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Mitigating financial stress in a bank-financed economy: equity injections into banks or purchases of assets?

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Non-technical summary

Research Question

When the severity of the 2007-09 financial crisis became apparent, governments and central banks alike introduced unconventional policy measures to mitigate the spillover effects from the financial sector to the real economy. Equity injections into banks and asset purchases were among the most frequently used measures. However, the measures were conducted to different degrees across the countries. Against this background, it is of interest to compare the same measures in an economy with the same structure in order to evaluate their effectiveness.

Contribution

This paper contributes to this discussion by comparing different measures within the same consistent framework of a New Keynesian dynamic stochastic general equilibrium (DSGE) model that allows for an elaborated financial sector with banks and a capital market and in which loans are the main source of funding. Thus, the structure reflects the euro area. We scrutinize the effects of outright purchases of both government and corporate bonds, as well as of injections of equity into banks.

Results

Our results indicate that the injection of equity into the banking sector is more efficient from a welfare perspective than asset purchases in order to mitigate tensions resulting from the banking sector. Outright asset purchases, by contrast, must be conducted on a larger scale in order to be quantitatively similarly successful in our economy, in which non-market-based financing is the predominant source to obtain external funds for non-financial corporations. However, too large equity injections start to harm welfare because they cause additional volatility at some point. Furthermore, the origin of the financial shock is important for the results. If financial stress does not stem from the banking sector in the first place, the welfare-improving range of equity injections into banks is very small because the default risk of non-financial firms matters.

Nicht-technische Zusammenfassung

Fragestellung

Im Zuge der Finanzkrise in den Jahren 2007-09 führten sowohl Regierungen als auch Zentralbanken Sondermaßnahmen ein, um die Übertragungseffekte aus dem Finanzsektor auf die Realwirtschaft abzumildern. Kapitalzuführungen in den Bankensektor und Wertpapierankaufprogramme gehörten zu den am häufigsten verwendeten Maßnahmen. Diese Maßnahmen wurden in den unterschiedlichen Ländern jedoch in einem unterschiedlichen Ausmaß durchgeführt. Vor diesem Hintergrund ist es von Interesse, die gleichen Maßnahmen in einer gleichen Modellökonomie zu untersuchen und zu bewerten.

Beitrag

Dieses Papier trägt zu dieser Diskussion bei, indem es unterschiedliche Maßnahmen zur Abmilderung einer Finanzkrise in einem einheitlichen konsistenten Rahmen untersucht. Dabei wird ein Neu-Keynesianisches allgemeines Gleichgewichtsmodell herangezogen, dass einen umfangreichen Finanzsektor mit Banken und Kapitalmarkt aufweist. In diesem Modell greifen nicht-finanzielle Unternehmen primär auf Buchkredite als externe Finanzierungsquelle zurück, womit das Modell die Struktur im Euroraum reflektiert. In diesem Rahmen werden Offenmarktkäufe von Staatsanleihen und Anleihen nicht-finanzieller Unternehmen sowie Kapitalzuführungen in den Bankensektor untersucht.

Ergebnisse

Die Ergebnisse zeigen, dass Kapitalzuführungen in den Bankensektor vor dem Hintergrund einer Wohlfahrtsbetrachtung effizienter sind als Offenmarktkäufe von Wertpapieren, um finanziellen Stress im Bankensektor abzumildern. Offenmarktkäufe von Wertpapieren müssen in dieser Ökonomie, in der Bankfinanzierung bei nicht-finanziellen Unternehmen dominiert, in einem stärkeren Ausmaß durchgeführt werden, um gleichermaßen quantitativ erfolgreich zu sein. Allerdings beginnen zu starke Kapitalzuführen die Wohlfahrt wiederum zu mindern, da sie ab einem bestimmten Punkt zusätzliche Volatilität induzieren. Zudem ist jedoch der Ursprung des Finanzstress für die Ergebnisse von Bedeutung. Entstammt der Finanzstress nicht dem Bankensektor, sondern ist er primär auf die Ausfallwahrscheinlichkeit von nicht-finanziellen Unternehmen zurückzuführen, ist der Bereich von Wohlfahrtssteigerungen bei Kapitalzuführungen in den Bankensektor sehr gering.

Bundesbank Discussion Paper No 19/2014

Mitigating Financial Stress in a Bank-Financed Economy: Equity Injections into Banks or Purchases of Assets?*

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Abstract

This paper compares the consequences of equity injections into banks with purchases of corporate and government bonds in a financial crisis situation using a New Keynesian model in which non-financial firms predominantly take non-market-based debt from banks instead of issuing securities. Our results show that equity injections into banks are more welfare enhancing than asset purchases following a financial shock located in the banking sector. Equity injections remove the frictions that have initiated the stress and, at the same time, relax borrowing conditions. Outright purchases also increase welfare but lower returns with negative effects on banks' profits, while the effect on asset prices to stabilize banks' balance sheets is of minor importance due to the dominance of non-market-based debt. Furthermore, we demonstrate that the origin of the financial shock matters crucially for the efficacy of measures.

Keywords: DSGE Model, Financial Frictions, Financial Accelerator, Unconventional Policy Measures, Asset Purchase Programs, Capital Injections into Banks.

JEL classification: E44, E58, E61.

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1 Introduction

When the severity of the 2007-09 financial crisis became apparent, governments and central banks alike introduced unconventional policy measures to mitigate the spillover effects from the financial sector to the real economy. Particularly given the large amount of financial resources used to fight the recession, policy makers are interested in assessing the efficacy of the unconventional measures taken. Moreover, it is also important to know which measures are most suited to which conditions. This paper contributes to this discussion by comparing different measures within the same consistent framework of a dynamic stochastic general equilibrium (DSGE) model that allows for an elaborated financial sector with banks and a capital market and in which loans are the main source of funding.

Countries and public agents took manifold measures during the financial crisis. On the one hand, central banks started to buy private assets and government bonds outright as well as providing liquidity to the banking sector.[1] On the other hand, policy measures conducted by the central banks were often flanked by operations undertaken by governments. Their actions to support the financial sector mainly centered on the recapitalization of banks.[2] A number of papers investigate empirically the success of unconventional monetary policy measures. Empirical studies mostly try to evaluate the effects on interest rates or yields, while the effect on the real economy is not explicitly modeled (D'Amico, English, Lopéz-Salido, and Nelson, 2012; Gagnon, Raskin, Remache, and Sack, 2011; Hamilton and Wu, 2012; Krishnamurthy and Vissing-Jorgensen, 2011; Swanson, 2011). The borrowing conditions for non-financial firms seemed to be affected positively in the USA (e.g. D'Amico et al., 2012; Gagnon et al., 2011; Krishnamurthy and Vissing-Jorgensen, 2011) and the UK (e.g. Joyce, Lasaosa, Stevens, and Tong, 2011; Joyce and Tong, 2012). Only few studies scrutinize empirically the effects of unconventional measures on the real economy. The study of Baumeister and Benati (2013) is geared to the USA and the UK, while Kapetanios, Mumtaz, Stevens, and Theodoridis (2012) focus on the UK. Both papers report significant effects from asset purchases on output and inflation. In this respect, the ECB's unconventional measures are also reported to be successful (see Fahr, Motto, Rostagno, Smets, and Tristani, 2011; Giannone, Lenza, Pill, and Reichlin, 2012; Peersman, 2011). An inherent problem with empirical work is that

[1] Outright purchases were primarily conducted by the Federal Reserve with its Large Scale Asset Purchase Programs (LSAP 1 to 3), the Bank of Japan and the Bank of England but also by the Eurosystem with its Covered Bond Purchase Programs (CBPP 1 and 2). Liquidity was provided in a variety of ways; the Federal Reserve offered banks *inter alia* the opportunity to obtain central bank money by putting advances forward as collateral. One major element of the Eurosystem's crisis resolution strategy was the introduction of full allotment for central bank lending in conjunction with longer-term refinancing operations (LTROs), which allowed banks to receive reserves for a longer fixed period of time. Similar policy instruments were also applied by the Bank of Japan. An essential tool for many central banks was the expansion of the list of assets eligible as collateral together with a reduction in haircuts for central bank lending.

[2] In the USA, the Treasury Department established the Troubled Asset Relief Program (TARP), which contained several instruments. One of these was the Capital Purchase Program (CPP), which provided additional capital to financial institutions in order to compensate for losses by buying preferred stocks, for instance. Similar tools were also used in Japan and in Europe. In Germany, for instance, the government introduced the Special Financial Market Stabilization Fund ("Finanzmarktstabilisierungsfonds") that not only guaranteed banks' capital issues but also recapitalized banks directly.

the effects of one specific measure cannot clearly be isolated because different measures were applied simultaneously which results in an identification problem.

To circumvent this problem, theoretical models have been developed to study the effects of different measures in isolation, i.e. policy tools are imitated to find an answer to the question of macroeconomic feedback effects. Gertler and Karadi (2011) and Gertler and Karadi (2013) can, in principle, demonstrate that asset purchases have important effects using New Keynesian DSGE models. The results of Dedola, Karadi, and Lombardo (2013) go in the same direction by stressing the potential of domestic programs to spill over internationally. Other models provide a more general result: asset purchases improve financial intermediation in times of financial stress but are ineffective in other cases (Cúrdia and Woodford, 2011; Eggertsson and Woodford, 2003; Williamson, 2012). Unlike other studies, Chen, Cúrdia, and Ferrero (2012) report only marginal effects of asset purchases on output and inflation for the USA.[3] Besides asset purchases, the recapitalization of banks, by providing net worth, seems to mitigate tensions in the financial sector very significantly (Christiano and Ikeda, 2013a; He and Krishnamurthy, 2013; Hirakata, Sudo, and Ueda, 2013; Sandri and Valencia, 2013; Zeng, 2013).

Following Gertler and Karadi (2011) and Gertler and Karadi (2013), outright purchases of assets seem to succeed in mitigating financial stress in economies which rely on market-based financing.[4] In a market-based economy, the stabilization of asset prices has two effects: on the one hand, the value of these assets is supported, which stabilizes the balance sheet of their holders. Asset purchases indirectly recapitalize the financial intermediaries in this environment, and lending to the non-financial sector is facilitated. On the other hand, borrowing conditions in the real sector improve at the same time. However, few papers evaluate the effects of outright purchases in an economy in which non-financial firms predominantly rely on non-market-based financing by taking loans, i.e. in an economy in which the second channel is of minor importance. Such a setting comes closer to the structure of the euro area's economy compared to the US economy.[5] Market-based debt is much more common in the USA than in the euro area, and equity consists mostly of outside equity in the USA and not of inside equity, as in the euro area.[6] From this point of view, it is of interest to investigate how asset purchases affect a non-market-based economy.

Our paper's main contribution is as follows: We draw on a fully specified New Keynesian general equilibrium model, in which non-financial firms predominantly take non-market-based loans from banks in order to investigate the efficacy of outright purchases of bonds and the recapitalization of banks in a financial crisis situation. We compare not only the qualitative properties but also the quantitative effects of the policy measures in a model economy that exhibits features of and is calibrated to the euro area. Besides investigating the dynamics, we evaluate the measures from a welfare perspective. In this respect, we differentiate between financial shocks with two different origins.

Banks are faced with constraints resulting from agency problems with their creditors

[3] Chen et al. (2012) estimate a DSGE model for the USA and simulate large-scale asset purchases.

[4] This conclusion follows from their setting in which assets with market-determined prices dominate the balance sheet of the financial intermediary.

[5] See Table 6 in the appendix.

[6] Market-based debt means that the debt instrument has a market-determined price that can change. Conversely, non-market-based debt is not traded on a market and has a price of unity.

(Christiano and Ikeda, 2013b; Gertler and Kiyotaki, 2010; Gertler and Karadi, 2011; Cúrdia and Woodford, 2011). Moreover, agency problems also exist between banks and non-financial firms (Bernanke, Gertler, and Gilchrist, 1999; Christiano, Motto, and Rostagno, 2014). For this reason, it is necessary to draw on a model that allows for financial frictions on both sides of banks' balance sheet, i.e. to allow for two-sided financial contracting. Some recent contributions construct such a framework by relying on the costly state verification framework on both sides of financial contracting (Hirakata, Sudo, and Ueda, 2011; Hirakata et al., 2013; Sandri and Valencia, 2013; Zeng, 2013). This allows defaults in both the real and the banking sector to be taken into account. However, changes in bank lending rates reflect market forces and costs related to bank defaults. We want to isolate market forces from default costs in the banking sector because the latter means bank runs or depositor insurances need to be taken into account. Nevertheless, bankruptcy costs stemming from the real sector might be relevant for the banking sector. For this reason, we combine the approaches of Bernanke et al. (1999) and Gertler and Kiyotaki (2010).[7] Thus, we assume a costly state verification problem between the financial sector and non-financial firms, while funders of banks are confronted with a costly enforcement problem. In doing so, we additionally introduce two distinct debt instruments for non-financial firms: non-market-based debt (loans) and market-based debt (corporate bonds). Consequently, our banks intermediate funds to non-financial firms by granting loans and buying corporate bonds. Furthermore, we allow our banks to hold government bonds.

In this framework, we scrutinize the effects of outright purchases of both government and corporate bonds, as well as of injections of equity into banks (build up of net worth). These measures are similar to the measures investigated in Gertler and Kiyotaki (2010), Gertler and Karadi (2013), Christiano and Ikeda (2013a), Hirakata et al. (2013), Sandri and Valencia (2013), and He and Krishnamurthy (2013).[8] Compared to Gertler and Kiyotaki (2010), our approach makes two additional contributions to the literature: firstly, we apply a New Keynesian model with nominal and financial frictions instead of a real business cycle framework, and secondly, we model the distinct policy measures within the same model. Gertler and Kiyotaki (2010) basically apply the same modeling framework; nevertheless, they tailor their exact model to the policy measure under investigation. This can potentially neglect important feedback effects, which we do not exclude a priori through the construction of our model. As in our case, Christiano and Ikeda (2013a) also allow for tax-financed measures conducted by the government.[9] Furthermore, they also compare the effects of different intervention policies that are close to ours across different models but do not embed these measures into a macroeconomic model as we do.[10] Although Gertler and Karadi (2013) also consider purchases of government bonds in a New Keynesian model, our framework allows for one additional asset on banks'

[7]This setting is similar to Rannenberg (2013).

[8]Both papers introduce financial friction between the banks and their creditors. In the model of Gertler and Kiyotaki (2010), banks can divert a fraction of the financial resources they receive from their creditors, which is why bank net worth is important to guarantee repayment. Christiano and Ikeda (2013a) formulate, *inter alia*, the financial frictions slightly differently by stating that bankers must make an effort to choose projects with good returns (hidden action). Similarly, net worth helps to stabilize the pay-off.

[9]In their model, the tax is a lump-sum tax rather than a distortionary tax on wages as in our case.

[10]Their focus is on the qualitative properties of different financial sector models.

balance sheets, whereas the main financial instrument in our model are loans rather than securities, as in their model.[11] He and Krishnamurthy (2013), by contrast, do not rely on the New Keynesian framework. Regarding the question of capital injections, Hirakata et al. (2013) and Sandri and Valencia (2013) are closer to us. They draw on the costly state verification problem to motivate both financial frictions and investigate equity injections. However, we are able to investigate equity injections and asset purchases in the same framework simultaneously, which they are not.

Our results indicate that the injection of inside equity, i.e. enhancing banks' net worth, is more efficient from a welfare perspective than asset purchases in order to mitigate tensions resulting from the banking sector.[12] Outright asset purchases, by contrast, must be conducted on a larger scale in order to be quantitatively similarly successful in our economy, in which non-market-based financing is for non-financial corporations the predominant source to obtain external funds. However, too large equity injections start to harm welfare because they cause additional volatility at some point. Furthermore, the origin of the financial shock is important for the results. If financial stress does not stem from the banking sector in the first place, the welfare-improving range of equity injections into banks is very small because the default risk of non-financial firms matters.

Our results complement those of Gertler and Karadi (2011) or Gertler and Karadi (2013) who investigate asset purchases for an economy in which banks predominantly hold securities. In those cases, asset purchases stabilize the value of banks' assets and consequently banks' net worth. In our case, asset purchases primarily reduce returns, which also weakens banks' net worth by reduced profits. Because of the dominance of non-market-based debt in banks' balance sheets, the stabilizing role of asset purchases on asset prices is of minor importance. Thus, equity injections into banks are very powerful if the banking sector causes financial stress because equity injections alleviate financial frictions.

The remainder of the paper is organized as follows. Section 2 provides a description and derivation of the model. In Section 3, we discuss calibration and the obtained steady state values. Dynamics are presented in Section 4. Here we start with a comparison of the dynamics resulting from our model with those of standard models following a monetary policy shock and a productivity shock. Then we discuss two types of financial shock before turning to the investigation of the policy measures. Section 5 concludes.

2 Model

The modeling framework relies on the well-known class of DNK models, as outlined in Smets and Wouters (2003) or Christiano, Eichenbaum, and Evans (2005). A standard DNK model is extended to include a financial sector in the sense that we introduce both a bank and a capital market which both allocate financial resources. There is a financial contracting problem between the real sector and the financial market and between the bank and its creditors. While in the first case lenders are confronted with a costly state verification problem, as outlined in Bernanke et al. (1999), the agency problem between

[11] In addition, equity injections are not addressed in their model.

[12] These results are principally in line with Christiano and Ikeda (2013a) and He and Krishnamurthy (2013).

the bank and its shareholders is modeled as proposed by Gertler and Kiyotaki (2010) and Gertler and Karadi (2011). This allows us to abstract from default problems in the banking sector and is proposed and discussed by Rannenberg (2013). Our model consists of households, two types of entrepreneur, intermediate goods firms, final goods firms, mutual funds, banks and a public sector as active agents.

A continuum of households save, consume and supply labor to the intermediate goods firms. Households receive income from labor and from financial assets to consume a bundle of final goods, purchased from final goods firms. The financial wealth of households arises from holdings of corporate and government bonds, and bank deposits.

We distinguish between two types of entrepreneur (type A and type B entrepreneurs) to introduce a role for different debt instruments. Both entrepreneurs process newly produced physical capital which is exposed to the individual skills of each entrepreneur and is then rented out to intermediate goods firms. Related to the entrepreneur, we allow for two different stocks of capital.[13] The two types of entrepreneur own different types of capital which are both used complementarily in the production of intermediate goods. Both types of entrepreneur can finance their projects by raising external funds in excess of their net worth. Both types of physical capital are rented out to intermediate goods firms, which combine physical capital with rented labor to produce differentiated intermediate goods. The intermediate goods firms sell their goods in a market of monopolistic competition to final goods producers. Finally, the final goods firms bundle the differentiated goods into a homogenous final good. The final good can be used for consumption, in capital utilization, as investment goods, or as government expenditures.

Banks hold two different types of asset received from the private sector: loans and bonds from entrepreneurs. Moreover, lending banks purchase government bonds. They obtain funds from households through deposits.

2.1 Households

The economy is populated by a continuum of households which are indexed by h with $h \in (0, 1)$. Each h-th household decides on the supply of labor, how much to consume and to save, and on the allocation of its wealth. Households' utility function is given in Equation (1)

$$E_0^j \sum_{j=0}^{\infty} \beta^j \left[\frac{\left(C_{h,t+j} - h^C C_{t-1+j}\right)^{1-\sigma}}{1-\sigma} - \kappa \frac{\left(N_{h,t+j}\right)^{1+\varphi}}{1+\varphi} \right] \tag{1}$$

with discount factor β and the remaining variables described in this subsection. Households evaluate consumption relative to an external habit stock that is the value of the last period's aggregate consumption. In this respect, the term h^C reflects the importance of external habits with $h^C \in (0, 1)$, and σ determines the elasticity of intertemporal substitution.

The households supply differentiated labor services ($N_{h,t}$) to the intermediate goods sector. Because of a monopolistically competitive labor market in which labor services are imperfect substitutes, each household has market power to set its nominal wage (W_t).

[13]This is a slight modification of standard DNK models. A similar approach is often applied if impatient and patient households are introduced, for example, with applications to housing markets.

Following Erceg, Henderson, and Levin (2000), we assume, in analogy to Calvo pricing, that the household is not able to renegotiate its nominal wage each period. Instead, it can only reoptimize with a specific probability $(1-\gamma^w)$. In periods in which the household cannot renegotiate, it follows an indexation rule $\tilde{W}_t = (\pi_{t-1})^{\xi^w} (\pi)^{1-\xi^w} W_{t-1}$, where ξ^w is the weighting parameter. A labor agency is introduced that buys differentiated labor from households and pays the individual wage in order to produce a representative labor aggregate as output

$$N_t = \left[\int_0^1 N_{h,t}{}^{\frac{\theta^\omega - 1}{\theta^\omega}} dh \right]^{\frac{\theta^\omega}{\theta^\omega - 1}}, \tag{2}$$

where θ^w is the degree of substitution. By minimizing the costs of producing this aggregator, the labor agency takes the wage rates of each differentiated labor input as given. From this optimization problem follows the demand for labor of household h for use in goods production

$$N_{h,t} = N_t \left(\frac{W_{h,t}}{W_t} \right)^{-\theta^w}. \tag{3}$$

By combining Equations (2) and (3), one obtains the aggregate wage index

$$W_t = \left[\int_0^1 W_{h,t}^{1-\theta^w} dh \right]^{\frac{1}{1-\theta^w}}. \tag{4}$$

With the knowledge of demand for its labor, the household can proceed with determining the optimal wage rate $(W^*_{h,t})$ and the optimal labor supply $(N^*_{h,t})$. Thus, it maximizes

$$\max_{\{W_{h,t}\}} E_t \sum_{s=0}^{\infty} (\beta\gamma^w)^s \left[-\kappa \frac{\left(N^*_{h,t+s}\right)^{1+\varphi}}{1+\varphi} + \lambda_{h,t+s} \frac{\Psi^w_{t+s} \left(1-\tau^w_t\right) W^*_{h,t}}{P_{t+s}} N^*_{h,t+s} \right] \tag{5}$$

by making use of Equation (3). The term φ reflects the inverse Frisch elasticity. Changes in rates of inflation until date s, which are important for indexation, are summarized in Ψ^w_{t+s} in Equation (5). Before utility maximization is carried out, the optimal nominal wage emerges from a sub-problem in which the household minimizes its disutility of labor by choosing its nominal wage given the labor demand of firms.[14]

Similar to Gertler and Kiyotaki (2010) or Gertler and Karadi (2011), we assume that some household members become banker managers who operate banks. The share of household members in the banking sector in each period is s^{BM}. In order to keep the shares constant over time, we assume that exactly the same number of workers become bankers as bankers return to the goods producing sector. The probability of staying a banker p^{BM} is exogenously fixed and does not change over time. The profits each bank manager potentially earns are not transferred to the household before the bank manager leaves the bank, which happens with a probability of $\left(1-p^{BM}\right)$.[15] In addition, a specific share s^e of households becomes entrepreneurs. Like bank managers, entrepreneurs survive with a probability of p^e. During the time they are entrepreneurs, household members

[14] The derivation is presented in the appendix.

