Current Topics in Macroeconomic Policies for the European Monetary Union

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Erklärung zu Koautoren

Die vorliegende Dissertation umfasst eine Einleitung (Kapitel 1) und drei Forschungspapiere (Kapitel 2 bis 4). Kapitel 1 und 2 wurden alleine verfasst, während Kapitel 3 und 4 in Ko-Autorenschaft entstanden sind. Ko-Autor des Kapitel 3 ist Oreste Tristani. Pau Rabanal ist Ko-Autor des 4. Kapitels. Für die Dissertation sind diese Kapitel gegenüber den gemeinsam verfassten Manuskripten redaktionell leicht angepasst worden. Diese Veränderungen verantwortet allein der Autor der vorliegenden Dissertation. Eine Liste mit Vorveröffentlichungen von Kapiteln befindet sich auf Seite 192.

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Chapter 1

Introduction

In 1999, eleven European countries launched the European Monetary Union (EMU) and voluntarily transferred their prerogatives to a newly created supranational institution, the European Central Bank (ECB).[1] Looking at its short history, the EMU has been characterized by some ups and downs. On the one hand, it has grown over time—up to today, 19 European countries have joined the EMU—the euro established itself alongside the U.S. dollar, Japanese yen, and pound sterling as an international currency, and the ECB has quickly earned the credibility of financial market participants as well as policy makers. On the other hand, the economic heterogeneity among member states and the fact that a full economic integration is lacking in the EMU, has been a crucial impediment to a smooth transmission of monetary policy across the euro area. This has always attracted a lot of criticism and is moreover seen as having encouraged the build-up of intra-area imbalances prior to the Global Financial Crisis of 2008-09. The crisis, together with the subsequent European Sovereign Debt Crisis, has become the ECB's greatest challenge as some member states came under heavy attack by financial markets questioning the cohesion and irreversibility of the union.

In this thesis I take a close look at the main challenges the ECB has faced since the start of the EMU. I shed light on some key issues which are unique to the EMU and, therefore, essential for policy makers to understand. In detail, this thesis takes stock of both the *conventional* and *unconventional* monetary policy implemented by the ECB since 1999 and evaluates it not only from a union-wide perspective but also from the viewpoint of its individual member states. Given the far-reaching impact of the Global Financial Crisis, a central element is the evaluation of the new policy tools implemented in response to this crisis in order to enhance financial stability. In

[1] In this thesis, I follow the convention in scientific writing and do not distinguish between the ECB and the Eurosystem.

doing so, I offer guidance on the way forward regarding the coordination of the single monetary policy with these new policy instruments.

The introductory chapter is organized as follows. Section 1.1 lays out the most relevant questions that emerged from the history of the EMU and are answered in the subsequent chapters. Given the historical context, section 1.2 discusses the outline and scope of the thesis. It also comprises detailed reviews of the following chapters.

1.1 Motivation

The EMU is first and foremost a monetary and not a political union. Its member states share a common monetary policy but besides this the union lacks a deeper integration along several dimensions. Its legal framework remains disparate, the diversity of languages forms an obstacle especially for the integration of labor markets, and a comprehensive coordination of fiscal policy is missing. Furthermore, at the time the euro was introduced, the member states saw no need to improve the coordination of financial market regulation and supervision. On these grounds, much criticism had been voiced in the 1990s against the creation of the EMU. According to the theory of *optimal currency areas*, the planned union was not considered to be optimal.[2] Taking the U.S. as a benchmark of a well-functioning monetary union, it was argued that shocks were too asymmetrically distributed among countries (Bayoumi and Eichengreen, 1993a,b), that labor mobility was too low (Decressin and Fatás, 1995) and that wages were too rigid (OECD, 1999, Ch. 4). Furthermore, the Stability and Growth Pact, which was introduced to ensure fiscal discipline among member states, was seen as too strict to allow fiscal policy to work as a well-functioning shock absorber (Eichengreen, 1997; Eichengreen and Wyplosz, 1998). These critics expected that the business cycle synchronization within the EMU would further deteriorate (Krugman, 1993) and that the *one size* policy of the ECB would both lower the standard of living and raise inflation (Feldstein, 1997).[3]

In the years after the introduction of the euro, the developments in the euro area turned out to be different from what had originally been predicted by EMU critics. During the first ten years, the consensus emerged that the degree of economic integration among euro area countries had increased rather than decreased (e.g. Mongelli

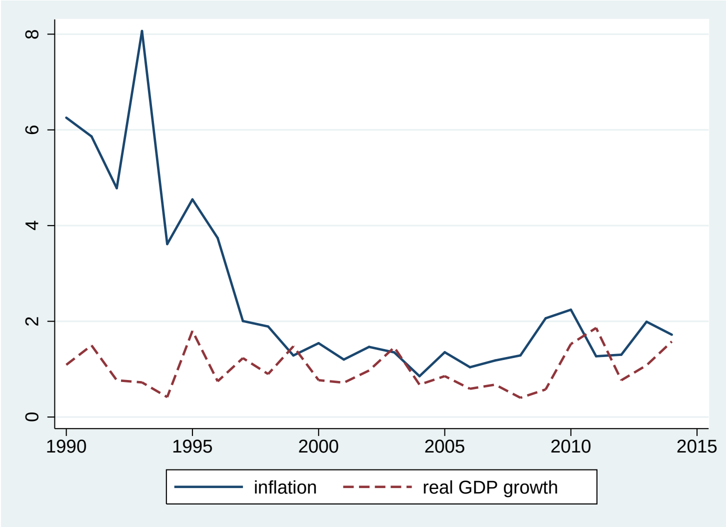
[2]The theory of *optimal currency areas* has its origin in the studies by Mundell (1961), McKinnon (1963) and Kenen (1969).

[3]However, not all studies at that time came to such a conclusion. E.g. Frankel and Rose (1997, 1998) argue that *optimal currency area* criteria are endogenous and that the euro once introduced would facilitate trade and with it business cycle synchronization.

and Wyplosz, 2009). Inflation rate differentials as well as the synchronization of business cycles improved since the beginning of the 1990s. But the dispersion in inflation and real GDP growth rates never fully disappeared, as countries in the euro area periphery outgrew the ones in the core (Benalal *et al.*, 2006). Whereas inflation did not diverge much since the start of the European Sovereign Debt Crisis, economic growth drifted apart after 2009 and the euro area has witnessed a desynchronization of business cycles (Gächter *et al.*, 2012). However, taking the U.S. as a benchmark, the relative heterogeneity—even after 2009—has not increased significantly. Figure 1.1 relates the dispersion in inflation and real GDP growth in the euro area to the corresponding dispersion among U.S. states. In contrast to the dispersion in output growth, the standard deviation of inflation among euro area countries considerably exceeded the standard deviation among U.S. states prior to 1999, but fell to comparable low levels thereafter. Since the introduction of the euro, the dispersion in both measures has remained on comparable levels. This now raises the question of the adequacy of the ECB's monetary policy for its member states. On the one hand, given the observed level of heterogeneity, the ECB's *one size* policy is unlikely to fit all member states at all times. On the other hand, economic heterogeneity does not seem to be unusual for large currency areas. For this reason, chapter 2 takes stock of the heterogeneity in the EMU from the viewpoint of its individual member states and puts it into perspective with comparable currency areas.

The primary objective of monetary policy (not only for the ECB) is price stability. Following the literature on optimal monetary policy, such stabilization can be achieved through a simple policy rule, where the short-term rate is adjusted in response to inflation as well as output changes (see e.g. the contributions in the volume edited by Taylor, 1999). This—prior to the crisis prevailing—consensus is shaped by the concept of *devine coincidence* (Blanchard and Galí, 2007). According to that, price stability should be sufficient for keeping economic activity as close as possible to its potential (i.e. the welfare relevant level). Optimal monetary policy would thus deliver stable prices and at the same time minimize the distance of output and employment from first best. Furthermore, together with a light touch of microprudential regulation, price stability was also seen as being sufficient for financial stability.[4]

[4]One form of financial instability already acknowledged before the recent crisis were asset price bubbles. However, the role of monetary policy was seen to be passive during a build-up of such a bubble. Only after the bursting of a bubble, monetary policy should be accommodative to *mob up*. This viewpoint was coined as *Jackson Hole Consensus* by Issing (2009). However, it has already been challenged before the crisis, e.g. by Cecchetti *et al.* (2000).



Note: The figure shows the relative dispersion in inflation and real GDP growth in the euro area. For both economic indicators, this dispersion is expressed as the ratio of the standard deviation among EA12 countries to the standard deviation among U.S. states. Source: International Financial Statistics, IMF. See appendix 2.A for further details on the data.

Figure 1.1: Euro Area Relative Dispersion

This consensus made policy makers and academics alike blind to the developments in the run-up to the recent crisis. Whereas the degree of business cycle synchronization improved and aggregate inflation was at its target, capital flows, credit expansions as well as leverage of households and businesses showed signs of overheating in some euro area member states. With the introduction of the euro, risk premia deteriorated especially in the peripheral countries of the union. Fueled by large capital inflows, credit growth accelerated leading to a consumption and investment boom as well as asset price bubbles in these countries. When the crisis hit, all problems came at once: a sudden stop of capital flows, concerns about debt sustainability, a severe slump in private demand and increased credit rate spreads that all helped to amplify the bust side of the business cycle.[5]

For the ECB the Global Financial Crisis basically posed two challenges: It had to act decisively and quickly to lean against its direct impact and—together with policy makers all over the world—it had to re-think its macroeconomic policy approach. The crisis had its outset in summer 2007 as tensions in money markets emerged world-

[5]See e.g. IMF (2011) for a detailed explanation of the build-up and unwinding of these imbalances in the euro area.

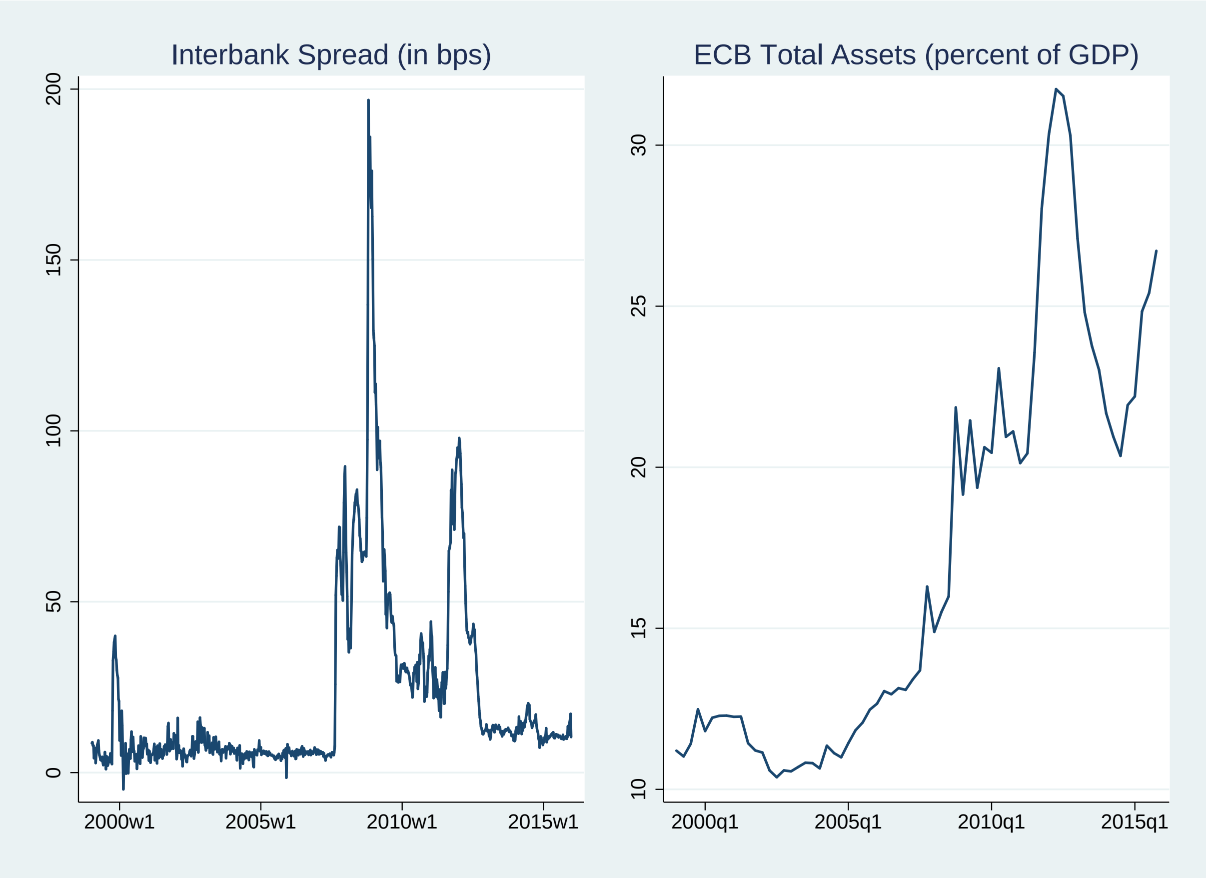
wide and spreads between secured and unsecured money market rates skyrocketed. Figure 1.2 depicts this spread for the euro area measured as the difference between the 3-month Euribor and the 3-month overnight index swap (OIS) rate. As apparent from the left panel, this interbank spread was quoted below 10 basis points (bps) before the crisis, but it increased to 70 bps by the end of 2007. The filing for bankruptcy of Lehman Brothers in 2008 aggravated the financial crisis and interbank spreads approached 200 bps. At the same time, interbank transaction volumes fell dramatically and lending among financial intermediaries broke down. During the crisis, banks thus found themselves without access to this most immediate source of liquidity as financial intermediaries with excess liquidity preferred hoarding it instead of lending it out even at short maturities.[6] Since interbank markets play an important role in the liquidity management of banks, these turmoils spread to the real economy and households as well as firms saw their access to credit deteriorate.

Central banks around the world reacted to these tensions with aggressive monetary policy easing. They significantly decreased interest rates, but more importantly, started to provide liquidity at a large scale. The latter became known as *unconventional monetary policy*. Prior to the crisis, such an expansion of the monetary base was regarded as having no effect on real variables (e.g. Wallace, 1981; Eggertsson and Woodford, 2003). Instead, by communicating the path of the short-term interest rate (e.g. via a transparent policy function), monetary policy would be transmitted along the yield curve of government bonds and across private financial asset classes, including bank loans. This transmission mechanism crucially depends on the assumption of efficient financial markets (in the spirit of Fama, 1970). With market segmentation, the perfect substitutability between different financial assets breaks down and monetary policy can affect yields above and beyond controlling the short-term interest rate.

Given the financial structure of the euro area, where banks are the primary source of credit to the economy, the unconventional measures in the euro area focused on repairing the bank lending channel in order to prevent a credit crunch. The impairment of the interbank market triggered not only a severe recession, but also meant that the transmission of the ECB policy rate to bank lending rates via the interbank market had broken down. As a consequence, the ECB adapted its existing monetary policy framework rather than introducing new policy tools and started to provide liquidity to bank counterparties on a large scale.[7] This included the granting of full and unlimited ac-

[6]Heider *et al.* (2009) show how the presence of asymmetric information in the interbank market can lead to a breakdown of this market.

[7]For this reason, the ECB calls its policy *non-standard* instead of *unconventional*. By contrast, the Federal Reserve (Fed) and the Bank of England followed a different approach. Given that the financial



NOTE: The figure shows the spread between the 3-month Euribor and the 3-month OIS rate (weekly frequency) as well as ECB total assets (quarterly frequency). Total assets are expressed as a percentage of the four-quarter moving sum of EMU GDP. Sources: Haver Analytics and Thomson Reuters Datastream.

Figure 1.2: Euro Area Interbank Spreads and ECB Balance Sheet

cess to liquidity at a fixed rate and the expansion of maturities at which liquidity was offered.[8] In doing so, the ECB substituted the private intermediation and became an important source of funding for financial intermediaries. From 2008 onwards, monetary policy was therefore not only implemented by controlling the short-term interest rates but also by explicitly using the central bank balance sheet as a policy tool. As apparent from figure 1.2 (right panel), the balance sheet of the ECB remained relatively stable at about 12 percent of GDP prior to the crisis. It henceforward increased to

structure in these two economies are more market-based than bank-based, the unconventional monetary policy was primarily based on large-scale purchases of government and private sector assets.

[8]For further details on the exact policy response, see e.g. Trichet (2010).

over 30 percent in 2012. Chapter 3 studies the macroeconomic consequences of these money market tensions associated with the financial crisis of 2008–09. The objective of this chapter is to provide a quantitative assessment of the macroeconomic impact of the ECB's non-standard measures. By computing the counterfactual responses of key macroeconomic variables in the absence of such an intervention, the chapter analyzes the importance of the liquidity injected by the ECB.

The current crisis did not only require the introduction of unconventional instruments, which have hitherto been hardly used, but it also questioned the policy approach of central banks in general. The main lesson learned from the crisis is that central banks cannot be content with just stabilizing prices. In order to guarantee economic stability, central banks also need to have realistic financial stability objectives (Blanchard *et al.*, 2010). As a starting point, it is now recognized that conventional monetary policy is too blunt of an instrument to address imbalances within the financial sector or to prevent asset price bubbles. An early consensus which has emerged from this financial turmoil is the need to further strengthen macroprudential regulation in dealing with sector-specific fluctuations.[9] Ideally, monetary policy will focus on stabilizing prices as well as output, whereas macropudential policy will target threats to financial stability and will thus aim at improving the robustness of the financial system to exogenous as well as endogenous shocks (Svensson, 2012).[10] However, both policies will affect each other's objective and thus need to be coordinated. Chapter 4 analyzes the introduction of macroprudential policy in the euro area. Given the observed heterogeneity among its member states, this chapter studies how macroprudential policies—either on the national or on the European level—should be coordinated with the monetary policy of the ECB.

1.2 Outline and Reviews

As laid out in the previous section, the research agenda of this thesis is driven by topical issues in macroeconomic policies in the EMU and revolves around two core

[9]The Bank of England (2009) lists several reasons why the short-term interest rate may be ill-suited and should be supported by other measures to combat financial imbalances.

[10]Several studies have also stressed the benefits of a monetary policy reacting to asset prices, house prices or credit growth in models with financial frictions (Christiano *et al.*, 2007; Prakash *et al.*, 2012), financial variables like stability indicators (Gray *et al.*, 2011) or credit spreads (Cúrdia and Woodford, 2010; De Fiore and Tristani, 2013). However, in chapter 4 we will show that at least for the euro area a mix of monetary and macroprudential policy is better suited for stabilizing the economy than having monetary policy react to financial variables.

questions: (i) the importance of the heterogeneity among EMU member states and its influence on (optimal) policy and (ii) the ECB's response to the Global Financial Crisis and the lessons policy makers should learn from it. These questions are addressed by using quantitative models. However, since they cannot be answered using a single theoretical framework, the point of departure differs across chapters. I have selected models that help to bring out the importance of key factors that are unique to the euro area and that are, therefore, essential for policy makers to understand.

