effectiveness of the banking system (see Christiano and Ikeda 2014).

4.2.7 Final goods production

The output goods Y_t used for investments, private and public consumption is produced by firms in a perfect competitive environment using effective capital $\bar{K}_t$ as the only input factor. For simplicity, I set labor to one. The production function is given by

$$Y_t = \bar{K}_t^{\alpha}, \ 0 < \alpha < 1.$$

Given the production function the return on effective capital $r_t^{\bar{K}}$ is defined by the marginal productivity of capital:

$$r_t^{\bar{K}} = \alpha \bar{K}_t^{\alpha - 1}.$$

As labor is constant and equal one, the capital returns decline when capital increases.

4.2.8 The public sector

The government consumes G_t and finances its consumption by issuing government bonds B_t^G and a lump-sum tax T_t. Thus, its period budget constraint is given by:

$$G_t + B_{t-1}^G R_{t-1}^G = B_t^G + T_t,$$

G_t is unproductive and does not increase household's welfare.

4.2.9 Equilibrium

I restrict my analysis to symmetric equilibria, where all savers, banks, and firms behave in an identical way. There will be no arbitrage opportunities and all markets will be clear. The clearing of the good market requires

$$Y_t = C_t + I_t + G_t.$$

4.3 Calibration

In this chapter I describe my calibration strategy. The baseline model is the one in which the search effort is not observable and no equity requirement constraint is imposed. δ and β are set following standard parameter values used in the literature. The value for the share of capital α in the output production function comes from the Annual Macroeconomic Database. The return parameter of good firms $\exp(g)$ is normalized to one. Table 4.1 presents the chosen parameter values.

Table 4.1: Non-estimated parameter values

Parameter	Value	Source
α	0.4370	Annual Macroeconomic Database (AMECO)
δ	0.0250	In line with Iacoviello and Neri (2010)
β	0.9987	In line with Christiano and Ikeda (2014)
$\exp(g)$	1.0000	Normalization of the return parameter, good firms

The rest of the parameters are calibrated using a moment-matching strategy. From Bloomberg, I get quarterly financial data for banks in the euro area from 2000 until 2014. As targets, I choose the mean ratio of non-performing assets to total assets, the mean leverage ratio, the mean cross-sectional standard deviation of the return on equity (ROE), [9] the mean return on equity,[10] the mean public-debt-to-GDP-ratio, and the mean public-consumption-to-GDP-ratio in the euro area. As public debt is a stock variable and the model is calibrated to quarterly frequency, quarterly GDP is only one fourth of annual GDP, implying that the quarterly debt to GDP ratio in the data is 4×74.37 percent (see Pfeifer 2017). Moreover, I use the allocative efficiency of the banking system in Europe as a target for the calibration. The data are taken from Tsionas, Assaf, and Matousek (2015). Considering these empirical targets, I choose $\bar{a}$, $\bar{b}$, b, γ, $\bar{G}$, and $\bar{B}^G$ to minimize the squared relative distance between the model's moments in the steady-state and the corresponding empirical targets. The estimated parameters as well as the comparison of the model's moments and the corresponding empirical moments can be found in Table 4.2. In order to find reasonable parameter values many constraints are set for the optimization routine: All Lagrange multipliers have to be of the right sign and the probability of finding a good debtor has to be strictly smaller than one also for the first-best case, where effort is observable and no leverage constraint is present. In addition, profits of the banks, the return on equity and the chosen effort have to be positive. The overall fit of the model is quite good. However, the return on equity is too small.

4.4 The first-best case

To understand the subsequent sections, it is important to describe the first-best case, where effort is observable. Consequently, there is no hidden action problem and a regulation of the banking sector is not necessary. The equity requirement constraint is thus not-existent. In the following, it will be shown that the limited liability constraint does not hold anymore and that government bonds are neutral for the steady-state of the economy. Thus, the Modigliani-Miller theorem applies and Ricardian equivalence holds.

As effort is observable in the first-best case, banks can commit to an effort level.

[9] Defined as $[p(e_t)(1-p(e_t))]^{0.5} \frac{R_t^G B_t^G + R_{t+1}^g L_t - R_{g,t+1}^d d_t}{N_t}$ similar to Christiano and Ikeda (2014).

[10] Defined as $400 \cdot \left(\frac{(((N_t + d_t - B_t^G)(p(e_t) R_{t+1}^g + (1-p(e_t)) R_{t+1}^b) + B_t^G R_t^G) - R_t^M d_t)}{N_t} - 1 \right)$ similar to Christiano and Ikeda (2014).

Table 4.2: Estimated parameter values and the model's goodness of fit

Targets	Empirical value	Model's value
Non-performing loans/total assets	0.0557	0.0513
Leverage ratio	14.292	14.295
Return on equity (ROE)	0.0591	0.0052
Cross-sectional standard deviation of ROE	0.2073	0.2327
Allocative efficiency	0.8780	0.9861
Public debt/GDP	0.7437*4	0.7445*4
Public consumption/GDP	0.2037	0.2034

Parameter	Meaning	Estimated value
$\bar{a}$	Slope of effort function	0.9423
$\bar{b}$	Constant of effort function	0.0479
b	Return parameter, bad firms	-0.3153
$\tilde{T}$	Exogenous influx of new equity	1.2477
γ	Fraction of profit for new equity	0.7985
$\bar{B}^G$	Steady-state public debt	18.985
$\bar{G}$	Steady-state public consumption	1.2984

Notes: For the calibration a moment-matching strategy is used. To find the squared relative distance minimizing parameter values I use the NOMAD algorithm from the OPTI-Toolbox for MatLab.

Thus, the contract is described by:

$$\max_{\{e_t,\, R^d_{g,t+1},\, R^d_{b,t+1},\, d_t\}} E_0 \sum_{t=0}^{\infty} \beta^t \Bigg[\lambda_{t+1} \Big[B^G_t R^G_t + L_t(p(e_t)R^g_{t+1} + (1-p(e_t))R^b_{t+1}) -$$
$$(p(e_t)R^d_{g,t+1} + (1-p(e_t))R^d_{b,t+1})d_t \Big] - \frac{1}{2}e_t^2$$
$$+ \mu_{t+1}[p(e_t)R^d_{g,t+1}d_t + (1-p(e_t))R^d_{b,t+1}d_t - R^M_t d_t]$$
$$+ \nu_{t+1}[B^G_t R^G_t + (N_t + d_t - B^G_t)R^b_{t+1} - R^d_{b,t+1}d_t] \Bigg].$$

One can see that in the first-best case the ex post set effort of banks is not relevant. There is no hidden action problem, which means banks cannot set effort ex post. The corresponding first-order conditions for the solution of this maximization problem can be found in the Appendix 4.A.4.