[15] The reason why bankers exit lending banks is to guarantee that the lending banks do not accumulate equity indefinitely (see Gertler and Karadi (2011) or Gertler and Kiyotaki (2010)).

accumulate net wealth, which is transferred back to the household when they leave the entrepreneurial sector.

Households place deposits (D_t) with banks, buy risk-free bonds which consist of short-term $\left(B_t^{short,gov}\right)$ and long-term government bonds (B_t^{gov}) and (short-term) bonds issued by a public agency $\left(B_t^{IA}\right)$.[16] On holdings of short-term government bonds and agency's bonds, summarized as short-term public sector debt B_t^{PS}, they receive the risk-free rate i_t, while they obtain the risk-free return $r_t^{B,gov}$ on long-term government bonds which bear a coupon of i_0^{gov} and are traded at price $Q_t^{B,gov}$.[17]

In order to allow for longer-term bonds, we follow Woodford (2001) and assume that only a fraction of the government bonds ($\rho^{B,gov}$) issued last period are repaid this period.[18] Regarding the definition of the bond rate ($r_t^{B,gov}$) we obtain

$$r_t^{B,gov} = \pi_t \left(\frac{\rho^{B,gov} Q_t^{B,gov} + i_0^{gov}}{Q_{t-1}^{B,gov}} \right) - 1 \tag{6}$$

for government bonds. In addition, deviations in the holdings of government bonds from their steady state value (B_h^{gov}) entail costs

$$\Theta_t^{gov,H} = \frac{\upsilon^{B,gov}}{2} \left(B_{h,t+j}^{gov} - B_h^{gov} \right)^2 Q_{h,t+j}^{B,gov} \tag{7}$$

with $\upsilon^{B,gov}$ as a scaling parameter. This approach is based on Gertler and Karadi (2013) and takes arguments from the "preferred habitat" theory of the term structure into account.

Furthermore, households own intermediate goods firms and receive dividend payments ($Div_{h,t}$) at the end of the period from them. Taken together, households earn money from interest payments on their bond and deposit holdings, labor income and the dividends paid by intermediate goods firms. Since the supply of differentiated labor leads to different streams of income, we follow Erceg et al. (2000) and assume that households bought state-contingent securities with a lump-sum transfer. This is to make sure that all agents are able to consume the same amount each period, i.e. to equalize income differences among the continuum of households. Households' expenditures are allotted to consumption, to lump-sum taxes, to lump-sum transfers including payments to entrepreneurs and bank managers, $\Xi_{h,t}$, and to the purchase of financial assets, i.e. public sector bonds, corporate bonds, and deposits.

[16] We introduce long-term bonds mainly because we want to allow government bonds to have a time-varying market price, similar to Gertler and Karadi (2013).

[17] In the following, we mean default-free if we talk about risk-free rates and spreads.

[18] Chen et al. (2012) also allow for a maturity structure. While they use the yield-to-maturity in their model, we draw on the period return.

The budget constraint in real terms becomes

$$
\begin{aligned}
& (1+i_{t-1+j})\frac{B^{n,PS}_{h,t-1+j}}{P_{t+j}} + \left(1+r^{B,gov}_{t+j}\right)\frac{Q^{B,gov}_{t-1+j}B^{n,gov}_{h,t-1+j}}{P_{t+j}} \\
+ \quad & \left(1+r^{D}_{t-1+j}\right)\frac{D^{n}_{h,t-1+j}}{P_{t+j}} + (1-\tau^{w}_{t})\frac{W_{h,t+j}}{P_{t+j}}N_{h,t+j} + \frac{Div_{h,t+j}}{P_{t+j}} + \Xi_{h,t+j} \\
\geq \quad & C_{h,t+j} + T_{t+j} + \frac{D^{n}_{h,t+j}}{P_{t+j}} + \frac{B^{n,PS}_{h,t+j}}{P_{t+j}} + \Theta^{gov,H}_{t},
\end{aligned}
$$

where the superscript n denotes nominal terms.

From the no-arbitrage conditions follow that each household holds the same amount of assets, which is why we can aggregate easily. First-order conditions can be found in the technical appendix.

2.2 Final goods firms

We assume that there is a continuum of intermediate goods producers in a market with monopolistic competition where the i-th firm sells the i-th differentiated good to final goods firms. The final goods sector is characterized by a representative final goods producer that operates under conditions of perfect competition. The final good (Y_t) is a composite of the continuum of differentiated intermediate goods $(\int_0^1 Y_{i,t}{}^{\frac{\theta-1}{\theta}} di)$ purchased from the monopolistic competitive firms in the intermediate goods market (see, for example, Smets and Wouters, 2003). The composite good arises from applying a bundling technology (Dixit-Stiglitz aggregator)

$$
Y_t = \left[\int_0^1 Y_{i,t}{}^{\frac{\theta-1}{\theta}} di\right]^{\frac{\theta}{\theta-1}} \tag{8}
$$

where the parameter θ determines the degree of substitution among the intermediate goods. By taking the prices of the intermediate goods as well as the price of the final good as given, the final goods firm maximizes its profits by choosing the amount of intermediate goods and the amount of output of final goods. From the optimization problem follows the demand function for intermediate goods

$$
Y_{i,t} = Y_t\left(\frac{P_{i,t}}{P_t}\right)^{-\theta} \tag{9}
$$

where P_{it} is the price of the i-th intermediate good and P_t the price of the final good.

2.3 Intermediate goods firms

The intermediate goods firms plan to rent capital $(\widetilde{K}_{i,t})$ from the entrepreneurs and homogeneous labor $(\widetilde{N}_{i,t})$ from the households for use in production. As in standard DNK models, we assume a standard production function of the Cobb-Douglas type with constant returns to scale and fixed costs (Ω)

$$Y_{i,t} = exp\left(A_t\right)\left(\widetilde{K}_{i,t}\right)^{\alpha}\left(\widetilde{N}_{i,t}\right)^{1-\alpha} - \Omega_i, \tag{10}$$

where the term α is the share of capital in production. The term A_t allows for (stationary) shocks on total factor productivity with disturbance ϵ_t^A

$$A_t = \rho^A A_{t-1} + \epsilon_t^A,$$

where ρ^A is an autoregressive parameter. We allow for different types of capital in the production process such that $\widetilde{K}_{i,t} = \left(\widetilde{K}_{i,t1}^A\right)^{\zeta^{ws}}\left(\widetilde{K}_{i,t}^B\right)^{1-\zeta^{ws}}$, where A and B refer to type A and B entrepreneurs and ζ^{ws} is the share of utilized type A entrepreneurs' capital in utilized total capital. We modify the production technology because we later introduce two different debt instruments. For this reason, we will attribute the production of one capital good to one specific debt instrument.[19]

As is well known, the optimization problem each intermediate goods firm faces is twofold. On the one hand, firms minimize their real costs by choosing inputs given their production technology. Thus,

$$\begin{aligned} &\min_{\{\widetilde{K}_{i,t},\widetilde{N}_{i,t}\}} r_t^{k,A}\widetilde{K}_{i,t}^A + r_t^{k,B}\widetilde{K}_{i,t}^B + w_t\widetilde{N}_{i,t} \\ s.t. \qquad Y_{i,t} \;&=\; A_t\left(\left(\widetilde{K}_{i,t}^A\right)^{\zeta^{ws}}\left(\widetilde{K}_{i,t}^B\right)^{1-\zeta^{ws}}\right)^{\alpha}\left(\widetilde{N}_{i,t}\right)^{1-\alpha} - \Omega_i. \end{aligned}$$

The terms $r_t^{k,A}$ and $r_t^{k,B}$ are the cost of capital and w_t is the real wage. The first order conditions for the minimization problem of each intermediate goods firm are presented in the technical appendix from Equations (66) to (69). With their help it can be shown that the ratio of type B entrepreneurs' capital to type A entrepreneurs' capital as well as the capital to labor ratios are the same across all firms.

Since the intermediate goods firms operate in a market with monopolistic competition, they are basically free to set the price optimally given the demand for their goods as presented in Equation (9). Based on Calvo (1983), optimal pricing is only possible with a probability of $1-\gamma$. Furthermore, we assume that the remaining fraction of firms that cannot optimize their price set the price equal to its value last period multiplied by the past rate of inflation (π_{t-1}) which is weighted by the steady state rate of inflation (π).[20]

[19] Fisher (1999) also introduces heterogeneous financially constrained firms and proceeds similarly. In contrast to him, we do not introduce two complete goods producing sectors with fixed input shares and a bundling technology to produce the final good. Instead, we split up the physical stock of capital. Our approach allows us in a sense to endogenize the financing decision in terms of the intermediate goods by varying the capital input.

[20] The price indexation is a combination of the indexation rules in Erceg et al. (2000) and Smets and Wouters (2003) and can also be found in Christiano et al. (2014), whereas we replace the target inflation rate with the steady state rate of inflation.

Consequently, the optimization problem becomes

$$\max_{\{P_{i,t}^*\}} E_t \sum_{j=0}^{\infty} \beta^j \gamma^j \left[Y_{i,t} \left(P_{i,t}^* - mc_{i,t+j} P_{t+j} \right) \right].$$

The optimal price of the intermediate good is denoted by $P_{i,t}^*$ and $mc_{i,t}$ represents the marginal costs. The first-order conditions can be found in the technical appendix.

2.4 Capital producers

The economy is populated by capital producers that are owned by households and work in a market of perfect competition. Capital producers produce two different sorts of capital. By doing so, they combine undepreciated physical capital with investment goods of class e to produce new physical capital of the same class.

$$K_t^e = K_{t-1}^e (1 - \delta^e) + I_t^e \left[1 - \Psi \left(\frac{I_t^e}{I_{t-1}^e} \right) \right] \tag{11}$$

Equation (11) presents the law of motion of capital, where K_t^e is the capital stock, δ^e the rate of depreciation and I_t^e the amount of investment goods. Since adjusting the capital stock involves costs, the term $\Psi \left(\frac{I_t^e}{I_{t-1}^e} \right)$ describes the cost function which is, following Christiano et al. (2005), defined as

$$\Psi \left(\frac{I_t^e}{I_{t-1}^e} \right) = \frac{\upsilon^e}{2} \left(\frac{I_t^e}{I_{t-1}^e} - 1 \right)^2. \tag{12}$$

Capital producers maximize their profits by determining the amount of newly produced investment goods. For convenience, investment goods have the same price as physical capital.

$$\max_{\{I_t^A, I_t^B\}} E_t \sum_{e=A,B} \left(\sum_{j=0}^{\infty} \beta^j Q_{t+j}^e \left[K_{t+j}^e (1 - \delta^e) + I_{t+j}^e \left[1 - \Psi \left(\frac{I_{t+j}^e}{I_{t-1+j}^e} \right) \right] - K_{t+1+j}^e \right] \right).$$

2.5 Entrepreneurs

In reality, it is often the case that access to the financial market is restricted for some kinds of enterprises. The difference in entrepreneurs' size can be seen as one reason why different financial segments are used (see, for instance, Krishnaswami, Spindt, and Subramaniam, 1999). Nevertheless, size-related transaction costs are only one explanation for the varying access to the capital market. In principle, the availability of sufficient public information on creditworthiness mainly explains why firms enter the capital market (see Diamond, 1984; Fama, 1985; Boot and Thakor, 1997 or Denis and Mihov, 2003). Since our aim is to look at different ways of financing debt, we need to introduce two different financial sectors, which is rarely done in the literature. Fisher (1999), for example, introduces heterogeneity in a setting similar to Bernanke et al. (1999) and distinguishes between a financially constrained and an unstrained sector.[21] De Fiore and Uhlig (2012) embed a framework of heterogeneous firms developed in De Fiore and Uhlig (2011) in a general equilibrium model. As opposed to Fisher (1999), all firms have private information, whereas financial intermediaries have different degrees of access to information.[22]

We principally follow Bernanke et al. (1999) and assume that the economy is populated by a continuum of entrepreneurs that buy capital from capital producers and transform the capital into new capital exposed to an idiosyncratic processing risk. After observing the shock, the entrepreneurs rent the capital out to goods producers and receive rents from them. Since the entrepreneurs finance the capital purchases from their own net worth and external funds, the realization of the idiosyncratic shock affects their capacity to service debt (e.g. Bernanke et al., 1999; Christiano et al., 2014).

By introducing two financially constrained firms, our model is closely related to the approaches of Fisher (1999) and De Fiore and Uhlig (2012). We split the continuum of entrepreneurs, with $m \in [0, 1]$, into two groups $e \in [A, B]$ with $A : m \in [0, \varrho)$ and $B : m \in [\varrho, 1]$. Both groups face different degrees of credit constraint because entrepreneurs' creditors have different degrees of insight into shocks to their skills (i.e. to their productivity ω_t^e). The productivity shock on type A entrepreneurs' skills ω_t^A can be observed by paying a fixed fraction μ^A of the amount that can be recovered in the case of a default. Similarly, the productivity process of the type B entrepreneurs ω_t^B is not exclusive to the borrowers. However, it can only be discovered paying a greater fraction μ^B, with $\mu^B > \mu^A$, of the realizable assets. Since monitoring type B entrepreneurs is more costly than monitoring type A entrepreneurs, the former will solely rely on bank finance, while the latter issue bonds in the capital market, which is basically in line with De Fiore and Uhlig (2011).[23] Both entrepreneurs are modeled in accordance with BGG with the possibility of a steady state default, whereas the default risk of a type B entrepreneur is greater than for a type A entrepreneur.[24]

[21]In his model, the continuum of firms consists of two groups: one which has private information on their shock and one which shares the same information set with the financial intermediaries. Hence, the first group is credit constrained because lenders are confronted with a costly state verification problem (CSV) while the second group is unconstrained.

[22]De Fiore and Uhlig (2011) introduce three different shocks to the productivity of goods producers. The first shock is common knowledge, while the second can only be observed in relation to costs. Finally, the third shock is private. Each shock plays its own role. While the first shock introduces heterogeneity across firms, the second justifies the existence of a bank. The last shock is important for the credit constraint.

[23]In our model, each group makes use of only one specific form of debt finance. This is basically similar to De Fiore and Uhlig (2011).

[24]For the sake of simplicity, we could call our two types of entrepreneur "small" (B) and "large" (A), although this distinction does not follow from their individual net worth, i.e. the net worth of the smallest entrepreneur in the A-group is not necessarily greater than that of the largest in the B-group. The labeling of the entrepreneurs would be arbitrary. We could have also defined one group "high-risk" and another group "low-risk" entrepreneurs (see, for instance, Bolton and Freixas, 2000) but we do not want to stress the difference in risk too much. A more severe conceptual assumption is that there is no transition between the groups. However, Levy and Hennessy (2007) also work with an ad hoc assumption concerning the distinction between two types of firms. In their model, endowment issues are relevant for the decision between equity and debt finance. The same is true for Fisher (1999) who makes an ad hoc assumption concerning credit constrained and unconstrained firms. Although the decision process is endogenized to a higher extent, each firm in De Fiore and Uhlig (2011, 2012) relies on one type of financing in the end. Nevertheless, our assumption is rather ad hoc but could be relaxed in a further

For capital processing, the entrepreneurs' individual skills are of importance and the entrepreneurs decide on the capital utilization ($u^e_{m,t}$), which can be varied. The skills of both type A and B entrepreneurs are subject to idiosyncratic shocks which affect the physical properties of the capital. These shocks $\omega_{m,t}$ are drawn from a lognormal distribution with unit mean and are independent over time and across entrepreneurs. For the m-th entrepreneur, we obtain the amount of processed capital $\hat{K}^e_{m,t}$

$$\hat{K}^e_{m,t} = \omega^e_{m,t} K^e_{m,t}. \tag{13}$$

Both types of entrepreneur finance the capital purchases with their own net worth ($NW^e_{m,t+1}$) and external funds $\left(L^e_{m,t+1}\right)$

$$L^e_{m,t+1} = Q^e_t K^e_{m,t+1} - NW^e_{m,t+1} \tag{14}$$

where Q^e_t is the real price of entrepreneurs' capital. For type A entrepreneurs, this means that they borrow from the capital market, proxied by mutual funds, the difference between the value of their desired capital investment and their own net worth by issuing bonds $B_{m,t}$ at real price $Q^{B,corp}_t$, i.e. $L^A_{m,t+1} = Q^{B,corp}_t B_{m,t+1}$. Type B entrepreneurs obtain loans $\left(L^e_{m,t+1} = L_{m,t+1}\right)$ from banks.

For the case where the value of the project is exactly equal to the debt service, we can define $\overline{\omega}^e_{m,t+1}$ as a productivity threshold for which the borrower is just able to satisfy the debt contract

$$\overline{\omega}^{e,ex\,ante}_{m,t+1} \left(1 + E_t\left(R^{k,e}_{m,t+1}\right)\right) Q^e_t K^e_{m,t+1} = Z^e_{t+1} L^e_{m,t+1}, \tag{15}$$

with Z^e_{t+1} as the gross contract rate. We depart from the original BGG model and do not assume that the contract rate is state-contigent, which means that the contract is signed before the shocks materialize. Thus, we follow slightly Benes and Kumhof (2011) and Zhang (2009) and replace the realized capital return by the expected capital return. This timing convention proxies reality more closely, particularly for bank financing, and allows for unexpected defaults in the period of the shocks. As a consequence, the productivity threshold must be understood as an *ex ante* value. Given the expected gross return of the project and its value as well as the borrowed amount, this threshold is linked to the default-free risky bond rate. Equation (15) accordingly characterizes the optimal contract. Since the contract is negotiated based upon the expected capital return, we have to distinguish between ex ante and ex post thresholds. After the shock has occurred, the realized (gross) capital return emerges as

$$1 + R^{k,e,\omega}_{m,t} = \pi_t \frac{\left(r^{k,e}_{m,t} u^e_t - \Gamma(u^e_{m,t})\right) + Q^e_t(1-\delta^e)}{Q^e_{t-1}} \omega^e_{m,t} = (1 + R^{k,e}_{m,t})\omega^{e,ex\,post}_{m,t}. \tag{16}$$

For the entrepreneur, there automatically arise two different scenarios in terms of debt service. If the realized idiosyncratic shock is greater than (or equal to) the ex post threshold, he will be able to repay his debt as contractually agreed and keep the difference as net earnings. However, a realization of the shock that is below the ex post threshold level results in a default, and the entrepreneur has to liquidate the remaining amount

extension of the model.

completely in order to satisfy its lenders. As a consequence, the shock also affects the realized return on capital, as denoted by $R^{k,e}_{m,t}$ and given in Equation (16). Thus, the ex post productivity threshold $\left(\overline{\omega}^{e,ex\,post}_{m,t+1}\right)$, below which defaults occur, turns out to be

$$\overline{\omega}^{e,ex\,post}_{m,t+1} = \frac{Z^e_{t+1} L^e_{m,t+1}}{\left(1 + R^{k,e}_{m,t+1}\right) Q^e_t K^e_{m,t+1}} \tag{17}$$

with variables as already defined (see, for instance, Zhang, 2009).[25]

Based upon these considerations, the expected earnings of the m-th entrepreneur $(\mathcal{E}^e_{m,t})$ can be calculated based upon the expected capital return and the ex ante productivity threshold as

$$\mathcal{E}^e_{m,t} = E\left\{\left(\begin{array}{c} \int_{\overline{\omega}^{e,ex\,ante}_{m,t+1}}^{\infty} \omega^e dF\left(\omega^e; \sigma^e_t\right) \\ -\left[1 - F\left(\overline{\omega}^{e,ex\,ante}_{m,t+1}; \sigma^e_t\right)\right] \overline{\omega}^{e,ex\,ante}_{m,t+1} \end{array}\right)\left(1 + R^{k,e}_{t+1}\right) Q^e_t K^e_{m,t+1}\right\}.$$

The first term on the right-hand side characterizes the expected earnings from the project by taking all realizations for $\omega^e_{m,t+1} \geq \overline{\omega}^{e,ex\,ante}_m$ into account, and the second term on the right-hand side reflects the payments to satisfy the debt contract. For $\omega^e_{m,t+1} < \overline{\omega}^{e,ex\,ante}_m$, the entrepreneur would be left with no earnings. The function $F\left(\omega^e_{m,t+1}; \sigma^e_t\right)$ in Equation (18) is the cumulative density function for realization of ω^e_m which means that its value for $\overline{\omega}^{e,ex\,ante}_m$ is the related ex ante default probability. The standard deviation σ^e_t of the distribution can be time-varying, i.e. deviating from its steady state value σ^e, and obeys an i.i.d. stochastic process where the variance of log ω is σ^2_t and ρ^σ is an autoregressive parameter

$$log\left(\sigma^e_t\right) = \left(1 - \rho^\sigma\right) log\left(\sigma^e\right) + \rho^\sigma log\left(\sigma^e_{t-1}\right) + \epsilon^{fin}_t.$$

A time-varying standard deviation gives rise to the possibility of a "financial risk shock" $\left(\epsilon^{fin}_t\right)$, which increases the range of realizations of the shocks (see, for instance, Christiano et al. (2014)). The financial risk shock affects both entrepreneurs simultaneously.