Chapter 2 takes stock of the heterogeneity in the EMU from the viewpoint of its individual member states and compares it with the heterogeneity measured for other larger currency areas. The main metric used for assessing and comparing heterogeneity are Taylor-rule implied interest rates. Since Taylor rules are standard in the literature and known to describe actual policy interest rate levels well, the chapter relies on a single equation model. In contrast, chapter 3 and 4 study the transmission of targeted policies designed to address financial stability issues and therefore rely on general equilibrium models.[11] The framework used in these two chapters incorporates financial frictions to account for a financial accelerator mechanism and how this affects the transmission of macroeconomic policies. The way financial frictions are modeled, however, differs across these two chapters. Chapter 3 focuses on the role of banks in the EMU during the crisis, the macroeconomic impact of the interbank market turmoils and the reaction of the ECB to these tensions. The framework thus follows the idea of Gertler and Karadi (2011) modeling an agency problem between banks and their creditors. The guiding research question in chapter 4 is whether policy makers should react to the volatility of credit and asset price cycles giving the recent experience in real estate booms in some countries of the euro area. For this reason, in the model used in chapter 4 households both consume non-durable goods and invest in housing. The financial accelerator mechanism in this chapter is thus included on the household side in the spirit of Bernanke *et al.* (1999).

When selecting a theoretical framework, the complexity of the model is kept to a minimum required for the purpose of the policy analysis. The advantage of estimating a single Taylor rule equation in chapter 2 is that I can easily account for the characteristics of EMU member states without increasing the complexity of the model. This is a useful starting point to approach the topic of heterogeneity through the eyes

[11] In all chapters, macroeconomic policies are described by simple rules, which react to observable variables, even when computing the welfare-based optimal policy. The advantage of such simple policy rules (compared with Ramsey-optimal policies) is that they can be easily implemented as they offer direct guidance to policy makers. However—as shown in chapter 4—such simple operational rules may lead to policy mistakes as the first-best optimum can be state-dependent.

of a monetary policy maker. However, such an approach comes with its own caveats. When I compute the member state specific interest rate policy, which would prevail if monetary policy focused solely on the economic conditions of that member state, the framework cannot account for possible feedback effects between such a member state specific policy and the economy. Furthermore, the framework is prone to the Lucas critique so that it is less suited for normative questions regarding optimal policies. For these reasons, chapter 3 and 4 rely on a Dynamic Stochastic General Equilibrium (DSGE) framework. DSGE models allow for feedback effects of a policy transmission and are less subject to the Lucas critique. This makes it possible to evaluate the policies applied during the recent crisis using a counterfactual analysis (chapter 3) or to compute the welfare-based optimal policy (chapter 4). Chapter 3 follows a positive approach and analyzes the non-standard policy of the ECB from an ex-post point of view. The model replicates the tensions in money markets and the liquidity provisions by the ECB to the banking sector. The impact of these central bank interventions is measured by computing the counterfactual responses of key macroeconomic variables in the absence of these interventions. In contrast, chapter 4 conducts a normative analysis of the optimal coordination of monetary and macroprudential policies. In doing so, the chapter offers guidance on how to improve macroeconomic stability in the future. Based on the findings of chapter 2 that larger currency areas are prone to heterogeneity, chapter 4 takes up this subject by differentiating between two regions of the EMU. Given that particular peripheral countries in the euro area have experienced a pronounced boom and bust cycle, chapter 4 differentiates between a core and periphery region of the EMU. However, in contrast to the framework of chapter 2, the DSGE model of chapter 4 became too complex, if one would like to include all euro area countries.[12]

In the following, I provide an introductory review of each essay.

1.2.1 Review of Chapter 2 on Monetary Policy Stress published in *International Economics and Economic Policy*[13]

The ECB's *one size* policy, never a perfect fit for each and every member of the common currency area, has frequently caught considerable attention. Since the introduction of

[12]Of course, there are DSGE models that include all euro area member states. See e.g. Angeloni and Ehrmann (2007) who build a 12-country model of the euro area. However, they rely on a very stylized representation of the economy whereas the model in chapter 4 also incorporates different types of households, production sectors and a financial sector for each region.

[13]Quint, D. (2016). Is it Really More Dispersed?. *International Economics and Economic Policy*, 13(4), 593-621.

the euro, the ECB has been under political pressure as its policy is usually evaluated from a national rather than a European perspective. Against this background, public or political debates habitually arrive at the conclusion that the interest rate policy of the ECB is misguided.

This chapter takes an unbiased look at the stress from the common monetary policy in the euro area. Following Clarida *et al.* (1998), I define monetary policy stress as the difference between the actual observed policy rate and the optimal rate, which would prevail if a country was setting interest rates in line with national economic conditions, based on a Taylor rule. As in Sturm and Wollmershäuser (2008), the Taylor rule is assumed to be similar to the policy function of the ECB. Following Woodford (2001), I explicitly take into account the fact that the natural rate of interest is time varying—a feature particularly relevant for countries with structurally higher (or lower) growth rates. The approach allows decomposing monetary policy stress into a structural and cyclical part. Calculating summary statistics for these measures—such as the weighted standard deviation or the weighted mean of the absolute stress measures—allows comparing levels of stress across time and currency areas.

I find that monetary policy stress within the euro area has been steadily decreasing prior to the recent financial crisis. Although it has picked up again lately, stress levels stayed below what has been observed in the first years of the euro. The decomposition of stress identifies the driving force behind these results. The euro started amidst high levels of monetary policy stress, driven by large differences between member states' underlying growth trends and the associated real natural rates. These differences were particularly developed between the peripheral countries of Greece, Ireland, and Spain compared with the rest of the euro area members. This pattern softened over time leading to an overall downward trend in stress for the euro area until 2009. With the start of the European Sovereign Debt Crisis in 2009, monetary policy stress increased again due to the anew divergence in trend growth. This divergence was mainly driven by Germany and Greece moving into opposite directions. A comparison with the U.S. and pre-euro Germany reveals that current monetary policy stress levels in the euro area are not higher than in other comparable currency areas. There is also an interesting parallel between the decline in euro area stress levels during the first ten years of the EMU and the drop in German stress levels after their surge following German reunification. This suggests that subjecting a relatively heterogeneous set of economies to a single monetary policy can come at a price.

1.2.2 Review of Chapter 3 on Liquidity Provision to Banks as a Monetary Policy Tool
joint work with Oreste Tristani

As described in section 1.1, central banks around the world reacted to the Global Financial Crisis of 2008–09 with aggressive monetary policy easing. This included the use of conventional policy instruments in the form of lowering short-term interest rates. Also, central banks started to implement monetary policy through *unconventional* policy instruments.

The objective of this chapter is to provide a quantitative assessment of the macroeconomic impact of the ECB's non-standard policy implemented between 2007 and 2012. This assessment necessarily requires a structural model because we wish to compute the counterfactual scenario that would have been observed had non-standard measures not been implemented. Given the financial system of the euro area, the theoretical framework furthermore needs to include an explicit characterization of the interbank market, which is obviously needed to properly analyze the disruption of that market.[14] To this end, we augment the theoretical framework of Smets and Wouters (2003) with the financial sector as in Gertler and Kiyotaki (2010). In our model, banks are heterogeneous and are either in short or abundant supply of liquidity. This creates the necessity of an interbank market where banks can trade liquidity. As in Gertler and Karadi (2011), banks have the temptation to embezzle assets financed by either deposits from households or interbank borrowing. This incentive problem produces a leverage constraint, so that banks are required to hold equity (and thus "to have skin in the game"). In a financial crisis, the incentive problem becomes more severe and liquidity-constrained banks find it harder to obtain funding which leads to a tightening of lending conditions for the private sector and triggers a recession. In these circumstances, the provision of large amounts of liquidity by the central bank, even if at market interest rates can reduce the adverse consequences of a crisis.

We estimate our model by using a Bayesian variant of an impulse matching approach developed in Christiano *et al.* (2010). To do so, we first identify an *interbank liquidity shock* in a structural VAR. A reason for concern is, however, that the increase in interbank spreads over the financial crisis went along with a generalized increase in overall uncertainty. This could have increased all measures of risk in financial mar-

[14] Much of the existing theoretical literature focuses on the effects of the unconventional measures implemented in the U.S. or the UK. Accordingly, these theoretical frameworks are suited for analyzing asset purchase programs, but they are less suited for analyzing the transmission mechanism of the non-standard policy in the euro area.

kets. In the spirit of Bassett *et al.* (2014), we thus use regression analysis to remove the portion of changes in interbank spreads which is associated with changes in uncertainty. Our empirical exercise shows that a widening of our measure of liquidity spread is met by an increase in the amount of central bank liquidity. Nevertheless, it leads to a widening of lending spreads and thus to a tightening of lending conditions for the private sector and to a reduction in economic activity, especially in investment.

Given our estimated structural model, we show that the impairment of the interbank market due to increases in liquidity risk was a major determinant of the Great Recession. According to our model, these market tensions produced sizable real effects and accounted for over 30 percent of the fall in aggregate investment. Our counterfactual no-policy scenario, in which the ECB would not have implemented its non-standard measures, suggests that the ECB played an important role in attenuating the macroeconomic impact of the interbank market breakdown. Without this intervention, interbank spreads would have been at least 100 bps higher and their adverse impact on investment would have been twice as severe. These effects are somewhat larger than estimated in other studies (e.g. Lenza *et al.*, 2010; Giannone *et al.*, 2012; Fahr *et al.*, 2013).

1.2.3 Review of Chapter 4 on Optimal Monetary and Macroprudential Policy

joint work with Pau Rabanal,
published in *International Journal of Central Banking*[15]

The use of macroprudential policies to stabilize business cycles has received considerable attention lately. The recent financial crisis has been blamed on loose monetary policy and regulatory policies that encouraged the build-ups of liquidity mismatches, credit growth and leverage in the financial sector. In addition, Claessens *et al.* (2009) and Crowe *et al.* (2013) have shown that the combination of credit and housing boom episodes amplifies the business cycle and in particular, the bust side of the cycle (measured as the amplitude and duration of recessions). Therefore, there is wide recognition that the best way to avoid a large recession in the future is precisely to reduce the volatility of credit and asset price cycles and their effects on the broader macroeconomy.

However, the search for an appropriate toolkit to deal with financial sector and housing cycles, including its adequate calibration as well as beneficial and detrimental

[15] Quint, D. and Rabanal, P. (2014). Monetary and Macroprudential Policy in an Estimated DSGE Model of the Euro Area. *International Journal of Central Banking*, **10** (2), 169–236.

side effects has only recently begun. In particular, a key question to be addressed is what should be the role of macroprudential regulation. Should it be used as a countercyclical policy tool, leaning against the wind of large credit and asset price fluctuations, or should it just aim at increasing the buffers of the banking system (provisions and capital requirements), thereby minimizing financial-sector risk, as currently envisioned in Basel III?

This chapter contributes to this debate by addressing the optimal mix of monetary and macroprudential policy needed within the euro area. We take into account the heterogeneity observed within this currency union and the fact that country- and sector-specific boom and bust cycles cannot directly be addressed by monetary policy. We study the interaction between monetary and macroprudential policies in a standard New Keynesian model, extended with financial frictions. The model includes two countries—a core and periphery—which share the same currency. Following Iacoviello and Neri (2010) each country features two sources of heterogeneity. On the supply side, we include two sectors, producing either non-durable or durable goods. We interpret the former as consumption goods, while the latter can be seen as housing, which can also be pledged as collateral. On the demand side, we differentiate between savers and borrowers. As in Iacoviello (2005) this creates a credit market in each country. The model includes a financial accelerator mechanism on the household side in the spirit of Bernanke *et al.* (1999). Changes in the balance sheets of borrowers due to house price fluctuations thus affect the spread between lending and deposit rates. In addition, risk shocks in the housing sector affect conditions in the credit market and in the broader macroeconomy. In the spirit of Benigno (2004) and Rabanal (2009) savings and investment at the country level need not to be balanced period by period as credit demand in one region can be met by funding coming from elsewhere in the union. The model includes several nominal and real frictions to fit the data, as in Smets and Wouters (2003) as well as Iacoviello and Neri (2010).

The model is estimated with Bayesian methods. Data for the core is obtained by aggregating data for France and Germany whereas the periphery is represented by Greece, Ireland, Italy, Portugal, and Spain. Bayesian estimation of the model allows us to understand the structural features and shocks that drive fluctuations in the core and periphery. In doing so, we account for the economic heterogeneity observable across these regions and the possible burden this puts on policy makers. Once the model is estimated with historical data, we proceed to study what government policies besides standard monetary policy can be used to reduce the volatility of business cycles. We start with studying the potential welfare gains from extending monetary policy rules to include credit indicators. Next, we introduce macroprudential policy and analyze the interaction between monetary and macroprudential policy. The macroprudential instrument targets credit spreads by affecting the fraction of liabilities that financial intermediaries can lend. We use this framework to evaluate the role of macroprudential policies at the euro-area and national level.

We find that introducing macroprudential policy will improve EMU-wide welfare more than allowing monetary policy to directly take into account financial market development. Introducing macroprudential policy reduces macroeconomic volatility. It "lends a hand" to monetary policy by reducing accelerator effects and, thus, requiring smaller responses of the nominal interest rate. However, optimal macroprudential regulation affects savers and borrowers differently. While it will always increase the welfare of savers, its effect on borrowers depends on the shock that hits the economy. In particular, macroprudential policy entails welfare costs for borrowers under technology shocks, by increasing the countercyclical behavior of lending spreads.

Bibliography

Angeloni, I. and Ehrmann, M. (2007). Euro Area Inflation Differentials. *The B.E. Journal of Macroeconomics*, **7** (1), 1–36.

Bank of England (2009). *The Role of Macroprudential Policy*. Bank of England Discussion Paper.

Bassett, W. F., Chosak, M. B., Driscoll, J. C. and Zakrajšek, E. (2014). Changes in Bank Lending Standards and the Macroeconomy. *Journal of Monetary Economics*, **62**, 23–40.

Bayoumi, T. A. and Eichengreen, B. (1993a). Is There a Conflict Between EC Enlargement and European Monetary Unification? *Greek Economic Review*, **15**, 131–154.

— and — (1993b). Shocking Aspects of European Monetary Unification. In F. Torres and F. Giavazzi (eds.), *Adjustment and Growth in the European Monetary Union*, Cambridge: Cambridge University Press, pp. 193–230.

Benalal, N., del Hoyo, J. L. D., Pierluigi, B. and Vidalis, N. (2006). *Output Growth Differentials Across the Euro Area Countries - Some Stylised Facts*. ECB Occasional Paper 45.

Benigno, P. (2004). Optimal Monetary Policy in a Currency Area. *Journal of International Economics*, **63** (2), 293–320.

Bernanke, B. S., Gertler, M. and Gilchrist, S. (1999). The Financial Accelerator in a Quantitative Business Cycle Framework. In J. B. Taylor and M. Woodford (eds.), *Handbook of Macroeconomics*, vol. 1, San Diego and Amsterdam: North-Holland, pp. 1341–1393.

Blanchard, O., Dell'Ariccia, G. and Mauro, P. (2010). Rethinking Macroeconomic Policy. *Journal of Money, Credit and Banking*, **42** (s1), 199–215.

— and Galí, J. (2007). Real Wage Rigidities and the New Keynesian Model. *Journal of Money, Credit and Banking*, **39** (1), 35–65.

Cecchetti, S., Genberg, H., Lipsky, J. and Wadhwani, S. (2000). *Asset Prices and Central Bank Policy*. Geneva Reports on the World Economy 2, Geneva: International Centre for Monetary and Banking Studies.

Christiano, L., Motto, R. and Rostagno, M. (2007). *Two Reasons Why Money and Credit May be Useful in Monetary Policy*. NBER Working Paper 13502.

Christiano, L. J., Trabandt, M. and Walentin, K. (2010). DSGE Models for Monetary Policy Analysis. In B. M. Friedman and M. Woodford (eds.), *Handbook of Monetary Economics*, vol. 3, San Diego and Amsterdam: North-Holland, pp. 285–367.

Claessens, S., Kose, M. A. and Terrones, M. E. (2009). What Happens During Recessions, Crunches and Busts? *Economic Policy*, **24** (60), 653–700.

Clarida, R., Galí, J. and Gertler, M. (1998). Monetary Policy Rules in Practice: Some International Evidence. *European Economic Review*, **42** (6), 1033–1067.

Crowe, C., DellAriccia, G., Igan, D. and Rabanal, P. (2013). How to Deal With Real Estate Booms: Lessons From Country Experiences. *Journal of Financial Stability*, **9** (3), 300–319.

Cúrdia, V. and Woodford, M. (2010). Credit Spreads and Monetary Policy. *Journal of Money, Credit and Banking*, **42** (s1), 3–35.

De Fiore, F. and Tristani, O. (2013). Optimal Monetary Policy in a Model of the Credit Channel. *The Economic Journal*, **123** (571), 906–931.

Decressin, J. and Fatás, A. (1995). Regional Labor Market Dynamics in Europe. *European Economic Review*, **39** (9), 1627–1655.

Eggertsson, G. B. and Woodford, M. (2003). The Zero Bound on Interest Rates and Optimal Monetary Policy. *Brookings Papers on Economic Activity*, **34** (1), 139–235.

Eichengreen, B. (1997). Saving Europe's Automatic Stabilisers. *National Institute Economic Review*, **159** (1), 92–98.

— and Wyplosz, C. (1998). The Stability Pact: More Than a Minor Nuisance? *Economic Policy*, **13** (26), 65–113.

Fahr, S., Motto, R., Rostagno, M., Smets, F. and Tristani, O. (2013). A monetary policy strategy in good and bad times: lessons from the recent past. *Economic Policy*, **28** (74), 243–288.

Fama, E. F. (1970). Efficient Capital Markets: A Review of Theory and Empirical Work. *The Journal of Finance*, **25** (2), 383–417.

Feldstein, M. (1997). The Political Economy of the European Economic and Monetary Union: Political Sources of an Economic Liability. *Journal of Economic Perspectives*, **11** (4), 23–42.

Frankel, J. A. and Rose, A. K. (1997). Is EMU More Justifiable Ex Post Than Ex Ante? *European Economic Review*, **41** (35), 753–760.

— and — (1998). The Endogeneity of the Optimum Currency Area Criteria. *The Economic Journal*, **108** (449), 1009–1025.

Gächter, M., Riedl, A. and Ritzberger-Grünwald, D. (2012). Business Cycle Synchronization in the Euro Area and the Impact of the Financial Crisis. *Monetary Policy & the Economy*, **2**, 33–60.