In addition, as shown in the Appendix 4.A.6 the limited liability constraint is not binding, leading to the following first-best effort choice (as shown in the Appendix

4.A.7):

$$\begin{aligned} e_t &= p'(e_t)E_t\lambda_{t+1}L_t(R^g_{t+1} - R^b_{t+1}) \\ \Leftrightarrow e_t &= p'(e_t)E_t\lambda_{t+1}(N_t + d_t - B^G_t)(R^g_{t+1} - R^b_{t+1}) \end{aligned} \tag{4.21}$$

Comparing the first-best effort (Equation (4.21)) with the chosen effort level when effort is unobservable (Equation (4.9)), one can see that in the first-best case the effort level is no longer negatively dependent on the level of the deposits. Equation (4.21) simply says that the higher the amount of loans and the higher the spread between the returns of a good firm and those of a bad firm, the higher the search effort of the banks. In addition, equity and deposits have the same positive effect on effort. Thus, in the first-best case the total amount of the balance is relevant for the effort choice and not the exact composition as it is the case when effort is unobservable. Thus, the Modigliani-Miller theorem applies. "By committing to care for d_t as if these were the banker's own funds, the banker is able to obtain better contract terms from the mutual fund. The banker is able to commit to the effort in (4.21) because e_t is observable to the mutual fund." (see Christiano and Ikeda 2014, p. 222) Therefore, in the first-best case, optimality leads the banks and the mutual funds to act as if they were one person.

In addition, as Christiano and Ikeda (2014) show, the state-contingent interest rates on the deposits of the banks are not uniquely pinned down. The reason is that the limited liability constraint is not binding anymore. It would be, however, compatible with the zero-profit constraint to set non state-contingent interest rates $R^d_{g,t+1} = R^d_{b,t+1} = R^M_t$ or state contingent interest rates $R^d_{g,t+1} = R^g_{t+1}$ and $R^d_{b,t+1} = R^b_{t+1}$.

Both the Modigliani-Miller theorem and Ricardian equivalence apply. One might think that the amount of government bonds has a negative effect on the effort level (see Equation (4.21)). However, government bonds are in fact neutral for the steady-state level of this economy. For the proof, start with Equation (4.42) and insert (4.45) as well as (4.44). This leads to the following equation:

$$R^M_t = p(e_t)R^g_{t+1} + (1 - p(e_t))R^b_{t+1}.$$

Using Equation (4.16) this leads to:

$$R_t^M = R_t^G.$$

The profit of the bank is therefore given by:

$$\begin{aligned} \Pi_{t+1}^B &\equiv R_t^M(B_t^G + L_t - d_t) \\ \Leftrightarrow \Pi_{t+1}^B &= R_t^M N_t. \end{aligned} \tag{4.22}$$

Insert Equation (4.22) into the law of motion for equity (4.4):

$$N_t = \gamma R_{t-1}^M N_{t-1} + \tilde{T}. \tag{4.23}$$

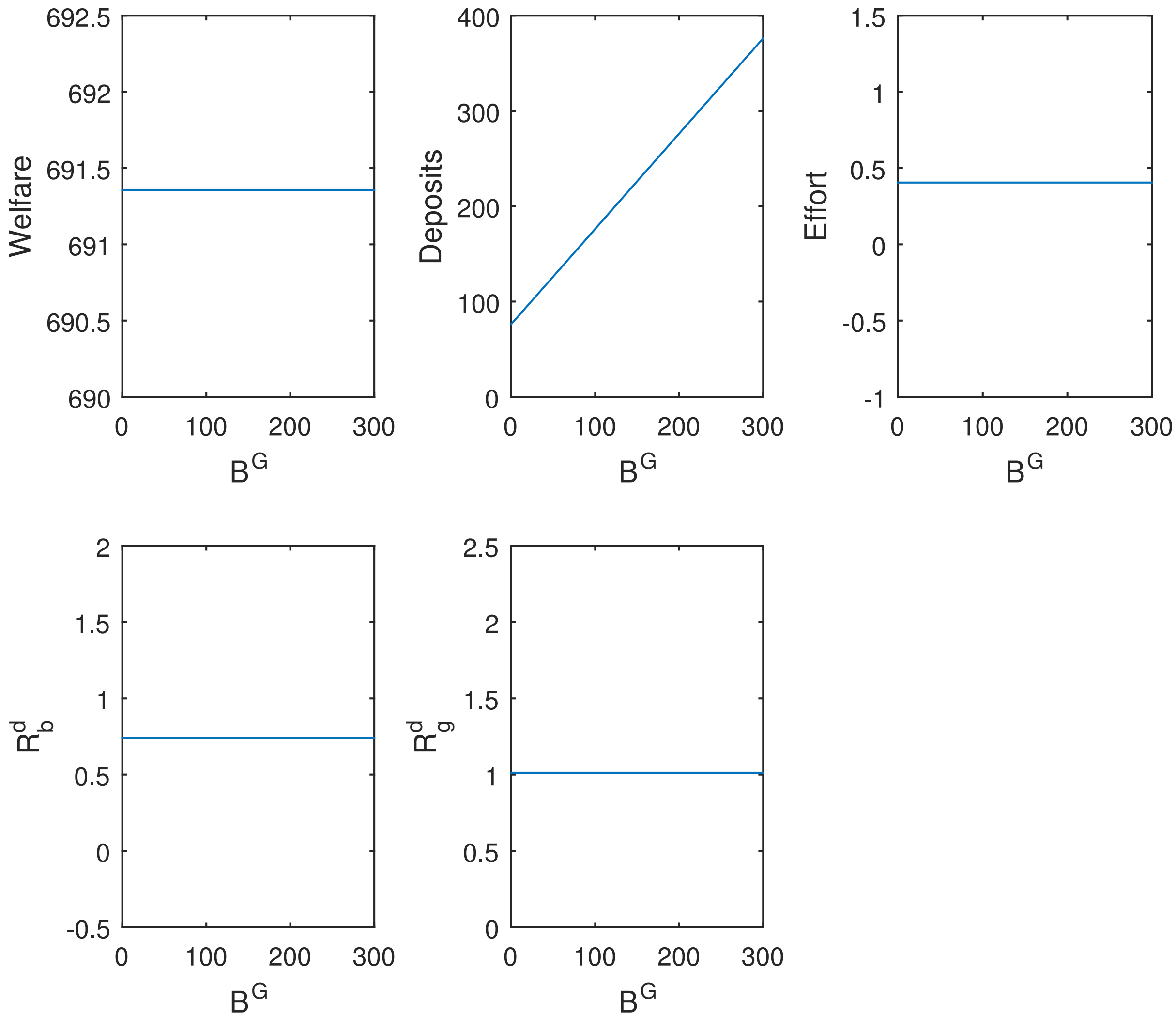
In the steady-state, Equation (4.23) can be written as:

$$N^{ss} = \frac{\tilde{T}}{\left(1 - \frac{\gamma}{\beta}\right)}. \tag{4.24}$$

Since the value in the bracket of Equation (4.24) is strictly non-zero, equity is constant and exogenously given by $\tilde{T}$, γ, and β. Thus, one can see from the balance sheet identity that an increase in the government bonds leads ceteris paribus to a one-for-one increase in deposits. This one-for-one increase in B^G and d cancels each other out in Equation (4.21). Thus, government bonds have no effect on the effort level of the banks, nor do they have any effect on the accumulation of capital. See also Figure 4.1, which shows the effect of government bonds on the steady-state of the economy in the first-best case.

The fact that neither debt nor taxes show up anywhere in the equilibrium conditions (expect in the non-binding limited liability constraint) means that the mix of debt and taxes is both indeterminate and irrelevant. Thus, Ricardian equivalence hold that, given constant government consumption, an increase in the government bonds increases the lump-sum taxes. However, this also increases the banks' profits, thus canceling each other out in the household budget constraint.

Figure 4.1: The effect of government bonds in the first-best case



Notes: This figure shows the effect of different values of the government bonds B^G on the long-run equilibrium of the economy, in the case effort is observable and no equity requirement constraint is imposed.

4.4.1 First-best effort versus ex post chosen effort

The ex post effort choice (Equation (4.9)) and the first-best effort choice (Equation (4.21)) differ only in one term. This term, which I call Δ_t, is defined as:

$$\Delta_t \equiv E_t \lambda_{t+1} d_t p'(e_t)(R^d_{g,t+1} - R^d_{b,t+1}). \tag{4.25}$$

Δ_t measures the inefficiency and distortion caused by the hidden action problem. This distortion stems from the binding limited liability constraint. If effort is unobservable, the mutual fund sets state-dependent interest rates $R^d_{g,t+1}$ and $R^d_{b,t+1}$, leading to a positive spread $R^d_{g,t+1} - R^d_{b,t+1}$, which reduces the incentive to exert search effort.

This can be shown if one rewrites Equation (4.25) in the following way (see Appendix 4.A.3):

$$\Delta_t = -\frac{\eta_t}{1 - \frac{\eta_t p'(e_t)}{p(e_t)}}. \tag{4.26}$$

For η_t it holds (see Appendix 4.A.2):

$$\eta_t = -E_t \frac{p(e_t)\nu_{t+1}}{\lambda_{t+1} p'(e_t)}. \tag{4.27}$$

ν_{t+1} is the Lagrange multiplier for the limited liability constraint. One can see that the higher ν_{t+1} is, the smaller is η_t by continuity and the bigger is the distortion of the effort decision measured by Δ_t. Thus, ν_{t+1} is a measure for the degree of sub-optimality caused by the hidden action problem. If the limited liability constraint is not binding, meaning ν_{t+1} is zero, Δ_t would also be zero, which means that the bank would set the effort level in an efficient way equal to the first-best effort level.

In addition, Equation (4.25) shows that the distortion measured by Δ_t increases in the amount of deposits. A higher deposits amount d_t leads to a stricter limited liability constraint (see Equation (4.11)), which tends to increase the spread $R^d_{g,t+1} - R^d_{b,t+1}$, reducing the incentives for the bank to exert search effort. As I show later, a higher amount of government bonds leads to a higher amount of deposits, which tends to lead to a stricter limited liability constraint if the investment in government bonds can be fully financed by debt.