Entrepreneurs' net worth $(NW^e_{m,t})$ arises from two sources: the net value $(NV^e_{m,t})$ of the project and transfers from households (w^e_m). In order to prevent entrepreneurs from accumulating net worth indefinitely, which would make external funding unnecessary, we follow BGG and assume that in each period entrepreneurs leave the market with a given probability of $1 - p^e$ and are exactly replaced by new entrepreneurs just endowed with households' transfers to keep the population of entrepreneurs stable. For the evolution of net worth we obtain

$$NW^e_{m,t+1} = p^e NV^e_{m,t} + w^e_m. \tag{18}$$

The optimal bond contract for the lenders reveals that the lenders want to earn as much as they receive by investing in a risk-free asset. That is the reason why lenders' opportunity costs must be equal to the risk-free rate. Where the idiosyncratic shock exceeds the cut-off value, the lender receives the contractual interest payments. The converse probability of the default probability at the cut-off value of the shocks yields the probability of contractual payments. For the range of realizations of the shocks that are below the ex ante cut-off value $\overline{\omega}^{e,ex\,ante}_m$, the assets of the borrower are expected to be

[25] Note that the realized rate of return enters Equation (17).

liquidated in order to partly redeem the debt contract. Before collecting the remaining assets, the lender has to observe the state of the borrower. Information is asymmetrically distributed, however. While the entrepreneur can always assess its situation, the financial intermediary cannot observe the state of the entrepreneur at no charge. As a consequence, the creditor has to pay transaction costs, which lower its repayments in the case of a default. It is assumed that the transaction costs are proportional to the realizable assets. These considerations are summarized in Equation (19)

$$\begin{aligned} & \left[1 - F\left(\overline{\omega}^{e,ex\,ante}_{m,t+1}; \sigma^e_t\right)\right] Z^e_{m,t+1} L^e_{m,t+1} \\ & + (1-\mu^e) \int_0^{\overline{\omega}^{e,ex\,ante}_{m,t+1}} \omega^e \left(1 + E_t\left(R^{k,e}_{t+1}\right)\right) Q^e_t K^e_{m,t+1} dF\left(\omega^e; \sigma^e_t\right) \\ = \; & (1 + r^e_t) L^e_{m,t+1} \end{aligned} \tag{19}$$

with $r^A_t = E_t\left(r^{B,corp}_{t+1}\right)$ and $r^B_t = r^L_t$. While the current risk-free loan rate r^L_t enters the participation constraint for the type B entrepreneur, the expected (risk-free) bond return $E_t\left(r^{B,corp}_{t+1}\right)$, which is defined as

$$r^{B,corp}_t = \pi_t \left(\frac{\rho^{B,corp} Q^{B,corp}_t + i^{corp}_0 - \frac{\Upsilon^{B,e}_t}{Q^{B,corp}_{t-1} B^{corp}_{h,t-1}}}{Q^{B,corp}_{t-1}} \right) - 1, \tag{20}$$

becomes relevant in intermediaries' participation constraint for the type A entrepreneurs. As with government bonds, we allow for long-term bonds with a specific maturity structure, which is modeled according to Woodford (2001) with maturity parameter $\rho^{B,corp}$.[26] While $Q^{B,corp}_t$ is the price of the bond, i^{corp}_0 denotes fixed coupon payments. Regarding the loan contract of type B entrepreneurs, the loan rate is not state-contingent. For the bond rate, the same is, in principle, true although it only holds for expected terms. What can be seen in Equation (20) is that, as long as the default is not unexpected, its costs are taken into account in bond pricing. Nevertheless, the contract is written before the productivity shock on ω^A is realized, i.e. before the capital return is known. As a consequence of the non-state contingent nature of the contracts, deviations of the realized capital return from its expected value matter to debt servicing capacity (see Equation (17)) and, therefore, affect intermediaries' return. From this setting it follows that financial intermediaries face ex post losses $\left(\Upsilon^{B,e}_t\right)$ that can cannot be completely diversified ex ante (as is assumed in the original BGG setting). These ex post losses are defined as

$$\Upsilon^{B,e}_t = \begin{array}{c} \left(F(\omega^{e,ex-post}_t) - F(\omega^e_{t-1})\right) Z^e_{t-1} L^e_{t-1} \\ + \left(1 - \mu^{f,e}\right) \left(\begin{array}{c} K^e_{t-1} Q^e_{t-1} G(\omega^e_{t-1}) \left(1 + E_{t-1}(R^{k,e}_t)\right) \\ -K^e_{t-1} Q^e_{t-1} \left(1 + R^{k,e}_t\right) G(\omega^{e,ex-post}_t) \end{array} \right) \end{array}. \tag{21}$$

which is similar to Benes and Kumhof (2011). Ex post losses can occur if the realization of the shock leaves the realized capital return below its expected value so that the risky

[26] See Kühl (2014) for the implications of introducing bonds with a maturity into the BGG approach.

contract rate is not sufficient to compensate the intermediaries for all defaults. The losses can be split up into two parts: the additional losses, because the realized default rate $F(\overline{\omega}_t^{e,ex\,post})$ is above its ex ante value $F(\overline{\omega}_t^{e,ex\,ante})$ (upper line on the right-hand side in Equation (21)), and the reduced amount of realizable assets through defaults (lower line on the right-hand side in Equation (21)).

Each entrepreneur maximizes its expected profits from Equation (18) by choosing the amount of capital and the cut-off point given the corresponding intermediaries' expected zero-profit conditions as presented in Equation (19).[27]

In an environment with a contract period of one period, the net value is equivalent to net earnings, which are simply the earnings net of the costs of the credit. Hence, we obtain for the aggregated net value

$$\begin{aligned} NV_t^e \;=\; & \frac{1}{\pi_t}\Bigg[\left(1+R_t^{k,e}\right)Q_{t-1}^e K_t^e \\ & -\left((1+r_t^e)+\frac{\mu\int_0^{\overline{\omega}^{e,ex\,post}}\omega dF\left(\omega;\sigma_t\right)\left(1+R_t^{k,e}\right)Q_{t-1}^e K_t^e}{Q_{t-1}^e K_t^e - NW_t^e}\right)\left(Q_{t-1}^e K_t^e - NW_t^e\right)\Bigg], \end{aligned} \tag{22}$$

where we have made use of the aggregated version of Equation (18). In conjunction with Equation (18) and the omission of indexes, we obtain the aggregated law of motion for the entrepreneurs' net worth. In order to be compensated ex ante for default costs, the creditors add them to the risk-free rate as a fixed proportion (μ^e) of realizable assets.

After processing the capital with the help of individual skill, the entrepreneurs decide on capital utilization, which entails costs in the form of

$$\Gamma(u_{m,t}^e) = \frac{r^{k,e}}{\psi^{k,e}}\left(\exp\left[\psi^{k,e}\left(u_{m,t}^e - 1\right)\right] - 1\right). \tag{23}$$

The aggregate amount of physical capital distributed to the intermediate goods sector, after the second stage is accomplished, is obtained by aggregating over the distribution of the productivity shock and over the continuum of entrepreneurs.

$$\hat{K}_{t+1} = \int_0^{\varrho}\int_0^{\infty} u_{m,t}\omega K_{m,t} dF\left(\omega\right) f(m)dm + \int_{\varrho}^{0}\int_0^{\infty} u_{m,t}\omega K_{m,t} dF\left(\omega\right) f(m)dm = u_t K_t. \tag{24}$$

Equation (24) shows that shocks to entrepreneurs' skills do not matter for the economy as a whole because the idiosyncratic risk can be diversified perfectly and the utilization rate is identical across all entrepreneurs.

[27]An important difference between the original BGG setting and our setting is that the intermediaries expect zero profits in our model, while in the BGG model zero profits hold every period (see, for instance, Benes and Kumhof, 2011).

2.6 Financial intermediaries

2.6.1 Mutual funds

Mutual funds are introduced to proxy the capital market. This idea is lent on Bernanke et al. (1999) and Christiano et al. (2014). Our mutual funds serve as intermediaries that channel funds from banks, rent them out by buying bonds from type A entrepreneurs and operate on zero profits. Our main objective is to model the linkage between the issuance of bonds and the financing by banks. In a decentralized market structure, different banks could earn different ex post returns (see Equation (15)) because some banks hold bonds issued by entrepreneurs that do not default, while some have purchased bonds from entrepreneurs that do. By introducing mutual funds, we easily circumvent this problem because we assume that mutual funds manage the market portfolio. Indeed, they are of no economic importance given the property of (expected) zero-profits as a by-product of entrepreneurs' optimizing problem, which we discussed in the previous section. Because of the non-state contingency we have introduced, ex post losses can occur that cannot be diversified away. We simply assume that these losses are redistributed to the bond holders via a reduced pay-off.

2.6.2 Banking sector

Since households cannot provide funds to the entrepreneurial sector directly, we introduce a banking sector, which is basically lent on Gertler and Kiyotaki (2010) and Gertler and Karadi (2011). Our economy is populated by a continuum of lending banks n with $n \in [0, 1]$. In addition to loans the lending banks can grant to type B entrepreneurs directly, they also buy (corporate) bonds issued by type A entrepreneurs.[28] In addition, each lending bank buys government bonds. Hence, each n-th lending bank holds three assets and the total assets $A^B_{n,t}$ evolves as

$$A^B_{n,t} = L_{n,t} + Q^{B,corp}_t B^{corp}_{n,t} + Q^{B,gov}_t B^{gov}_{n,t} . \tag{25}$$

Following the arguments outlined in the previous sections, the loan rate r^L_t is negotiated before the shocks are realized such that it becomes non-state contingent. As a result, ex post defaults can occur, which must be borne by the lending bank. In the corporate bond market, unexpected losses materialize in the ex post period return $r^{B,corp}_t$ as a result of unexpected changes in the price of the corporate bonds (see again Equation (20)). Government bonds have a return of $r^{B,gov}_t$. The return on total assets before losses on loans results as

$$r^A_t = \left(1 + r^L_{t-1}\right) \frac{L_{n,t-1}}{A^B_{n,t-1}} + \left(1 + r^{B,corp}_t\right) \frac{Q^{B,corp}_{t-1} B^{corp}_{n,t-1}}{A^B_{n,t-1}} + \left(1 + r^{B,gov}_t\right) \frac{Q^{B,gov}_{t-1} B^{gov}_{n,t-1}}{A^B_{n,t-1}} - 1. \tag{26}$$

Goodfriend and McCallum (2007) argue that the production of loans can be associated with costs that result from monitoring. Although monitoring costs are already taken into

[28] Notice that they do not buy bonds directly from type A entrepreneurs. More precisely, they buy bonds from mutual funds which in turn hold bonds issued by type A entrepreneurs. For the sake of simplicity, we argue that lending banks buy bonds from entrepreneurs but technically the funds are intermediated by mutual funds.

account through the BGG approach, giving loans to the non-financial sectors might be associated with sales costs.[29] Consequently, we attribute costs $\Theta^L_{n,t}$ to the issuance of loans relative to bank's balance sheet

$$\Theta^L_{n,t} = \frac{\kappa^L}{2}\left(1 - \varsigma^{B,corp}_{n,t} - \varsigma^{B,gov}_{n,t}\right)^2 \tag{27}$$

with $\varsigma^{B,corp}_{n,t} = \frac{Q^{B,corp}_t B^{corp}_{n,t}}{A^B_{n,t}}$, $\varsigma^{B,gov}_{n,t} = \frac{Q^{B,gov}_t B^{gov}_{n,t}}{A^B_{n,t}}$ and κ^L is a scaling parameter. In the same vein, holdings of corporate bonds might entail costs which are similarly captured by

$$\Theta^{B,corp}_{n,t} = \frac{\kappa^{B,corp}}{2}\left(\varsigma^{B,corp}_{n,t}\right)^2. \tag{28}$$

This formulation is similar to Kirchner and van Wijnbergen (2012), who attribute costs to holdings of securities. However, we define the costs in shares and not in deviations from a desired level.[30] Looking at funding, the bank borrows from households at the rate r^D_t.[31]

In addition to debt, the lending bank can build up inside equity $E^I_{n,t}$ by retaining earnings. Thus, the balance sheet constraint becomes

$$L_{n,t} + Q^{B,corp}_t B^{corp}_{n,t} + Q^{B,gov}_t B^{gov}_{n,t} = E^I_{n,t} + D_{n,t}. \tag{29}$$

Taking all costs together, the overall costs arise as $\Theta_{n,t} = \Theta^L_{n,t} + \Theta^{B,corp}_{n,t}$. Regarding the costs the lending banks have to bear, we follow Kirchner and van Wijnbergen (2012) and express the costs in terms of inside equity. With this information at hand, we can define the law of motion for inside equity that is written in real terms, while financial assets are denominated in nominal terms

$$\begin{aligned} E^I_{n,t} &= \left(1 + r^L_{t-1}\right) L_{n,t-1}\frac{1}{\pi_t} + \left(1 + r^{B,corp}_t\right) Q^{B,corp}_{t-1} B^{corp}_{n,t-1}\frac{1}{\pi_t} \qquad (30)\\ &+ \left(1 + r^{B,gov}_t\right) Q^{B,gov}_{t-1} B^{gov}_{n,t-1}\frac{1}{\pi_t} \\ &\quad - \left(1 + r^D_{t-1}\right) D_{n,t-1}\frac{1}{\pi_t} - \Theta_{n,t-1}E^I_{n,t-1}\frac{1}{\pi_t} + E^{I,gov}_{n,t} - \Upsilon_{n,t} \\ &= R^A_t A^B_{n,t-1}\frac{1}{\pi_t} - R^D_{t-1} D_{n,t-1}\frac{1}{\pi_t} - \Theta_{n,t-1}E^I_{n,t-1}\frac{1}{\pi_t} + E^{I,gov}_{n,t} - \Upsilon_{n,t}. \qquad (31) \end{aligned}$$

Here, we deviate from Gertler and Karadi (2011) who discuss real assets.[32] The term $E^{I,gov}_{n,t}$ in Equations (30) and (31) captures capital injections by a public agent, while $\Upsilon_{n,t}$ comprises losses from the loan portfolio and costs for equity injections, i.e. $\Upsilon_t = \Upsilon^A_t + i_{t-1}E^{I,gov}_{t-1}/\pi_t$, where we assume that banks have to pay the risk-free rate for equity injections. Equation (31) simplifies Equation (30) by summarizing all assets $A^B_{n,t}$ and liabilities $D_{n,t}$ in conjunction with the corresponding gross rates R^A_t and R^D_t.

In the setting described by Gertler and Kiyotaki (2010) or Gertler and Karadi (2011),

[29] A similar argument is also taken into account by Cúrdia and Woodford (2011).

[30] This approach prevents corner solutions and preserves determinacy.

[31] Because of the formulation of the bank, these loans comprise both deposits and bank bonds. From this point of view, the interest rate is an "average" rate on bank's debt.

[32] In this context, they consider real bonds which are completely hedged against inflation.

the lending banks maximize the present value of their net worth, i.e. the value of the bank $V_{n,t}$, i.e. the discounted sum of retained earnings (inside equity in our model). In our case, the bank managers would choose $L_{n,t}$, $B^{corp}_{n,t}$, $B^{gov}_{n,t}$, and $D_{n,t}$ optimally.

$$V_{n,t} = \max_{\left\{L_{n,t}, B^{corp}_{n,t}, B^{gov}_{n,t}, D_{n,t}\right\}} E_t \sum_{i=0}^{\infty} \left(1 - p^{BM}\right) \left(p^{BM}\right)^{i+1} \Lambda_{t,t+1+i} E^{I}_{n,t+1+i} \tag{32}$$

As explained in Section 2.1, a fraction s^{BM} of household members becomes bank managers. While they operate a lending bank, they accumulate wealth by retaining earnings. However, it is not guaranteed that they will remain bank managers forever; the probability of being a bank manager is p^{BM}. Only when bank managers leave the lending bank do they transfer the rest of their wealth back to the households. Thus, the term $\left(1 - p^{BM}\right)$ in Equation (32) reflects this transfer, while $\Lambda_{t,t+1}$ is the bank specific discount factor which is households' pricing kernel $\beta\frac{\lambda_{t+1}}{\lambda_t}$.

In section 2.5, we have already described the agency problem between the real sector and the financial sector. In Gertler and Karadi (2011), this relationship is completely free from financial frictions. However, there are financial frictions between the banks and their creditors in their model. We additionally adapt this approach and consequently introduce two different channels of financial frictions because of two-sided financial contracting: between the real sector and the financial sector and between the banks and their creditors.[33] With respect to the former, we utilize a costly state verification problem in the vein of BGG, as already outlined. In the latter case, we lean on Gertler and Kiyotaki (2010) and assume that bank managers can divert part of the bank's resources and redistribute the money back to households rather than paying it back to creditors. Like Rannenberg (2013), we combine a BGG-type problem with a GK-type problem.[34] An advantage of this approach is that we are able to investigate the different frictions separately by abstracting from a risky bank environment.[35]

GK-type financial frictions aim at a moral hazard/costly enforcement problem between borrowers and lenders. The borrower, i.e. the bank, is not willing to meet its obligations completely in each period. If the borrower unilaterally reduces its pay-off and does not discharge all payment obligations, the lender can initiate bankruptcy proceedings against the borrower. However, the fraction θ^{IC} of available funds that may have been diverted cannot be recovered because of high enforcement costs. Hence, the lenders only retrieve the fraction $1 - \theta^{IC}$ of available funds. As a result, the lenders will only give funds to the bank if the value of the bank is sufficient to guarantee the repayment of funds net of diversion. Thus, the incentive constraint of the lenders becomes

$$V_{n,t} \geq \theta^{IC} A^{B}_{n,t}. \tag{33}$$

The left-hand side of Equation (33) is net worth (discounted sum of expected inside equity) as defined in Equation (32), while the right-hand side comprises the amount of diversion.

[33]This setting is basically similar to Hirakata et al. (2013), Meh and Moran (2010), Sandri and Valencia (2013), and Zeng (2013).

[34]Looking at the financial sector, the main difference between the model in Rannenberg (2013) and ours is that we allow for the bank to have a more sophisticated balance sheet.

[35]The treatment of risky banks would require either an insurance mechanism or the need to deal with bank runs.

Thus, Equation (32) is maximized subject to Equation (33).

Regarding the optimization problem, we follow Kirchner and van Wijnbergen (2012) and assume that it can be divided into one main problem and one sub-problem. At the first level, the bank managers decide on total assets, while portfolio managers decide on the composition of the assets at the second level.

Bank managers In order to solve the optimization problem at the first stage, we follow Gertler and Kiyotaki (2010) and obtain an expression for the value function that is linear in quantities.

$$\begin{aligned} V_{n,t} &= \upsilon_t^A A_{n,t}^B - \upsilon_t^D D_{n,t} - \upsilon_t^{IE} E_{n,t}^I + \eta_{n,t}^{OE,gov} - \eta_{n,t}^A \\ &= (\upsilon_t^A - \upsilon_t^D) A_{n,t}^B + (\upsilon_t^D - \upsilon_t^{IE}) E_{n,t}^I + \eta_{n,t}^{IE,gov} - \eta_{n,t}^A \end{aligned} \tag{34}$$

After optimizing Equation (34) subject to Equation (33), we get the first order conditions

$$A_{n,t}^B : (\upsilon_t^A - \upsilon_t^D) = \frac{\lambda_t^{IC} \theta^{IC}}{1+\lambda_t^{IC}} \tag{35}$$

and

$$\lambda_t^{IC} : \left(\upsilon_t^A - \upsilon_t^D\right) A_{n,t}^B + \left(\upsilon_t^D - \upsilon_t^{IE}\right) E_{n,t}^I + \eta_{n,t}^{IE,gov} - \eta_{n,t}^A \geq \theta_t^{IC} A_{n,t}^B. \tag{36}$$

With the help of the method of undetermined coefficients, we can deduce values for the unknown parameters in Equation (34)

$$\upsilon_t^A = E_t \left(\Lambda_{t,t+1} \Omega_{t+1} R_t^A \frac{1}{\pi_{t+1}} \right), \tag{37}$$

$$\upsilon_t^D = E_t \left(\Lambda_{t,t+1} \Omega_{t+1} R_t^D \frac{1}{\pi_{t+1}} \right), \tag{38}$$

$$\upsilon_t^{IE} = E_t \left(\Lambda_{t,t+1} \Omega_{t+1} \Theta_{n,t} \frac{1}{\pi_{t+1}} \right), \tag{39}$$

$$\eta_{n,t}^{IE,gov} = E_t \Lambda_{t,t+1} \left(\Omega_{t+1} E_{n,t}^{I,gov} + \left(1 + \lambda_{t+1}^{IC}\right) \eta_{n,t+1}^{IE,gov} \right), \tag{40}$$

$$\eta_{n,t}^A = E_t \Lambda_{t,t+1} \left(\Omega_{t+1} \Upsilon_{n,t} + \left(1 + \lambda_{t+1}^{IC}\right) \eta_{n,t+1}^A \right) \tag{41}$$

with

$$\Omega_t = \left(\left(1 - p^{BM}\right) + p^{BM} \left(1 + \lambda_t^{IC}\right) \left(\upsilon_t^D - \upsilon_t^{IE}\right) \right) \tag{42}$$

and are able to find an economic interpretation for the first order conditions.[36] Equation (37) is the expected discounted marginal return of one additional unit of assets, while Equation (38) represents the expected discounted marginal costs of one additional unit of external funds. Equation (39) gives the expected discounted marginal costs of holding entrepreneurial and government bonds. The variable $\eta_{n,t}^{IE,gov}$ in Equation (40) is the expected discounted gain from an additional unit of external capital injections conducted by a government institution, i.e. the gain from the recapitalization of the bank. As explained above, the bank can suffer losses from its holdings of assets and potentially has to pay for the capital injections; the term $\eta_{n,t}^A$ in Equation (41) reflects these facts and represents the expected discounted costs.

[36] Derivations can be found in the appendix.

Consequently, Equation (35) states that the net marginal profits on one additional unit of assets must be equal to the costs related to diversion. The variable λ_t^{IC} is the Lagrange multiplier and signifies how much the incentive constraint binds. The second first order condition, as presented in Equation (36), says that the gain from extending the balance sheet must be greater than or equal to the additional incentive to divert. It holds with equality if the shadow price of the incentive constraint is positive.[37] By combining both first order conditions, total assets can be expressed as a function of inside equity by taking government's recapitalization and losses from the loan portfolio into account (Equation (43)).

$$A_{n,t}^B = \phi_{n,t}^{IE} E_{n,t}^I + \phi_{n,t}^{\eta} (\eta_{n,t}^{IE,gov} - \eta_{n,t}^A) \tag{43}$$

with

$$\phi_{n,t}^{IE} = \frac{\lambda_t^{IC} \left(\upsilon_t^D - \upsilon_t^{IE} \right)}{\upsilon_t^A - \upsilon_t^D}, \tag{44}$$

$$\phi_{n,t}^{\eta} = \frac{\lambda_t^{IC}}{\upsilon_t^A - \upsilon_t^F}. \tag{45}$$

As opposed to Gertler and Karadi (2011), for instance, the variable $\phi_{n,t}^{IE}$ is not the leverage ratio in our model; rather it is a gross leverage ratio before taking government interventions and losses into account.

Portfolio managers After having determined total assets, portfolio managers decide on the composition of assets. To find the optimal values, the law of motion for inside equity can be rewritten with the help of the definitions outlined above.

$$\begin{aligned} E_{n,t+1}^I = & R_t^L \left(1 - \varsigma_{n,t}^{B,corp} - \varsigma_{n,t}^{B,gov} \right) A_{n,t}^B \frac{1}{\pi_{t+1}} + E\left(R_{t+1}^{B,corp} \right) \varsigma_{n,t}^{B,corp} A_{n,t}^B \frac{1}{\pi_{t+1}} \\ & + E\left(R_{t+1}^{B,gov} \right) \varsigma_{n,t}^{B,gov} A_{n,t}^B \frac{1}{\pi_{t+1}} - R_t^D A_{n,t}^B \frac{1}{\pi_{t+1}} - \Theta_{n,t} E_{n,t}^I \frac{1}{\pi_{t+1}} + E_{n,t+1}^{I,gov} - \Upsilon_{n,t+1} \end{aligned} \tag{46}$$

In Equation (46), the value for inside equity available in period $t+1$ is expressed in terms of total assets and inside equity. Since portfolio managers have the same objective as bank managers, the optimization problem is aimed at maximizing inside equity. The difference is that bank managers evaluate the present and the future, from which the total asset position results, while portfolio managers optimize each period given total assets. Thus, portfolio managers choose $\varsigma_{n,t}^{B,corp}$ and $\varsigma_{n,t}^{B,gov}$ optimally. From the maximization problem, we obtain first order conditions that can be rewritten such that

$$\left(E\left(R_{t+1}^{B,corp} \right) - R_t^L \right) \frac{A_{n,t}^B}{E_{n,t}^I} = \kappa^{C,corp} \varsigma_{n,t}^{B,corp} - \kappa^{C,L} \varsigma_{n,t}^L, \tag{47}$$

and

$$\left(R_t^L - E\left(R_{t+1}^{B,gov} \right) \right) \frac{A_{n,t}^B}{E_{n,t}^I} = \kappa^{C,L} \varsigma_{n,t}^L \tag{48}$$

[37] See, for an economic interpretation, Kirchner and van Wijnbergen (2012), for example.

arise. From Equation (47) it is clear that there is a positive relationship between the spread between the expected return of corporate bonds and the loan rate and the share of corporate bonds corrected by the share of loans. All else being equal, an increase in the spread between the expected rate of return on corporate bonds and the loan rate raises the share of corporate bonds in banks' assets. A similar relationship exists for the spread between the loan rate and the expected return on government bonds. If loans earn more money than government bonds per unit of leverage, the loan position is increased.