Gertler, M. and Karadi, P. (2011). A Model of Unconventional Monetary Policy. *Journal of Monetary Economics*, **58** (1), 17–34.

— and Kiyotaki, N. (2010). Financial Intermediation and Credit Policy in Business Cycle Analysis. In B. M. Friedman and M. Woodford (eds.), *Handbook of Monetary Economics*, vol. 3, San Diego and Amsterdam: North-Holland, pp. 547–599.

Giannone, D., Lenza, M., Pill, H. and Reichlin, L. (2012). The ECB and the Interbank Market. *The Economic Journal*, **122** (564), F467–F486.

Gray, D. F., García, C. J., Luna, L. and Restrepo, J. E. (2011). Incorporating Financial Sector Risk Into Monetary Policy Models: Application to Chile. In R. Alfaro (ed.), *Financial Stability, Monetary Policy, and Central Banking*, vol. 15, Santiago: Central Bank of Chile, pp. 159–197.

Heider, F., Hoerova, M. and Holthausen, C. (2009). *Liquidity Hoarding and Interbank Market Spreads: The Role of Counterparty Risk*. ECB Working Paper 1126.

Iacoviello, M. (2005). House Prices, Borrowing Constraints, and Monetary Policy in the Business Cycle. *American Economic Review*, **95** (3), 739–764.

— and Neri, S. (2010). Housing Market Spillovers: Evidence From an Estimated DSGE Model. *American Economic Journal: Macroeconomics*, **2** (2), 125–164.

International Monetary Fund (2011). Financial Integration, Growth, and Imbalances. In *Regional Economic Outlook Europe: Strengthening the Recovery*, Washington, DC: International Monetary Fund, pp. 53–89.

ISSING, O. (2009). Asset Prices and Monetary Policy. *Cato Journal*, **29** (1), 45–51.

KENEN, P. B. (1969). The Theory of Optimum Currency Areas: An Eclectic View. In R. A. Mundell and A. K. Swoboda (eds.), *Monetary Problems of the International Economy*, Chicago and London: The University of Chicago Press, pp. 41–60.

KRUGMAN, P. (1993). Lessons of Massachusetts for EMU. In F. Torres and F. Giavazzi (eds.), *Adjustment and Growth in the European Monetary Union*, Cambridge: Cambridge University Press, pp. 241–261.

LENZA, M., PILL, H. and REICHLIN, L. (2010). Monetary Policy in Exceptional Times. *Economic Policy*, **25** (4), 295–339.

MCKINNON, R. I. (1963). Optimum Currency Areas. *American Economic Review*, **53** (4), 717–725.

MONGELLI, F. P. and WYPLOSZ, C. (2009). The Euro at Ten - Unfulfilled Threats and Unexpected Challenges. In B. Mackowiak, F. P. Mongelli, G. Noblet and F. Smets (eds.), *The Euro at Ten - Lessons and Challenges, 5th ECB Central Banking Conference, 13-14 November 2008*, Frankfurt am Main: European Central Bank, pp. 24–57.

MUNDELL, R. A. (1961). A Theory of Optimum Currency Areas. *American Economic Review*, **51** (4), 657–665.

OECD (1999). *EMU Facts, Challenges and Policies*. Paris: OECD Publishing.

PRAKASH, K., RABANAL, P. and SCOTT, A. M. (2012). Monetary and Macroprudential Policy Rules in a Model with House Price Booms. *The B.E. Journal of Macroeconomics*, **12** (1), 1–44.

RABANAL, P. (2009). Inflation Differentials Between Spain and the EMU: A DSGE Perspective. *Journal of Money, Credit and Banking*, **41** (6), 1141–1166.

SMETS, F. and WOUTERS, R. (2003). An Estimated Dynamic Stochastic General Equilibrium Model of the Euro Area. *Journal of the European Economic Association*, **1** (5), 1123–1175.

STURM, J.-E. and WOLLMERSHÄUSER, T. (2008). *The Stress of Having a Single Monetary Policy in Europe*. CESifo Working Paper 2251.

SVENSSON, L. (2012). Comments on Michael Woodford: 'Inflation Targeting and Financial Stability'. *Sveriges Riksbank Economic Review*, **1**, 33–39.

Taylor, J. B. (ed.) (1999). *Monetary Policy Rules*. Chicago: University of Chicago Press.

Trichet, J.-C. (2010). State of the Union: The Financial Crisis and the ECB's Response Between 2007 and 2009. *Journal of Common Market Studies*, **48** (s1), 7–19.

Wallace, N. (1981). A Modigliani-Miller Theorem for Open-Market Operations. *American Economic Review*, **71** (3), 267–274.

Woodford, M. (2001). The Taylor Rule and Optimal Monetary Policy. *American Economic Review*, **91** (2), 232–237.

Chapter 2

Monetary Policy Stress[1]

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Chapter 3

Liquidity Provision to Banks as a Monetary Policy Tool

3.1 Introduction

The Global Financial Crisis of 2008–09 was followed by a decline in GDP of approximately 5 percent both in the euro area and in the U.S. The GDP component most severely affected by the recession was aggregate investment, which fell by about 15–20 percent in both monetary areas. The crisis motivated aggressive monetary policy responses worldwide, including the adoption of non-standard monetary policy measures with ensuing, sizable increases in the size of central banks' balance sheets. For instance, during the years following August 2007 the ECB balance sheet more than doubled (figure 1.2 in chapter 1).

The type of non-standard measures adopted in the euro area—especially in the first years after the start of the crisis—are different from those implemented in the U.S. and by other major central banks. While, for example, the Fed purchased government bonds and mortgage backed securities, the ECB measures mostly took the form of liquidity operations vis-à-vis banks.[1] The fragmentation of the euro area banking sector caused by the financial crisis produced severe malfunctionings, and at times a complete dry-up of the interbank market. Asymmetric information and time-varying perceptions of counterparty risk made cash-rich banks unwilling to lend to banks with liquidity shortages. The latter banks, even if healthy and solvent, thus faced the risk of being forced into bankruptcy. Moreover, negative externalities on the real economy in the form of a credit crunch or asset fire sales became a threat.

[1] Another difference, whose role we do not explore in this chapter, has to do with the ECB's reliance on repo operations, rather than outright purchases.

The ECB interventions were tailored to address such money market malfunctioning. Large amounts of liquidity were provided to financial institutions, subject to adequate collateral, through various repo operations with different maturities.

The objective of this chapter is to provide a quantitative assessment of the macroeconomic impact of the ECB's non-standard measures. More precisely, we focus on the period 2007–2012 which was characterized by severe tensions in money markets. We thus do not focus on the years following 2012 when the zero lower bound became binding and non-standard policy increasingly relied on large asset purchases.[2] In doing so, we proceed in two steps. We start by empirically investigating the causal link between interbank liquidity shocks and economic recessions. To identify liquidity shocks in a structural VAR, we start from the interbank spread, i.e. the spread between 3-month (uncollateralized) Euribor rates and the rate on 3-month overnight index swaps (OIS).[3] This spread is an indicator of money market stress, which increases when banks are less willing to lend to each other. As such, it is also a measure of interbank market liquidity. The spread could however reflect, not only liquidity risk, but might also be driven by uncertainty shocks. This may become crucial at times of market stress, when uncertainty increases and disentangling the two sources of risk is especially difficult. To attain a more precise measure of liquidity risk, we use regression analysis on weekly data to identify the component of interbank spreads which is orthogonal to the contemporaneous increase in uncertainty, measured by the VSTOXX. The orthogonal component is our measure of euro area liquidity spreads in the VAR analysis. Our main identification assumption is then that shocks to (our measure of) liquidity spreads are instantaneously passed through to lending rates to the non-financial sector. Our first result is that a standard liquidity shock leads to a sizable increase in bank lending spreads and to a sizable fall in private investment.

It goes without saying that the VAR impulse responses reflect not only the financial shock, but also the policy response of the ECB to this shock. To compute the counterfactual scenario that would have been observed if non-standard measures had not been implemented, we construct a structural model and use the VAR impulse responses to calibrate some key model parameters. More specifically, we start from the Smets and Wouters (2003) framework and extend it by including a version of the interbank market model proposed by Gertler and Kiyotaki (2010). In our model, banks cannot exclusively rely on external financing, because they have the temptation to

[2]Especially since 2015 non-standard policy in the euro area relies on large asset purchase programs comparable to the approaches taken by the U.S. Fed and the Bank of England after 2008.

[3]The OIS rate is a good proxy for risk-free rates, because the swap contract does not require the exchange of the principal.

embezzle bank assets. This incentive problem produces a leverage constraint, so that banks are required to hold equity (or "to have skin in the game"). Funding can be obtained in the form of either retail deposits, or deposits from other banks. At any point in time, banks which customer firms have good investment opportunities will tend to borrow on the interbank market, while other banks will be net lenders. The theoretical framework used in this chapter thus also picks up on the topic of heterogeneity, focusing however on the heterogeneity within the banking sector of the euro area.

Under normal circumstances, the interbank market works frictionlessly and the aforementioned incentive problem is very mild so that interbank spreads remain close to zero. However, when the temptation to embezzle assets financed through interbank loans increases, the incentive problem becomes more severe, the leverage constraint faced by borrowing banks becomes tighter, and all spreads increase. With the ensuing rise in bank lending rates, credit dries up and aggregate investment falls. In these circumstances, the provision of large amounts of liquidity by the central bank, even if at market interest rates, can reduce the adverse consequences of the crisis on investment. Central bank interventions allow liquidity-constrained banks to continue financing firms with good investment opportunities, even if cash-rich banks are unwilling to lend on the interbank market.

We assume that the severity of the interbank friction increases during a financial crisis and interpret such an increase as corresponding to the liquidity shock we identified in the VAR. We then estimate the new parameters of our extended Smets and Wouters (2003) model by matching impulse responses to the liquidity shock in the model and in the VAR. Given the estimated parameters, we can compute the counterfactual no-policy scenario. The model indicates that in the absence of non-standard measures the fall in investment after a liquidity shock would be much deeper. To gauge the total effects of the ECB's non-standard measures over the financial crisis period, we use our measure of liquidity spreads and back out the sequence of liquidity shocks which generated it, according to the model. We then ask three related questions.

First, we investigate whether the liquidity shocks can account for a sizable share of the observed, large fall in aggregate investment after the financial crisis of 2008–09. We focus on investment because it is the component of the national accounts which was most heavily affected by the crisis. Our results suggest that the real effects of the liquidity shocks were indeed sizable. According to our model the interbank market shock produced sizable real effects, as it accounts for over 30 percent of the fall in investment during the Great Recession. It is conceivable that other disturbances–

for example an increase in macroeconomic uncertainty, as argued by Bloom (2009)– contributed to account for the rest of the fall in aggregate investment.

Given this result, we turn to our second question, which is to analyze the effectiveness of the ECB's non-standard measures. In the model, we can switch off the central bank interventions and compute the resulting counterfactual scenario. The results of this exercise suggest that the effect of the non-standard measures was sizable. In their absence, interbank spreads would have been at least 100 basis points higher and their adverse impact on investment would have been twice as severe.

Finally, we investigate the repercussions of the interbank market shock on inflation. We find them to be negligible, so that no policy interest rate response is warranted through the Taylor rule. The main reason for this result is that, by construction in the model, lending spreads have no impact on households' consumption Accordingly, consumption does not need to fall in response to the financial crisis. Our findings therefore suggest that other shocks also played a role during the Great Recession and accounted for inflation and policy rate developments.

This chapter fits into the recent literature which evaluates the non-standard policy measures implemented by central banks during the Great Recession. Using structural VAR models, Peersman (2011) and Boeckx *et al.* (2014) capture non-standard measures by looking at the expansion of the ECB balance sheet and studying its transmission effects. By affecting interest rate spreads of banks, the expansion of the balance sheet is effective in stabilizing the economy. Boeckx *et al.* (2014) further analyze how individual euro area countries were affected by these policies showing that the transmission was heterogenous among member states. Other studies explicitly conduct a counterfactual exercise to evaluate the impact of the non-standard measures. Within a Bayesian VAR framework, Lenza *et al.* (2010) as well as Giannone *et al.* (2012) show that these policies had a significant effect in dampening the recession during the crisis.

As these studies rely on a reduced-form approach, closer to our approach are Fahr *et al.* (2013) as well as Cahn *et al.* (2014). Both papers use estimated DSGE models to evaluate the policy by the ECB during the recent crisis. The former uses a counterfactual exercise to focus on the unlimited supply of liquidity to banks at a fixed rate (so-called fixed-rate-full-allotment) as well as the effect of the expansions of maturities at which liquidity was provided (so-called longer term refinancing operations with maturities of more than three month). Since Fahr *et al.* (2013) apply the framework by Christiano *et al.* (2010a) their model does not explicitly include a characterization of the interbank market. Similar to this chapter, Cahn *et al.* (2014) use the framework by Gertler and Kiyotaki (2010) to better capture the bank lending channel of the non-standard measures. However, they solely focus on the macroeconomic effects of the long term refinancing operations.

Many other studies focus on the effects of the non-standard policy conducted in the U.S. using a DSGE model. Amongst them, Gertler and Karadi (2013) show that this policy worked by replacing the private intermediation which broke down as financial markets froze up. Del Negro *et al.* (2011) attribute the effectiveness of the unconventional policies to the binding of the zero lower bound and the presence of nominal frictions. Christiano *et al.* (2015) conduct a counterfactual analysis focusing on how forward guidance dampened the effects of the recession.

The rest of the chapter is organized as follows. Section 3.2 presents the VAR evidence on the impulse responses of the economy to a liquidity shock. Our structural model is described in section 3.3 whereas section 3.4 presents the estimation of selected structural parameters, based on the impulse response matching methodology. Our main results on the macroeconomic impact of the liquidity shock during the crisis and on the no-policy counterfactual are presented in section 3.5. Section 3.6 draws some concluding remarks.

3.2 VAR Evidence

In August 2007 tension in the euro (as well as in the U.S. dollar and sterling) money market emerged. Spreads between secured and unsecured money market rates spurred and transaction volumes declined significantly. The interbank spread—as shown in figure 3.1 or 3.2—was quoted at 8 basis points on average before the crisis, but it increased by more than 60 basis points in the second half of 2007. The filing for bankruptcy of Lehman Brothers in September 2008 aggravated this development as interbank spreads reached almost 200 basis points in response. This led to a breakdown of the interbank market and triggered a severe recession as lending conditions for firms tightened and investment as well as output fell. The response by the ECB included an unlimited supply of liquidity to banks at a fixed rate, significant changes in the requirements for collateral and the expansion of maturities at which liquidity was offered. These measures resulted in an increase of liquidity provided to euro area banks by 350 billion EUR right after the bust of Lehman Brothers (corresponding to 15 percent of euro area quarterly GDP). Until 2011 these non-standard measures ranged

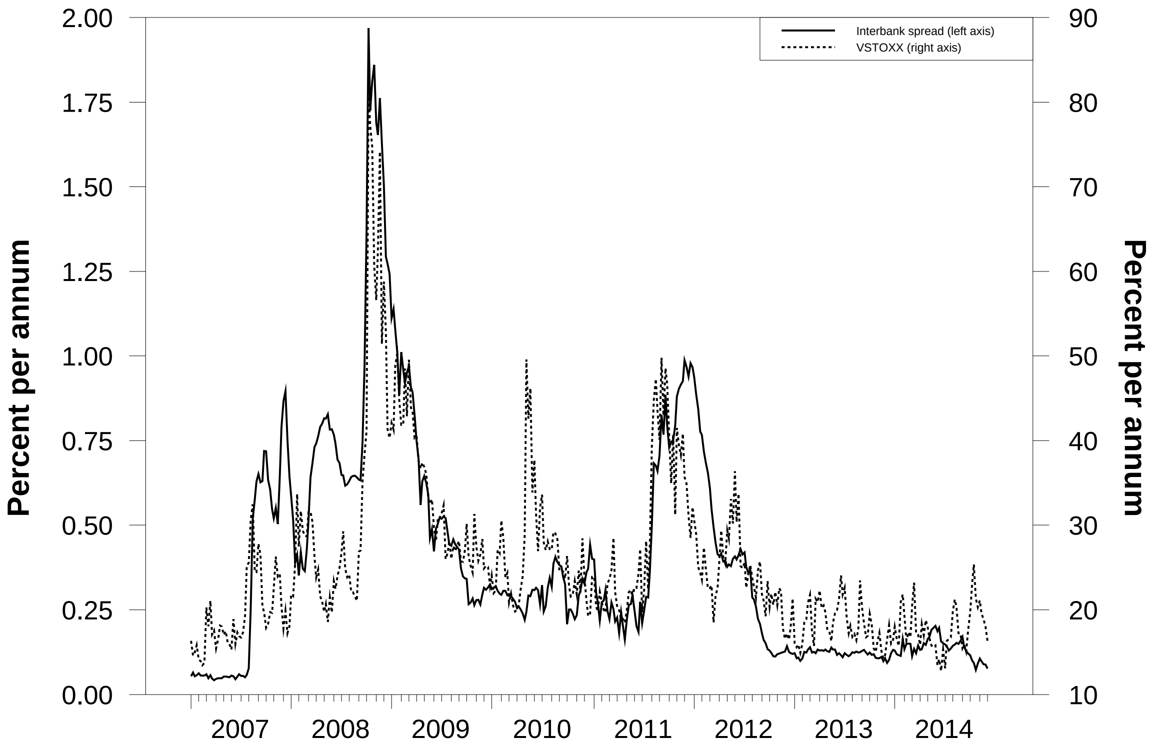

Figure 3.1: Euro Area Interbank Spreads and Stock Market Volatility

between 10 and 20 percent of quarterly GDP. They increased to 40 percent after the European Sovereign Debt Crisis intensified in 2011.[4]

In this section, we provide empirical evidence on the macroeconomic effects of interbank liquidity shocks. The financial crisis experience is crucially important in this respect. Under well-functioning and integrated financial markets, any bank liquidity needs should be quickly and efficiently satisfied by the interbank market. Liquidity shocks would therefore be expected to have no macroeconomic impact.[5]

A key step in our analysis is the selection of a measure of spreads which reflects interbank liquidity risk. We start from interbank spreads, i.e., the spread between 3-month (uncollateralized) Euribor rates and the rate on 3-month overnight index swaps (OIS). The latter is a good proxy for risk-free rates, because the OIS contract does not require an exchange of the principal. The interbank spread is an indicator of money

[4]Lenza *et al.* (2010) provide an overview on how the ECB reacted to the financial crisis and compare its non-standard measures with the policies conducted by the U.S. Fed and the Bank of England.