4.5 Overview

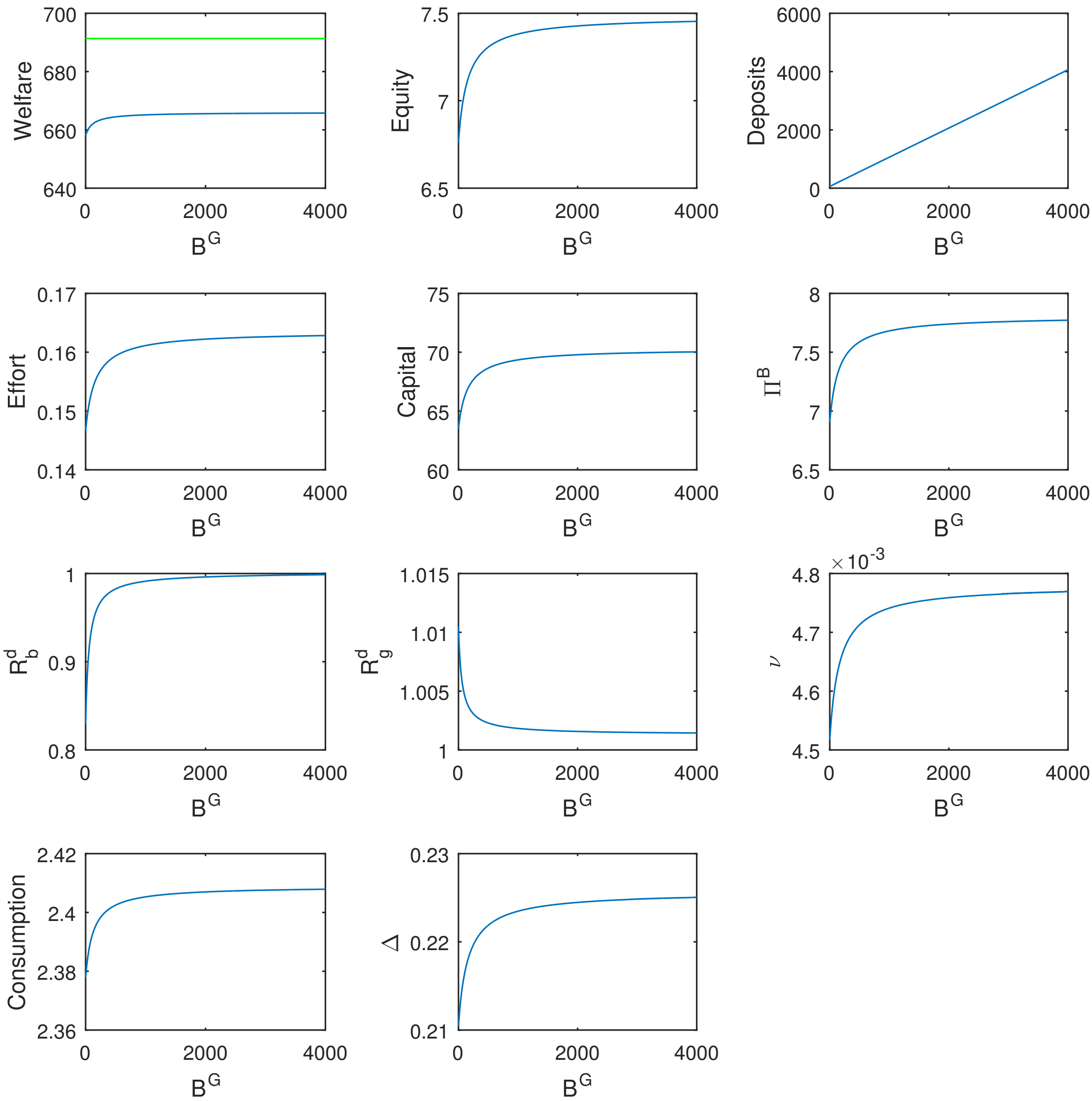
Many different model variations have been discussed so far. Therefore, I briefly summarize the main insights. The economy with observable effort is the first-best case. The economy with unobservable effort has a hidden action problem, leading to a lower effort level than in the first-best case. This problem can be reduced by introducing an equity requirement constraint, which increases the amount of equity of the banks and leads to higher incentive to exert costly search effort. Imposing an equity requirement constraint in the case of observable effort is sub-optimal since an equity requirement constraint is not needed in this economy. There is no hidden action problem, which needs to be solved. If effort is observable, the limited liability constraint is not binding. If effort is unobservable, the limited liability constraint is generally binding, leading to a distortion of the effort choice as described above measured by the term Δ. Next the effects of the possibility to invest into government bonds are discussed. As will be shown later, government bonds have an effect on Δ and thus on the allocation of the economy. Consequently, the amount of government bonds will influence the optimal equity requirement constraint. These effects are described in the following sections.

4.5.1 The effect of government bonds on the long-run equilibrium

Prior to investigating how government bonds influence the long-run optimal leverage constraint, I analyze the effect of an increasing amount of government bonds on the long-run equilibrium of the economy for a given value of $\Gamma^{N,L}$. The steady-state of the economy describes this long-run equilibrium. Figure 4.2 shows the effect of an increasing amount of government bonds for a given $\Gamma^{N,L}$. Here I choose the value for $\Gamma^{N,L}$ to be 0.105 in line with the current regulation. In the European implementation of the Basel III regulation, government bonds are seen as riskless assets. I follow this regulation and set $\Gamma^{N,BG}$ equal to zero. Additionally, I choose very high values for B^G to show the asymptotic properties of an increasing amount of government bonds on the economy's steady-state.

The amount of government bonds has reverse effects on the effort choice of banks. The first effect, which influences the effort choice positively, operates through the banks' profit. Equation (4.5) shows that an increase in the government bonds tends to increase the profit (see also Figure 4.2). A higher profit increases the amount of equity (see Equation (4.4) and Figure 4.2). A higher amount of equity improves banks' incentive to search for good firms (see Equation (4.9)). However, government bonds also have reverse effects on the effort choice, which operates through the limited liability

Figure 4.2: Effect of B^G given $\Gamma^{N,L}$ on the model's steady state



Notes: This figure shows the effect of different values of the government bonds given a chosen value for $\Gamma^{N,L} = 0.105$ on the long-run equilibrium of the economy. The green line in the plot for the welfare shows the value of the welfare in the first-best case. Welfare is defined as: $\frac{U(C^{ss}, e^{ss})}{1-\beta}$, where $U(C^{ss}, e^{ss})$ is steady-state utility of the private household: $\log(C^{ss}) - \frac{\Phi^e}{2}(e^{ss})^2$.

constraint. As Equations (4.12) and (4.3) show, a higher amount of government bonds tends to reduce the spread between R^d_g and R^d_b, which increases the incentive to exert the search effort e (see Equation (4.9)). Government bonds generate a safe return also in the case in which the bank has found a bad debtor (see Equation (4.12)). Thus, mutual funds can set a higher R_b^d and accordingly a lower R_g^d. This makes implementing the costly search effort more attractive for the banks (see Equation (4.9)). However, since government bonds can be completely financed with debt d (see Equation (4.13)) a higher amount of government bonds leads to an equally higher amount of deposits d (see Figure 4.2). This tends to reduce the incentive to exert search effort (see Equation (4.9)). The limited liability constraint gets tighter, as one can see from the increasing positive ν in Figure 4.2. The explanation is that the binding limited liability constraint has a negative effect on the effort choice of the bank. This is measured by the increase in Δ (see Equation (4.26)). Δ measures the negative effect of a binding limited liability constraint on the effort for given values of government bonds. Thus, a bigger Δ means a stronger negative effect of the binding limited liability constraint on the effort choice of the banks. It can be seen that a bigger amount of government bonds means a bigger Δ. Thus, an increase in the government bonds increases the distortion of the effort choice.

However, considering all the effects, one can see that the positive effect dominants the negative one. Therefore, when government bonds increase the effort increases as well. This increases the allocative effectiveness of the banking system and thus the accumulation of capital. This results in an increase in the final goods production. Higher output leads to higher private consumption. The increase in the private consumption outweighs the increase in the effort level, which has a negative effect on the overall welfare. Hence, the welfare level rises, although Δ becomes greater. However, the increasing Δ prevents the economy to reach the first-best case.