Aggregation By starting with the link between inside equity and the sum of assets (Equation (43)), we can rewrite this expression to obtain

$$\frac{A^B_{n,t}}{E^I_{n,t}} = \frac{\upsilon^D_t - \upsilon^{IE}_t}{\theta^{IC} - \frac{\eta^{IE,gov}_{n,t}}{A^B_{n,t}} + \frac{\eta^A_{n,t}}{A^B_{n,t}} - (\upsilon^A_t - \upsilon^D_t)} = \widetilde{\phi}^{IE}_{n,t}. \tag{49}$$

As one can see in Equation (49), the leverage ratio $\widetilde{\phi}^{IE}_{n,t}$ is equal to all individuals if the terms $\frac{\eta^{IE,gov}_{n,t}}{A^B_{n,t}}$ and $\frac{\eta^A_{n,t}}{A^B_{n,t}}$ are identical to all lending banks. One necessary condition for this to hold is that the Lagrangian multiplier for the enforcement constraint is identical across all individuals which is the case as long as the assets can be completely diverted to the same extent across individuals, as one can see in Equation (35). Departing from Equations (40) and (41), it is easy to show by forward iteration and the validity of the transversality condition that the two terms are (nearly) identical to all individuals in the neighborhood of the steady state, i.e. as long as the sum of assets does not vary to much.[38] Thus, we can drop the indexes in Equation (49).

Knowing that the leverage ratio $\frac{A^B_t}{E^I_t}$ is identical to all lending banks, we see from the first order conditions resulting from portfolio managers' maximization problem that the share of loans depends solely on the spread between the loan rate and the expected return on government bonds and is consequently identical to all individuals. Knowing the share of loans in banks' portfolio, it can be shown with the help of Equation (47) that the share of corporate bonds is also free from individual characteristics. Hence, the portfolio composition is the same across all lending banks. Thus, aggregation of quantities across the individuals can simply be conducted by integration.

For the sum of assets we get $A^B_t = \int_0^1 A^B_{n,t} dn = \widetilde{\phi}^{IE}_t \int_0^1 E^I_{n,t} dn = \widetilde{\phi}^{IE}_t E^I_t$ and for each asset class $L_t = \int_0^1 L_{n,t} dn = \zeta^L_t \widetilde{\phi}^{IE}_t E^I_t$, $Q^{B,corp}_t B^{corp}_t = \int_0^1 Q^{B,corp}_t B^{corp}_{n,t} dn = \zeta^{B,corp}_t \widetilde{\phi}^{IE}_t E^I_t$, and $Q^{B,gov}_t B^{gov}_t = \int_0^1 Q^{B,gov}_t B^{gov}_{n,t} dn = \zeta^{B,gov}_t \widetilde{\phi}^{IE}_t E^I_t$ respectively. The aggregation of liabilities works similarly and the aggregate amount of external finance evolves as $D_t = \left(\widetilde{\phi}^{IE}_t - 1\right) \int_0^1 E^I_{n,t} dn$.

Regarding inside equity, the aggregate amount can be split up. Since a fraction of bank managers resign, bank managers continue to operate a lending bank with probability p^{BM}. While the exiting bank managers' inside equity is no longer available, the remaining inside equity is a fraction of aggregate inside equity

$$E^{I,old}_t = p^{BM} E^I_t.$$

[38] This is a conventional assumption particularly in models that work with collateral constraints, see Iacoviello (2005), for instance.

New bank managers fill the gap created by the exit of old bank managers and enter the market in order to start operating a lending bank. From their households they obtain an endowment with which inside equity is built up

$$E_t^{I,new} = \gamma^{BM} R_t^A A_{t-1}^B \frac{1}{\pi_t}$$

that is a fraction γ of assets. Consequently, aggregate inside equity is the sum of both components

$$E_t = E_t^{I,old} + E_t^{I,new}$$

and the law of motion for aggregate net worth becomes

$$\begin{aligned} E_t^I &= \left(p^{BM} + \gamma^{BM}\right) \left(R_{t-1}^L L_{t-1} \frac{1}{\pi_t} + R_t^{B,corp} Q_{t-1}^{B,corp} B_{t-1}^{corp} \frac{1}{\pi_t} + R_t^{B,gov} Q_{t-1}^{B,gov} B_{t-1}^{gov} \frac{1}{\pi_t} \right) \\ &- p^{BM} \left(R_{t-1}^D D_{t-1} \frac{1}{\pi_t} - E_t^{I,gov} + \Upsilon_t^B \right). \end{aligned}$$

2.7 Public sector

2.7.1 Fiscal authority

Having defined the private sector, we come to the description of the public sector, which consists of a fiscal agent, the central bank, and an intervention authority. The authorities of the public sector do not face an optimization problem. To finance government expenditures G_t, the fiscal authority uses internal funds, i.e. from tax revenues (T_t) and profits received from the intervention authority $\left(\mathcal{P}_t^{IA}\right)$, and external funds, i.e. from the issuance of short-term $B_t^{short,gov}$ and long-term government bonds B_t^{gov} in the capital market traded at price $Q_t^{B,gov}$. Short-term government bonds are in zero net supply. The budget constraint of the fiscal agent is given in Equation (50).

$$G_t + \left(1 + r_t^{B,gov}\right) Q_{t-1}^{B,gov} B_{t-1}^{gov} = \mathcal{P}_t^{IA} + T_t + Q_t^{B,gov} B_t^{gov} \tag{50}$$

Tax revenues stem from labor income such that we have $T_t = \tau_t^w w_t N_t$ with τ_t^w as the tax rate. Our fiscal agent adjusts the tax rate on labor income in order to stabilize the level of real government debt, where the term ξ^{BG} is a positive number which reflects the fact that governments' insolvency is ruled out by conducting a passive fiscal policy (see, for example, Leeper, 1991). The tax rule is presented in Equation (51).

$$\tau_t^w - \tau^w = \rho^w \left(\tau_{t-1}^w - \tau^w\right) + (1 - \rho^w) \;\; \xi^{BG} \left(Q_{t-1}^{B,gov} B_{t-1}^{gov} - Q_s^{B,gov} B_s^{gov} \right) \tag{51}$$

Furthermore, the fiscal agent aims to effect smooth changes in the tax rate (with autoregressive parameter ρ^w). To complete the fiscal authority, we specify government expenditures as a fixed proportion of output.

2.7.2 Central bank

The central bank conducts monetary policy by controlling the policy rate i_t^{PR}.[39] For this purpose, it obeys a Taylor (1993)-type monetary policy rule, the objective of which is to set the policy rate according to

$$\left(1+i_t^{PR}\right)=\left(1+i_{t-1}^{PR}\right)^{\rho^{smooth}}(1+i)^{\left(1-\rho^{smooth}\right)}\left(\frac{\pi_t}{\pi}\right)^{\phi^\pi\left(1-\rho^{smooth}\right)}\left(\frac{Y_t}{Y_{t-1}}\right)^{\phi^y\left(1-\rho^{smooth}\right)}\epsilon_t^i. \tag{52}$$

As can be seen in Equation (52), the central bank applies interest rate smoothing, with smoothing parameter ρ^{smooth}. Since the economy possesses a non-zero steady state rate of inflation, the central bank's main interest lies in keeping the distance between the rate of inflation and the target rate of inflation (π) close to zero. In addition, the last period's real output growth also affects the policy rate. The term ϕ^π is the weight given to inflation and ϕ^y to output growth. Furthermore, the term ϵ_t^i represents an unexpected monetary policy shock.

2.7.3 Intervention authority

In order to investigate crisis resolution policies, we introduce an intervention authority that is assigned to the public sector. It has full credibility and is able to issue risk-less short-term debt. The reason why we introduce an intervention authority is that we want to sever the direct link to taxes on the one hand and do not want to assign the policies solely to the central bank on the other hand.[40] In the end, the balance sheet of the intervention authority feeds into the public sector's balance sheet.

Regarding crisis resolution policies, we allow the intervention authority to conduct outright purchases of corporate bonds $B_t^{corp,IA}$ and of government bonds $B_t^{gov,IA}$. As interventions rules, we have

$$B_t^{corp,IA}=\xi^{corp,IA}\left(x_{t-l}^{corp}-x^{corp}\right) \tag{53}$$

for corporate bonds and

$$B_t^{corp,IA}=\xi^{gov,IA}\left(x_{t-l}^{gov}-x^{gov}\right), \tag{54}$$

for government bonds, respectively. A similar rule can also be established for the recapitalization of the bank

$$E_t^{I,IA}=\xi^{EI,IA}\left(x_{t-l}^{EI}-x^{EI}\right). \tag{55}$$

The terms $\xi^{corp,IA}$, $\xi^{gov,IA}$, and $\xi^{EI,IA}$ reflect sensitivity parameters and x_t denotes a stress indicator for the corresponding asset.

[39] The policy rate is the risk-free rate.

[40] Although outright asset purchases are usually conducted by central banks, recapitalization of banks is sometimes undertaken by authorities with government guarantees. The latter are endowed with their own resources and operate in the capital market on their own. Profits can be redistributed to the fiscal authority or, in appropriate circumstances, losses are balanced by the fiscal authority. Smets and Trabandt (2012) also sever the link between central bank profits and the government. In their model, transfers from the central bank to the government depend on a rule which is directed to central bank's holdings of government bonds. From this point of view, our approach is quite similar to theirs.

With the help of this knowledge, we can formulate the resource constraint of the intervention authority which is given in Equation (56)

$$Q_t^{B,corp} B_t^{corp,IA} + Q_t^{B,gov} B_t^{gov,IA} + E_t^{I,IA} = B_t^{IA}. \tag{56}$$

The profits arise as the difference in the returns and the costs

$$\mathcal{P}_t^{IA} = r_t^{B,gov} Q_{t-1}^{B,gov} B_{t-1}^{gov,IA} \frac{1}{\pi_t} + r_t^{B,corp} Q_{t-1}^{B,corp} B_{t-1}^{corp,IA} \frac{1}{\pi_t} + i_{t-1} E_{t-1}^{I,IA} \frac{1}{\pi_t} - i_{t-1} B_{t-1}^{IA} \frac{1}{\pi_t}.$$

2.8 Market clearing

In the following equation, we present the market clearing condition for our economy

$$\begin{aligned} Y_t &= I_t^A + I_t^B + C_t + G_t + K_{t-1}^A \, \Gamma_t^A + \Gamma_t^B \, K_{t-1}^B + \Psi_t^A + \Psi_t^B \\ &+ K_{t-1}^A \, Q_{t-1}^A \, \frac{\left(1 + R_t^{k,A}\right) G(\omega_t^A) \, \mu^{f,A}}{\pi_t} + K_{t-1}^B \, Q_{t-1}^B \, \frac{\left(1 + R_t^{k,B}\right) G(\omega_t^B) \, \mu^{f,B}}{\pi_t}. \end{aligned} \tag{57}$$

Investment spending by type A and type B entrepreneurs constitutes aggregate investment $I_t^A + I_t^B$. Since changes in the stock of capital are related to costs, the resources spent in both sectors are expressed in $K_{t-1}^A \, \Gamma_t^A + \Gamma_t^B \, K_{t-1}^B + \Psi_t^A + \Psi_t^B$. In addition, monitoring type A and B entrepreneurs by the financial intermediaries absorbs resources, which is embodied in the second line of Equation (57). The market for physical capital clears by equating capital supply and capital demand $\widehat{K}_t^e = \widetilde{K}_t^e$.

In terms of asset holdings, a continuum of households meets a continuum of lending banks. The market for corporate bonds clears by introducing mutual funds in the intermediation process, which hold the market portfolio, $\int_0^1 B_{n,t}^{corp} dn + B_t^{corp,IA} = B_t^{corp,B} + B_t^{corp,IA} = \int_0^{\varrho} B_{m,t}^{corp} dm$, where $B_t^{corp,B}$ denotes aggregate holdings of banks. In the market for loans, it is also assumed that each lending bank holds the market portfolio of loans.[41] The market clearing condition results as $\int_0^1 L_{n,t} dn = \int_{\varrho}^1 L_{m,t} dm$. Regarding the asset market for government bonds, the demand for assets resulting from the continuum of households and banks equals the supply of government bonds, $\int_0^1 B_{h,t}^{gov} dh + \int_0^1 B_{n,t}^{gov} dn + B_t^{gov,IA} = B_t^{gov,H} + B_t^{gov,B} + B_t^{gov,IA} = B_t^{gov}$. Accordingly, the market for the intervention authority's bonds clears, $\int_0^1 B_{h,t}^{IA} dh = B_t^{IA}$. The deposit rate r_t^D is linked to the policy rate.

3 Calibration and steady state

In this section, we discuss the parameterization of the model and the steady state values. Our calibration is chosen to reflect the euro area as a whole. The parameterization for the real and the policy sector can be found in Table 1, while Table 2 provides the values for the financial sector. Table 3 presents the steady state values of the model (in the right-hand column) in conjunction with the average data for the euro area for the corresponding variable. The entire model is calibrated quarterly.

[41] For technical reasons, as for corporate bonds, we need an aggregator that guarantees the same pay-off per unit of loans.

Most of the parameters concerning the standard block in our DNK model are based on the estimates for the euro area obtained by Smets and Wouters (2003), Christoffel, Coenen, and Warne (2008), and Amisano and Tristani (2010). We set the inverse Frisch elasticity, φ, to 2.5. The curvature on utility of consumption, σ, is set to 1.4 and the parameter for habit formation in consumption, h^C, has the value of 0.6. We assume that households are able to renegotiate their wage with a probability of 0.24, from which follows that γ^w is 0.76. Lagged inflation enters with a weight (ξ^w) of 0.75 in the indexation rule for non-optimizing wages. All these parameter values stem from Smets and Wouters (2003). The wage elasticity in the labor aggregator, θ^w, equals 6 and is similar to Gerali, Neri, Sessa, and Signoretti (2010). The steady state value for hours worked is 0.33 of the total hours available.

Table 1: Calibration of parameters - real and policy sector

Description	Symbol	Value
Panel A: Household Sector		
Discount factor	β	0.9953
Inverse of Frisch elasticity of goods' production labor	φ	2.5
Curvature on utility of consumption	σ	1.4
Habit formation	h^C	0.60
Probability for non-reoptimization of wages	γ^w	0.76
Wage elasticity in labor aggregator	θ^w	5
Share of lagged inflation in indexation rule for wages	ξ^w	0.75
Steady state labor input in goods' production	N_s	0.33
Maturity parameter for corporate bonds	ρ^B	0.971
Maturity parameter for government bonds	$\rho^{B,gov}$	0.967
Panel B: Intermediate and Final Goods' Producing Sectors		
Capital share in intermediate goods' production	α	0.3
Share of type A entrepreneurs' capital	ζ^{ws}	0.07
Depreciation rate - type A and type B entrepreneurs	$\delta^A = \delta^B$	0.025
Price elasticity in final goods' production	θ	6.5
Probability for non-adjusting of prices - Calvo pricing	γ	0.9
Investment adjustment costs	υ	6.9
Capital utilization adjustment costs	ψ	0.15
Share of lagged inflation in indexation rule for prices	ξ	0.45
Panel C: Monetary and fiscal policy		
Taylor rule - interest smoothing	ρ_i	0.6
Taylor rule - inflation	ϕ_π	1.7
Taylor rule - output growth	ϕ_y	0.10
Policy rate, free-risk rate, annualized	r^{CB}, i	3.7 %
Steady state rate of inflation, annualized	π_s	1.8 %
Sensitivity parameter in tax rule	ξ^{BG}	0.007
Share of government expenditures on steady state output	G/Y	0.2

The capital share in production, α, is calibrated to 0.3, which is standard. Since we have introduced two different types of capital for use in production, we need the corresponding weights. Through the weight, ζ^{ws}, the relative share of loans to bonds is determined accordingly. To match the properties of the euro area in the steady state (loan-to-bond ratio: 9.9), we set ζ^{ws} to 0.07 so that the steady state loan-to-bond ratio in our model becomes 9.76.[42] Concerning the rate of depreciation, δ, we attribute to both

[42]The data reflect the sector of non-financial corporations and stem from the integrated euro area

sectors the conventional value of 0.025. For our parameter for adjustment costs in the capital stock, we once again make use of the estimate in Smets and Wouters (2003). The term υ has the value of 6.9 in both sectors. Our parameter for the costs resulting from variations in the capital utilization, ψ, is set to 0.15 in both sectors, which is between the values provided by Smets and Wouters (2003) and Christoffel et al. (2008). In line with both references, we base the probability that goods producers cannot reoptimize their prices, γ, on their estimate of 0.9. Using the same source, we set the share of lagged inflation in the indexation rule for prices, ξ, to 0.45. Following the estimates of Amisano and Tristani (2010), the price elasticity in final goods production, θ, has the value of 6.5, which is between the values for their non-linear model (6.373) and for their linear model (6.914). As a result of our calibration exercise, the value of the scaling parameter for disutility of labor in households' utility, κ , as well as the fixed costs in intermediate goods production, Ω, are pinned down by the steady state.

Table 2: Calibration of parameters - financial sector

Description	Symbol	Value
Panel A: type A entrepreneurs		
Share of realized profits lost in case of default due to monitoring	$\mu^{A,f}$	0.12
Variance of idiosyncratic productivity parameter	σ_s^A	0.05
Business failure rate in steady state	$F(\omega_s^A)$	0.008
Survival probability of entrepreneurs	$p_s^{A,f}$	0.978
Return on corporate bonds in the steady state, annualized	r^B	3.95%
Panel B: type B entrepreneurs		
Share of realized profits lost in case of default due to monitoring	$\mu^{B,f}$	0.22
Variance of idiosyncratic productivity parameter	σ_s^B	0.09
Business failure rate in steady state	$F(\omega_s^B)$	0.008
Survival probability of entrepreneurs	$p_s^{B,f}$	0.978
Loan rate in the steady state, annualized	r^L	4.02%
Panel C: Banking sector		
Survival rate of bank managers	p^{sp}	0.975
Equity-to-total-assets ratio	ϕ^{IE}	6

After having calibrated the intermediate and final goods producing sector, we turn to the entrepreneurs. Since we have two different sectors, we decide to attribute different risk parameters to them. As in BGG, we assume that the share of realized profits lost in the case of a default is 0.12 for the type A entrepreneurs, which is a conventional assumption (see, for example, Christiano, Motto, and Rostagno, 2003; Gertler, Gilchrist, and Natalucci, 2007). For the type B entrepreneurs, we follow the argument that monitoring is more costly compared to market financing which feeds into a value for μ^B of 0.22. This is quite close to the value that is estimated for the euro area by von Heideken (2009) but guarantees that the transfer from households to entrepreneurs is a positive number. To set the business failure rate $F(\overline{\omega})$, we take an average value of bankruptcy rates in the euro area of 0.008.[43] We use this value for both sectors. By contrast, we set two different variances for the log of the idiosyncratic productivity variable, $\log(\omega)$; for the type A

accounts.

[43] The data stem from different publications by the company Creditreform.

entrepreneurial sector it is 0.05 and 0.09 for the type B entrepreneurs. With these values we are very close to the euro area's value in Christiano, Motto, and Rostagno (2010). In line with the latter, we assume that the survival probability of entrepreneurs, p^f, is 0.978 in both sectors.

With this calibration we get a debt-to-output ratio in the real economy of 3.59, which is very close to the euro area figure (3.58). The same is true of the sectoral ratios. While the loan-to-output ratio in the steady state of our model is 3.25, it is 3.12 in the euro area. Regarding the (corporate) bonds-to-output ratio, we observe a ratio of 0.31 for the euro area, whereas our model yields 0.33 in the steady state. Our debt-to-equity ratio (loans plus bonds to both types of entrepreneurs' net worth) amounts to 0.83, which is slightly higher than the historical average value, which equals 0.7 for the euro area.[44]

In our model, we allow for a specific maturity structure for corporate bonds. The average maturity of corporate bonds in the euro area between 1999 and 2007 is about 6.5 years.[45] As a consequence, we set the parameter ρ^B to a value of 0.971, which yields an average maturity of 6.5 years. Our model is able to distinguish between risky and risk-free spreads.[46] The spread between the risk-free bond rate and the risk-free rate can be interpreted as the difference in the yields on corporate bonds with the highest creditworthiness, those of AAA rated issuers, and government bonds. Among other factors, liquidity premiums can be seen as driving this spread (Longstaff, Mithal, and Neis, 2005). Although we do not explicitly incorporate liquidity issues in our model, liquidity premiums might result from limits to arbitrage. Limits to arbitrage arise in our model because of portfolio costs. From this point of view, we calibrate the spread between the risk-free bond rate and the risk-free rate according to the difference between yields on AAA rated corporate bonds in the euro area and German government bonds with a maturity of 5 to 7 years, which is 25 basis points.[47]

The calibration of the risk-free loan rate r^L is more difficult because credit conditions are reported without classifying creditworthiness. Furthermore, the period for which conditions are fixed cannot be directly compared to the maturity. As a solution, we compute the volume-weighted loan rate based on the annualized rates agreed for new businesses as reported in the ECB's MIR statistics, and establish the spread to the risk and maturity weighted yield of non-financial corporations. In the pre-crisis period, we obtain a value of roughly 7 basis points, which we extrapolate by adding it to the risk-free bond rate to obtain the risk-free loan rate.[48]

The calibration of the risk-free rates together with the calibration of the risk parameters in the BGG partly pin down the steady state values for the remaining spreads.

[44] By using similar data, De Fiore and Uhlig (2011) report a value of 0.64, which is slightly below our historical values because we also include more recent data.

[45] We obtain this number by analyzing all corporate bonds issued between 1999 and 2007 in euro area member countries. The maturities are weighted by the amount issued. Similar values are reported in European Central Bank (2012).

[46] Recall that the asset specific risk-free rates deviate from the risk-free rate because of limits to arbitrage. Hence, the asset specific risk-free rates exceed the risk-free rate in the steady state because of portfolio costs for both the lending banks and households.

[47] AAA rated bonds nevertheless convey a default risk. However, we believe that our proceeding is an adequate way to calibrate the model. Yields on German government bonds are taken because they have a high degree of liquidity and the highest credit rating throughout the period.

[48] For the euro area, De Fiore and Uhlig (2011) report bond spreads that exceed loan spreads. Our calculations of spreads with different maturities and risk attitudes do not support their findings.