[5]The Global Financial Crisis of 2008–09 has led to an increase in attention towards macro-financial linkages, but the literature has mostly focused on the impact of a tightening of banks' credit supply conditions on economic activity–see e.g. Ciccarelli *et al.* (2015) and Bassett *et al.* (2014).

Table 3.1: Impact of Changes in Implied Volatility on the Interbank Spread

Variable	Coeff	StdError	T-Stat	Signif
Constant	−0.000729582	0.000092215	−7.91172	0.00000000
VSTOXX	0.027084630	0.001484309	18.24730	0.00000000

NOTE: Based on weekly data from 2007:01:05–2014:12:05, Newey-West standard errors, $\overline{R}^2 = 0.6412$. Variables are measured in quarterly units. VSTOXX is a measure of implied volatility derived from EURO STOXX 50 Index Options.

market stress, which increases when banks are less willing to lend to each other. However, the interbank spread is not only a proxy for liquidity risk. The increase in interbank spreads over the financial crisis went along with a generalized increase in overall uncertainty, which increased all measures of risk in financial markets. This fact is illustrated in figure 3.1, which plots the interbank spread against the VSTOXX—a measure of implied volatility derived from EURO STOXX 50 Index Options. Over the crisis period, the two series are highly correlated: the correlation coefficient over the 2007–2014 period is 0.48. There is therefore a risk to confound the effects of interbank liquidity shocks—which we are interested in—with those of uncertainty shocks.

In the spirit of Bassett *et al.* (2014), we use regression analysis to identify the component of interbank spreads which is orthogonal to the contemporaneous increase in uncertainty. Based on weekly data over the 2007–2014 sample,[6] we regress the interbank spread on the VSTOXX and use the regression residual as an indicator of liquidity spreads which is not contaminated by the effects of uncertainty shocks. This methodology is obviously likely to lead to an underestimation of liquidity premia, because the component of the interbank spread explained by changes in uncertainty may also be associated with liquidity risk.

The results of this regression, reported in table 3.1, confirm the high degree of comovement between the two series. As a factor affecting the interbank spread, the VSTOXX variable is highly statistically significant. The $\overline{R}^2$ of the regression is about 65%. We use the residual of this regression as our benchmark measure of euro area liquidity spreads.

The theoretical framework by Gertler and Kiyotaki (2010) introduced in section 3.3 does not allow for true counterparts risk so that in equilibrium banks never de-

[6]The data is also available at the daily frequency, but does not overlap completely because the financial instruments are quoted in different markets that observe different holiday calendars. See appendix 3.B for further details on the data set.

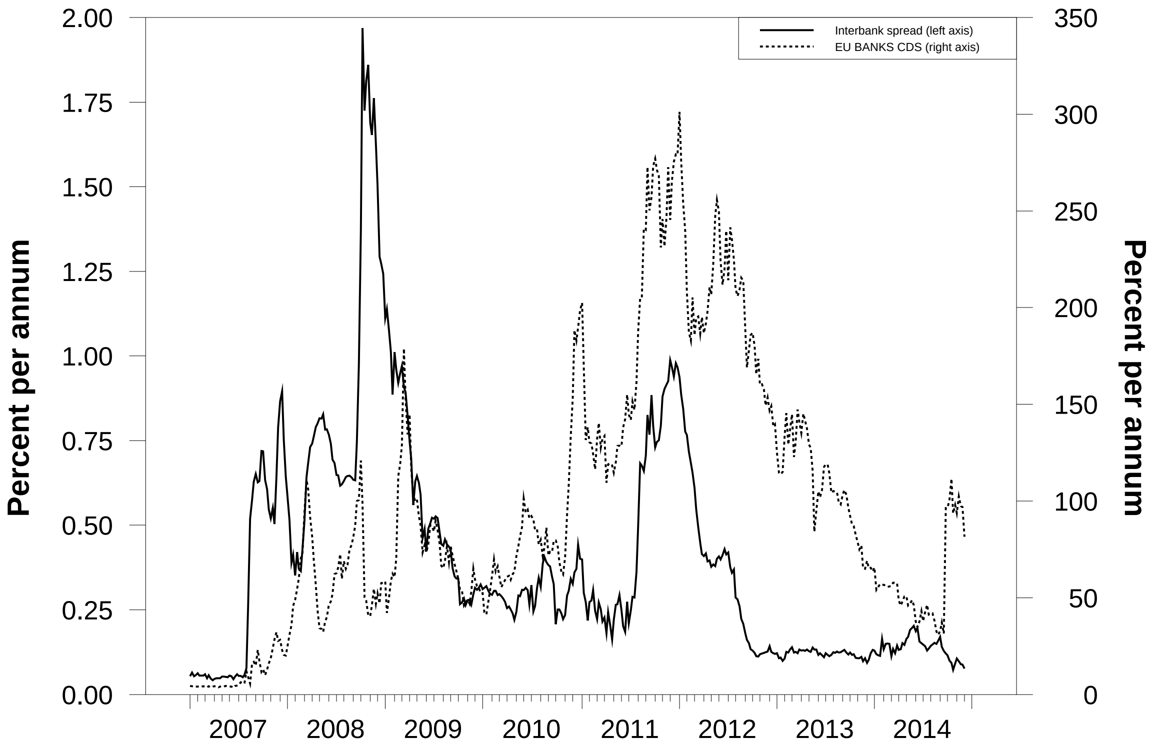

Figure 3.2: Euro Area Interbank Spreads and Bank CDS Spreads

fault. As a robustness check, we add to the regressors in table 3.1 direct measures of banks' counterparty risk, as captured by banks' CDS spreads. CDS spreads are also correlated with interbank spreads, as witnessed by figure 3.2, which shows the interbank spread together with the median spread between CDS on senior debt and CDS on subordinated debt for the European Union large banking groups. Moreover, sovereign CDS spreads can also be considered as proxies for banks' counterparty risk, because of the adverse feedback loop between euro area banks and sovereigns—see e.g. ECB (2014).[7]

In table 3.2 we report the results of the alternative specification where banks and sovereign CDS spreads are added to the regression. The implied volatility measure remains highly significant, but some CDS measures also prove to be significant. The $\overline{R}^2$ increases to almost 70%. We thus use the residual of this regression as a second measure of euro area liquidity spreads.

[7]Including CDS spreads together with the VSTOXX will probably lead to collinearity in the regression model. Since we are only interested in the predictive power of the model as a whole and not in single predictor variables, we can neglect this problem.

Table 3.2: Factors Affecting the Interbank Spread

Variable	Coeff	StdError	T-Stat	Signif
Constant	−0.000587862	0.000105074	−5.59477	0.00000002
VSTOXX	0.025407731	0.002002144	12.69026	0.00000000
DE CDS	−0.001652779	0.001743806	−0.94780	0.34323158
FR CDS	0.003208114	0.001235333	2.59696	0.00940521
ES CDS	−0.001721115	0.000305887	−5.62664	0.00000002
IT CDS	−0.000027026	0.000349038	−0.07743	0.93828200
EU Banks CDS	0.001454328	0.000514306	2.82775	0.00468764

NOTE: Based on weekly data from 2007:01:05–2014:12:05, Newey-West standard errors, $\overline{R}^2 = 0.6944$. Variables are measured in quarterly units. *VSTOXX* is a measure of implied volatility derived from EURO STOXX 50 Index Options; *EU Banks CDS* is the median spread between CDS Senior Debt 5-Year and CDS Subordinated Debt 5-Year for the European Union Large Banking Groups; *DE CDS*, *FR CDS*, *ES CDS* and *IT CDS* are CDS U.S. Dollar Senior Debt 5-Year for Germany, France, Spain and Italy, respectively.

Having derived a measure of liquidity spreads, we convert it to the quarterly frequency and include it in a VAR. The other time series in the VAR are those that we will use in the structural model. They include real GDP, consumption, investment, inflation, the bank lending spread, and the non-standard liquidity operation by the ECB. Bank lending spreads are measured as the difference between the interest rates on loans to non-financial corporations for up to one year and the 3-month OIS rate. The ECB's non-standard liquidity operations are determined by the sum of the two items on the ECB's balance sheet "lending to euro area credit institutions related to monetary policy operations" and "securities held for monetary policy purposes". Both items are measured in terms of quarterly GDP.[8] We estimate the model over the available EMU sample, i.e. from 2001Q1 until 2014Q3.[9] The VAR includes one lag of all variables based on the Akaike and Schwarz information criteria.[10]

Table 3.3 reports the VAR residuals correlation matrix. Since we are only interested in the impulse response to a liquidity shock, we focus on column 5, which corresponds to our measure of liquidity spreads. The column shows that the reduced form inno-

[8] These operations exclude any liquidity injections carried out for lender of last resort reasons.

[9] Our measure of liquidity spreads that we derived above ranges from 2007 to 2014. Since we assume that liquidity shocks did not occur prior to 2007, the liquidity spread is thus equal to the Euribor-OIS spread for the period 2001–2006.

[10] See appendix 3.B for further details on the data set.

Table 3.3: VAR Residuals Correlation Matrix

	Y	C	I	ΔP	R_b/R	R_k/R	M/Y	R
Y	1.0000	0.4477	0.7767	0.2985	**0.1317**	-0.5051	0.0275	0.6758
C	0.4477	1.0000	0.3000	-0.1058	**-0.1227**	-0.2290	-0.1707	0.1626
I	0.7767	0.3000	1.0000	0.2942	**0.1215**	-0.3756	0.1165	0.4900
ΔP	0.2985	-0.1058	0.2942	1.0000	**0.1383**	-0.1080	0.1968	0.2326
R_b/R	0.1317	-0.1227	0.1215	0.1383	1.0000	0.2098	0.0837	0.0316
R_k/R	-0.5051	-0.2290	-0.3756	-0.1080	**0.2098**	1.0000	0.4920	-0.8648
M/Y	0.0275	-0.1707	0.1165	0.1968	**0.0837**	0.4919	1.0000	-0.2163
R	0.6758	0.1626	0.4900	0.2326	**0.0316**	-0.8648	-0.2163	1.0000

NOTE: Y is real GDP, C is consumption, I is aggregate investment, ΔP is inflation, R_b/R is the measure of liquidity spreads derived from the regression in table 3.1, R_k/R is the bank lending spread, M/Y is liquidity provided by the ECB (measured in terms of quarterly GDP), R is the OIS rate.

vations to this variable are almost orthogonal to the other residuals. Except for one, all correlations coefficients are close to, or below 0.1. More specifically the correlation with innovations to the amount of ECB liquidity M/Y is 0.08 and the correlation with innovations to the policy rate R is 0.03. We are therefore confident that our liquidity shocks will not be confounded with the ECB policy response through either standard measures—the policy rate—or non-standard liquidity provision. Only in the case of the lending spread R_k/R we observe a slightly higher correlation coefficient of 0.2.

Given this evidence, we identify liquidity shocks in a recursive fashion using a Cholesky decomposition with the variables ordered as in table 3.3. Since the innovations to our measure of liquidity spread R_b/R are virtually orthogonal to the innovations in the equations for the policy rate R and the stock of ECB liquidity M/Y, the key assumption in the Cholesky identification is that the correlation between innovations to liquidity spreads and innovations to lending spreads R_k/R is due to structural liquidity shocks. Conversely, this assumption implies that shocks to bank lending spreads do not have contemporaneous effects on liquidity spreads.

Impulse responses to a liquidity shock are shown in figure 3.3 together with 68% confidence bands.[11] The shock produces a short-lived annualized increase in liquidity spreads by 10 basis points. Bank lending spreads increase on impact by about 5 basis points and remain persistently at this higher level. Aggregate investment falls by 20 basis points on a quarterly rate. Consumption also tends to fall, even if its reaction

[11] Confidence bands are based on a bootstrapped sample of 10,000 draws.

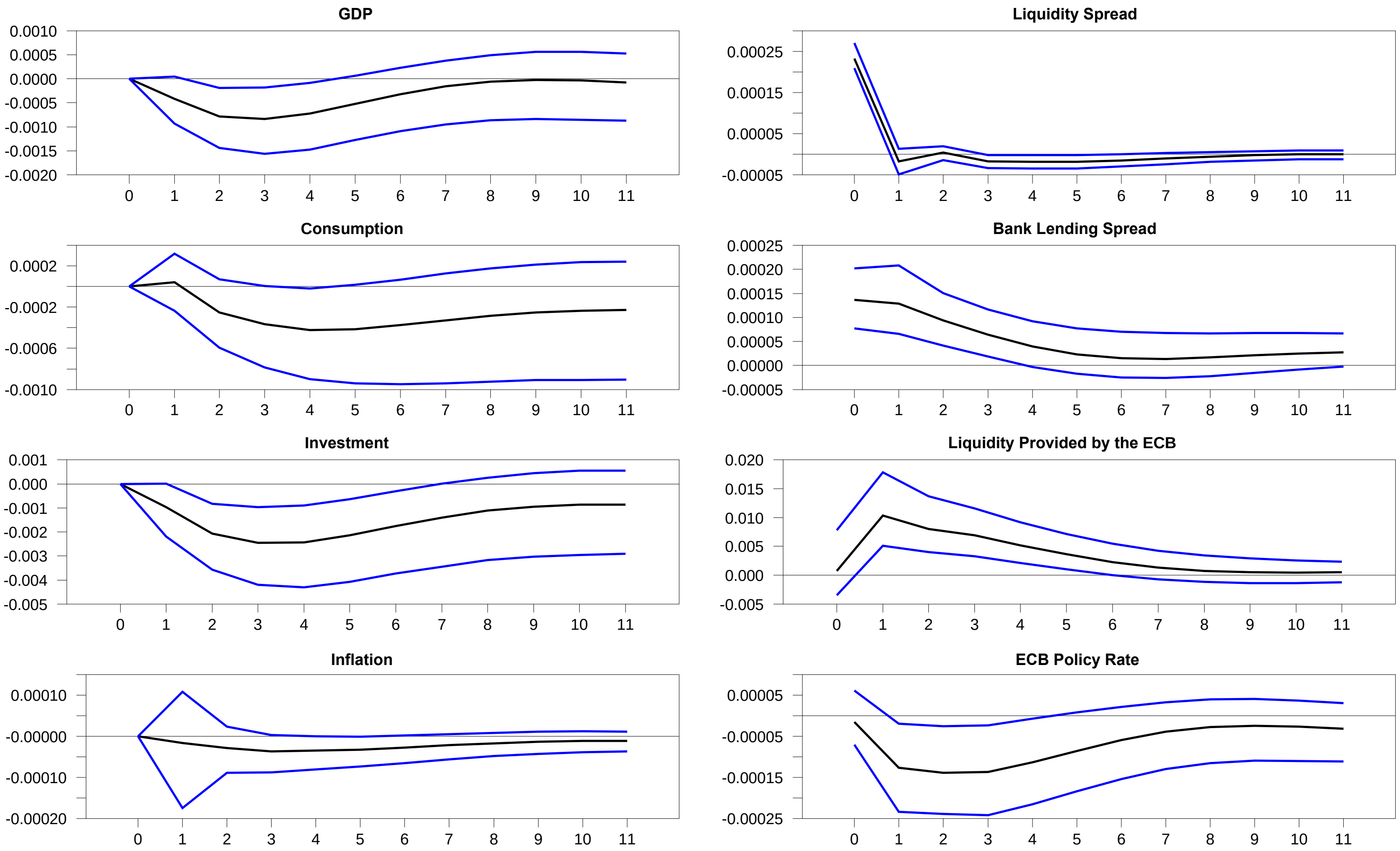

Figure 3.3: Impulse Responses to a Bank Liquidity Shock—Benchmark Identification

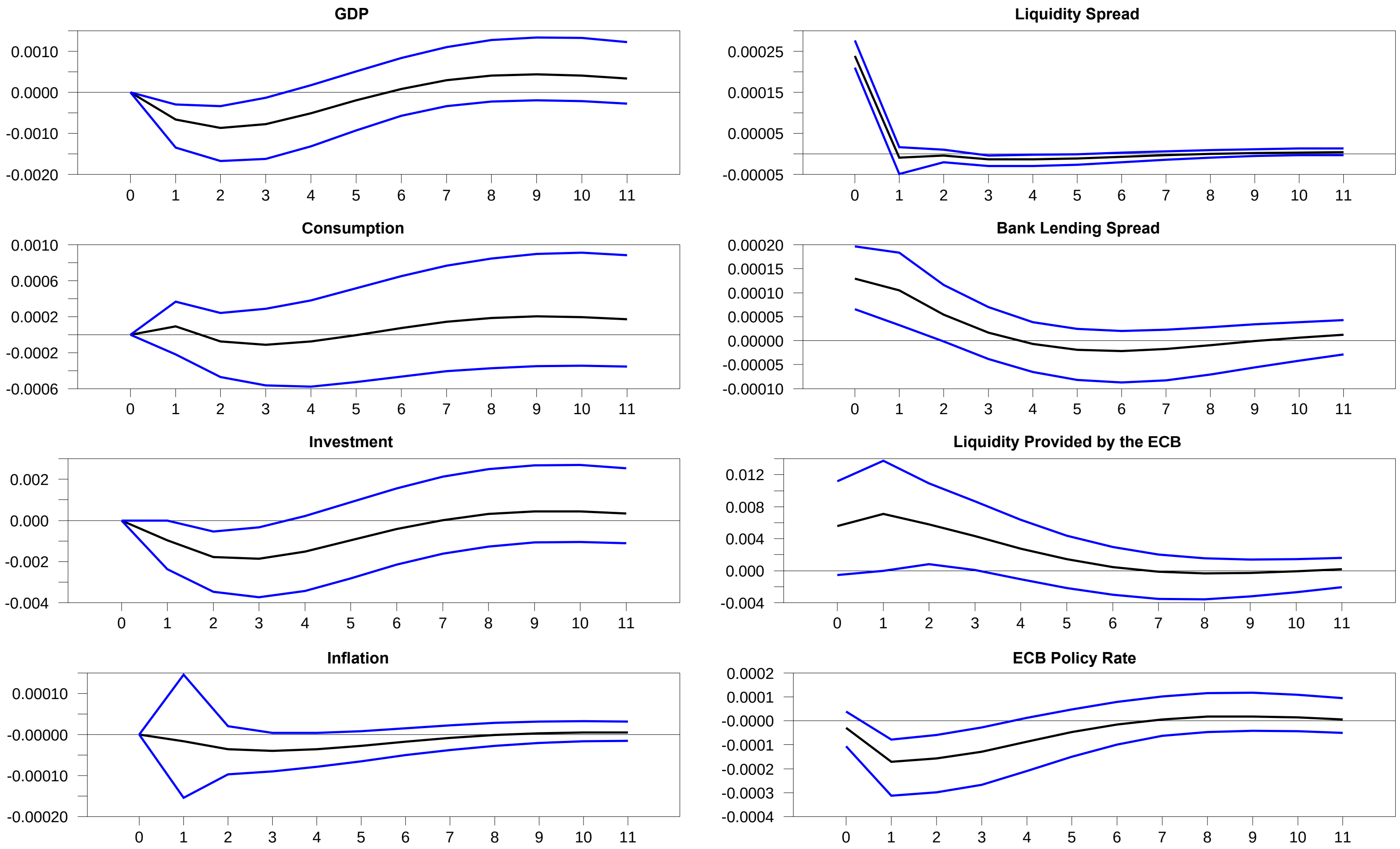

Figure 3.4: Impulse Responses to a Bank Liquidity Shock—Alternative Identification

is barely significant at 68% confidence levels. As a result, GDP decreases by about 8 basis points on a quarterly rate. Inflation tends to fall slightly, but insignificantly so. The liquidity shock is met by an increase in the amount of liquidity provided by the ECB, which could cushion the effect of the shock on real variables. The policy rate also declines slightly. Figure 3.4 shows the same impulse responses based on our second measure of liquidity spreads. The results are broadly consistent with the ones in figure 3.3. We therefore focus on our benchmark VAR when matching impulse responses.