4.5.2 The effect of government bonds on the long-run optimal equity requirement constraint

This section describes the effect of the amount of government bonds on the long-run optimal equity requirement constraint. The long-run is described by the model's steady-state. I choose to look at the long-run, since the aim of an equity requirement constraint is a sustainable, stable, and sound banking system. Thus, the focus of this regulation lies on the long-run stability of financial system and not on the short-run dynamics.[11] Therefore, it is natural to analyze the long-run effects of an equity requirement constraint and to find the optimal design for this regulation. As already mentioned, the European regulation does not require any equity holdings when investing in European government bonds. Therefore, I set $\Gamma^{N,BG}$ to zero. An optimal value for Γ^{L} then maximizes the overall welfare Ω_t defined as:

$$\Omega_t = \sum_{t=0}^{\infty} \beta^t \left[\log(C_t) - \frac{1}{2} e_t^2 \right]. \tag{4.28}$$

The optimal value for $\Gamma^{L,*}$ in the steady-state is then given by:

$$\Gamma^{L,*} = argmax\ \Omega(C^{ss}, e^{ss}) = argmax\ \frac{U(C^{ss}, e^{ss})}{1-\beta}, \tag{4.29}$$

where

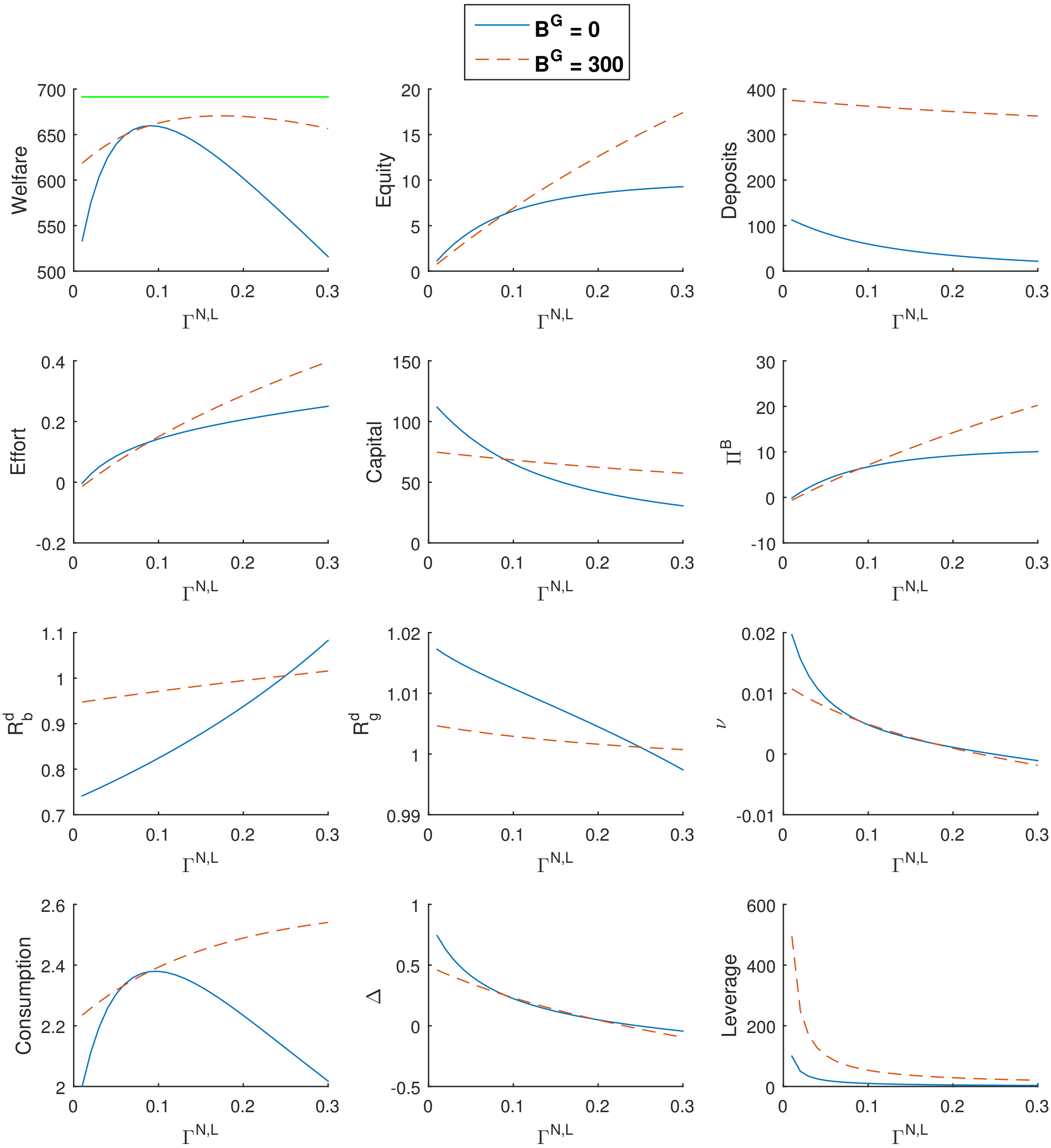
$$U(C^{ss}, e^{ss}) = \log(C^{ss}) - \frac{\Phi^e}{2} \left(e^{ss}\right)^2.$$

Of course, the optimal $\Gamma^{L,*}$ leads directly to the optimal equity requirement $\Gamma^{N,L,*} = 1 - \Gamma^{L,*}$.

To understand the effects of an equity requirement constraint, I present at first how different values for $\Gamma^{N,L}$, given two arbitrary chosen values for the amount of the government bonds, influence the steady-state of the economy. Figure 4.3 shows the results. Table 4.3 summarizes them. It shows that introducing an equity requirement constraint increases welfare, as it reduces the bank's leverage and therefore increases its incentive to exert costly search effort, which reduces Δ. To begin with, one sees that a stricter equity regulation (a higher $\Gamma^{N,L}$) leads, up to a certain point, to a higher welfare level. Therefore, in the present case the effort is unobservable. A stricter equity requirement constraint therefore increases the incentive of the banks to exert costlier search effort. As Equation (4.9) shows, the composition of the liability side of the bank is relevant for its effort decision. The higher the amount of equity relative to the amount of debt (deposits) is, the more attractive it is for the bank to search for good firms. Therefore, as Figure 4.3 shows, a reduction in debt d, stemming from the stricter leverage constraint, leads to an increase in e. e increases because the spread $(R_g^d - R_b^d)$

[11] Short-run dynamics are in the focus of regulations such as anti-cyclical capital buffer.