Table 3: Steady state values

		EMU	Model
Panel A: Real sector			
Households' consumption to output ratio	C/Y	0.57[1]	0.61
Investment to output ratio	I/Y	0.18[1,2]	0.19
Capital to output ratio	K/Y	7.2[1,2]	7.54
Panel B: Banks			
Loans relative to credits to non-fin. sector	$L/\left(L+Q^{B,corp}B^{corp}\right)$	0.92[3]	0.91
Loan-to-asset ratio	L/A^{B*}	0.8[3]	0.8
Total bank assets to output	A^{B*}/Y,A^{B}/Y	11.9, 5.2[3]	4.1
Debt (deposits + bonds) to total assets	D^{IB}/A^{B}	0.77[3]	0.83
Panel C: Entrepreneurs			
Spread (BBB-AAA), 5-7 years, annualized	$Z^e - r^e$	0.59 pp[5]	0.59 pp, 0.94 pp
Spread (AAA-DE), 5-7 years, annualized	$r^e - i$	0.25 pp[5]	0.25 pp, 0.32 pp
Spread (BBB-DE), 5-7 years, annualized	$Z^e - i$	0.84 pp[5]	0.84 pp, 1.26 pp
Cost of external finance, contractual rate, annualized	Z	4.8 %[5]	4.5 %, 5.0 %
Net worth to output for entrepreneurs	NW/Y	5.3[6]	3.9, 0.25, 3.71
Debt to equity ratio	$(L+Q\cdot B)/NW$	0.7[6]	0.9
Debt to (fixed) assets	$(L+Q\cdot B)/K$	0.45[6]	0.48
Bonds to output ratio	$Q\cdot B/Y$	0.31[6]	0.33
Loans to output ratio	L/Y	3.12[6]	3.25
Debt to output ratio	$(L+Q\cdot B)/Y$	3.58[6]	3.59
Loans to bonds	$L/Q\cdot B$	9.9[6]	9.76

1) ECB national accounts. 2) Integrated Euro Area Accounts, households. 3) Balance sheet items. ECB. 4) Eurosystem balance sheet. 5) Merrill Lynch, ECB interest rate statistics. 6) Integrated Euro Area Accounts, non-financial corporations. Values for output are measured quarterly. If three values are reported in the columns, the first entry relates to the aggregate while the second shows the number for large entrepreneurs and the third for type B entrepreneurs. If two values are given, the first is the number for large entrepreneurs and the second for type B entrepreneurs. Total assets as implied by the model are denoted by A^{B*}.

Following Bernanke et al. (1999), the credit spread can be defined as the difference between the risky-bond rate Z^A and the risk-free bond rate. Our calibration exercise yields a value of 0.59, which is equal to the spread between the yields of BBB and AAA rated corporate bonds with a maturity of 5 to 7 years. Analogously, the spread between yields on BBB rated corporate bonds and German government bonds with a maturity of 5 to 7 years, which is 0.84, corresponds to the spread of the pre-crisis period.

Based upon the OECD central government debt statistics, the average maturity of government bonds in the euro area is slightly below 6 years. Consequently, we set the parameter $\rho^{B,gov}$, which controls the maturity in our model, to 0.967. In line with this maturity, we calibrate the quarterly discount factor of households, β, to 0.9953, which corresponds to an annual risk-free rate of 3.7%. The latter is the average yield on German government bonds in the pre-crisis period. In setting the survival rate of bank managers operating a lending bank we depart slightly from Gertler and Karadi (2011) and assume that bankers operate a bank for 10 years and exit thereafter, i.e. the survival rate is 0.975. Based again on banks' aggregate balance sheet, 13% of banks' total assets are allotted to government bonds. The leverage ratio is set to 6, which corresponds to the value in Gertler and Karadi (2013).

Summing up, our calibrated values are mostly in line with historical averages for the euro area. However, the size of the banking system relative to output in our model is well below the reality. While the ratio of total assets to GDP is 12 (or approximately 3 on an annual basis) in the euro area, the corresponding number in our model is 4.12 (or 1.03 on an annual basis). This remarkable difference might result from the fact that total assets in our model are determined by the calibration exercise regarding the entrepreneurs. We have therefore neglected several assets on banks' balance sheets. Nevertheless, the values for the steady state of the real sector and some of those for the financial sector fit quite well.

Next, we discuss the policy parameters. Our monetary authority puts a weight of 1.7 on the inflation objective, ϕ_π, and a weight of 0.1 on changes in real production, ϕ_y. The autoregressive parameter in the Taylor rule, ρ_i, is 0.8. Our economy exhibits a non-zero steady state rate of inflation, π_s, of 0.45 per cent on a quarterly base, which results in an annual value of 1.8 per cent and is close to but below the ECB's target rate. Government's indebtedness is set to 70% of GDP, from which a tax rate in the steady state of 0.29 results. Regarding the tax rate, the fiscal agent reacts with a sensitivity of 0.01 (ξ^{BG}) to changes in government debt.[49] This value guarantees fiscal solvency and it is set to the lower bound at which the model becomes unstable.

Table 4: Second moments of central variables

		EMU	Model
Panel A: Standard deviations			
Output growth, annual	$\Delta Y/Y$	1.27[1]	1.27
Investment growth, annual	$\Delta I/I$	3.14[1]	3.32
Panel B: Correlations			
Output growth, investment growth	$corr\,(\Delta Y/Y,\, \Delta I/I)$	0.36[2]	0.43
Output growth, inflation	$corr\,(\Delta Y/Y,\, \pi)$	0.27[2]	0.33
Output growth, leverage ratio	$corr\,\left(\Delta Y/Y,\, \phi^{IE}\right)$	0.47[1,2]	0.1

1) ECB national accounts. 2) Balance sheet items. ECB. Averages for the EMU are calculated for the period from Q1 1999 to Q4 2007.

Before we complete the description of the calibration exercise and the steady state values, we present selected second moments for key variables by activating a monetary policy, a technology shock, and an aggregate risk shock. The standard deviation of the monetary policy shock is 0.0011, and 0.0185 for the productivity shock. For the risk shock, we choose a standard deviation of 0.041 which stems from Christiano et al. (2014). The simulated standard deviation of annual output growth in our model matches the euro area average from 1999 to 2007, while the standard deviation for investment growth with a value of 3.32 only differs slightly from the euro area's average (3.14). Regarding the correlation coefficient between output growth and investment growth, we are close to its historical average. The same is also true of the correlation between annual output growth and the rate of inflation. A further central variable in our model is banks' leverage ratio, which shows a historical average of 0.47 between 1999 and 2007. The value implied by our model is quite far away from this number; however, it is positive in contrast to the Gertler and Karadi (2011) setting. Although the correlation coefficient between the leverage ratio and output growth implied by our model deviates from its historical average, its sign corresponds with reality.

Overall, our model is very good at replicating some features of real data.

[49]Following Leeper (1991), monetary policy is active, while fiscal policy takes a passive stance.

4 Evaluating policy measures for mitigating a financial crisis

In this section, we evaluate policy measures that are aimed at mitigating financial stress, in other words we discuss outright purchases of assets and capital injections into the banking sector. Concretely, we relate the amount of purchases or of equity injections to the magnitude of financial stress. Before turning to the evaluation, we will discuss sources of financial stress because our model is able to distinguish between two different origins.

4.1 Simulating financial stress

Our first financial shock is fundamentally similar to the capital quality shock in Gertler and Karadi (2011).[50] We draw on the "risk shock" stemming from the BGG part of the model, which is aimed at the variance of entrepreneurs' productivity shock σ_t^e (see Christiano et al., 2014, for example). Hence, we increase entrepreneurial risk, which raises bankruptcies. From this point of view, it is a shock that stems from the real sector, namely the entrepreneurial sector, and impacts on the financing conditions of non-financial enterprises. Because of the setup, the shock can be seen as financial stress in a perfectly diversified economy. Defaults are reflected in monitoring costs, which drives borrowing costs upwards; however, lenders' investment decisions depend solely on risk-free rates because risk can be diversified completely. Christiano et al. (2014) see this shock as being very important for the business cycle.

To obtain our second financial shock, we adapt the idea behind the capital quality shock to induce stress into the banking sector. However, we aim to focus on developments that originate in the banking sector and then spill over to the real sector rather than occurring simultaneously in both sectors. To this end, we induce a shock on banks' returns (Equation 26),

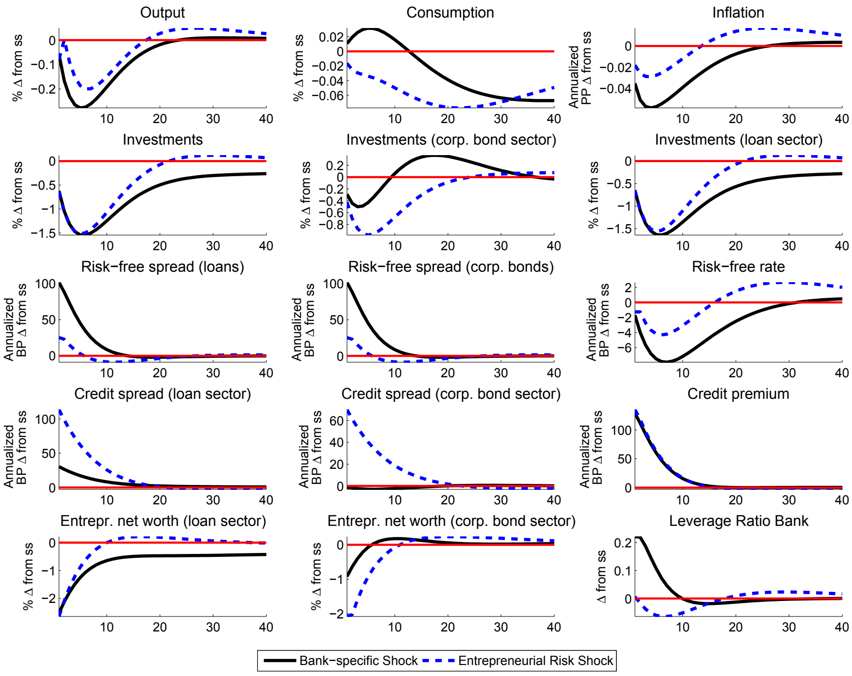
$$\begin{aligned} r_t^A &= \left[\left(1 + r_{t-1}^L\right) \frac{L_{n,t-1}}{A_{n,t-1}^B} + \left(1 + r_t^{B,corp}\right) \frac{Q_{t-1}^{B,corp} B_{n,t-1}^{corp}}{A_{n,t-1}^B} + \left(1 + r_t^{B,gov}\right) \frac{Q_{t-1}^{B,gov} B_{n,t-1}^{gov}}{A_{n,t-1}^B} - 1 \right] \\ &\quad \times exp(shock_t^{rA}), \end{aligned} \tag{58}$$

whereas $shock_t^{rA} = \rho^{rA} shock_{t-1}^{rA} + \epsilon_t^{rA}$ with ρ^{rA} as an autoregressive parameter and the disturbance ϵ_t^{rA}. The shock drives the return on assets downwards and affects banks' profits directly. From this point of view, the shock can be interpreted as losses from an undiversified portfolio because creditors can recover fewer assets. In terms of interpretation, it comes close to a pure loan supply shock (Peek, Rosengren, and Tootell, 2003; Gilchrist and Zakrajsek, 2012).

In order to highlight the differences in the results of the two sources of financial stress, we compare the dynamics of relevant variables in response to these shocks. In doing so, we calibrate the return shock in such a way that investment behaves identically during the

[50] Regarding the simulation of a financial crisis, we depart from Gertler and Kiyotaki (2010) or Gertler and Karadi (2011). In their models, financial stress is induced by shocking the quality of capital, which has two consequences: it directly reduces the value of banks' assets and as a consequence their net worth, and it causes production to drop (with further consequences for the real economy and, therefore, for banks' balance sheets).

Figure 1: Effects of a shock on bankers' profits (black solid) and on entrepreneurial risk (blue dashed)



Note: The risk-free spread is defined as the difference between the asset specific risk-free return and the policy rate $(r_t^e - i_t)$, while the credit spread is the difference between the expected return on capital and the corresponding asset specific risk-free rate $\left(E\left(R_{t+1}^{k,e}\right) - r_t^e\right)$. The credit premium is the spread between the expected return on capital and the policy rate of the two capital-producing sectors weighted by the share of sector-specific capital in overall capital $\left(E\left(R_{t+1}^k\right) - i_t\right)$.

first year after the shock and achieves the same minimum value, which is then roughly also true of output. This is happening while the aggregate credit premium responds identically in both cases. As can be seen in Figure 1, both shocks cause a recession, mainly driven by a drop in investment which coincides with a lower rate of inflation. The bank profit shock is given by the solid black lines and the dynamics resulting from the risk shock are given by the dashed blue lines. A first obvious result is that the effect of the profit shock on the real economy is more persistent than that of the risk shock, although the response of investment in the first year is the same.

A major difference occurs with respect to interest rate spreads, i.e. risk-free spreads as the difference between the asset specific risk-free rate and the policy rate, and credit spreads as the difference between the expected return on capital and the asset specific risk-free rate. While both risk-free spreads rise after the risk shock, credit spreads remain virtually constant (with a slight tendency to decrease in the corporate bond sector) after the profit shock. Here, the different nature of the shocks is evident. Since the profit shock depresses banks' equity position, lending to the non-financial sector shrinks and an excess demand for credit emerges. The rise in risk-free rates, which is even stronger than the increase in the policy rate, contributes to a fall in investment. As a result, the profit shock raises mainly the risk-free spreads rather than credit spreads. For the risk shock, the situation is different. Entrepreneurial risk increases, which is why credit spreads rise predominantly. The fact that the pattern for premiums is similar in both cases is because entrepreneurs reduce their demand for capital, which causes the price of capital to drop. A lower capital price reduces entrepreneurs' net worth. However, the aggregate credit premium (the capital weighted spreads between the expected returns on capital and the risk-free rate), which includes both components, behave similarly. An important distinction arises regarding banks' leverage ratio. While the leverage ratio falls for the risk shock, it increases for the profit shock on impact.

Comparing the two different financial shocks, we see that the combination of financial frictions between non-financial corporations and financial intermediaries with financial frictions between financial intermediaries, namely banks, and their creditors produces different dynamics in terms of spreads. Our modelling approach regarding the combination of the BGG framework with the GK framework is appealing since we are able to compare a financial shock in a completely diversified economy (risk shock) with a financial shock in an economy in which the banking sector is not working efficiently (profit shock) and can evaluate the driving forces. This allows us to scrutinize the adequacy of our policy measures, which we do in the next section.

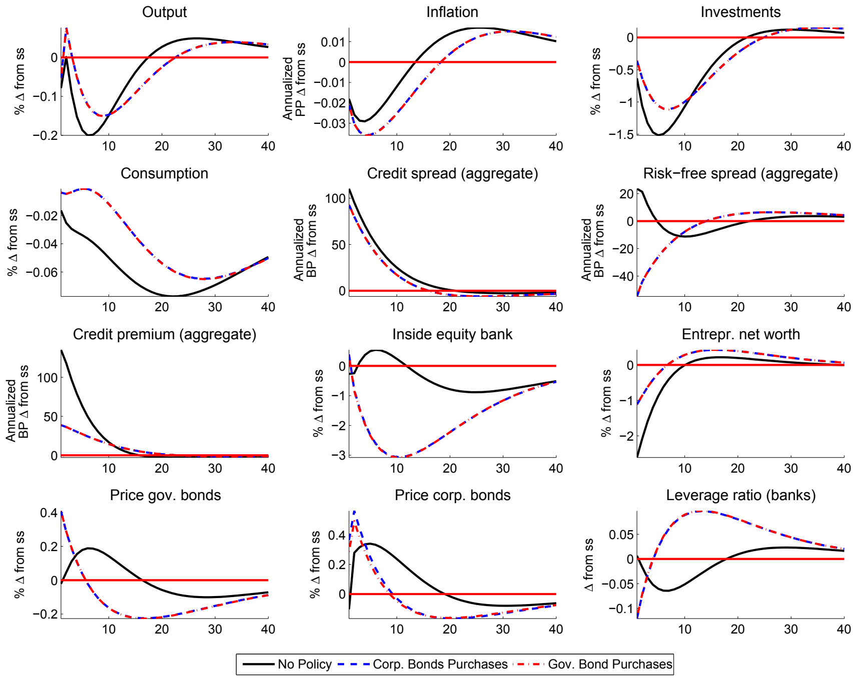
4.2 Policy instruments

4.2.1 Asset purchases

During the financial crisis, various financial assistance programs were introduced to prevent the economy from slowing down and to support the recovery. On the one hand, assets were purchased outright. The ideas behind asset purchase programs can be manifold (see, for example, Brett and Neely, 2013). During the financial crisis, some segments of the financial market were malfunctioning; extraordinary price dispersion could not be removed by market forces. Purchase programs were therefore intended to remove these obstacles. Outright purchases by governments have the same fundamental objective as purchases of private assets, but also aim at reducing borrowing costs by influencing the benchmark risk-free rate. Where the policy rate set by central banks reaches the zero lower bound, asset purchases can therefore be used to influence longer-term borrowing conditions. In general, a necessary condition for asset purchases to be effective is that the Wallace Irrelevance proposition of full arbitrage does not hold, i.e. limits to arbitrage exist (Chen et al., 2012; Christiano and Ikeda, 2013a; Cúrdia and Woodford, 2011; Eggertsson and Woodford, 2003). Hence, the main channel by which asset purchases work is by influencing the relative price of assets (Andrés, López-Salido, and Nelson, 2004). Limits to arbitrage also exist for the assets under consideration in our model, i.e. corporate and government bonds.[51] However, we concentrate only on those cases in which unconventional measures can be used to mitigate tensions on the financial market and do not treat the case of an instrument in a zero-lower-bound environment. As known from the previous section, the policy rate is reduced as a response to the drop in inflation. From this point of view, our policy measures constitute additional policy tools.

[51]Limits to arbitrage are introduced in our model by allowing for segmented capital markets. Because of transaction costs, portfolio adjustment or portfolio costs, and financial frictions in the banking sector,

Figure 2: Purchases of government bonds and of corporate bonds as a response to an entrepreneurial risk shock



Note: see note for Figure 1. The aggregate credit premium is the capital-weighted average of the spread between the return on capital and the policy rate in the two sectors. Entrepreneurial net worth is the capital-weighted entrepreneurial net worth of the two sectors.

In order to relate asset purchases to financial conditions, as done by Gertler and Karadi (2011), for instance, we draw on the policy rules as presented in Equations (53) and (54), which link the volume of purchases to a specific crisis indicator. Usually the credit spread, as defined by the difference between the return on capital and the risk-free rate, is a reliable crisis indicator. However, our model is rich in different sorts of crisis indicators. To calculate the above-mentioned credit spread, we have two options: to calculate it with the asset specific risk-free rate (as done in Figure 1) or with the help of the policy rate. Alternatively, we could use the external finance premium as defined by Bernanke et al. (1999) or the spread between the risky rates (Z_t^e) and a risk-free rate. Since our model features two different sources of financial frictions, the spread between the expected rate of capital and the policy rate comprises distortions from both frictions. However, we need to choose the sector because every indicator appears in each sector. We opt to link the volume of purchases to the capital-weighted average of the spread between the return on capital and the policy rate. From this point of view, we keep close to the literature.

In Figure 2, we depict the effects of asset purchases conducted by the intervention authority in response to the risk shock. The black solid line represents what happens

differences in returns cannot be removed completely by the households (see Andrés et al. (2004)).

where there is no policy response, i.e. the pure shock, while the blue dashed lines represent the dynamics resulting from the purchases of corporate bonds and the dashed red lines with dots the dynamics as a result of buying government bonds.

Both policy measures show the same qualitative and quantitative responses for most variables. Bond purchases by the intervention authority increase the price of this asset class, which is why the return on the respective bond falls. A standard story is that loans and other assets now appear more attractive to the bank, which means that the bank should buy the other bonds and grant more loans to the private sector (see, for example, Gertler and Karadi, 2013). However, this is only partly true in our model for both purchases of corporate bonds and government bonds.

Purchases of corporate bonds reduce the (expected) return on corporate bonds, which is why the corresponding risk-free spread shrinks and both banks and households reduce their holdings of corporate bonds. Although funds are available to invest in other assets, the reduction in returns lessens banks' profits and initiates a stronger reduction in inside equity. As a consequence, banks' leverage ratio rises even more strongly that in the initial shock scenario. As a result of the higher leverage ratio, the loan supply is even reduced by the purchases rather than being stimulated. While there is only a marginal effect on credit spreads, risk-free spreads are mainly reduced through the policy measures. Similar effects also arise in the case of purchases of government bonds. Contrary to Gertler and Karadi (2013), the net worth of banks, i.e. inside bank equity in our model, does not improve. In our model, inside bank equity is depressed even further because asset returns fall by more than the cost of liabilities. Because of the financial frictions between the banking sector and its creditors, banks cut their balance sheets. Again, the reduction in returns lowers banks' profits and increases the leverage ratio.

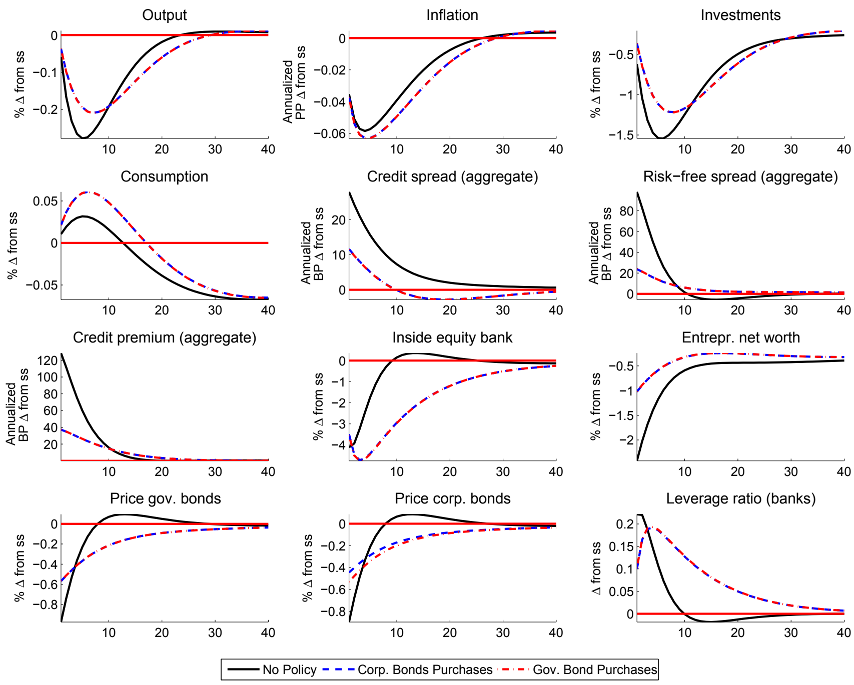
The effects of asset purchases in the case of the profit shock are fundamentally very similar to those of the risk shock (see Figure 3). Again, outright purchases mainly reduce credit spreads but risk-free spreads only slightly. From the reduction in risk-free spreads a more persistent fall in inside equity results which drives banks' leverage ratio upwards. This bank leverage effect impairs investment in the third year which is why output falls short of its no policy trajectory at this time.

From the results derived in this subsection, outright purchases of government or corporate bonds represent a policy tool in our model to mitigate financial stress regardless of its source, i.e. whether stemming from the real economy or from the banking sector. In our model, outright purchases conducted by a public agent, however, also weaken financial health of the bank because smaller asset returns reduce bank profits. From this point of view, our channel is similar to the channel highlighted in Benes and Kumhof (2011) who stress the role of returns for the build up of bank equity but contrary to Gertler and Karadi (2013) who stress the asset price channel.