To summarize, we document that a liquidity shock is met by an increase in the amount of central bank liquidity. Nevertheless, it leads to an increase in lending spreads and a reduction in economic activity, especially investment. The shock has smaller, possibly statistically negligible effects on consumption and inflation. We will use the impulse responses to estimate some key parameters of our structural model, which is described in the next section.

3.3 Model

We rely on a general equilibrium model based on Smets and Wouters (2003) augmented with a banking sector as in Gertler and Kiyotaki (2010). The banking sector is composed of a retail and a wholesale market. The former market allows banks to raise deposits from households, while the latter is an interbank market where banks provide funding to each other. Both markets are characterized by an agency problem à la Gertler and Karadi (2011). Bankers can divert a fraction of the bank assets financed by either retail or wholesale deposits. These frictions give rise to spreads between the return on capital, the interbank rate and the risk-free rate. In addition, we introduce the possibility of a liquidity provision to banks by the central bank. The key difference between our model and Gertler and Kiyotaki's (2010) is that we allow for the frictions on the wholesale market to be time-varying in a stochastic fashion.

Banks invest in non-financial firms that differ in their opportunities to issue debt. In each period a given fraction of firms can issue new assets while the remaining fraction merely rolls over its existing debt. The opportunity to issue new assets arrives randomly to firms, but before the realization is known, firms and banks already engage in a business relationship. We make this assumption for two reasons. First, such a framework is supposed to reflect the relationship-based financial system that predominates in Europe. Second, it creates the necessity of an interbank market. After the realization of investment opportunities, banks are either in short or abundant supply of liquidity depending on their business relationship with firms. This liquidity is traded in the interbank market. In what follows we present the model in detail.

3.3.1 Households

Each household consists of a given fraction of workers and bankers. Workers supply labor to the production sector while bankers manage financial intermediaries. Both agents transfer their earnings to their household and perfectly pool their consumption risk. Each period a banker switches occupation with a probability of $1-\sigma$ and becomes a worker instead. The probability to switch occupation is independent of the duration agents have been bankers. Exiting bankers transfer the net worth they have accumulated during their term in office to their household. All exiting bankers are randomly replaced by workers, who will then become bankers. These new bankers obtain start-up capital from their household. While bankers are the owners of the bank they manage, it is assumed that households place their deposits in banks belonging to other households. This assumption is needed to motivate the moral hazard problem that will be introduced in subsection 3.3.3. Each household j consumes a non-durable consumption good C_{jt}, provides labor to firms L_{jt}, for which it earns the real wage W_{jt}, and holds deposits D_{jt}, which pay the real deposit interest rate R_t. Households maximize the following utility function:

$$E_0 \left\{ \sum_{t=0}^{\infty} \beta^t \left[\log\left(C_{jt} - hC_{jt-1}\right) - \frac{\left(L_{jt}\right)^{1+\varphi}}{1+\varphi} \right] \right\}, \tag{3.1}$$

where β stands for the discount factor, $h \in (0,1)$ measures the influence of past consumption on utility and φ denotes the inverse elasticity of labor supply. The budget constraint is given by:

$$C_{jt} + D_{jt} + T_{jt} = R_{t-1}D_{jt-1} + W_{jt}L_{jt} + \Pi_t, \tag{3.2}$$

with Π_t denoting profits from firms as well as transfers from exiting bankers net the start-up capital granted to new bankers. Finally, households pay lump-sum taxes T_{jt} to finance any government expenditures.[12]

[12]Taxes are non-distortionary and thus do not affect the dynamics of the model. Their only purpose is to close the model.

The maximization of the utility function (3.1) subject to the budget constraint (3.2) with respect to consumption C_{jt} and deposit holdings D_{jt}, yields the following first-order conditions:

$$\Xi_t = \frac{1}{C_t - hC_{t-1}} - \beta E_t \left[\frac{h}{C_{t+1} - hC_t} \right], \tag{3.3}$$

$$\Xi_t = \beta R_t E_t \Xi_{t+1}, \tag{3.4}$$

with Ξ_t being the Lagrange multiplier of the budget constraint. Since all households behave in the same way, we can drop the subscript j. Equation (3.3) denotes marginal utility of consumption while equation (3.4) describes the standard Euler equation for consumption.

Following Smets and Wouters (2003) wages are assumed to be sticky. Households are monopolistic suppliers of differentiated labor services. Each household provides labor to intermediate goods producers for which they receive a household-specific wage W_{jt}. The aggregate labor demand by these firms is given by the following Dixit-Stiglitz type aggregator function:

$$L_t \equiv \left[\int_0^1 \left(L_{jt} \right)^{\frac{\varepsilon_L - 1}{\varepsilon_L}} dj \right]^{\frac{\varepsilon_L}{\varepsilon_L - 1}}, \tag{3.5}$$

where ε_L controls the elasticity of substitution among different types of labor and L_t denotes the aggregated labor demand. Given this functional form, the demand schedule for labor L_{jt} provided by an individual household is determined by:

$$L_{jt} = \left(\frac{W_{jt}}{W_t} \right)^{-\varepsilon_L} L_t, \tag{3.6}$$

which implies for the aggregated wage:

$$W_t = \left[\int_0^1 \left(W_{jt} \right)^{1-\varepsilon_L} dj \right]^{\frac{1}{1-\varepsilon_L}}. \tag{3.7}$$

Each period only a fraction $1 - \theta_w$ of wages can be re-negotiated. When negotiating wages, households maximize their utility (3.1) subject to their budget constraint (3.2) and to the demand schedule for labor (3.6). For the remaining fraction θ_w of wages which are not re-negotiated in the current period, we assume that these wages are indexed to past inflation and are mechanically adjusted according to the CPI inflation of the previous period. This indexation is however only partial, with $\chi_w \in (0, 1)$ controlling the intensity of the wage indexation. The optimization problem of household j is given by:

$$\max E_t \sum_{\tau=0}^{\infty} (\beta\theta_w)^\tau \left\{ -\frac{\left(L_{jt+\tau} \right)^{1+\varphi}}{1+\varphi} + \Xi_{t+\tau} \prod_{s=1}^{\tau} \frac{P_{t+s-1}}{P_{t+s}} \left(\frac{P_{t+s-1}}{P_{t+s-2}} \right)^{\chi_w} W_{jt} L_{jt+\tau} \right\}, \tag{3.8}$$

subject to future labor demand:

$$L_{jt+\tau} = \left(\prod_{s=1}^{\tau} \frac{P_{t+s-1}}{P_{t+s}} \left(\frac{P_{t+s-1}}{P_{t+s-2}} \right)^{\chi_w} \frac{W_{jt}}{W_{t+\tau}} \right)^{-\varepsilon_L} L_{t+\tau}. \tag{3.9}$$

This negotiation results in a mark-up for wages controlled by:

$$\begin{aligned} & \frac{\varepsilon_L - 1}{\varepsilon_L} W_t^* E_t \sum_{\tau=0}^{\infty} (\beta\theta_w)^{\tau} \, \Xi_{t+\tau} \left(\prod_{s=1}^{\tau} \frac{P_{t+s-1}}{P_{t+s}} \left(\frac{P_{t+s-1}}{P_{t+s-2}} \right)^{\chi_w} \right)^{1-\varepsilon_L} \left(\frac{W_t^*}{W_{t+\tau}} \right)^{-\varepsilon_L} L_{t+\tau}^{\mathcal{D}} \\ = \; & E_t \sum_{\tau=0}^{\infty} (\beta\theta_w)^{\tau} \left[\left(\prod_{s=1}^{\tau} \frac{P_{t+s-1}}{P_{t+s}} \left(\frac{P_{t+s-1}}{P_{t+s-2}} \right)^{\chi_w} \frac{W_t^*}{W_{t+\tau}} \right)^{-\varepsilon_L(1+\varphi)} (L_{t+\tau})^{1+\varphi} \right], \end{aligned} \tag{3.10}$$

with W_t^* denoting the optimal wage chosen at time t. As each household that renegotiates a new wage in period t faces the same decision problem, the optimal wage W_t^* is the same for all households. We thus do not need a subscript j for this variable. Given that households have market power when negotiating wages—due to the imperfect substitutability of labor determined by equation (3.5)—the fraction $\varepsilon_L/(\varepsilon_L - 1)$ denotes the desired mark-up, which households would choose in the absence of constraints on the frequency of wage adjustments. Given the optimal wage W_t^*, we can express the wage index (3.7) also recursively:

$$(W_t)^{1-\varepsilon_L} = \theta_w \left[\frac{P_{t-1}}{P_t} \left(\frac{P_{t-1}}{P_{t-2}} \right)^{\chi_w} W_{t-1} \right]^{1-\varepsilon_L} + (1-\theta_w) \left(W_t^* \right)^{1-\varepsilon_L}. \tag{3.11}$$

3.3.2 Firms, Technology, and Nominal Rigidities

We have four types of firms operating in the production sector. Intermediate goods producers combine labor and capital to produce intermediate goods which they sell to retailers. Retailers differentiate these goods and sell them to the final goods producers. In the final goods sector retail goods are combined to consumption goods, which are then consumed by households. While intermediate and final goods producers operate under perfect competition and are able to adjust prices every period, there is monopolistic competition and staggered price setting à la Calvo (1983) in the retail sector. Capital goods are constructed by capital goods producers using consumption goods as sole input. Creating capital is subject to flow adjustment costs.

Intermediate Goods Producers

Intermediate goods producers fulfill two tasks in this economy. They produce an intermediate good $Y_t^{\mathcal{M}}$, which will be the sole input for producing the final good Y_t, and they sell assets to banks in order to finance the capital stock K_t used in production. Intermediate firms differ in their investment opportunities and we differentiate between two types of firms. Each period a fraction γ^i of firms receives a signal allowing them to acquire new capital. The remaining fraction $\gamma^n = 1 - \gamma^i$ of intermediate goods producers cannot change their capital stock. The signal to firms is assumed to be *iid* across time. We will use the superscript $h = \{i, n\}$ to differentiate between investing and non-investing firms. All intermediate goods producers face an identical constant-returns-to-scale production function and we assume that labor is perfectly mobile across these firms. Therefore, we do not need to keep track of the distribution of capital across intermediate goods producers. Aggregate intermediate output $Y_t^{\mathcal{M}}$ can be expressed as a function of aggregate labor L_t and aggregate capital K_t:

$$Y_t^{\mathcal{M}} = K_t^{\alpha} L_t^{(1-\alpha)}, \tag{3.12}$$

with α being the share of capital in the production function. The law of motion for the capital stock is given by the sum of newly acquired capital I_t by investing firms, the depreciated capital stock $\gamma^i (1-\delta) K_t$ of these firms, and the depreciated capital stock $\gamma^n (1-\delta) K_t$ of non-investing firms in the current period:

$$\begin{aligned} K_{t+1} &= I_t + \gamma^i (1-\delta) K_t + \gamma^n (1-\delta) K_t \\ &= I_t + (1-\delta) K_t. \end{aligned} \tag{3.13}$$

The parameter δ is the depreciation rate which is assumed to be identical for both types of firms.

Intermediate goods producers completely finance their capital acquisitions in advance by issuing assets. They sell these assets to the bank with which they have built up a business relationship at the beginning of each period. In contrast to banks, intermediate goods producers face no constraints on obtaining funding. They use the capital stock as collateral so that the issued assets are claims against capital. Since we assume no frictions in originating these assets, the asset price is equal to the price of one unit of capital. However, as we will conjecture below, asset prices differ between the two types of firms. Let S_t^h be the claims issued by a firm of type h and Q_t^h the asset price of these claims (in real terms). The value of originated claims is then equal to the value of capital:

$$\begin{aligned} Q_t^i S_t^i &= Q_t^i \left[I_t + \gamma^i (1-\delta) K_t \right], \\ Q_t^n S_t^n &= Q_t^n \gamma^n (1-\delta) K_t. \end{aligned}$$

Since financing the capital stock is frictionless and intermediate goods producers issue perfectly contingent claims against their capital, these assets can either be interpreted as equity or perfectly state-dependent debt. Intermediate goods producers operate under perfect competition and earn zero profits. Each period, they sell their products to retailers at a real price of $P_t^{\mathcal{M}}$. They pay workers a wage W_t and banks a real dividend Z_t. Solving the optimization problem of intermediate goods producers yields:

$$\begin{aligned} W_t &= (1-\alpha)\, P_t^{\mathcal{M}} \frac{Y_t^{\mathcal{M}}}{L_t}, \\ Z_t &= \alpha P_t^{\mathcal{M}} \frac{Y_t^{\mathcal{M}}}{K_t}, \end{aligned}$$

which determines the labor demand and gross profits per unit of capital, respectively. For banks the gross rate of return on assets is then given by the dividend Z_t they collect as well as the price development of assets. Since the price depends on the type of firm, we define the return (in real terms) between period $t-1$ and t as:

$$R_{kt}^{hh'} \equiv \frac{Z_t + (1-\delta)\, Q_t^{h'}}{Q_{t-1}^{h}}, \tag{3.14}$$

with h being the type of firm at time $t-1$ and h' being the type of firm at time t. Since the capital stock depreciates at the rate of δ between periods, the value at time t is given by $(1-\delta)\, Q_t^{h'}$.

Retailers

Retailers merely repackage intermediate goods. They do this at no cost and one unit of intermediate goods can be transferred into one unit of retail goods. In doing so, they differentiate these goods and since retailers operate under monopolistic competition, each retailer i adds a mark-up to the marginal costs (given by the price of intermediate goods $P_t^{\mathcal{M}}$). Retailers then sell their goods $Y_{it}^{\mathcal{R}}$ at a price P_{it}. Retail prices are assumed to be sticky, with $1-\theta_p$ being the probability that retailers can readjust prices in the current period. We also assume price indexation to past inflation so that the fraction θ_p of retailers, who do not adjust their prices in the current period, mechanically change their price according to the inflation of the previous period. Retailers solve the following optimization problem:

$$\max_{P_{i,t}} E_t \sum_{s=0}^{\infty} (\theta_p)^s\, \Lambda_{t,t+s} \left\{ \left[\prod_{\tau=1}^{s} \left(\frac{P_{t+\tau-1}}{P_{t+\tau-2}} \right)^{\chi_P} \frac{P_{it}}{P_{t+s}} - P_{t+s}^{\mathcal{M}} \right] Y_{it+s}^{\mathcal{R}} \right\},$$

subject to future demand by final goods producers:

$$Y_{it+s}^{\mathcal{R}} = \left(\prod_{\tau=1}^{s} \left(\frac{P_{t+\tau-1}}{P_{t+\tau-2}} \right)^{\chi_P} \frac{P_{it}}{P_{t+s}} \right)^{-\varepsilon_y} Y_{t+s},$$

which will be derived below (equation 3.15). The parameter $\chi_P \in (0,1)$ controls the intensity of the price indexation, while $\Lambda_{t,t+s} = \beta^s \frac{\Xi_{t+s}}{\Xi_t}$ is the stochastic discount factor derived from the Euler equation (3.4). The first-order condition of the optimization problem is given by:

$$\frac{P_t^*}{P_t} = \frac{\varepsilon_y}{\varepsilon_y - 1} E_t \left[\frac{\sum_{s=0}^{\infty} (\beta\theta_p)^s \, \Xi_{t+s} \left(\prod_{\tau=1}^{s} \frac{P_{t+\tau-1}}{P_{t+\tau}} \left(\frac{P_{t+\tau-1}}{P_{t+\tau-2}} \right)^{\chi_p} \right)^{-\varepsilon_y} P_{t+s}^{\mathcal{M}} Y_{t+s}}{\sum_{s=0}^{\infty} (\beta\theta_p)^s \, \Xi_{t+s} \left(\prod_{\tau=1}^{s} \frac{P_{t+\tau-1}}{P_{t+\tau}} \left(\frac{P_{t+\tau-1}}{P_{t+\tau-2}} \right)^{\chi_p} \right)^{1-\varepsilon_y} Y_{t+s}} \right],$$

where P_t^* denotes the optimal price chosen at time t. As each retailer that resets its price in period t faces the same decision problem, the optimal price P_t^* is the same for all retailers. The factor $\varepsilon_y/(\varepsilon_y - 1)$ denotes the desired mark-up of retailers, which they would choose in the absence of constraints on the frequency of price adjustments. Profits earned by retailers are rebated lump sum back to households.