Figure 4.3: Effect of $\Gamma^{N,L}$ given B^G on the model's steady-state



Notes: This figure shows the effect of different values for $\Gamma^{N,L}$ given two arbitrary chosen values for the government bonds on the long-run equilibrium of the economy. The green line in the plot for the welfare shows the welfare level of an economy where effort is observable and no leverage constraint is imposed (the first-best case). This is the first-best case. Welfare is defined as: $\frac{U(C^{ss},e^{ss})}{1-\beta}$, where $U(C^{ss},e^{ss})$ is steady-state utility of the private household: $\log(C^{ss}) - \frac{\Phi^e}{2}(e^{ss})^2$.

Table 4.3: Effect a binding equity requirement constraint given $B^G = 18.985$ on the model's steady-state

Variable	non-observable effort, no equity constraint	non-observable effort, binding equity constraint
Leverage ratio	14.295	13.591
Effort	0.1324	0.1377
Δ	0.2549	0.2406
Welfare	659.722	659.905
$\Gamma^{N,L,*}$	N.A.	0.0940

Notes: Welfare is defined as: $\frac{U(C^{ss},e^{ss})}{1-\beta}$, where $U(C^{ss},e^{ss})$ is steady-state utility of the private household: $\log(C^{ss}) - \frac{\Phi^e}{2}(e^{ss})^2$. $\Gamma^{N,L,*}$ is set such that welfare is maximized.

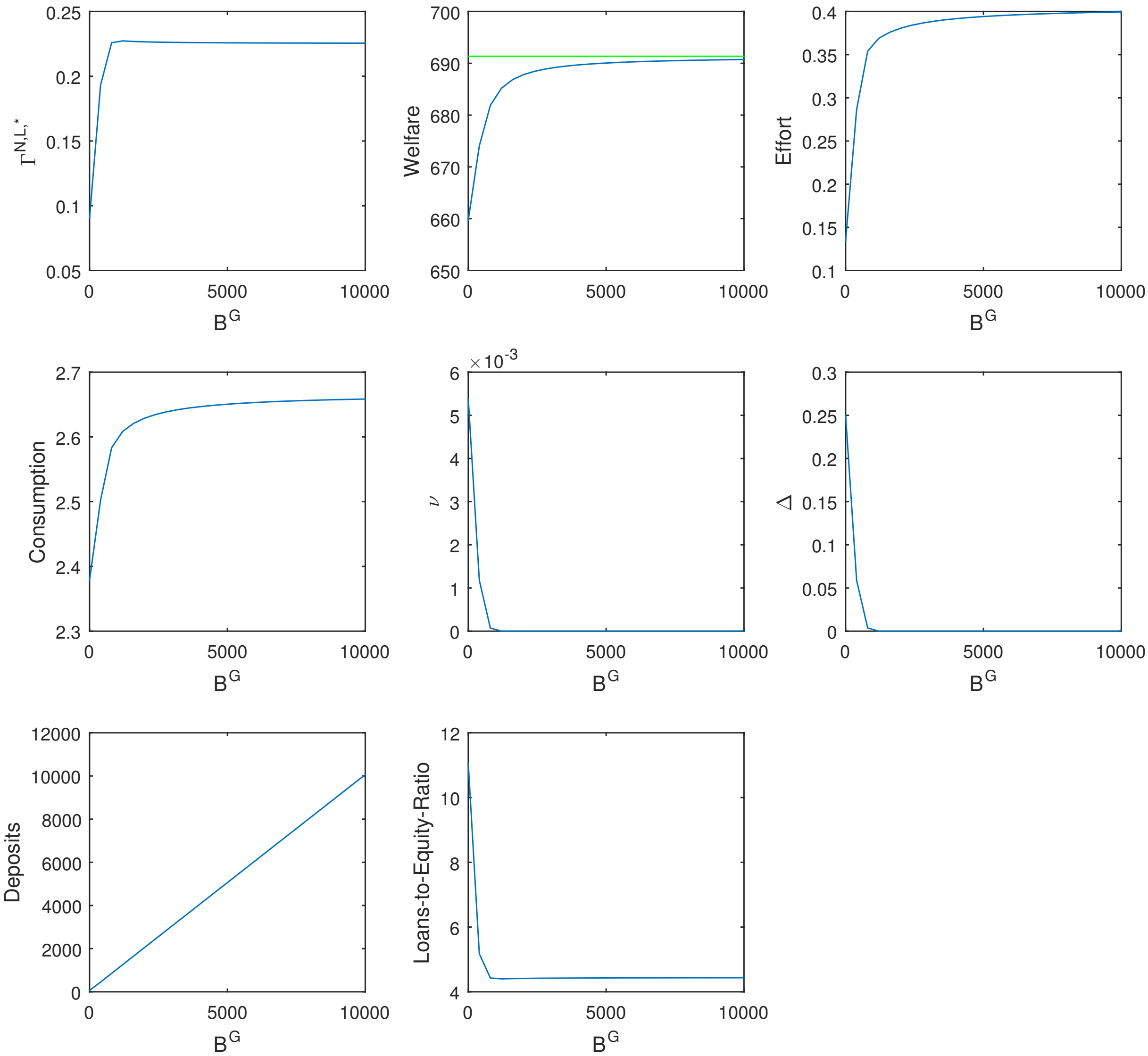
decreases. It falls since debt d falls, leading to a higher R_b^d (see Equation (4.12)) and a lower R_g^d (see Equation (4.3)). This improves the bank's incentive to exert a higher amount of search effort (see Equation (4.9)). In fact, the limited liability constraint that distorts the effort choice of banks, as already explained, gets slacker, as the falling Lagrange multiplier ν shows. As effort rises and the limited liability constraint gets less tight, the term Δ measuring the inefficiency due to the non-observability of effort falls too.

Consequently, with a higher search effort in the steady-state the banks allocative efficiency rises, and along with the accumulation of effective capital. However, the reduction in deposits is greater than the increase in equity, which increases since banks' profit increases. Therefore, total assets fall and total loans decrease, too. As total loans are equal to total raw capital and total raw capital is used to produce effective capital, total effective capital declines as well. Lower capital accumulation reduces the investments, outweighing here the reduction in output and leading to higher private consumption.