4.2.2 Equity injections

Equity injections into banks are the second type of policy measure that has been widely used during the financial crisis to mitigate financial stress. A central problem during the financial crisis was the erosion of banks' equity position, which has forced banks to delever. Zeng (2013) shows that equity injections can have real effects in an economy with perfect nominal flexibility. Similar results can also be obtained by applying different modelling

Figure 3: Purchases of government bonds and of corporate bonds as a response to bankers' profit shock



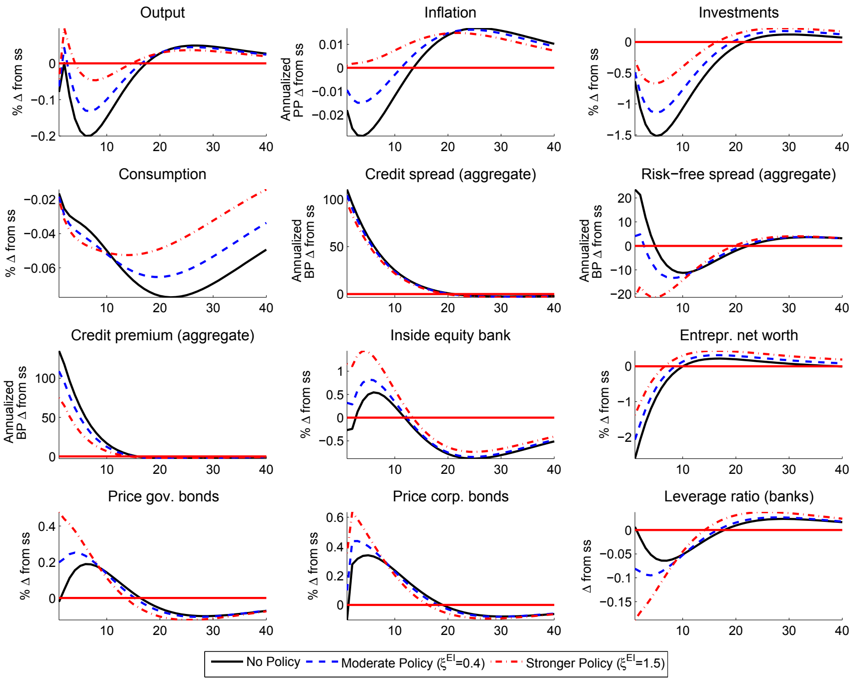
Note: see notes for Figures 1 and 2.

frameworks as done by Christiano and Ikeda (2013a), albeit without embedding them into a general equilibrium macro model. Hirakata et al. (2013) and Sandri and Valencia (2013) investigate equity injections in a general equilibrium model and stress their effectiveness in the banking sector. A similar result can be obtained in a continous-time general equilibrium model as developed by He and Krishnamurthy (2013). In this section, we investigate the effects of equity injections into banks within our New Keynesian general equilibrium model.

In Figures 4 and 5 the black lines represent the crisis situation without a policy response, i.e. the cases of the risk shock and the profit shock, respectively. The dashed blue lines show the effects of a moderate policy response in terms of resources used, while the red dashed lines with dots reflect a stronger policy response.

As in the models designed by He and Krishnamurthy (2013), Hirakata et al. (2013), and Sandri and Valencia (2013), direct equity injections also relax the borrowing constraint of banks in our model because the amount of inside equity rises and reduces banks' leverage (see Equation (36)). With the additional money that the bank receives, it expands its balance sheet by lending more to entrepreneurs of type B and by buying more bonds (corporate bonds and government bonds). Lower loan rates and bond returns stimulate entrepreneurs' net worth and investment in physical capital by relaxing financial frictions. Both credit spreads and risk-free spreads are lower compared to the no policy case in both investment sectors. The drop in investment is attenuated and output shrinks by less,

Figure 4: Equity injections into banks as a response to an entrepreneurial risk shock



Note: see notes for Figures 1 and 2.

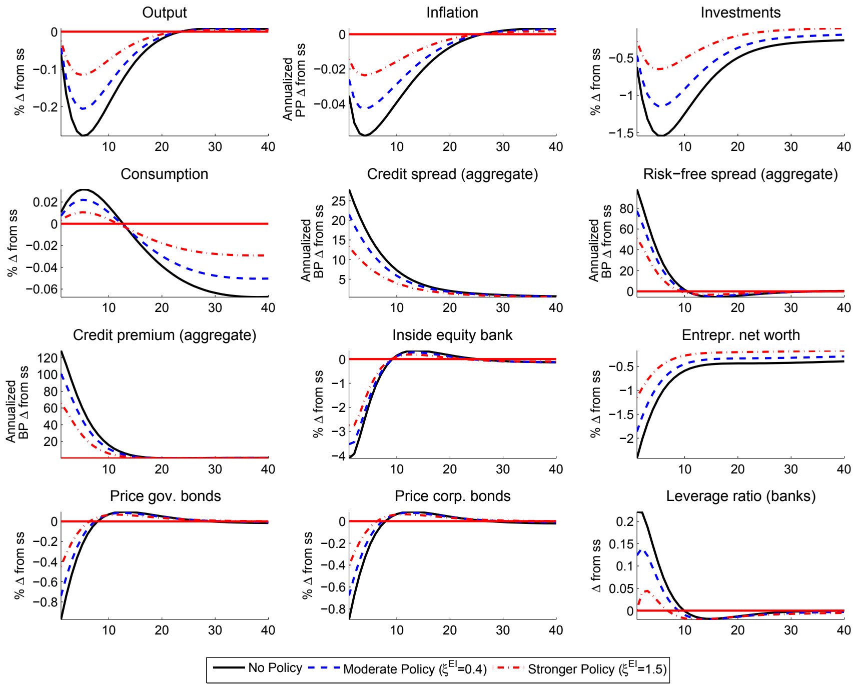
which also takes downward pressure from inflation. However, consumption initially falls by more but recovers faster because of wealth effects. Compared to the crisis situation, lower (risk-free) bond returns cut profits, which is why households reduce both their holdings of bonds and consumption even more.

For the profit shock, as presented in Figure 5, the effects are similar to the risk shock case, again. The drop in investment is attenuated, which causes output to fall by less compared to the no policy case. Differences occur with respect to the leverage ratio, the initial effect of the shock has increased banks' leverage ratio, whereas the additional bank equity reduces the leverage ratio.

As can be seen, an important advantage of injections of inside bank equity is that financial frictions are alleviated (see Gertler and Kiyotaki (2010) for the argument, for instance). Equity injections into banks are a particularly suitable response to the bank-specific shock because they neutralize the original consequences of the shock. Injections of bank equity reduce banks' borrowing constraint at the same time as improving the real sector's borrowing conditions for the bank-specific shock and seem to be more favorable than asset purchases in this case. For the bank-specific shock, asset purchases reinforce stress in the banking sector because of their consequences for bank equity. Since loans dominate banks' portfolio, the effects of the stabilization of asset prices as a result of the public purchases are outweighed by the effects in terms of returns on banks' profits.

In order to evaluate the differences among the measures, we need to look at indicators which allow comparisons. In this respect, we also take the welfare perspective, which is

Figure 5: Equity injections into banks as a response to bankers' profit shock



Note: see notes for Figures 1 and 2.

done in the next section.

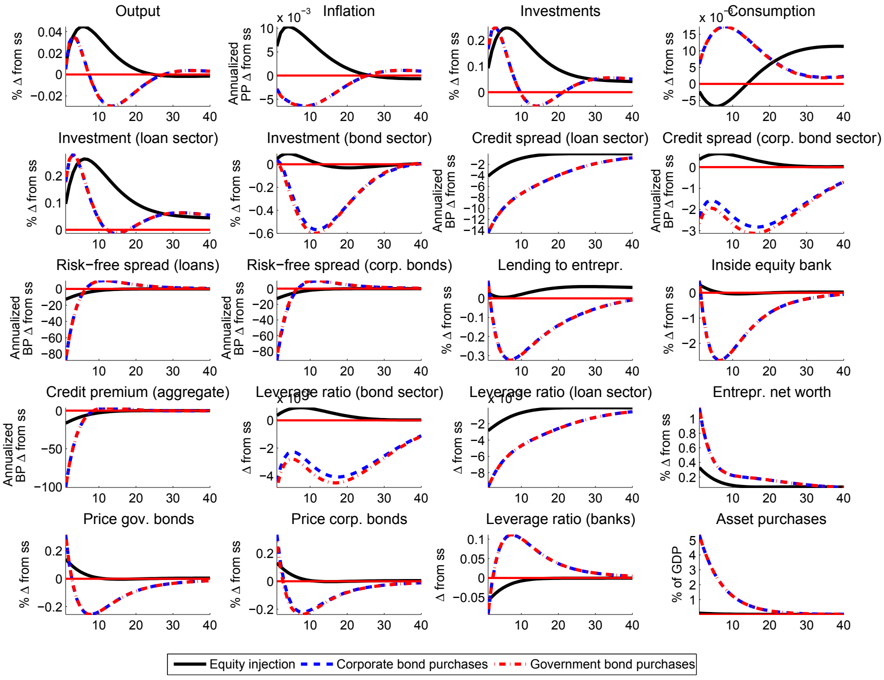
4.3 Evaluation of policy measures

There are two dimensions to evaluating policy measures. Firstly, we compare the qualitative effects of the responses across policy measures in more detail. For this purpose, we look at the pure policy responses which are not linked to a specific crisis indicator. In this connection, we also evaluate the effectiveness of measures by looking at the additional output effects given specific resources used. Secondly, we take the welfare perspective to complete the evaluation of measures' effectiveness.

4.3.1 Comparison of direct effects and effectiveness of policy measures

In Figure 6, the solid black lines represent the effects of an equity injection, while the blue dashed line and the red dashed line with dots show the responses to corporate bond and government bond purchases, respectively. For the asset purchases, we scale the initial volume of purchases to the same level, which amounts to 5% of GDP. For the equity injection case, the amount of interventions falls short of the other two cases. Here, we calibrate the intervention volume such that the peak in the response to investment roughly coincides with the peak for corporate bond purchases. Regarding the macroeconomic variables, output, inflation, consumption, and investment, the effects following corporate

Figure 6: Comparison of responses to pure policy shocks



Note: The Figure presents the pure responses to equity injections and purchases of government and corporate bonds. See also notes for Figures 1 and 2.

bond purchases are qualitatively nearly identical to the the impact of outright purchases of government bonds. A comparison of purchases of bonds with equity injections yields major differences. Aggregate investment is boosted on impact in all cases, which results in an increase in output, but output falls below the no policy case following the second year for bond purchases.

These qualitative differences can, in part, be traced back to developments in sectoral investment, although aggregate investment responds equally on impact. As already described, equity injections lower banks' leverage ratio, which has two effects: external borrowing is facilitated because both financial frictions are relaxed and additional financial resources are directly available. Thus, the loan rate decreases slightly and stimulates loan production. At the same time, corporate bond returns fall because of higher demand for corporate bonds, which reduces borrowing costs in the bond sector and contributes to the increase in investment in this sector.

As opposed to equity injections, investment in the bond sector is reduced in the case of bond purchases. As mentioned above, lower corporate bond returns weaken banks' balance sheet by increasing the leverage ratio. This effect is similar for government bond purchases. The drop in bank equity resulting from the reduction in lending rates drives banks' leverage ratio upwards. As a consequence, banks reduce their lending activities. For the less financially constrained bond sector, this volume effect outweighs the improve-

Table 5: Present value multiplier on output and investment as a response to the pure policy shocks

	Equity injections		Corporate bond purchases		Government bond purchases	
	4 quarters	8 quarters	4 quarters	8 quarters	4 quarters	8 quarters
Output	0.3906	0.6526	0.0061	0.0054	0.0060	0.0052
Investment	0.4504	0.7170	0.0098	0.01	0.0098	0.01

Note: The Table shows the multipliers on output and investment over one and two years following the pure policy shocks, i.e. equity injections and purchases of government and corporate bonds.

ment in borrowing conditions.[52] Because of the introduction of market-based debt, bond prices also affect entrepreneurial net worth in this sector.[53] Specifically, the support for corporate bond prices from the introduction of the policy measures reduces entrepreneurial net worth in the corporate bond sector and exerts upward pressure on the entrepreneurial leverage ratio with consequences for the credit spread in this sector. Thus, investment is reduced since banks need to adjust their asset holdings, while borrowing conditions are driven by the exogenous public intervention. This interrelationship becomes clear when the responses in terms of banks' leverage ratio are compared with the responses of bank equity, the price for corporate and government bonds, and aggregate lending to entrepreneurs. Asset purchases only stabilize banks' balance sheet in the first periods of the implementation of the policy. As public intermediation becomes weaker, bank deleveraging even drives bond prices downwards.

Obviously, output does not improve persistently in the case of outright purchases. When evaluating the effectiveness of measures, Figure 6 provides a first hint. While nearly the same output response is achieved, much more resources are spent for the purchase of bonds. In order to allow for qualitative comparisons among the measures, we use a simple indicator, which is known from fiscal policy analysis. We compute the present value multiplier over the first k quarters on the change in the macro variable X_t in response to the resources used for the corresponding policy measure PM. Similarly to Mountford and Uhlig (2009), the present value multiplier is defined as

$$PVM_k = \frac{\sum_i^k \beta^i \Delta X_{t+i}}{\sum_i^k \beta^i PM_{t+i}}.$$

We draw on the multipliers on output and (aggregate) investment and provide the present value multiplier for the next year and the next two years for every policy measure under consideration in Table 5.

[52] In a sense, this effect can be seen as a reflection of the different responses of more and less financially constrained firms to monetary policy shocks, as discussed by Gertler and Gilchrist (1994). Gertler and Gilchrist (1994) demonstrate that more financially constrained firms reduce bank borrowing after a contractionary monetary policy shock, whereas this is not the case for less constrained firms.

[53] Kühl (2014) investigates the effects of bond prices and maturities in the BGG framework. He shows that prolongation risk becomes apparent for longer maturities and can reverse the behavior of the external finance premium because bond prices also affect entrepreneurial net worth.

In line with the visual inspection, all measures exhibit a positive multiplier on both output and investment. However, the multiplier following equity injections is of a greater size than those for both purchases. Purchases of bonds are successful regardless of whether corporate or government bonds are purchased; the exact multipliers are even nearly identical for the specific cases. Regarding the qualitative responses, these results are broadly in line with those obtained by Gertler and Karadi (2013), who combine government debt with a state-contingent asset. Nevertheless, quantitative difference occur which can be traced back to the introduction of non-market debt in our model. From this point of view, equity injections are better suited to stabilize an economy since less resources are needed. The special role of equity is mainly responsible for this result. As already stressed, equity injections relax financial frictions in the banking sector by driving the leverage ratio down.

4.3.2 Welfare implications

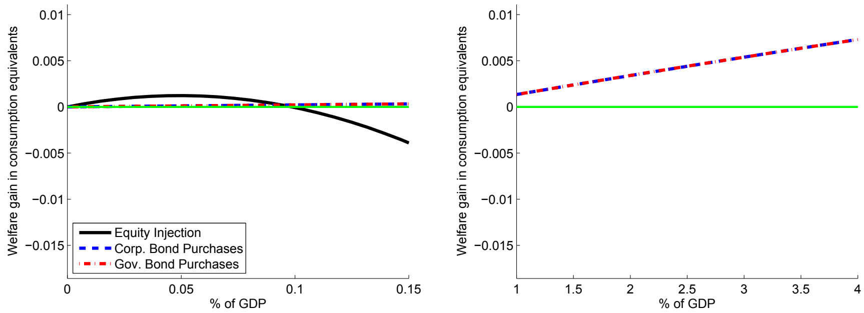
The comparison of measures has drawn on the quantitative effects on investment and output. However, the evaluation of different measures compared to a benchmark case (the crisis situation) must be carried out under the welfare perspective to assess their usefulness for the agents (following the arguments of Lucas (1987) in the sense of reducing business cycle fluctuations). Thus, we ask which of the three proposed measures is welfare improving and compare the welfare implications among the measures. Welfare will also depend on the amount of resources used, which is why we compute welfare for a range of resources used. Furthermore we depart slightly from a full-blown welfare analysis which starts from specific shocks and investigates different policy rules under this environment. Instead, we assume that a specific shock is known to the policy maker and he reacts with one specific measure to this shock, i.e. there is full information. This means that we treat the cases of both financial shocks separately and for each we shock calculate and measure the consumption equivalent welfare gain by increasing the initial intervention volume. Consumption equivalent welfare is calculated according to the approach discussed in Schmitt-Grohé and Uribe (2007) based upon

$$E_0 \sum_{t=0}^{\infty} \beta^t u\left(C_t, N_t\right) = E_0 \sum_{t=0}^{\infty} \beta^t u\left(\left(1+\lambda_t^c\right)\bar{C}, \bar{N}\right),$$

in which λ_t^c is the consumption equivalent that equates conditional welfare with the basic scenario.

In Figure 7, we present consumption equivalent welfare gains by implementing the policy measures following the risk shock. Figure 7 consists of two graphs: the left-hand side shows welfare gains for a range of resources from zero to 0.15% of GDP. In this range, equity injections following a risk shock first improve welfare before they start to lessen welfare significantly. Both types of asset purchase have similar welfare implications. While welfare remains nearly constant for smaller intervention volumes, with increasing intervention volumes, which are presented in the right-hand graph, welfare increases steadily and even exceeds the maximum achieved by capital injections. The reason why welfare deteriorates for larger equity injections following the risk shock is that the initial shock has already depressed asset returns and consumption, which is exacerbated by the policy measure. Thus, equity injections in a case where financial stress does not stem from the

Figure 7: Evaluation of the policy measures under the welfare perspective for the entrepreneurial risk shock



Note: The Figure reports the welfare gain measured in consumption equivalents by introducing one specific policy measure in response to one specific shock, whereas the intervention intensity in terms of resources expressed in percentage of GDP is varied.

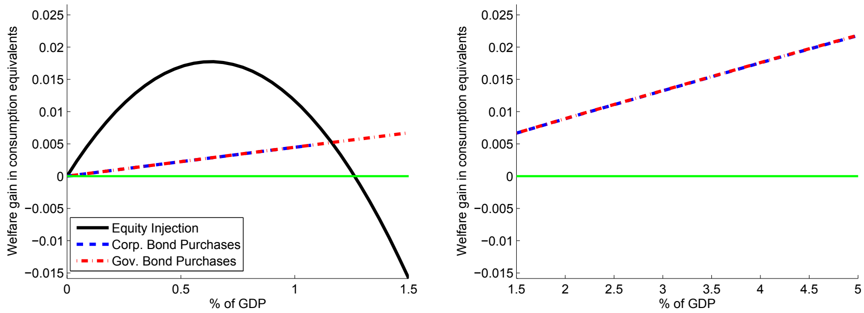
banking sector quickly lowers welfare if injections are too large. Up to first order, this is because households receive lower returns from their asset holdings, this induces greater business cycle fluctuations. Recall that a risk shock can be interpreted as a financial shock in a completely diversified economy. As long as risk has not returned to its normal level, outright asset purchases substitute private intermediation, reduce borrowing conditions, and mitigate the original shock (see again Figure 6 for the bond sector).

For the profit shock, as given in Figure 8, the evaluation of policy measures is again qualitatively similar for different ranges of intervention volume. Small amounts raised for equity injections clearly improve welfare, but the effect is negative for larger volumes. Again, asset purchases are welfare improving but equity injections are much more efficient in terms of alleviating the implications of the profit shock on households' welfare. The driving force behind this is a combination of different effects: risk-free returns shrink less strongly and consumption falls more strongly but recovers faster. From this point of view, equity injections improve welfare more efficiently in the case of a financial shock that distorts the main financial intermediary in the economy. Much larger volumes of outright purchases are needed to achieve the same welfare improvement. Nevertheless, excessively large equity injections also reduce welfare because they start to induce additional volatility.

As can be seen from our welfare analysis, outright purchases are strictly welfare improving for both types of shock, regardless of the resources used. However, the interventions conducted by the public intervention authority might be linked to costs (see Gertler and Kiyotaki, 2010). Dedola et al. (2013) and Gertler and Karadi (2011) use a quadratic costs function to address the fact that outright purchases, by increasing the amount of intervention, are not per se welfare enhancing. Since the effects of costs on welfare crucially depend on the functional form of the cost function and its parameters, we decide not to take account of these issues in our analysis. This does not mean that we deny that public interventions raise costs.[54] As can be seen in Figure 8, welfare improves with larger

[54] Moreover, in our model, the public sector balance sheet allows for stronger feedback effects as in Dedola et al. (2013) or Gertler and Karadi (2011), because we have a profit/loss redistributing channel

Figure 8: Evaluation of the policy measures under the welfare perspective for bankers' profit shock



Note: see note for Figure 7.

outright purchases. However, welfare rises faster for smaller equity injections. As long as the costs stemming from injections of equity into banks are not much greater than for outright purchases in cases of smaller equity injections, the welfare improving effects will remain. Moral hazard related to equity injections might be a factor that is not taken into account in our model. Larger outright purchases will also induce costs, which will stop the seemingly steady increase in welfare.

Our results are in line with recent work by He and Krishnamurthy (2013), though we achieve our results within a New Keynesian model and carefully distinguish between the sources of financial shocks.[55] Nevertheless, the mechanism that drives our results is very similar.

4.4 The impact of maturities

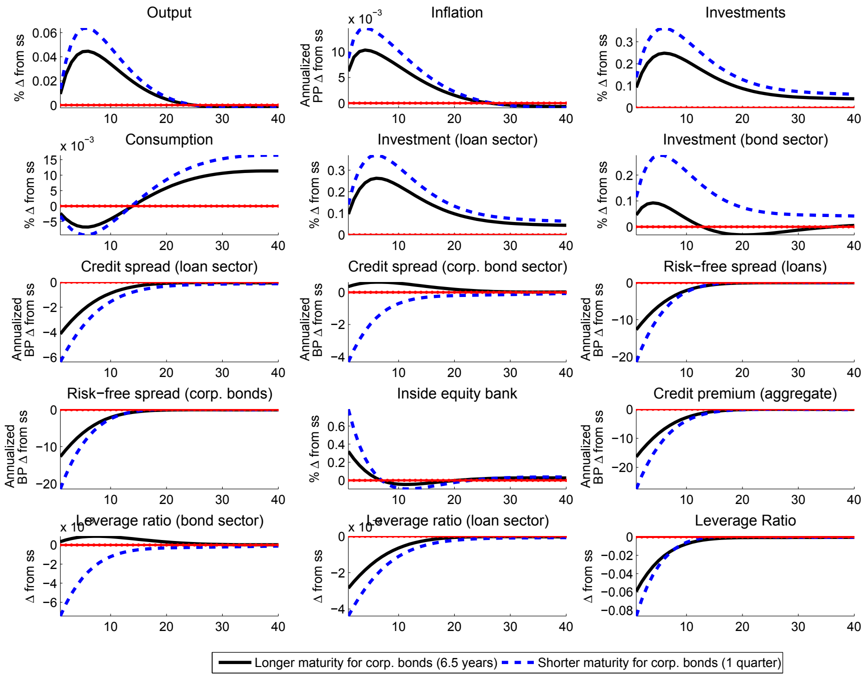
Since we have introduced average maturities in bond portfolios and different average maturities might have an impact on the results, we shed more light on their effects. The maturities in the main text were calibrated to reflect the corresponding euro area averages. However, it is of interest to see whether the results presented above depend on the average maturity.