Final Goods Producers

Final goods producers aggregate the differentiated goods $Y_{i,t}^{\mathcal{R}}$ they buy from retailers according to the following Dixit-Stiglitz type aggregator function:

$$Y_t = \left[\int_0^1 \left(Y_{it}^{\mathcal{R}} \right)^{\frac{\varepsilon_y - 1}{\varepsilon_y}} di \right]^{\frac{\varepsilon_y}{\varepsilon_y - 1}},$$

with ε_y being the price elasticity of retail goods. The final good Y_t is then either sold to households or used as input factor in the production of capital goods. The cost minimization of final goods producers leads to the demand function for retail goods:

$$Y_{it}^{\mathcal{R}} = \left(\frac{P_{it}}{P_t} \right)^{-\varepsilon_y} Y_t. \tag{3.15}$$

The price P_t is an aggregate of retail prices:

$$P_t = \left[\int_0^1 (P_{it})^{1-\varepsilon_y} di \right]^{\frac{1}{1-\varepsilon_y}},$$

and can be interpreted as the CPI index. Given the optimal price P_t^* and since the fraction of prices which are not revised in the current period are partially linked to past inflation, we can express the price index also recursively:

$$(P_t)^{1-\varepsilon_y} = \theta_p \left[P_{t-1} \left(\frac{P_{t-1}}{P_{t-2}} \right)^{\chi_w} \right]^{1-\varepsilon_y} + (1 - \theta_p) \left(P_t^* \right)^{1-\varepsilon_y}.$$

Capital Goods Producers

Capital goods producers provide new capital to the intermediate goods producers that received a signal allowing them to acquire new capital. They sell the new capital to these firms at the market price of Q_t^i. Creating capital is subject to flow adjustment costs so that capital goods producers solve the following profit maximization problem:

$$\max_{I_t} E_t \sum_{\tau=0}^{\infty} \Lambda_{t,t+\tau} \left[Q_{t+\tau}^i I_{t+\tau} - \left(1 + \mathcal{F}\left(\frac{I_{t+\tau}}{I_{t+\tau-1}}\right)\right) I_{t+\tau} \right]. \tag{3.16}$$

As in Christiano *et al.* (2005) the cost function $\mathcal{F}(\cdot)$ is convex ($\mathcal{F}''(\cdot) > 0$) and adjustment costs are zero in the steady state ($\mathcal{F}(1) = \mathcal{F}'(1) = 0$). Solving the optimization problem, the price of capital goods is equal to the marginal costs of investment goods production:

$$Q_t^i = 1 + \mathcal{F}\left(\frac{I_t}{I_{t-1}}\right) + \frac{I_t}{I_{t-1}} \mathcal{F}'\left(\frac{I_t}{I_{t-1}}\right) - E_t \Lambda_{t,t+1} \left[\left(\frac{I_{t+1}}{I_t}\right)^2 \mathcal{F}'\left(\frac{I_{t+1}}{I_t}\right) \right]. \tag{3.17}$$

Due to the adjustment costs, capital goods producers earn profits outside of the steady state. These are rebated lump sum back to households.

3.3.3 Banks

Banks channel funds from households to the production sector. They finance themselves through deposits collected from households and through retained earnings that they use to build up equity. Additionally, banks interact on an interbank market which allows those that are short of liquidity to borrow from those having abundant liquidity. We introduce the necessity of an interbank market by assuming the following timing: At the beginning of each period, banks and intermediate goods producers engage in a business relationship before these firms receive a signal on their ability to issue new assets. Based on the expected liquidity needs, banks collect deposits from households. After this retail market has closed, firms receive a signal and either issue new assets or merely roll over their existing debt. Therefore, banks are either in short or abundant supply of liquidity. Since the interbank market opens after firms and banks know about their investment opportunities, this market allows banks to manage their short-term liquidity needs. The collection of deposits in this model should thus be understood as longer-term financing. In addition to the aforementioned funding alternatives, we introduce the possibility of a liquidity provision by the central bank, which we will later interpret as the non-standard policy tools used by the ECB after 2007.

Besides creating the necessity of an interbank market, the assumption of banks and firms engaging in a business relationship before they have knowledge of their investment opportunities shall represent a banking-based financial system. In contrast to the U.S., the financing of firms heavily depends on banks in the euro area. For this reason we explicitly introduce a banking sector in our model in order to answer relevant questions regarding their role in the recent financial crisis. At the beginning of each period, banks choose the intermediate goods producers they want to finance. At the end of the period, claims to the intermediate goods producers are pooled across banks. As a result, ex-ante expected returns are equalized across banks at the beginning of each period. This simplification is useful to avoid keeping track of the distribution of net worth across banks.

According to the aforementioned timing, bank j first decides on the amount of deposits D_{jt} it borrows from households based on its expected investment opportunities. Next, after learning about its investment opportunities, bank j decides on the amount of firms' assets S_{jt}^h it buys for a given price Q_t^h, on the amount of interbank borrowing B_{jt}^h (a negative value indicates that bank j offers liquidity on the interbank market), and possibly on the amount of liquidity M_{jt}^h it borrows from the central bank. The superscript $h = \{i, n\}$ indicates whether the bank finances an investing firm ($h = i$), or a non-investing firm that merely rolls over its debt ($h = n$). Notice that due to our assumption on the timing, the amount of deposits D_{jt} is independent of the bank type, while everything else depends on the type indicated by the superscript h. The balance sheet of bank j thus reads:

$$Q_t^h S_{jt}^h = N_{jt}^h + D_{jt} + B_{jt}^h + M_{jt}^h, \tag{3.18}$$

with N_{jt}^h denoting the amount of net worth of bank j. Net worth is accumulated over time as the difference between earnings on assets and debt payments:

$$N_{jt}^h = \left[Z_t + (1-\delta)\, Q_t^h\right] S_{jt-1} - R_{t-1} D_{jt-1} - R_{bt-1} B_{jt-1} - R_{mt-1} M_{jt-1}, \tag{3.19}$$

where R_t, R_{bt}, and R_{mt} denote the real gross interest rates paid on deposits, interbank loans, and loans provided by the central bank, respectively. The gross returns on assets $\left[Z_t + (1-\delta)\, Q_t^h\right]$ do not only include the dividend payment Z_t from intermediate goods producers, but also the resale value of assets $(1-\delta)\, Q_t^h$, which depends on the type of bank. Due to financial frictions, which will be introduced below, banks can expect a premium between the return on assets and the interest payments on liabilities. Such a premium gives bankers an incentive to accumulate assets over time and to maximize the value of the bank. Since bankers have to exit the market at the end of each period with probability $1-\sigma$, the value of bank j measured at the end of the period (but measured before banks pool their claims to intermediate firms) is given by its expected terminal wealth:

$$V_{jt} = E_t \sum_{i=1}^{\infty} (1-\sigma)\, \sigma^{i-1} \Lambda_{t,t+i} N^h_{jt+i}, \tag{3.20}$$

with $\Lambda_{t,t+i}$ being the stochastic discount factor derived from the Euler equation (3.4) of households.

Financial frictions are modeled as in Gertler and Karadi (2011). We assume an agency problem between banks and their creditors as banks can divert a certain fraction of assets and transfer them to the household they belong to. When a banker diverts funds, the bank will be closed and the remaining fraction of assets serves as bankruptcy assets that is distributed among creditors, i.e. depositors, the central bank as well as those banks holding interbank claims against the defaulting bank. As in Gertler and Kiyotaki (2010), we assume that the degree of financial frictions differs among funding markets. Banks can divert assets financed by borrowing from households more easily than those financed by borrowing from other banks or the central bank. The way financial frictions are introduced results in an endogenous constraint on bank's ability to obtain funding. Creditors are only willing to provide funding to a bank as long as the banker has no incentive to divert assets. To ensure this, the value of the bank V_{jt} needs to exceed the gain a banker receives by diverting assets:

$$V_{jt} \geq \theta \left(Q^h_t S^h_{jt} - \omega_t B^h_{jt} - \omega_m M^h_{jt} \right). \tag{3.21}$$

According to this incentive constraint the value of the bank V_{jt} must exceed the fraction θ of assets that a banker can divert. As in Gertler and Kiyotaki (2010), ω_t and ω_m (with $\omega_t, \omega_m \in (0,1)$) measure the possibility of diverting funds financed by interbank borrowing B^h_{jt} and by borrowing from the central bank M^h_{jt}, respectively. With $\omega_t = 1$ or $\omega_m = 1$, banks cannot divert assets financed by interbank borrowing or the liquidity provision by the central bank. With $\omega_t < 1$ or $\omega_m < 1$, the respective creditors would lose $\theta\,(1-\omega_t)\, B^h_{jt}$ and $\theta\,(1-\omega_m)\, M^h_{jt}$ in a bankruptcy.

While ω_m will be constant, we depart from Gertler and Kiyotaki (2010) and assume ω_t to be time-varying, following an AR(1) process in logs:[13]

$$\log(\omega_t) = (1-\rho_\omega)\,\bar{\omega} + \rho_\omega \log(\omega_t) + e_{\omega,t}, \tag{3.22}$$

[13] In Gertler and Kiyotaki (2010) ω_t is not time-varying and the authors do not study the dynamics of an intensification of money market disruptions.

with $\bar{\omega}$ being the steady state of the shock and $e_{\omega,t}$ denoting the structural innovation to the shock. The variable ω_t can be interpreted as a liquidity shock, which indexes the willingness of banks to lend in the interbank market. In the policy exercise conducted in section 3.5 we will use a fall in ω_t to simulate the freezing up of the interbank market observed during the Global Financial Crisis.

Each bank maximizes its expected terminal wealth (3.20) subject to the balance sheet condition (3.18) and the incentive constraint (3.21). We can express the recursive formulation of a banker's optimization problem at time $t-1$ as:

$$\begin{aligned} & V_{jt-1}\left(S^h_{jt-1}, B^h_{jt-1}, M^h_{jt-1}, D_{jt-1}\right) \\ = \; & E_{t-1}\Lambda_{t-1,t} \sum_{h'=i,n} \gamma^{h'} \left\{ (1-\sigma) N^{h'}_{jt} + \sigma \max_{D_{jt}} \left[\max_{S^{h'}_{jt}, B^{h'}_{jt}, M^{h'}_{jt}} V_{jt}\left(S^{h'}_{jt}, B^{h'}_{jt}, M^{h'}_{jt}, D_{jt}\right) \right] \right\}. \end{aligned} \tag{3.23}$$

The value at the end of period $t-1$ is determined by the expected discounted value in the following period. With probability $1-\sigma$ the bank j will be closed in the next period so that its value will be given by the net worth N^h_{jt} accumulated until that point. With probability σ the bank will survive and will optimize over D_{jt}, S^h_{jt}, B^h_{jt}, and M^h_{jt}. With probability γ^i the bank will have investment opportunities in the following period, whereas with probability γ^n (with $\gamma^n = 1-\gamma^i$) the bank will merely re-finance existing investment projects. Notice that due to the timing, banks first optimize over the amount of deposits they collect from households. Since this is done before they know about their investment opportunities, D_{jt} does not depend on the type h. After receiving the signal, banks choose S^h_{jt}, B^h_{jt}, and M^h_{jt}, which will depend on the type of bank.

To solve the optimization problem, we assume that the value function V_{jt} is linear in its arguments:

$$V_{jt}\left(S^h_{jt}, B^h_{jt}, M^h_{jt}, D_{jt}\right) = \mathcal{V}_{st} S^h_{jt} - \mathcal{V}_{bt} B^h_{jt} - \mathcal{V}_{mt} M^h_{jt} - \mathcal{V}_t D_{jt}, \tag{3.24}$$

where $\mathcal{V}_{st}$,$\mathcal{V}_{bt}$, $\mathcal{V}_{mt}$, and $\mathcal{V}_t$ are the marginal value of assets, the marginal costs of interbank borrowing, the marginal costs of the liquidity injection by the central bank, and the marginal costs of deposits, respectively. The parameters $\mathcal{V}_{st}$,$\mathcal{V}_{bt}$, $\mathcal{V}_{mt}$, and $\mathcal{V}_t$ are measured at the end of the period (but measured before banks pool their claims to intermediate firms) and thus do not depend on the type of bank. The Lagrangian associated with the optimization problem reads:

$$\begin{aligned}\mathcal{L}_t &= V_{jt}\left(S_{jt}^h, B_{jt}^h, M_{jt}^h, D_{jt}\right) \\ &\quad +\lambda_t^h\left[V_{jt}\left(S_{jt}^h, B_{jt}^h, M_{jt}^h, D_{jt}\right) - \theta\left(Q_t^h S_{jt}^h - \omega_t B_{jt}^h - \omega_m M_{jt}^h\right)\right] \\ &= \left(1+\lambda_t^h\right)\left[\left(\mathcal{V}_{st} - \mathcal{V}_{bt} Q_t^h\right) S_{jt}^h + \left(\mathcal{V}_{bt} - \mathcal{V}_{mt}\right) M_{jt}^h + \left(\mathcal{V}_{bt} - \mathcal{V}_t\right) D_{jt} + \mathcal{V}_{bt} N_{jt}^h\right] \\ &\quad -\lambda_t^h \theta\left[\left(1-\omega_t\right) Q_t^h S_{jt}^h + \left(\omega_t - \omega_m\right) M_{jt}^h + \omega_t\left(N_{jt}^h + D_{jt}\right)\right],\end{aligned}$$

with λ_t^h being the Lagrange multiplier for the incentive constraint (3.21). This shadow price differs among banks as it depends on their type h. The first-order conditions for S_{jt}^h, D_{jt} and M_{jt}^h are:

$$\frac{\mathcal{V}_{st}}{Q_t^h} + \lambda_t^h\left(\frac{\mathcal{V}_{st}}{Q_t^h} - \theta\right) \leq \mathcal{V}_{bt} + \lambda_t^h\left(\mathcal{V}_{bt} - \theta\omega_t\right), (= \ if\ S_{jt}^h > 0), \tag{3.25}$$

$$\mathcal{V}_t + \bar{\lambda}_t \mathcal{V}_t \geq \mathcal{V}_{bt} + \bar{\lambda}_t\left(\mathcal{V}_{bt} - \theta\omega_t\right), (= \ if\ D_{jt} > 0), \tag{3.26}$$

$$\mathcal{V}_{mt} + \lambda_t^h\left(\mathcal{V}_{mt} - \theta\omega_m\right) \geq \mathcal{V}_{bt} + \lambda_t^h\left(\mathcal{V}_{bt} - \theta\omega_t\right), (= \ if\ M_{jt}^h > 0). \tag{3.27}$$

Equation (3.25) relates the marginal value of asset purchases with the marginal costs of interbank borrowing. Buying an additional unit of assets increases the value of the bank (in terms of goods) by $\frac{\mathcal{V}_{st}}{Q_t^h}$. At the same time, it relaxes the incentive constraint by $\left(\frac{\mathcal{V}_{st}}{Q_t^h} - \theta\right)$, which in turn increases the value of the bank by the factor λ_t^h. Financing the purchase of assets by interbank borrowing has marginal costs of $\mathcal{V}_{bt}$ and tightens the incentive constraint by $(\mathcal{V}_{bt} - \theta\omega_t)$. The latter lowers the value of the bank by the factor λ_t^h. In equilibrium, $S_{jt}^h > 0$ and the first-order conditions (3.25) holds with equality. We follow Gertler and Kiyotaki (2010) and conjecture $Q_t^i < Q_t^n$. This implies that in equilibrium, the supply of assets S_{jt}^i from firms with investment opportunities relative to the net worth of banks of type i will be larger than the supply of assets S_{jt}^n from firms without investment opportunities relative to the net worth of banks of type n. The asset price Q_t^i will therefore clear at a lower price than the asset price Q_t^n. From equation (3.25) we then get:

$$\lambda_t^i > \lambda_t^n \geq 0, \tag{3.28}$$

so that the incentive constraint is less binding for banks of type n compared with banks of type i. In what follows, we set $\lambda_t^n = 0$. Otherwise, if the incentive constraint binds tightly for non-investing banks, they will be reluctant to provide interbank market liquidity and rather refinance existing investment.[14]

[14]Gertler and Kiyotaki (2010) make this assumption, too, when analyzing frictions in the interbank market for $\omega_t = 0$.

Equation (3.26) relates the marginal costs of deposits with the marginal costs of interbank borrowing. Increasing deposits comes at costs of $\mathcal{V}_t$ and tightens the incentive constraint by the same amount. The latter affects the value of the bank by the factor $\bar{\lambda}_t$. In equilibrium, these costs are related to the costs of interbank borrowing and since $D_{jt} > 0$, the first-order condition (3.26) holds with equality. Banks choose the amount of deposits before they know about their investment opportunities. Therefore, when choosing D_{jt}, each banker takes the average shadow price $\bar{\lambda}_t$ into account. The average Lagrange multiplier across states is defined as:

$$\bar{\lambda}_t \equiv \gamma^i \lambda_t^i + \gamma^n \lambda_t^n,$$

which in our model simplifies to $\bar{\lambda}_t = \gamma^i \lambda_t^i$ due to $\lambda_t^n = 0$.

Finally, equation (3.27) relates the marginal costs of lending from the central bank with the marginal costs of interbank borrowing. Rearranging the first-order condition (3.27), we learn:

$$\mathcal{V}_{mt} - \mathcal{V}_{bt} \geq \frac{\theta \left(\omega_m - \omega_t\right) \lambda_t^i}{\left(1 + \lambda_t^i\right)} > \frac{\theta \left(\omega_m - \omega_t\right) \lambda_t^n}{\left(1 + \lambda_t^n\right)}. \tag{3.29}$$

Banks will use both sources of funding—interbank borrowing and liquidity injections by the central bank—if equation (3.29) holds with equality. This implies that only banks of type i will accept liquidity provided by the central bank. For $\omega_m = \omega_t$, these banks are indifferent between the two sources of funding and the marginal costs of these sources are identical ($\mathcal{V}_{mt} = \mathcal{V}_{bt}$). If $\omega_m > \omega_t$, interbank markets will be more distorted compared with the liquidity provision by the central bank and banks accept higher marginal costs for the liquidity injections ($\mathcal{V}_{mt} > \mathcal{V}_{bt}$).[15]

The first-order condition for λ_t^h is given by the incentive constraint (3.21), which together with equation (3.26) and (3.27) simplifies to:

$$\begin{aligned} \left[\theta \left(1 - \omega_t\right) - \left(\frac{\mathcal{V}_{st}}{Q_t^h} - \mathcal{V}_{bt}\right)\right] Q_t^h S_{jt}^h \quad \leq \quad & \left(\mathcal{V}_{bt} - \theta \omega_t\right) N_{jt}^h - \frac{\theta \omega_t}{1 + \bar{\lambda}_t} D_{jt}^h \\ & + \frac{\theta \left(\omega_m - \omega_t\right)}{1 + \lambda_t^h} M_{jt}^h, (= \; if \; \lambda_t^h > 0). \end{aligned} \tag{3.30}$$

[15]Given that the ECB provided liquidity conditional on the provision of adequate collateral, we ague that the marginal costs of central bank loans are indeed higher than interbank market loans.