As Figure 4.2 shows, a higher amount of government bonds increases the overall welfare. Therefore, the maximum welfare for $B^G = 300$ is higher than for $B^G = 0$ (see Figure 4.3). However, one can also see that the maximum of the welfare function shifts right. Thus, if government bonds increase, only a stricter equity requirement constraint leads to the welfare's maximum. With an increasing level of government bonds, there is an inefficiency stemming from a more binding limited liability constraint, as explained in Section 4.5.1. To compensate for this effect, a stricter equity requirement constraint is necessary in order to reach optimum welfare. In addition, in the case of $B^G = 0$ the welfare is lower than in the first-best case. Even if an equity requirement constraint is introduced, one cannot reach the first-best case, because two distortions are present in this model: The hidden effort problem and the limited liability constraint. Thus, two distortions cannot be solved with one instrument. However, having two instruments (an equity requirement constraint and government bonds), one can reach the first-best case. The second-best argument applies here. In Figure 4.4, I summarize this result.

Figure 4.4 shows for different values of the government bonds the corresponding welfare maximizing $\Gamma^{N,L,*}$. As already explained in Section 4.5.1, a higher amount of government bonds leads to a higher amount of debt (deposits). This higher deposits amount tends to reduce the incentive of banks to exert costly search effort (see Equation (4.9)), since in the case of unobservable effort the composition of the bank's balance sheet is important for the level of the search effort. Therefore, in line with Figure 4.4, the higher the amount of government bonds, the higher the amount of debt (deposits) is and the stricter the equity requirement constraint has to be in order to maximize the overall welfare. The stricter equity requirement constraint compensates for the higher amounts of deposits, leading to a lower loan-to-equity-ratio. Therefore, a greater amount of loans is financed by the banks' own equity, improving the incentives to exert a higher amount of search effort (see Figure 4.4). Additionally, the stricter equity requirement constraint reduces the Lagrange multiplier ν and the distortions caused by the binding limited liability constraint as the interest spread decreases. Consequently, the term Δ measuring the inefficiency due to the non-observability of effort and the binding limited liability constraint decreases, as well. This indicates that, due to the stricter equity requirement constraint and the higher amount of safe assets (government bonds), the economy gets closer to the first-best case. In fact, if one increases the government bonds further, one can reach the first-best level, although this happens only if one chooses an unrealistically high amount of government bonds. In addition, one can see, as soon as equity is so high, that the limited liability constraint is not binding anymore ($\nu = 0$), the optimal $\Gamma^{N,L,*}$ does not increase further, and a stricter equity requirement regulation is not necessary anymore. In fact, if the limited liability constraint is not binding anymore and consequently effort is equal to the first-best

Figure 4.4: Effect of B^G on the optimal $\Gamma^{N,L,*}$



Notes: This figure shows for different values of B^G the corresponding welfare maximizing $\Gamma^{N,L}$ and the corresponding steady-state for the given optimal $\Gamma^{N,L}$. The green line in the plot for the welfare shows the welfare level of an economy where effort is observable and no leverage constraint is imposed (the first-best case).

effort level, a stricter equity requirement constraint is no longer necessary. Therefore, restricting the amount of debt further would decrease welfare. However, increasing the amount of government bonds would increase welfare further.

4.6 Conclusion

In the present chapter, I have analyzed how a safe asset, in this case government bonds, influences a long-run optimal bank equity requirement regulation. A key finding of the presented analysis is that the higher the amount of government bonds, the stricter the equity requirement regulation needs to be in order to reach optimum welfare.

The European implementation of the Basel III banking regulation strongly favors government bonds issued by EU member countries. They are seen as riskless assets. Consequently, the risk weight is zero and no equity has to be held by banks, in case they buy these assets. In my model, that regulation design translates into the following channel: Government bonds have reverse effects on the search effort of banks. As there is a hidden action problem, this search effort is too low in comparison with the first-best case with observable effort. Government bonds have a positive effect on the effort choice of the banks. A higher amount of government bonds reduces the interest rate spread charged by banks' creditors. This enhances the benefits of increasing the search effort as banks that find a good debtor have to pay a smaller interest rate to the mutual funds. Therefore, the higher the amount of governments bonds is, the higher the search effort will be. Overall, this leads to a higher welfare level. However, as government bonds can be fully financed with debt, the higher the amount of government bonds, the higher the amount of banks' debt is. This increases the banks' leverage. As the limited liability constraint is binding, a higher amount of debt tends to lead to a more binding limited liability constraint. The limited liability constraint distorts the banks' choice of exerting costly search effort to find good debtors. Therefore, to compensate for this distortion, a stricter equity requirement constraint is needed to achieve maximum welfare.

It would be interesting to extend the model by introducing effort costs that are dependent on the loan amount in the economy. In addition, having distortionary taxes on the labor income could also be an interesting extension. I leave it to future researchers to analyze the effects of these extensions on the design of an optimal equity requirement constraint.

4.A Appendix

4.A.1 First order conditions of the bank's optimization problem

With respect to e_t:

$$\begin{aligned} &E_t\lambda_{t+1}((N_t + d_t - B_t^G)(R_{t+1}^g - R_{t+1}^b) - d_t(R_{g,t+1}^d - R_{b,t+1}^d))p'(e_t) - e_t \\ &+ E_t\mu_{t+1}(R_{g,t+1}^d - R_{b,t+1}^d)p'(e_t)d_t + \eta_t = 0. \end{aligned} \tag{4.30}$$

With respect to $R_{g,t+1}^d$:

$$-E_t\lambda_{t+1}p(e_t) + E_t\mu_{t+1}p(e_t) + \eta_t E_t\lambda_{t+1}p'(e_t) = 0. \tag{4.31}$$

With respect to $R_{b,t+1}^d$:

$$-E_t\lambda_{t+1}(1 - p(e_t)) + E_t\mu_{t+1}(1 - p(e_t)) - \eta_t E_t\lambda_{t+1}p'(e_t) - \nu_{t+1} = 0. \tag{4.32}$$

With respect to d_t:

$$\begin{aligned} &E_t\lambda_{t+1}\left(p(e_t)R_{t+1}^g + (1 - p(e_t))R_{t+1}^b - (p(e_t)R_{g,t+1}^d + (1 - p(e_t))R_{b,t+1}^d)\right) + E_t\nu_{t+1}(R_{t+1}^b - R_{b,t+1}^d) \\ &+ E_t\mu_{t+1}(R_{g,t+1}^d p(e_t) + (1 - p(e_t))R_{b,t+1}^d - R_t^M) \\ &+ E_t\eta_t(-\lambda_{t+1}p'(e_t))((R_{t+1}^g - R_{t+1}^b) - (R_{g,t+1}^d - R_{b,t+1}^d)) - \chi_t\Gamma^{N,L} = 0. \end{aligned}$$