In Figure 9, we compare the effects of the equity injections as presented in Figure 6, i.e. where the corporate bond portfolio has an average maturity of 6.5 years (bold lines), with those where we reduce the average maturity to one period (dashed blue lines). In terms of the macroeconomic variables, the qualitative responses do not change overall, although the quantitative results change slightly. Investment in the bond sector increases by more in the short average maturity case, which means that the slight decrease in the third year after implementation disappears. This result is related to the development of entrepreneurs' leverage ratio in the bond sector, which translates into the corresponding credit spread. As shown by Kühl (2014), developments in the corporate bond price

with feedback on taxes.

[55] The model of He and Krishnamurthy (2013) primarily works by affecting agents' risk sharing. Their conclusion is nevertheless very similar to ours.

Figure 9: Comparison of responses to pure equity injection shock for a longer average maturity (bold line) and an average maturity of one period (dashed blue line)

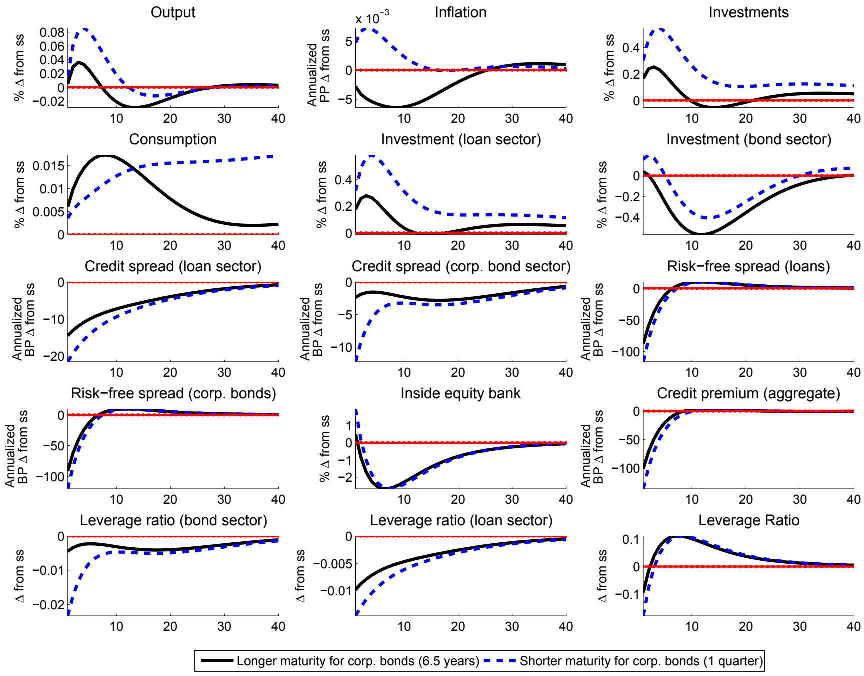


Note: The Figure presents the pure responses to equity injections with different average maturities. See also note for Figure 1.

also affect entrepreneurial net worth, which is particularly relevant for longer average maturities. Equity injections increase demand for bonds, causing prices to rise. This rise in corporate bond prices reduces entrepreneurial net worth in the bond sector, stimulates the credit spread and dampens the increase in investment in this sector. For shorter average maturities, entrepreneurial leverage ratios move in parallel in both sectors. As a consequence, aggregate investment, output and inflation rise more as a result of equity injections into the banking sector.

As seen in Figure 6, purchases of corporate and government bonds produce nearly identical responses in terms of the variables in which we are interested. For this reason, we rely solely on corporate bond purchases and compare the effects for longer and shorter average maturities (Figure 10). The qualitative responses of macroeconomic variables change more strongly than for equity injections into the banking sector. However, the differences in responses can be traced back to the same reasons as outlined for the equity injection case. Purchases of corporate bonds directly increase bond prices. Again, higher corporate bond prices tend to increase the entrepreneurial leverage ratio in the corporate bond sector. For shorter average maturities, the leverage ratio for type A entrepreneurs falls by more, meaning that the credit spread is also reduced by more, which stimulates investment in this sector. Since there is no noticeable effect on banks' leverage ratio, the behavior of investment in the bond sector shows the same pattern as for longer average

Figure 10: Comparison of responses to pure bond purchases shock for a longer average maturity (bold line) and an average maturity of one period (dashed blue line)



Note: The Figure presents the pure responses to purchases of corporate bonds for different average maturities. See also note for Figure 1.

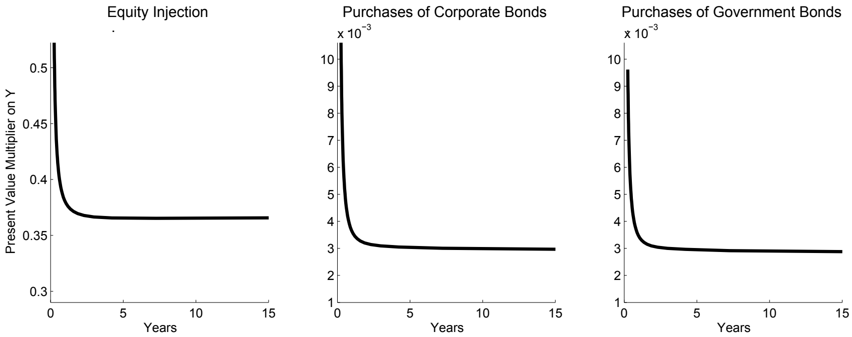
maturities, although an upward level shift takes place. Obviously, the volume effect as a result of the increase in banks' leverage ratio is outweighed by the improvement in borrowing conditions for this case. The slight change in investment and a more persistent increase in consumption, due to wealth effects, prevents output from falling in the second year after introducing the policy measure. At the same time, inflation is stimulated rather than being depressed.

Obviously, shorter average maturities coincide with an increase in the output multiplier. In order to gauge the effects on output of changing the average maturity, we vary the average maturity of corporate bonds on the x-axis in Figure 11 and compute, for each value, the corresponding output multiplier. Taken together, the pattern is very similar across the three measures. With longer average maturities, the multipliers shrink. However, the largest changes occur in the average maturity range of up to two years. For longer maturities, the reduction is nearly negligible. From this point of view, different average maturities do not affect the overall results.

4.5 The role of financial frictions

As mentioned, we calibrate our model to the euro area. In this respect, we are able to replicate many features of the economic structure such as credit spreads or maturities

Figure 11: Impact of maturities on output multipliers following equity injections, purchases of corporate and government bonds



Note: The Figure presents the output multiplier over four quarters by varying the average maturity of corporate bonds (see parameter $\rho^{B,corp}$ in Equation (20)). The Figure presents years on the x-axis.

of corporate bonds or government bonds. However, parameters which control financial frictions are set plausibly but without an empirical backing. In this section, we investigate which factors might alter the general results obtained in the preceding sections.

Since limits to arbitrage are crucial for obtaining non-trivial effects of outright purchases (Andrés et al., 2004), we focus on the factors that drive market segmentation in our model. In bankers' incentive constraint (Equation (33)), we assumed that all assets can be diverted equally. As in Gertler and Karadi (2013), we consequently assume now that assets can be diverted to different degrees. In principle, it is conceivable that money invested in the loan portfolio is easier to divert than money invested in bonds. Bonds are traded on a market and the price is publicly available, which makes it easier to monitor. By contrast, observation of the loan portfolio is usually exclusive to bankers. Consequently, the incentive constraint can be rewritten as

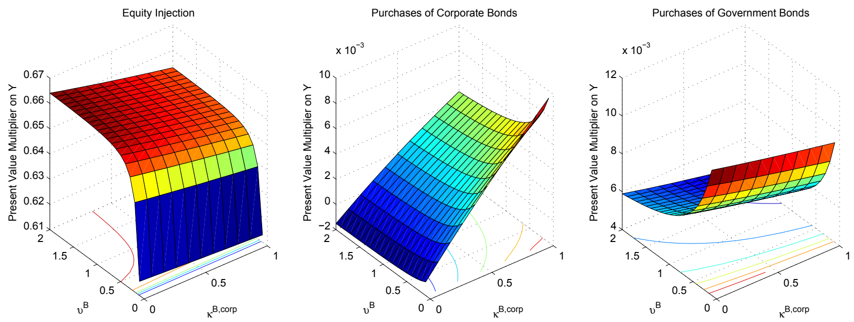
$$V_{n,t} \geq \theta^{IC} \left(\kappa^{L} L_{n,t} + \kappa^{B,Bcorp} Q_t^{B,corp} B_{n,t}^{corp} + \kappa^{B,gov} Q_t^{B,gov} B_{n,t}^{gov} \right), \tag{59}$$

where the parameters κ^L, $\kappa^{B,Bcorp}$, and $\kappa^{B,gov}$ range between 0 and 1 and express the percentage of money invested in the corresponding asset that can be diverted by bankers. As a consequence, from the modified incentive constraint it follows that the first order conditions, which are provided in the Appendix A.6, change.

In addition to the features that affect financial frictions in the banking sector, our household sector also exhibits financial frictions arising from portfolio costs as presented in Equation (7). These costs appear in the Euler equations and consequently affect the pricing of the assets directly. Similar costs can also be found for the banks (see Equations (27) and (28)). Unlike for households, these parameters are pinned down by the steady state because they result from the calibrated yield spreads, which is why we mainly focus on the other parameters controlling the frictions. Regardless of the considerations made above, we vary the values of the parameters over a broad range. For every parameter combination, we decide to report the present value multiplier on output.

In Figure 12, we provide the results for frictions that are related to corporate bonds

Figure 12: Impact of frictions relating to corporate bonds in the banking sector and government bonds in the household sector on the output multiplier over four quarters as a result of introducing policy measures



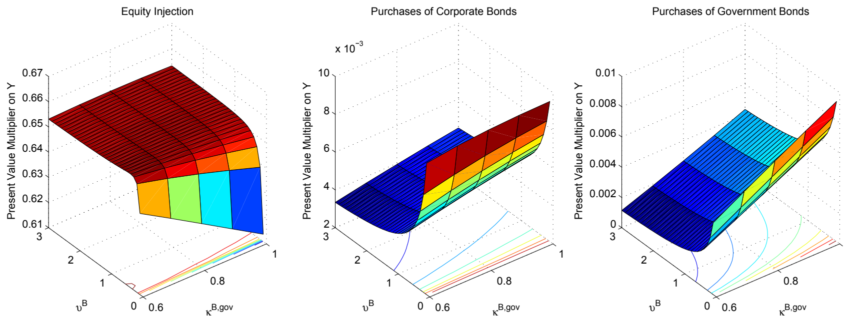
Note: The Figure presents the output multiplier over four quarters where the υ^B parameter in Equation (7) is varied, which controls the market segmentation related to government bonds with respect to households' portfolio decisions, as is the parameter $\kappa^{B,Bcorp}$ in Equation (59), which controls the financial frictions related to corporate bonds in the banking sector.

in the banking sector (x-axis) and to government bonds in the household sector (y-axis). In terms of equity injections and purchases of government bonds, the qualitative effects are very similar. Frictions in the banking sector do not matter much for effectiveness, frictions in the household sector mainly affect the magnitude of the multiplier. The larger portfolio costs for government bonds are, i.e. the greater market segmentation is, the larger the multiplier is for equity injections, while it is the other way round for purchases of government bonds. Frictions in the banking sector mainly matter for purchases of corporate bonds. The more money can be diverted from holdings of corporate bonds, the more effective corporate bond purchases are. With respect to frictions in the banking sector, these results are in line with what is expected. A higher degree of friction fosters limits to arbitrage and makes the proposed policy measures more effective. As a result, the multiplier even moves into negative territory for smaller degrees of friction in the banking sector in cases of corporate bond purchases because the effects on investment in the bond sector are not strong enough.

Output multipliers resulting from equity injections are not mainly affected by frictions with respect to government bonds in the banking sector. Again, frictions mainly matter if they manifest themselves in the household sector (see Figure 13, household sector on the y-axis and banking sector on the x-axis). Greater parameter values for portfolio costs increase the multiplier. For purchases of both corporate bonds and government bonds, the effects of frictions relating to government bonds in the banking sector are qualitatively identical to the previous case. Output multipliers increase more strongly for government bond purchases if banks divert more resources from holdings of government bonds.

In the last case, we again vary frictions in the household sector for government bonds (y-axis) and the share of loans that can be diverted in the banking sector (x-axis) as shown in Figure 14. Frictions in the banking sector mainly control the magnitude of the multiplier for equity injections and asset purchases. However, a similar shape arises for both asset purchases but with a reversed slope. The more money banks can divert

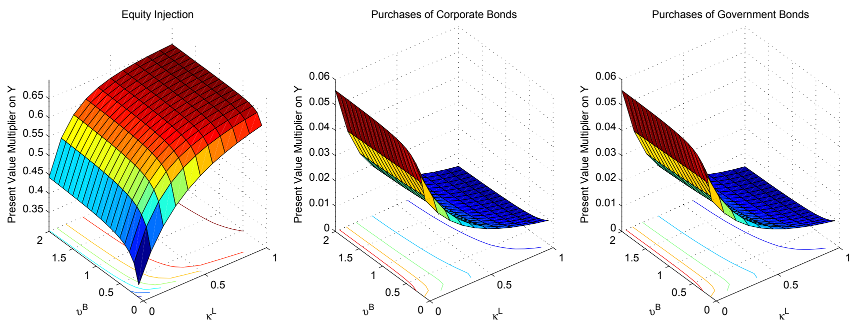
Figure 13: Impact of frictions relating to government bonds on the output multiplier over four quarters as a result of introducing policy measures



Note: The Figure presents the output multiplier over four quarters where the υ^{Bgov} parameter in Equation (7) is varied, which controls the market segmentation related to government bonds with respect to households' portfolio decisions, as is the parameter $\kappa^{B,gov}$ in Equation (59), which controls the financial frictions related to government bonds in the banking sector.

from the loan portfolio, the lower the multipliers are. As discussed in Section 4.3.1, asset purchases alter the returns and lower banks' profits. If frictions in the loan sector increase, the amplification mechanism is stronger and decreases output by more.

Figure 14: Impact of frictions relating to government bonds in the household sector and loans in the banking sector on the output multiplier over four quarters as a result of introducing policy measures



Note: The Figure presents the output multiplier over four quarters where the υ^{Bgov} parameter in Equation (7) is varied, which controls the market segmentation related to government bonds with respect to households' portfolio decisions, as is the parameter κ^{L} in Equation (59), which controls the financial frictions related to loans in the banking sector.

Summing up the results from this section: equity injections remain more effective by looking at the present value multiplier on output regardless of the characteristics of frictions. They do not turn into negative in the presented cases. The quantitative effects of outright purchases, however, heavily depend on the magnitude of frictions.

5 Conclusion

In this paper, we investigated the unconventional policy measures applied by central banks and governments to fight the fallout from the financial crisis. We draw on a New Keynesian stochastic general equilibrium model with a well-elaborated financial sector in which bank-financed debt plays a major role. From this point of view, our model is able to imitate the structure of the euro area to which we calibrate it. We combine an agency problem between the banking sector and capital producers with a costly state verification problem between the banking sector and non-financial corporations. As opposed to Hirakata et al. (2011), Hirakata et al. (2013), and Sandri and Valencia (2013), our bank is not risky since it cannot go bankrupt. Nevertheless, we allow for a loss distribution channel. An advantage of our framework is that it abstracts from defaults in the banking sector. We modeled two different sectors which allows us to distinguish between non-market-based debt, i.e. loans, and market-based debt, i.e. corporate bonds that are traded on the capital market. Furthermore, two sided financial contracting makes it possible to distinguish between two different sources of financial stress, i.e. the riskiness of the entrepreneurial sector and an exogenous drop in banks' net worth. This setting enabled us to investigate the effects of unconventional measures, equity injections and outright purchases, on the real economy and the financial sector. By using the same consistent framework, we were able to compare the efficacy of different policy measures and even evaluate their feedback effects.

It turns out that injections of inside equity into banks seem to be more efficient in terms of resources used. However, equity injections are welfare improving mainly if financial stress stems from the banking sector. They tend to be efficient because the build-up of inside equity relaxes banks' borrowing constraints and reduces borrowing conditions at the same time. Our results are in line with those of Christiano and Ikeda (2013a) and He and Krishnamurthy (2013), who utilize different frameworks. Outright purchases (of corporate bonds or government bonds) also improve welfare but only by utilizing more resources. They tend to reduce returns, which lowers banks' profits and weakens banks' balance sheets. Since banks' balance sheets are dominated by loans rather than securities, the price stabilizing role of asset purchases is of minor importance. From this point of view, our results complement the results obtained in the literature, where traded assets are accorded greater importance. If non-market-based debt dominates banks' balance sheets, as in the case of the euro area, equity injections into the banking sector might be more efficient if the financial shock originates in the banking sector. However, moral hazard problems resulting from banks' inherent option of drawing on public resources in cases of financial stress are not addressed in this paper.

A Model

A.1 Households

For the optimal real wage ($w^*_{h,t}$) one finally obtains

$$w^*_{h,t} = \left(\frac{\kappa \theta^w}{\theta^w - 1} \; \frac{E_t \sum_{s=0}^{\infty} \left(\beta \gamma^w\right)^s \left[w_{t+s}^{-\theta^w (1+\varphi)} \left(\Psi^w_{t+s} \frac{P_t}{P_{t+s}} \right)^{-\theta^w (1+\varphi)} N_{t+s}^{1+\varphi} \right]}{E_t \sum_{s=0}^{\infty} \left(\beta \gamma^w\right)^s \left[\lambda_{h,t+s} \left(1 - \tau^w_{t+s}\right) w_{t+s}^{-\theta^w} \left(\Psi^w_{t+s} \frac{P_t}{P_{t+s}} \right)^{1-\theta^w} N_{t+s} \right]} \right)^{\frac{1}{1+\varphi\theta^w}},$$

where the term θ^w is the degree of substitution between differentiated labor, φ reflects the inverse Frisch elasticity and Ψ^w_{t+s} comprises changes in rates of inflation until date s. The optimal labor supply is denoted with $N^*_{h,t}$. As the law of motion for the real wage, there arises

$$w_t^{1-\theta^w} = \left(1 - \gamma^w\right) \, w_t^{*1-\theta^w} + \gamma^w \left(\frac{\tilde{w}_t}{\pi_t} \right)^{1-\theta^w},$$

with $\tilde{w}_t = \pi_{t-1}^{\xi^w} \, \pi_s^{1-\xi^w} \, w_{t-1}$ for the non-optimizing real wage.

Resulting from utility maximization, we obtain the marginal utility of consumption

$$\lambda_{h,t} = \left(C_{h,t} - h^C C_{t-1} \right)^{-\sigma} \tag{60}$$

and the Euler Equation

$$E_t \pi_{t+1} = E_t \beta \frac{\lambda_{h,t+1}}{\lambda_{h,t}} (1 + i_t). \tag{61}$$

The first order condition for government bonds is

$$B_t^{gov,H} = B_s^{gov,H} + \frac{E_t \left[\frac{\frac{\beta \, \lambda_{t+1}}{\lambda_t} \left(1 + r_{t+1}^{B,gov}\right)}{\pi_{t+1}} \right] - 1}{\upsilon^{B,gov}}. \tag{62}$$

A.2 Intermediate goods firms

The ratio of the optimal price, resulting from the optimization problem, to the current price of the final good ($\pi^*_{i,t}$) results as

$$\frac{P^*_{i,t}}{P_t} = \pi^*_{i,t} = \frac{\theta}{\theta - 1} \frac{E_t \sum_{k=0}^{\infty} \beta^k \gamma^k \frac{P_{t+k}}{\psi_{t+k} P_t} Y_{i,t+k} \; mc_{i,t+k}}{E_t \sum_{k=0}^{\infty} \beta^k \gamma^k Y_{i,t+k}}, \tag{63}$$

where ψ_{t+k} captures the price indexation, i.e. $\left(\pi_{t-1}\right)^{\xi} (\pi)^{1-\xi}$ with indexation parameter ξ, and mc_t denotes marginal costs which are

$$mc_t = \left(\frac{r_t^{k,B}}{\left(1 - \zeta^{ws}\right) \alpha} \right)^{\alpha} \left(\frac{r_t^{k,A} \left(1 - \zeta^{ws}\right)}{r_t^{k,B} \zeta^{ws}} \right)^{\zeta^{ws} \alpha} \left(\frac{w_t}{1 - \alpha} \right)^{1-\alpha}. \tag{64}$$

Since all firms that can adjust the price optimally have the same optimum, we have dropped the indexes. Given the price aggregator, we obtain an expression for the evolution of the rate of inflation

$$(\pi_t)^{1-\theta} = \gamma \left((\pi_{t-1})^{\xi} (\pi)^{1-\xi} \right)^{1-\theta} + (1-\gamma) (\pi_t^* \pi_t)^{(1-\theta)} . \tag{65}$$

$$r_t^{k,A} = \varrho_t A_t \, \zeta^{ws} \alpha \left(\widetilde{K}_{it}^A \right)^{\zeta^{ws}\alpha - 1} \left(\widetilde{K}_{it}^B \right)^{(1-\zeta^{ws})\alpha} (N_{it})^{1-\alpha} \tag{66}$$

$$r_t^{k,B} = \varrho_t A_t \, (1-\zeta^{ws}) \, \alpha \left(\widetilde{K}_{it}^A \right)^{\zeta^{ws}\alpha} \left(\widetilde{K}_{it}^B \right)^{(1-\zeta^{ws})\alpha - 1} (N_{it})^{1-\alpha} \tag{67}$$

$$w_t = \varrho_t A_t \, (1-\alpha) \left(\widetilde{K}_{it}^A \right)^{\zeta^{ws}\alpha} \left(\widetilde{K}_{it}^B \right)^{(1-\zeta^{ws})\alpha} (N_{it})^{-\alpha} \tag{68}$$

$$Y_{it} = A_t \left(\widetilde{K}_{it}^A \right)^{\zeta^{ws}\alpha} \left(\widetilde{K}_{it}^B \right)^{(1-\zeta^{ws})\alpha} (N_{it})^{1-\alpha} - \Omega \tag{69}$$

The capital-to-capital ratio is

$$\frac{\widetilde{K}_{it}^B}{\widetilde{K}_{it}^A} = \frac{(1-\zeta^{ws}) \, r_{it}^{k,A}}{\zeta^{ws} r_{it}^{k,B}} = \frac{K_t^B}{K_t^A} . \tag{70}$$

The capital-labor ratio is

$$\frac{N_{it}}{\widetilde{K}_{it}^L} = \frac{(1-\alpha) r_{it}^{k,A}}{\zeta^{ws} \alpha w_{it}} = \frac{N_t}{K_t^A} . \tag{71}$$