Expression (3.30) determines the asset market clearing for both types of banks. Since investing banks use the central bank liquidity facilities and since $\lambda_t^i > 0$, we learn from equation (3.30):

$$S_t^i = \frac{1}{\left[\theta\left(1-\omega_t\right)+\mathcal{V}_{bt}\right]Q_t^i-\mathcal{V}_{st}}\left[\left(\mathcal{V}_{bt}-\theta\omega_t\right)N_t^i+\frac{\theta\left(\omega_m-\omega_t\right)}{1+\lambda_t^h}M_t -\frac{\gamma^i\theta\omega_t}{1+\bar{\lambda}_t}D_t^i\right]. \quad (3.31)$$

In contrast, non-investing banks do not use the central bank liquidity and since we set $\lambda_t^n = 0$, equation (3.30) reads:

$$S_t^n < \frac{1}{\left[\theta\left(1-\omega_t\right)+\mathcal{V}_{bt}\right]Q_t^n-\mathcal{V}_{st}}\left[\left(\mathcal{V}_{bt}-\theta\omega_t\right)N_t^n-\frac{\gamma^n\theta\omega_t}{1+\bar{\lambda}_t}D_t^n\right].$$

In appendix 3.A we relate the marginal value $\mathcal{V}_{st}$ as well as the marginal costs $\mathcal{V}_{bt}$, $\mathcal{V}_{mt}$, and $\mathcal{V}_t$ with the corresponding interest rates $R_{kt}^{hh'}$, R_{bt}, R_{mt}, and R_t. This yields:

$$\frac{\mathcal{V}_{st}}{Q_t^h} = E_t\Lambda_{t,t+1}\sum_{h'=i,n}\gamma^{h'}\Omega_{t+1}^{h'}R_{kt+1}^{hh'} \quad (3.32)$$

$$\mathcal{V}_{bt} = R_{bt}E_t\Lambda_{t,t+1}\sum_{h'=i,n}\gamma^{h'}\Omega_{t+1}^{h'} \quad (3.33)$$

$$\mathcal{V}_{mt} = R_{mt}E_t\Lambda_{t,t+1}\sum_{h'=i,n}\gamma^{h'}\Omega_{t+1}^{h'} \quad (3.34)$$

$$\mathcal{V}_{t} = R_{t}E_t\Lambda_{t,t+1}\sum_{h'=i,n}\gamma^{h'}\Omega_{t+1}^{h'}, \quad (3.35)$$

with Ω_t^h being the marginal value of net worth of a bank:

$$\Omega_t^h \equiv 1-\sigma+\sigma\left[\mathcal{V}_{bt}+\lambda_t^h\left(\mathcal{V}_{bt}-\theta\omega_t\right)\right]. \quad (3.36)$$

The marginal value of net worth Ω_t^h is a weighted average of marginal values for exiting and for continuing banks. With probability $1-\sigma$ a bank will exit, while with probability σ it stays active. In the latter case, an additional unit of net worth can be used to lower interbank borrowing which increases the value of the bank by $\mathcal{V}_{bt}+\lambda_t^h\left(\mathcal{V}_{bt}-\theta\omega_t\right)$. The product $E_t\Lambda_{t,t+1}\sum_{h'=i,n}\gamma^{h'}\Omega_{t+1}^{h'}$ in equations (3.32)–(3.35) can be interpreted as the *augmented stochastic discount factor*. It includes the standard stochastic discount factor $\Lambda_{t,t+1}$ weighted by the future marginal value of net worth $E_t\Omega_{t+1}^{h'}$. As this marginal value depends on the future bank type, we also need to take into account the probabilities γ^i and γ^n.

Every period, the fraction $1-\sigma$ of bankers leaving the market is replaced by new bankers. This assumption is introduced to prevent the net worth of banks to increase indefinitely. If bankers did not leave the market, they could accumulate enough equity to ensure that the incentive constraint (3.21) is never binding. When leaving the market, bankers transfer their net worth to their respective household. New bankers obtain start-up capital from their households proportional to the asset holdings of an exiting bank. We define aggregate net worth N_t^h for banks of type h as the sum of net worth of existing (old) banks N_{ot}^h and of new (young) banks entering the market N_{yt}^h:

$$N_t^h = N_{ot}^h + N_{yt}^h. \tag{3.37}$$

Net worth of existing banks is given by the difference of earnings from holding assets and interest payments on liabilities. As the mass of existing banks is σ and the mass of banks from type h is γ^h, aggregate net worth of existing banks is given by:

$$N_{ot}^h = \sigma\gamma^h \left\{ \left[Z_t + (1-\delta) Q_t^h \right] S_{t-1} - R_{t-1} D_{t-1} - R_{mt-1} M_{t-1} \right\},$$

where we have dropped the j subscript to denote aggregate bank variables. We assume that entering banks obtain a fraction $\xi / (1-\sigma)$ of the asset holdings of an exiting bank. Net worth of new banks is then given by:

$$N_{yt}^h = \xi\gamma^h \left[Z_t + (1-\delta) Q_t^h \right] S_{t-1}.$$

Notice that due to the aggregation, interbank loans cancel out in both definitions. Finally, the aggregate balance sheet for the entire banking sector obeys:

$$Q_t^i S_t^i + Q_t^n S_t^n = N_t^i + N_t^n + D_t + M_t.$$

3.3.4 Closing the Model

To close the model we impose market-clearing conditions for all markets. Furthermore, we define policy rules for the conventional monetary policy as well as the non-standard measures.

Market Clearing

In the financial market, the labor market, the intermediate goods sector, the retail goods sector as well as the capital goods sector supply has to be equal to demand. The government budget constraint requires that non-distortionary lump-sum taxes collected from households are used to finance the central bank liquidity injections. In the final goods sector output is equal to the demand of households, the demand for investment goods from capital producers, and the investment adjustment costs:

$$Y_t = C_t + I_t + F\left(\frac{I_t}{I_{t-1}}\right) I_t. \tag{3.38}$$

Central Bank Policies and Interest Rates

Monetary policy is conducted by the central bank with an interest rate rule that targets CPI inflation and real output growth. Following Smets and Wouters (2003), we introduce a Taylor-type rule prescribing that the nominal policy rate $R_t^{\mathcal{N}}$ reacts to the lagged interest rate, inflation, the growth rate of inflation, the output gap (which we proxy as deviation of real output from its steady state) as well as the growth rate of the output gap:

$$\frac{R_t^{\mathcal{N}}}{R^{\mathcal{N}}} = \left(\frac{R_{t-1}^{\mathcal{N}}}{R^{\mathcal{N}}}\right)^{1-\gamma_R} \left[\left(\frac{P_t}{P_{t-1}}\right)^{\gamma_\pi} \left(\frac{P_t}{P_{t-1}} / \frac{P_{t-1}}{P_{t-2}}\right)^{\gamma_{\Delta\pi}} \left(\frac{Y_t}{Y}\right)^{\gamma_Y} \left(\frac{Y_t}{Y} / \frac{Y_{t-1}}{Y}\right)^{\gamma_{\Delta Y}}\right]^{\gamma_R}. \tag{3.39}$$

The relationship between the nominal and the real risk-free interest rate is given by the Fisher equation:

$$R_t^{\mathcal{N}} = R_t E_t \pi_{t+1}. \tag{3.40}$$

A monetary policy rule as in equation (3.39) is standard in the literature and known to describe well actual policy interest rate levels over the decades before the Global Financial Crisis. For our model, we also need to specify a rule followed by the central bank for injecting liquidity in the market. Given the unprecedented nature of these non-standard monetary policy measures, we cannot rely on existing results in the literature. It is hard to capture the different types of non-standard measures adopted by the ECB over the crisis years through a unique non-standard "monetary policy instrument". One may argue that the actual non-standard monetary policy instrument was the interest rate on ECB loans to banks, R_{mt}, because the quantity of liquidity provided by the ECB was by and large demand-driven at the rate of the main refinancing operations (MRO). However, the actual interest rate on ECB liquidity was larger than the MRO rate, since such loans were conditional on the provision of adequate collateral to the ECB. We therefore specify the non-standard policy rule in terms of the quantity of liquidity provided by the ECB. The resulting interest rate R_{mt} will give us a model-implied valuation of the total costs of ECB liquidity—given by the sum of the actual MRO rate and the opportunity costs of the pledged collateral.

We assume that liquidity injections M_t relative to GDP were related to the interbank spread:

$$\log\left(\frac{M_t}{Y_t}\right) = \rho_M \log\left(\frac{M_{t-1}}{Y_{t-1}}\right) + \gamma_{R^b} \log\left(\frac{R_{bt}}{R_t} / \frac{R_b}{R}\right). \tag{3.41}$$

An important feature of this policy rule is that it assumes that all agents in the economy anticipate the ECB intervention given the widening of interbank spreads. Furthermore, equation (3.41) also assumes that liquidity injections are persistent, so that they would be withdrawn slowly in the face of a narrowing of spreads.

3.4 Parameter Estimation

We are interested in understanding the dynamics of key macroeconomic variables following a liquidity shock. Therefore, we estimate our model using the strategy in Christiano *et al.* (2010b) that minimizes the distance between the dynamic response to shocks in the model and in the structural VAR. In this section we describe the calibration of model parameters and present the impulse response matching strategy together with the estimation results.

3.4.1 Calibration

Model parameters, which cannot be identified by our impulse response matching strategy, are calibrated. For calibrating the parameters associated with the real economy we mainly follow Smets and Wouters (2003). Parameter values for the financial sector are taken from Gertler and Kiyotaki (2010).[16] The calibration is summarized in table 3.4. We set the discount factor of households to $\beta = 0.99$, which implies an annual risk-free interest rate of 4 percent. The capital share in production is equal to $\alpha = 0.3$ and we set the depreciation rate to $\delta = 0.025$, assuming an annualized depreciation rate of 10 percent. Smets and Wouters (2003) estimate for the euro area a habit formation parameter of $h = 0.592$ and an inverse Frisch elasticity of labor supply of $\varphi = 2.503$.[17] Furthermore, they estimate the probability of being able to adjust prices and wages to be equal to $\theta_p = 0.905$ and $\theta_w = 0.742$, respectively. The indexation of prices and wages is equal to $\chi_p = 0.477$ and $\chi_w = 0.728$, respectively. We set the elasticity of substitution between retail goods to $\varepsilon_y = 10$ and between labor to $\varepsilon_l = 3$. This implies a price mark-up of 10 percent and a wage mark-up of 50 percent.

Following Gertler and Kiyotaki (2010) we assume that on average bankers are in office for 10 years ($\sigma = (40 - 1)/40$). The transfer to entering bankers ξ as well as the fraction of divertable assets θ are calibrated to allow for an average leverage ratio of 4 and an average annualized spread between the return to capital R^{ii}_{kt} and the

[16]It is common to use this calibration, which is actually based on Gertler and Karadi (2011), even for the euro area (e.g. Villa, 2016). Changing these parameters, however, does not significantly alter our results.

[17]In contrast to our model, Smets and Wouters (2003) use external instead of internal habit formation.

Table 3.4: Calibrated Parameters

Households		
β	0.990	discount factor
h	0.592	habit parameter
φ	2.503	inverse Frisch elasticity
Non-Financial Sector		
α	0.300	capital share
δ	0.025	depreciation rate
θ_p	0.905	Calvo probability prices
χ_p	0.477	indexation of prices
θ_w	0.742	Calvo probability wages
χ_w	0.728	indexation of wages
ε_y	10.00	elasticity of substitution between retail goods
ε_l	3.000	elasticity of substitution between labor
Financial Sector		
σ	0.972	survival rate of bankers
ξ	0.002	transfer to entering bankers
θ	0.408	fraction of divertable assets
$\bar{\omega}$	0.990	average degree of interbank market frictions
ω_m	0.990	fraction of non-divertable central bank assets
Government		
γ_π	1.688	Taylor rule inflation coefficient
$\gamma_{\Delta\pi}$	0.151	Taylor rule inflation growth coefficient
γ_y	0.098	Taylor rule output gap coefficient
$\gamma_{\Delta y}$	0.158	Taylor rule output gap growth coefficient
γ_R	0.956	Taylor rule smoothing parameter

risk-free interest rate R_t of 100 basis points. We assume that in the steady state interbank market frictions are negligible and calibrate the average degree of interbank market frictions to $\bar{\omega} = 0.99$. Setting this parameter not equal to unity has practical reasons. As shown by Gertler and Kiyotaki (2010) with frictionless interbank markets ($\omega_t = 1$) the model simplifies to the framework of Gertler and Karadi (2011), making the differentiation between banks irrelevant. In such a setting, all banks are balance sheet constrained. However, under our calibration, with imperfect interbank markets ($\omega_t < 1$) only banks which have the opportunity to invest in new assets are constrained. Banks which have no investment opportunities in the current period are not balance sheet constrained. They have sufficient funds relative to their lending opportunities and are therefore willing to provide liquidity to other banks in the interbank market. For this reason, we do not allow the degree of interbank market frictions ω_t to increase to 1 in our exercise. In order to make banks in steady state indifferent between interbank loans and liquidity provided by the central bank we set $\omega_m = \bar{\omega}$. Finally, Smets and Wouters (2003) estimate the inflation coefficient and the inflation growth coefficient in the Taylor rule to be $\gamma_\pi = 1.688$ and $\gamma_{\Delta\pi} = 0.151$, respectively. The coefficients for the output gap and the growth in the output gap are $\gamma_y = 0.098$ and $\gamma_{\Delta y} = 0.158$, respectively. The inertia parameter is $\gamma_R = 0.956$.

3.4.2 Impulse Response Matching

The most relevant model parameters for the transmission of a liquidity shock ω_t to the real economy are estimated. We do so by matching the impulse responses identified in the VAR with the corresponding dynamic responses of the structural model. More specifically, we rely on the Bayesian version of this methodology proposed in Christiano *et al.* (2010b).

We will briefly summarize the methodology before presenting the estimation results and the matched impulse responses. Let $\hat{\Psi}$ be a vector in which we stack the estimated impulse responses and $\Psi(\Theta)$ be an analogous vector of the model-implied responses depending on the model parameters Θ. According to large sample theory and given the (unknown) true values of these model parameters Θ_0, we can express the asymptotic distribution of the estimated impulses as:

$$\hat{\Psi} \sim N\left(\Psi\left(\Theta_0\right), V\right).$$

Christiano *et al.* (2010b) show how to compute the likelihood of the data $\hat{\Psi}$ as a function of the model parameters Θ and the covariance matrix V. To do so, we need a consistent estimator of the matrix V. Following the authors, we use a bootstrap approach and compute

$$\bar{V} = \frac{1}{T}\sum_{i=1}^{T}\left(\Psi_i - \bar{\Psi}\right)\left(\Psi_i - \bar{\Psi}\right)',$$

with Ψ_i being the ith realization of the impulse responses obtained by the bootstrapping procedure and $\bar{\Psi}$ being the mean realization. We set $T = 10.000$. Finally, our estimator for the covariance matrix V includes only the diagonal elements of $\bar{V}$.[18] Given the likelihood function and the priors on the model parameters Θ, we can then use the standard steps in Bayesian estimation to obtain the posterior distribution of Θ.

We summarize the priors and posteriors for the estimated parameters in table 3.5. The posterior distributions are obtained by the Metropolis-Hasting algorithm with 250.000 draws. We opt for a standard Beta prior centered at 0.75 for the persistence of the liquidity shock ρ_ω as well as the persistence parameter in the policy function ρ_M. The prior mean for the coefficient in the policy function γ_{R_b} as well as the fraction of firms without investment opportunities γ^n is taken from the calibration used in Gertler and Kiyotaki (2010). To let the data speak, we choose prior standard deviations for these two parameters which correspond to fairly loose priors. This means, with 95 percent probability the coefficient in the policy function γ_{R_b} lies between 60 and 140 while the fraction of firms without investment opportunities γ^n lies between 53 percent and 92 percent. The posterior mean for the coefficient of the policy function indicates that an annualized increase in the liquidity spread by 100 basis points leads to a mean liquidity provision of 19 percent (relative to quarterly GDP) by the ECB. Our posterior mean of 80 percent for the fraction of firms without investment opportunities is a little bit higher than the calibrated value by Gertler and Kiyotaki (2010). We opt for a rather low prior mean for the inverse of the elasticity of net investment to the price of capital η, because financial frictions in our model already restrain producers in their ability to invest. The posterior mean of 1.4 is slightly lower than the calibrated value used by Gertler and Kiyotaki (2010). The standard deviation of the liquidity shock is estimated to be 0.03.

We tried to include other parameters in the estimation, especially parameters related to the financial sector like the economy-wide leverage ratio or the survival rate of bankers. Since these parameters do not seem to affect the dynamic responses significantly, we rather keep them at their standard calibrated values.

Figure 3.5 shows the impulse responses of the VAR together with the matched responses by the model. The model does very well at capturing the responses of the liquidity spread R_{bt}/R_t, the bank lending spread R_{kt}/R_t as well as the liquidity provision M_t/Y_t to banks by the central bank.[19] It does a reasonable job at matching

[18]Christiano *et al.* (2010b) discuss possible transformations of the matrix $\bar{V}$, which can be used to assign different weights to impulse responses in the estimation. For transparency reasons, they finally stick to $\bar{V}$ and also use its diagonal elements.

[19]Our model implied lending rate R_{kt} reported in the impulse responses is a weighted average of the gross return on assets $R_{kt}^{hh'}$.

Table 3.5: Prior and Posterior Distributions

	Parameters	Priors			Posterior	
			Mean	SD	Mean	95% C.S.
η	investment adjustment costs	Gamma	1.00	0.50	1.40	[0.55,2.37]
γ_n	fraction of firms without investment opportunities	Beta	0.75	0.1	0.80	[0.73,0.88]
γ_{R_b}	coefficient non-standard policy rule	Normal	100	20.0	75.99	[75.99,106.99]
ρ_M	persistence non-standard policy rule	Beta	0.75	0.10	0.81	[0.70,0.91]
ρ_ω	persistence liquidity shock	Beta	0.75	0.10	0.82	[0.75,0.90]
σ_ω	std. dev. liquidity shock	Gamma	0.10	0.05	0.03	[0.02,0.05]

the drop in investment I_t and to a lesser extent the drop in output Y_t. The model understates the drop in the short-term interest rate R_t and wrongly predicts a small increase in inflation P_t/P_{t-1}. Thus, our model does not capture well the response of the standard monetary policy to a liquidity shock. Standard policy seems to be accommodative, although prices do not change. One possible explanation for this is that standard monetary policy might respond differently than it is described by a Taylor rule based on the estimation exercise of Smets and Wouters (2003). The model predicts a small increase in consumption C_t in contrast to the estimated decrease in private spending. In the Gertler and Karadi (2011) framework, such a countercyclical reaction of consumption to financial shocks is typical. As banks lower their demand for deposits together with a drop in the return on deposits, households increase rather than decrease their consumption spending. This countercyclical behavior of households also explains why the model underpredicts the fall in output. Overall, the model does well at accounting for the impact of an impaired interbank market on the banking sector and its transmission to the real economy. In the next section we will use the model to provide a quantitative assessment of the macroeconomic impact of the ECB's non-standard measures.