4.A.2 Proof 1

Subtract Equation (4.31) from Equation (4.32):

$$\mu_{t+1} = \lambda_{t+1} + \nu_{t+1}. \tag{4.33}$$

Substitute out μ_{t+1} in Equation (4.31):

$$\begin{aligned} &E_t\nu_{t+1}p(e_t) + E_t\eta_t\lambda_{t+1}p'(e_t) = 0 \\ \Leftrightarrow\ &\eta_t = -E_t\frac{p(e_t)\nu_{t+1}}{\lambda_{t+1}p'(e_t)}. \end{aligned} \tag{4.34}$$

Since $p(e_t)$, $p'(e_t)$, λ_t and ν_t are strictly positive. η_t is always negativ.

4.A.3 Proof 2

Use Equation (4.33) to substitute out μ_{t+1} in Equation (4.30):

$$\begin{aligned}
& E_t\lambda_{t+1}((N_t + d_t - B_t^G)(R_{t+1}^g - R_{t+1}^b) - d_t(R_{g,t+1}^d - R_{b,t+1}^d))p'(e_t) - e_t \\
& + E_t(\lambda_{t+1} + \nu_{t+1})(R_{g,t+1}^d - R_{b,t+1}^d)p'(e_t)d_t + \eta_t = 0 \\
\Leftrightarrow\ & E_t\lambda_{t+1}((N_t + d_t - B_t^G)(R_{t+1}^g - R_{t+1}^b))p'(e_t) - e_t \\
& + E_t\nu_{t+1}(R_{g,t+1}^d - R_{b,t+1}^d)p'(e_t)d_t + \eta_t = 0.
\end{aligned} \tag{4.35}$$

Insert the Equation (4.9) into Equation (4.35):

$$\begin{aligned}
& E_t\lambda_{t+1}((N_t + d_t - B_t^G)(R_{t+1}^g - R_{t+1}^b))p'(e_t) \\
& - \lambda_{t+1}((N_t + d_t - B_t^G)p'(e_t)(R_{t+1}^g - R_{t+1}^b) - d_t p'(e_t)(R_{g,t+1}^d - R_{b,t+1}^d)) \\
& + E_t\nu_{t+1}(R_{g,t+1}^d - R_{b,t+1}^d)p'(e_t)d_t + \eta_t = 0,
\end{aligned} \tag{4.36}$$

which is equivalent to:

$$E_t(\nu_{t+1} + \lambda_{t+1})(R_{g,t+1}^d - R_{b,t+1}^d)p'(e_t)d_t + \eta_t = 0 \tag{4.37}$$

Insert $\nu_{t+1} = -\frac{\eta_t\lambda_{t+1}p'(e_t)}{p(e_t)}$ from Equation (4.27):

$$\begin{aligned}
& E_t\left(-\frac{\eta_t\lambda_{t+1}p'(e_t)}{p(e_t)} + \lambda_{t+1}\right)(R_{g,t+1}^d - R_{b,t+1}^d)p'(e_t)d_t + \eta_t = 0 \\
\Leftrightarrow\ & E_t\lambda_{t+1}(R_{g,t+1}^d - R_{b,t+1}^d)p'(e_t)d_t = -\frac{\eta_t}{1 - \frac{\eta_t p'(e_t)}{p(e_t)}} \\
\Leftrightarrow\ & \Delta_t = -\frac{\eta_t}{1 - \frac{\eta_t p'(e_t)}{p(e_t)}}.
\end{aligned} \tag{4.38}$$

4.A.4 First order conditions of the bank's optimization problem in the first-best case

With respect to e_t:

$$E_t\lambda_{t+1}(L_t(R^g_{t+1}-R^b_{t+1})-d_t(R^d_{g,t+1}-R^d_{b,t+1}))p'(e_t)+E_t\mu_{t+1}(R^d_{g,t+1}-R^d_{b,t+1})p'(e_t)d_t-e_t=0. \tag{4.39}$$

With respect to $R^d_{g,t+1}$:

$$-E_t\lambda_{t+1}p(e_t)+E_t\mu_{t+1}p(e_t)=0. \tag{4.40}$$

With respect to $R^d_{b,t+1}$:

$$-E_t\lambda_{t+1}(1-p(e_t))+E_t\mu_{t+1}(1-p(e_t))-E_t\nu_{t+1}=0. \tag{4.41}$$

With respect to d_t:

$$\begin{aligned}&E_t\lambda_{t+1}\left(\left(p(e_t)R^g_{t+1}+(1-p(e_t))R^b_{t+1}\right)\right)-\left(p(e_t)R^d_{g,t+1}+(1-p(e_t))R^d_{b,t+1}\right)\Big)+\\&E_t\mu_{t+1}\left(p(e_t)R^d_{g,t+1}+(1-p(e_t))R^d_{b,t+1}-R^M_t\right)+E_t\nu_{t+1}(R^b_{t+1}-R^d_{b,t+1})=0.\end{aligned} \tag{4.42}$$

4.A.5 Proof 3

Adding Equation (4.40) and Equation (4.41), one gets:

$$\mu_{t+1}=\lambda_{t+1}+\nu_{t+1}. \tag{4.43}$$

Inserting Equation (4.43) into Equation (4.40) leads to:

$$\nu_{t+1}=0. \tag{4.44}$$

4.A.6 Proof 4

Adding Equation (4.40) and Equation (4.41), one gets:

$$\mu_{t+1}=\lambda_{t+1}+\nu_{t+1}. \tag{4.45}$$

Inserting Equation (4.45) into Equation (4.40) leads to:

$$\nu_{t+1} = 0. \tag{4.46}$$

4.A.7 Proof 5

Using Equations (4.39), (4.45), and (4.46) one gets the following first-best effort choice:

$$\begin{aligned} e_t &= p'(e_t) E_t \lambda_{t+1} L_t (R^g_{t+1} - R^b_{t+1}) \\ \Leftrightarrow e_t &= p'(e_t) E_t \lambda_{t+1} (N_t + d_t - B^G_t)(R^g_{t+1} - R^b_{t+1}) \end{aligned} \tag{4.47}$$

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