A.3 Final goods firms

$$1 = \gamma \left(\frac{\tilde{\pi}_t}{\pi_t} \right)^{1-\theta} + (1-\gamma) \, \pi_t^{*1-\theta} \tag{72}$$

$$\tilde{\pi}_t = \pi_{t-1}^{\xi} \, \pi_s^{1-\xi} \tag{73}$$

$$\pi_t^* = \frac{\theta}{\theta - 1} \frac{NP_t}{DP_t} \tag{74}$$

$$NP_t = mc_t \, \lambda_t \, Y_t + \beta \, \gamma \left(\frac{\tilde{\pi}_{t+1}}{\pi_{t+1}} \right)^{(-\theta)} NP_{t+1} \tag{75}$$

$$DP_t = \lambda_t \, Y_t + \beta \, \gamma \left(\frac{\tilde{\pi}_{t+1}}{\pi_{t+1}} \right)^{1-\theta} DP_{t+1} \tag{76}$$

$$mc_t = \frac{\left(\frac{r_t^{k,B}}{(1-\zeta^{ws}) \, \alpha} \right)^{\alpha} \left(\frac{r_t^{k,A} \, (1-\zeta^{ws})}{r_t^{k,B} \, \zeta^{ws}} \right)^{\zeta^{ws} \, \alpha} \left(\frac{w_t}{1-\alpha} \right)^{1-\alpha}}{exp \left(\epsilon_t^A \right)} \tag{77}$$

A.4 Capital goods producers

For type A capital good:

$$Q_t^A = \frac{1 - \frac{\lambda_{t+1}\,\beta\,Q_{t+1}^A}{\lambda_t}\,\upsilon^A\,\left(\frac{I_{t+1}^A}{I_t^A}\right)^2\,\left(\frac{I_{t+1}^A}{I_t^A} - 1\right)}{\left(1 - \frac{\upsilon^A}{2}\,\left(\frac{I_t^A}{I_{t-1}^A} - 1\right)^2 - \left(\frac{I_t^A}{I_{t-1}^A} - 1\right)\,\frac{\upsilon^A\,I_t^A}{I_{t-1}^A}\right)}$$

For type B capital good:

$$Q_t^B = \frac{1 - \frac{\lambda_{t+1}\,\beta\,Q_{t+1}^B}{\lambda_t}\,\upsilon^B\,\left(\frac{I_{t+1}^B}{I_t^B}\right)^2\,\left(\frac{I_{t+1}^B}{I_t^B} - 1\right)}{\left(1 - \frac{\upsilon^B}{2}\,\left(\frac{I_t^B}{I_{t-1}^B} - 1\right)^2 - \left(\frac{I_t^B}{I_{t-1}^B} - 1\right)\,\frac{\upsilon^B\,I_t^B}{I_{t-1}^B}\right)}$$

A.5 Entrepreneurs

The maximization problem of each e-type entrepreneur is

$$\begin{aligned} &\max_{\left\{K_{m,t+1}^e,\overline{\omega}_{m,t+1}^e\right\}} \left(1 - \Gamma^f(\overline{\omega}_{m,t+1}^e)\right)\left(1 + E_t\left(R_{t+1}^{k,e}\right)\right)Q_t^e K_{m,t+1}^e \\ &s.t.\quad \left[\Gamma^f(\overline{\omega}_{m,t+1}^e) - \mu^e G(\overline{\omega}_{m,t+1}^e)\right]\left(1 + E_t\left(R_{t+1}^{k,e}\right)\right)Q_t^e K_{m,t+1}^e \\ &\qquad = (1 + r_t^e)\left(Q_t^e K_{m,t+1}^e - NW_{m,t+1}^e\right) \end{aligned} \tag{78}$$

We obtain two optimality conditions: the first-order condition of the contract (Equation (79)) and the budget constraint of the entrepreneurs (Equation (80))

$$\begin{aligned} 0 \;=\;& FP_{t+1}^e\left(1 - \Gamma^f(\overline{\omega}_{t+1};\sigma_t)\right) \\ +\;& \frac{\Gamma_{\varpi}^f(\overline{\omega}_{t+1};\sigma_t)}{\left(\Gamma_{\varpi}^f(\overline{\omega}_{t+1};\sigma_t) - \mu G_{\varpi}(\overline{\omega}_{t+1};\sigma_t)\right)}\left(\left[\Gamma^f(\overline{\omega}_{t+1};\sigma_t) - \mu G(\overline{\omega}_{t+1};\sigma_t)\right]FP_t^e - 1\right) \end{aligned} \tag{79}$$

and

$$\left[\Gamma^f(\overline{\omega}_{t+1};\sigma_t) - \mu G(\overline{\omega}_{t+1};\sigma_t)\right]FP_{t+1}^e\frac{Q_t^e K_{t+1}^e}{NW_{t+1}^e} - \left(\frac{Q_t^e K_{t+1}^e}{NW_{t+1}^e} - 1\right) = 0, \tag{80}$$

where $\Gamma^f(\overline{\omega}) = \overline{\omega}\int_{\overline{\omega}}^{\infty}F_{\varpi}(\overline{\omega})\,d\varpi + \int_0^{\overline{\omega}}\varpi F_{\varpi}(\overline{\omega})\,d\varpi$, $G(\overline{\omega}) = \int_0^{\overline{\omega}}\varpi F_{\varpi}(\overline{\omega})\,d\varpi$, and $\Gamma_{\varpi}^f(\overline{\omega}) = 1 - F(\overline{\omega})$.[56] The term FP_{t+1}^e in Equations (79) and (80) can be interpreted as a premium for external finance and is defined as

$$FP_t^e = \frac{\left(1 + E_t\left(R_{t+1}^{k,e}\right)\right)}{(1 + r_t^e)}$$

with $FP_t^A = \frac{\left(1+E_t\left(R_{t+1}^{k,A}\right)\right)}{\left(1+E_t\left(r_{t+1}^{B,corp}\right)\right)}$ for type A and $FP_t^B = \frac{\left(1+E_t\left(R_{t+1}^{k,B}\right)\right)}{\left(1+r_t^L\right)}$ for type B entrepreneurs.

In the optimum, the real cost of capital $(r_t^{k,e})$ is related to the adjustment costs on capital utilization (u_t^e)

$$r_t^{k,e} = r^{k,e}\exp\left[\psi^{k,e}\,(u_t^e - 1)\right] \tag{81}$$

[56]The expression X_Y denotes the partial derivative of X with respect to Y.

and is free of individual characteristics, i.e. every entrepreneur chooses the same utilization rate.

A.6 Financial frictions in the banking sector

As a variation of the model in the main text, we allow for different degrees of asset diversion. By making use of bank's balance sheet constraint, and of the definition for $\varsigma_{n,t}^{B,corp}$ and $\varsigma_{n,t}^{B,gov}$, we can rewrite the incentive constraint from Equation (33) and obtain the expression

$$V_{n,t} \geq \theta^{IC}\left(\kappa^{B,L}\left(1-\varsigma_{n,t}^{B,corp}-\varsigma_{n,t}^{B,gov}\right)+\kappa^{B,corp}\varsigma_{n,t}^{B,corp}+\kappa^{B,gov}\varsigma_{n,t}^{B,gov}\right)A_{n,t}^{B}. \tag{82}$$

The parameters $\kappa^{B,L}$, $\kappa^{B,corp}$, and $\kappa^{B,gov}$ control the share that can be diverted from the respective asset class. The optimization problem at the first stage remains the same and the conjectured function does not change

$$V_{n,t} = (\upsilon_t^A-\upsilon_t^F)A_{n,t}^B+(\upsilon_t^F-\upsilon_t^{IE})E_{n,t}^I+\eta_{n,t}^{IE,gov}-\eta_{n,t}^A\ . \tag{83}$$

After optimizing Equation (83) subject to Equation (82), we obtain the new first order conditions

$$A_{n,t}^B:\ (\upsilon_t^A-\upsilon_t^F) = \frac{\lambda_t^{IC}\theta^{IC}\left(\kappa^{B,L}\left(1-\varsigma_{n,t}^A\right)+\kappa^{B,corp}\varsigma_{n,t}^{B,corp}+\kappa^{B,gov}\varsigma_{n,t}^{B,gov}\right)}{\left(1+\lambda_t^{IC}\right)} \tag{84}$$

and

$$\lambda_t^{IC}:\ \begin{array}{c}\left(\upsilon_t^A-\upsilon_t^F\right)A_{n,t}^B+\left(\upsilon_t^F-\upsilon_t^{IE}\right)E_{n,t}^I+\eta_{n,t}^{IE,gov}-\eta_{n,t}^A\\ \geq\theta^{IC}\left(\ \kappa^{B,L}\left(1-\varsigma_{n,t}^A\right)+\kappa^{B,corp}\varsigma_{n,t}^{B,corp}+\kappa^{B,gov}\varsigma_{n,t}^{B,gov}\ \right)A_{n,t}^B\end{array} \tag{85}$$

which differ only slightly from those in the main text. As a result, the variables $\phi_{n,t}^{IE}$ and $\phi_{n,t}^{\eta}$ in Equation (35) get a different meaning. Thus, we have

$$A_{n,t}^B = \phi_{n,t}^{IE}E_{n,t}^I+\phi_{n,t}^{\eta}(\eta_{n,t}^{IE,gov}-\eta_{n,t}^A) \tag{86}$$

with

$$\phi_{n,t}^{IE} = \frac{\upsilon_t^F-\upsilon_t^{IE}}{\theta^{IC}\left(\ \kappa^{B,L}\left(1-\varsigma_{n,t}^A\right)+\kappa^{B,corp}\varsigma_{n,t}^{B,corp}+\kappa^{B,gov}\varsigma_{n,t}^{B,gov}\ \right)-(\upsilon_t^A-\upsilon_t^F)}, \tag{87}$$

$$\phi_{n,t}^{\eta} = \frac{1}{\theta^{IC}\left(\ \kappa^{B,L}\left(1-\varsigma_{n,t}^A\right)+\kappa^{B,corp}\varsigma_{n,t}^{B,corp}+\kappa^{B,gov}\varsigma_{n,t}^{B,gov}\ \right)-(\upsilon_t^A-\upsilon_t^F)}. \tag{88}$$

The equations from the second stage of the optimization problem do not change.

B Tables

Table 6: Balance sheets of non-financial corporations in the euro area and in the USA (1999-2013, averages in € billion)

	Euro area		USA	
	€ billion	%	US$ billion	%
Total assets	29,048.9	100	24,472.6	100
Total financial assets	13,258.4	45.6	11,756.2	48.0
Total fixed assets	15,790.5	54.4	12,716.5	52.0
Total debt	10,409.6	35.8	9,747.1	39.8
Loans	6,436.8	22.2	2,266.0	9.3
Debt securities	649.4	2.2	4,006.0	16.4
Other debt	3,323.4	11.4	3,475.2	14.2
Total equity	18,639.3	64.2	14,725.5	60.2
Shares and other equity	10,805.1	37.2	14,302.1	58.4
Capital reserves	7,834.2	27.0	423.4	1.7

Note: For both economic areas, the data stem from the corresponding flow of funds statistics. In the case of the USA, foreign direct investment (FDI) ranks among the liabilities. For the sake of comparability, the item "Shares and other equity" is the sum of equity outstanding and FDI. Since intercompany debt is a subcategory of FDI, we adjust for these flows and attribute this item to loans. "Other debt" consists of trade payables, taxes payable, pension fund contributions payable and other debt.

References

Amisano, G. and O. Tristani (2010). Euro area inflation persistence in an estimated nonlinear dsge model. *Journal of Economic Dynamics & Control 34*, 1837–1858.

Andrés, J., J. D. López-Salido, and E. Nelson (2004). Tobin's imperfect asset substitution in optimizing general equilibrium. *Journal of Money, Credit and Banking 36*, 665–690.

Baumeister, C. and L. Benati (2013). Unconventional monetary policy and the great recession: Estimating the macroeconomic effects of a spread compression at the zero lower bound. *International Journal of Central Banking 9*(2), 165–212.

Benes, J. and M. Kumhof (2011, June). Risky bank lending and optimal capital adequacy regulation. IMF Working Paper WP/11/130, International Monetary Fund.

Bernanke, B. S., M. Gertler, and S. Gilchrist (1999). The financial accelerator in a quantitative business cycle framework. In J. Taylor and M. Woodford (Eds.), *Handbook of Macroeconomics*. Elsevier.

Bolton, P. and X. Freixas (2000). Equity, bonds, and bank debt: Capital structure and financial market equilibrium under asymmetric information. *Journal of Political Economy 108*(2), 324–351.

Boot, A. W. A. and A. V. Thakor (1997). Financial system architecture. *Review of Financial Studies 10*(3), 693–733.

Brett, W. F. and C. J. Neely (2013, January/February). Four stories of quantitative easing. *Federal Reserve Bank of St. Louis Review*, 51–88.

Calvo, G. A. (1983). Staggered price setting in a utility-maximizing framework. *Journal of Monetary Economics 12*, 383–398.

Chen, H., V. Cúrdia, and A. Ferrero (2012). The macroeconomic effects of large-scale asset purchase programmes. *The Economic Journal 122*, F289–F315.

Christiano, L., R. Motto, and M. Rostagno (2003). The great depression and the friedman-schwartz hypothesis. *Journal of Money, Credit and Banking 35*(6), 1119–1197.

Christiano, L., R. Motto, and M. Rostagno (2010, May). Financial factors in economic fluctuations. Working Paper Series 1192, European Central Bank.

Christiano, L. J., M. Eichenbaum, and C. E. Evans (2005). Nominal rigidities and the dynamic effects of a shock to monetary policy. *Journal of Political Economy 113*(1), 1–45.

Christiano, L. J. and D. Ikeda (2013a). Government policy, credit markets and economic activity. In M. D. Bordo and W. Roberds (Eds.), *The Origins, History, and Future of the Federal Reserve - A Return to Jekyll Island*, Studies in Macroeconomic History. Cambridge University Press.

Christiano, L. J. and D. Ikeda (2013b). Leverage restrictions in a business cylce model. Working Paper No. 18688, NBER.

Christiano, L. J., R. Motto, and M. Rostagno (2014). Risk shocks. *American Economic Review 104*(1), 27–65.

Christoffel, K., G. Coenen, and A. Warne (2008, September). The new area-wide model of the euro area - a micro-founded open-economy model for forecasting and policy analysis. Working Paper Series 944, European Central Bank.

Cúrdia, V. and M. Woodford (2011). The central-bank balance sheet as an instrument of monetary policy. *Journal of Monetary Economics 58*, 54–79.

D'Amico, S., W. English, D. Lopéz-Salido, and E. Nelson (2012). The federal reserve's large-scale asset purchase programmes: Rationale and effects. *The Economic Journal 122*, F415–F446.

De Fiore, F. and H. Uhlig (2011). Bank finance versus bond finance. *Journal of Money, Credit, and Banking 43*, 1399–1421.

De Fiore, F. and H. Uhlig (2012). Corporate debt structure and the financial crisis. Technical report, mimeo.

Dedola, L., P. Karadi, and G. Lombardo (2013). Global implications of national unconventional policies. *Journal of Monetary Economics 60*, 66–85.

Denis, D. J. and V. T. Mihov (2003). The choice among bank debt, non-bank priate debt, and public debt: Evidence from new corporate borrowings. *Journal of Financial Economics 70*, 3–28.

Diamond, D. W. (1984). Financial intermediation and delegated monitoring. *Review of Economic Studies 51*(3), 393–414.

Eggertsson, G. B. and M. Woodford (2003). The zero bound on interest rates and optimal monetary policy. *Brookings Papers on Economic Activity 34*(2003-1), 139–235.

Erceg, C. J., D. W. Henderson, and A. T. Levin (2000). Optimal monetary policy with staggered wage and price contracts. *Journal of Monetary Economics 46*(2), 281–313.

European Central Bank (2012, Feburary). Corporate indebtness in the euro area. Monthly Bulletin.

Fahr, S., R. Motto, M. Rostagno, F. Smets, and O. Tristani (2011). Lessons for monetary policy strategies from the recent past. In M. Jarocinski, F. Smets, and C. Thimann (Eds.), *Approaches to Monetary Policy Revisited - Lessons from the Crisis*, pp. 26–66. European Central Bank.

Fama, E. F. (1985). What's different about bonds. *Journal of Monetary Economics 15*, 29–39.

Fisher, J. D. M. (1999). Credit market imperfections and the heterogeneous response of firms to monetary shocks. *Journal of Money, Credit and Banking 31*(2), 187–211.

Gagnon, J., M. Raskin, J. Remache, and B. Sack (2011). The financial market effects of the federal reserve's large-scale asset purchases. *International Journal of Central Banking 7*(1), 3–43.

Gerali, A., S. Neri, L. Sessa, and F. M. Signoretti (2010). Credit and banking in a DSGE model of the euro area. *Journal of Money, Credit and Banking 42*(6), 107–141.

Gertler, M. and S. Gilchrist (1994). Monetary policy, business cycles, and the behavior of small manufacturing firms. *Quarterly Journal of Ecconomics 109*(2), 309–340.

Gertler, M., S. Gilchrist, and F. M. Natalucci (2007). External constraints on monetary policy and the financial accelerator. *Journal of Money, Credit and Banking 39*(2-3), 295–330.

Gertler, M. and P. Karadi (2011). A model of unconventional monetary policy. *Journal of Monetary Economics 58*, 17–34.

Gertler, M. and P. Karadi (2013). Qe 1 vs. 2 vs. 3... a framework for analyzing large scale asset purchases as a monetary policy tool. *International Journal of Central Banking 9*(S1), 5–53.

Gertler, M. and N. Kiyotaki (2010). Financial intermediation and credit policy in business cycle analysis. In *Handbook of Monetary Economics*, Volume Volume 3A. Elsevier.

Giannone, D., M. Lenza, H. Pill, and L. Reichlin (2012). The ECB and the interbank market. *The Economic Journal 122*, F467–F486.

Gilchrist, S. and E. Zakrajsek (2012). Credit spreads and business cycle fluctuations. *American Economic Review 102*(4), 1692–1720.

Goodfriend, M. and B. T. McCallum (2007). Banking and interest rates in monetary policy analysis: A quantitative exploration. *Journal of Monetary Economics 54*, 1480–1507.

Hamilton, J. D. and J. C. Wu (2012). The effectiveness of alternative monetary policy tools in a zero lower bound environment. *Journal of Money, Credit and Banking S44*(1), 3–46.

He, Z. and A. Krishnamurthy (2013). Intermediary asset pricing. *American Economic Review 103*(2), 732–770.

Hirakata, N., N. Sudo, and K. Ueda (2011). Do banking shocks matter for the U.S. economy? *Journal of Economic Dynamics & Control 35*, 2042–2063.

Hirakata, N., N. Sudo, and K. Ueda (2013). Capital injections, monetary policy, and financial accelerators. *International Journal of Central Banking 9*(2), 101–145.

Iacoviello, M. (2005). House prices, borrowing constraint, and monetary policy in the business cylce. *American Economic Review 95*(3), 739–764.

Joyce, M. A. S., A. Lasaosa, I. Stevens, and M. Tong (2011). The financial market impact of quantitative easing in the united kingdom. *International Journal of Central Banking 7*(3), 113–161.

Joyce, M. J. S. and M. Tong (2012). QE and the gilt market: A disaggregated analysis. *The Economic Journal 122*, F348–F384.

Kapetanios, G., H. Mumtaz, I. Stevens, and K. Theodoridis (2012). Assesing the economy-wide effects of quantitative easing. *The Economic Journal 122*, F316–F347.

Kühl, M. (2014). The financial accelerator and market-based debt instruments: A role for maturities? Discussion Paper No 08/2014, Deutsche Bundesbank.

Kirchner, M. and S. van Wijnbergen (2012). Fiscal deficits, financial fragility and the effectiveness of government policies. Discussion Paper No 20/2012, Deutsche Bundesbank.

Krishnamurthy, A. and A. Vissing-Jorgensen (2011). The effects of quantitative easing on interest rates: Channels and implications for policy. *Brookings Papers on Economic Activity Fall*, 215–265.

Krishnaswami, S., P. A. Spindt, and V. Subramaniam (1999). Information asymmetry, monitoring, and the replacement structure of corporate debt. *Journal of Financial Economics 51*, 407–434.

Leeper, E. M. (1991). Equilibria under 'active' and 'passive' monetary and fiscal policies. *Journal of Monetary Economics 27*, 129–147.

Levy, A. and C. Hennessy (2007). Why does capital structure choice vary with macroeconomic conditions? *Journal of Monetary Economics 54*, 1545–1564.

Longstaff, F. A., S. Mithal, and E. Neis (2005). Corporate yield spreads: Default risk or liquidity? New evidence from the credit default swap market. *The Journal of Finance 60*, 2213–2254.

Lucas, R. E. (1987). *Models of Business Cycles.* Basil Blackwell.

Meh, C. A. and K. Moran (2010). The role of bank capital in the propagation of shocks. *Journal of Economic Dynamics & Control 34*, 555–576.

Mountford, A. and H. Uhlig (2009). What are the effects of fiscal shocks? *Journal of Applied Econometrics 24*, 960–992.

Peek, J., E. S. Rosengren, and G. M. Tootell (2003). Identifying the macroeconomic effect of loan supply shocks. *Journal of Money, Credit and Banking 35*(6), 931–946.

Peersman, G. (2011). Macroeconomic effects of unconventional monetary policy in the euro area. Working Paper Series 1397, European Central Bank.

Rannenberg, A. (2013). Bank leverage cycles and the external finance premium. Discussion Paper 55/2013, Deutsche Bundesbank.

Sandri, D. and F. Valencia (2013). Financial crises and recapitalizations. *Journal of Money, Credit and Banking 45*(2), 59–86.

Schmitt-Grohé, S. and M. Uribe (2007). Optimal simple and implementable monetary and fiscal rules. *Journal of Monetary Economics 54*, 1702–1725.

Smets, F. and C. Trabandt (2012, September). Government debt, the zero lower bound and monetary policy. mimeo.

Smets, F. and R. Wouters (2003). An estimated dynamic stochastic general equilibrium model of the euro area. *Journal of the European Economic Association 1*(5), 1123–1175.

Swanson, E. T. (2011). Let's twist again: A high-frequency event-study analysis of operation twist and its implications for QE2. *Brookings Papers on Economic Activity Spring*, 151–207.

Taylor, J. B. (1993, December). Discretion versus policy rules in practice. *Carnegie-Rochester Conference Series on Public Policy 39*(1), 195–214.

von Heideken, V. Q. (2009). How important are financial frictions in the United States and the euro area? *Scandinavian Journal of Economics 111*(3), 567–596.

Williamson, S. D. (2012). Liquidity, monetary policy, and the financial crisis: A new monetarist approach. *American Economic Review 102*(6), 2570–2605.

Woodford, M. (2001). Fiscal requirements for price stability. *Journal of Money, Credit and Banking 33*(3), 669–728.

Zeng, Z. (2013). A theory of the non-neutrality of money with banking frictions and bank recapitalization. *Economic Theory 52*(2), 729–754.

Zhang, L. (2009). Bank capital regulation, the lending channel and business cycle. Discussion Paper Series 1: Economic Studies No 33/2009, Deutsche Bundesbank.