3.5 The Financial Crisis in the Euro Area

In this section, we study the financial crisis and its macroeconomic consequences through the lens of our model. We begin by looking again at the impulse responses of a one standard deviation liquidity shock and compare the model impulse responses with the counterfactual case of the absence of ECB's non-standard intervention. To

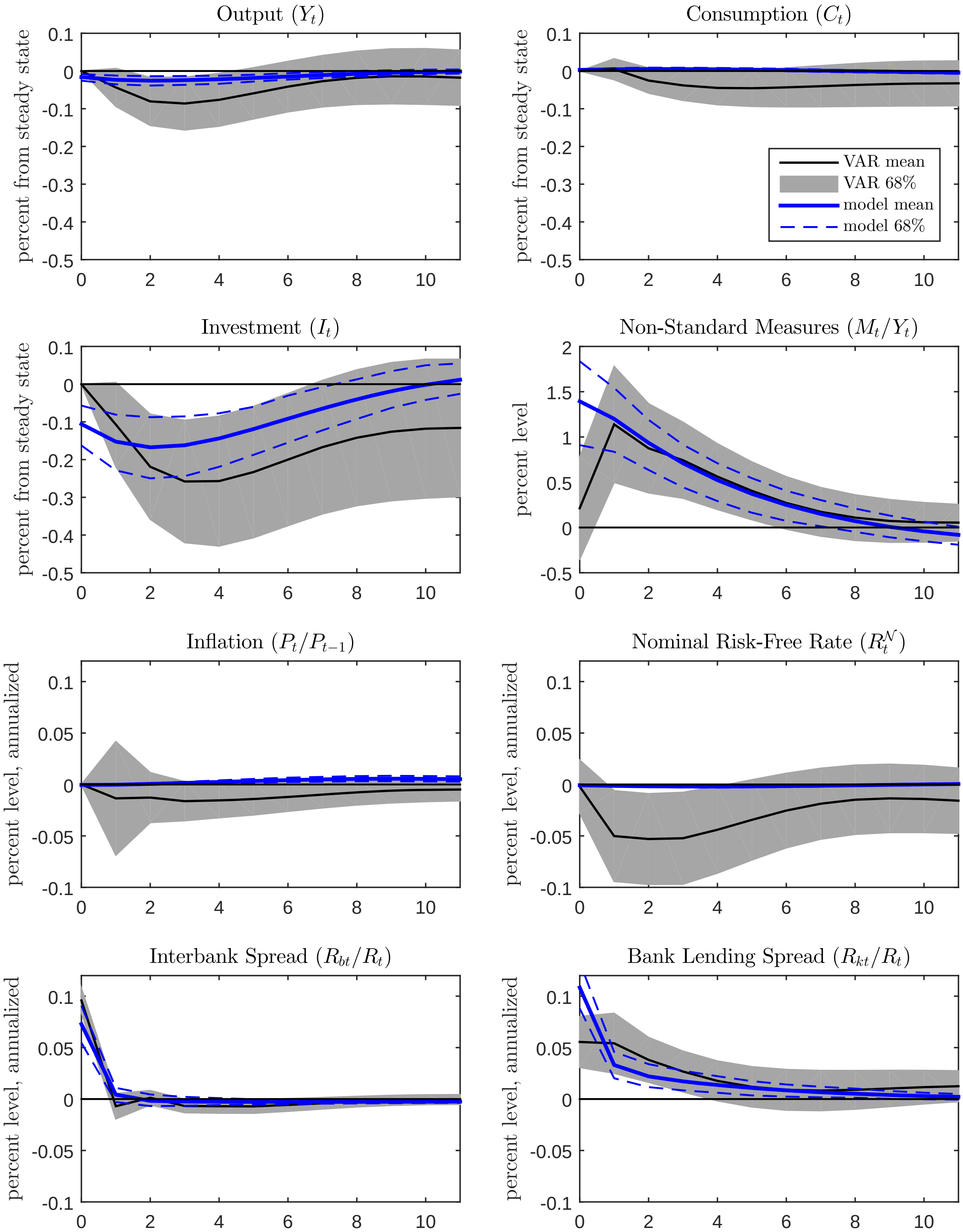

Figure 3.5: Impulse Response Matching

understand the mechanism at work behind the non-standard policy rule, we also study the case in which the monetary policy intervention is unexpected, i.e. akin to a liquidity supply shock. Finally, we provide an accounting for the financial crisis by simulating the path of the interbank market shock ω_t which replicates the surge in the liquidity spread over the 2007–2012 period. Given this path, we can then compute its effect on all endogenous variables and compare them with their empirical counterparts to evaluate how much of the Great Recession is due to the interbank market tensions we have identified with our model. Moreover, we can compute a counterfactual scenario for the period 2007–2012.

3.5.1 The Effects of the Liquidity Shock—A Counterfactual Analysis

To assess the effects of the ECB's non-standard measures, figure 3.6 depicts the impulse responses of a one standard deviation liquidity shock ω_t (solid line) and compares them with the effects of such a shock in the absence of the liquidity injections (dashed line). Thus, in the counterfactual analysis, the liquidity injection by the central bank is no longer described by the policy function (3.41), but we set $M_t = 0$.

The comparison of the benchmark model with the counterfactual analysis shows that the provision of liquidity to the financial sector helps to dampen the effect of ω_t on spreads and via this on the real economy. Without the intervention, the surge on impact of the liquidity spread as well as the bank lending spread increases by a factor of three. Furthermore, the effect of ω_t does not die off as quickly as it does when the central bank intervenes. With the liquidity injections, the tensions in the interbank market—measured by the liquidity spread R_{bt}/R_t—already disappear after two quarters. In contrast, the tensions will last for 2 years, if we set $M_t = 0$. Similar effects hold for the credit conditions for the non-financial sector R_{kt}/R_t, although the non-standard policy is not able to bring down rates as quickly as in the interbank market. This has consequences for the real economy. Without the non-standard policy the maximal decline in investment as well as output is three times as large. Under both scenarios, the model-implied responses of consumption, inflation as well as the short-term rate are economically insignificant.

In summary, the liquidity provision under the non-standard policy serves as a powerful tool to counteract tensions in the interbank market and to attenuate the spillovers to the real economy. In the next section, we will look in more detail at how the non-standard policy in our model acts on the economy.

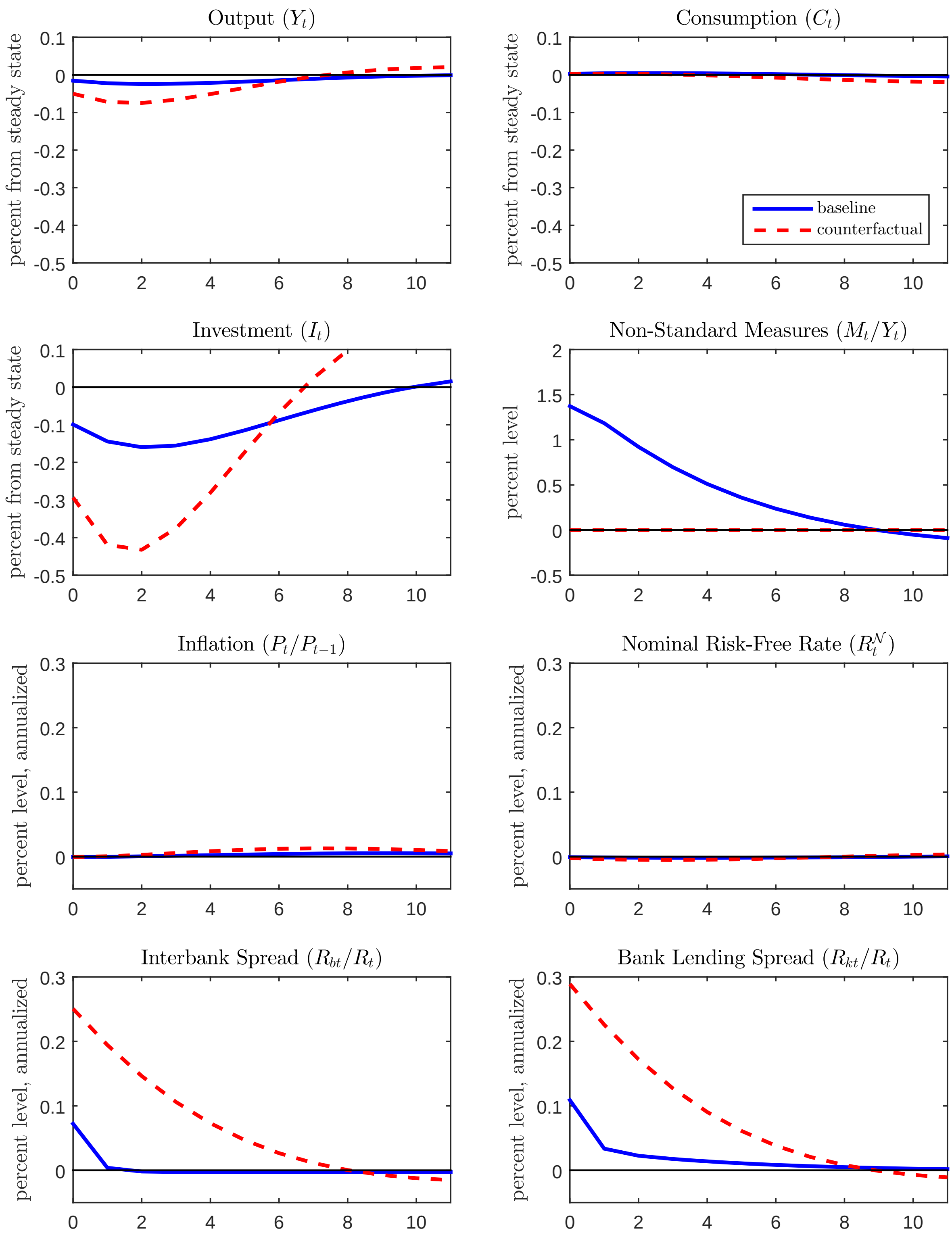

Figure 3.6: Impulse Response of the Counterfactual No-Policy Scenario

3.5.2 Understanding the Non-Standard Policy Rule

From the counterfactual analysis in the previous section we know that the liquidity injection by the ECB has a significant effect on spreads as well as investment and output. Now we want to better understand the effects of such a liquidity injection. We add an innovation to the non-standard policy function (3.41) and normalize this surprise liquidity injection in period $t = 0$ to be equal to the response of the non-standard policy to a one standard deviation liquidity shock. The impulse responses of such a non-standard policy shock are shown in figure 3.7. As the magnitude of the liquidity injection due to the non-standard policy shock is equal to the rule-based injection in response to the liquidity shock ω_t (and since we linearize our model), we can compare the two effects: Does a surprise injection of around 1.5 percentage points (relative to quarterly GDP) lead to an economic improvement of equal size to a rule-based—and thus expected—increase in liquidity in response to a liquidity shock? This is not the case. The surprise injection lets spreads decrease by 60 basis points, while the improvement in investment and output is merely 0.1 percent and 0.02 percent, respectively. Compared with the counterfactual analysis of figure 3.6, where spreads improved by merely 20 basis points in response to the intervention by the central bank, the effect on the real economy was much bigger. Investment and output improved by a maximum of 0.3 percent and 0.05 percent, respectively.

One reason why a surprise liquidity injection does not have an equal effect on the real economy is that it cannot influence the expectations of agents. Another reason is that due to our calibration, the liquidity injection is clearly tailored to an impaired interbank market. We calibrate $\omega_m = \bar{\omega}$, so that during normal times—when the interbank market is not impaired—the central bank has no advantage over private lending and central bank liquidity is merely a substitute for interbank lending. As soon as interbank markets are impaired, $\omega_t < \omega_m$ and the central bank gains a clear advantage over private lenders. By substituting interbank lending with central bank lending, policy makers can directly affect the incentive constraint (3.21): the right hand side of the constraint declines by $\theta\left(\omega_m - \omega_t\right)$. In our framework the central bank can thus even lend at a higher rate than the interbank market rate ($R_{mt} > R_{bt}$) during a financial crisis. The small accommodative effect shown in figure 3.7 comes from the influence of the liquidity injection on assets prices. By "forcefully" injecting liquidity into the financial sector, asset prices rise and even under a crowding out of interbank liquidity, the incentive constraint (3.21) loosens so that banks are able to provide more credit to the non-financial sector. The non-standard policy rule (3.41) is

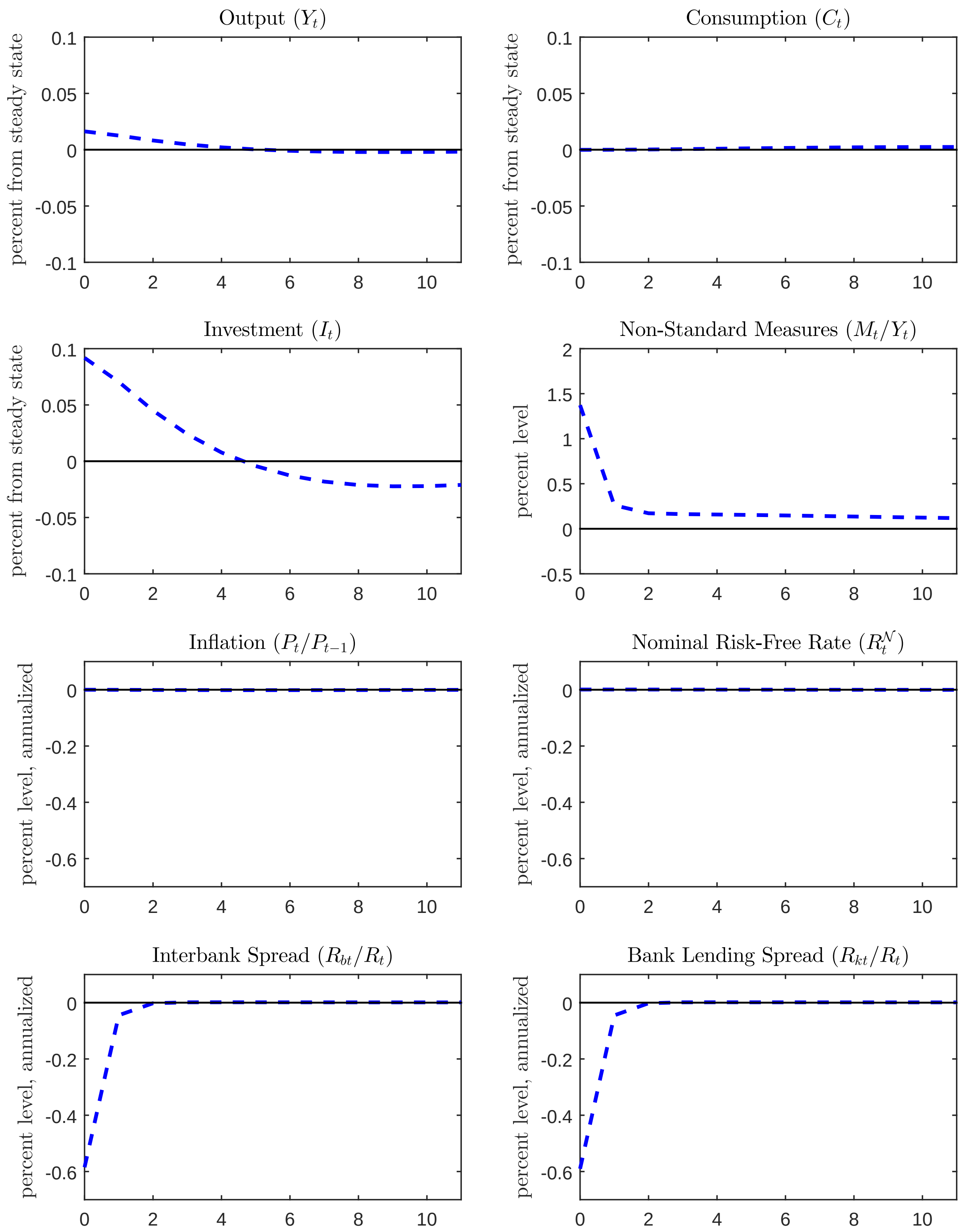

Figure 3.7: Impulse Response to a Non-Standard Policy Shock

thus a powerful tool during crisis periods, but it has only minor effects during normal times.

3.5.3 Accounting for the Financial Crisis

Up to now we have only looked at a one standard deviation of the interbank market shock. During the financial crisis the economy was hit by a sequence of these shocks that caused a longer lasting impairment of the interbank market. In this section, we simulate the impairment of the euro area interbank market for the period 2007–2012. This allows us to evaluate how much of the Great Recession is due to the interbank market tensions we have identified with our model. Furthermore, it allows us to make a statement regarding the total effect of the impaired interbank market on the economy. In a second step, we will again conduct a counterfactual analysis to assess the total effect of the ECB's non-standard measures.

To simulate the impairment of the interbank market, we determine the path of the liquidity shock ω_t which replicates the surge in the interbank spread R_{bt}/R_t during 2007–2012. Taking the reduced form first order state-space representation of our model, we can extract a series of innovations to ω_t which are needed to match the path of R_{bt}/R_t. Knowing this path, we can then compute the effects of the liquidity shock on all endogenous variables and compare them with their empirical counterparts.[20]

This part of our analysis is based on several assumptions. First, we need to assume that in 2007 we start in the steady state of the model and that after the controlled period (i.e. after 2012) agents expect all variables to return to their steady state. This implies that agents know that any disturbances in the interbank market are only temporary. Second, while agents expect the central bank to intervene as soon as the economy is hit by a liquidity shock according to its non-standard policy rule (3.41), the innovations to ω_t, which we back out in this exercise, are unforeseen by all agents in every period. They only know how these innovations decay given the definition of the shock (3.22). Finally, we need to restrict the interbank market shock to the interval $[0; 1]$, since the model can also be solved with negative values for ω_t. Especially, when we try to fit the peaks of the interbank spread, which were caused by the Lehman bust or which accompanied the intensification of the European Sovereign Debt Crisis after 2011, we back out negative values for ω_t. In these cases, we set $\omega_t = 0$.

Figure 3.8 shows the impact of the liquidity shock ω_t over the period 2007q2–2012q4. Besides the path of the shock, we report the model implied values of output Y_t, investment I_t, the ECB's liquidity injections in terms of quarterly GDP M_t/Y_t, the

[20] See appendix 3.C for further details.

interbank spread R_{bt}/R_t, and the bank lending spread R_{kt}/R_t (solid lines). For all endogenous variables the figure depicts the change in the data relative to their pre-crisis values (dashed line).[21] Since we assume that in 2007q2 all variables start at their steady state values, we normalize the data for comparison. Note that we report our measure of the interbank spread identified in section 3.2 and not the Euribor-OIS spread. For output as well as investment figure 3.8 reports not only the raw data (the dashed line), but also a grey shaded area corresponding to different assumptions on these variables' trend. We consider two alternative measures of the trend, derived either from the HP-Filter (over the sample 2000q1–2014q3) or by estimating a linear pre-crisis trend (over the sample 2000q1–2007q2).[22] The shaded area represents deviations from these two trends normalized to be zero in 2007q2. Since we do not want to take a stand on whether the trend has changed due to the Great Recession, we report these different possibilities. Finally, we do not report the other endogenous variables we have shown in the previous figures as their simulated path does not make much sense.

By construction, the model closely matches our measure of the interbank spread R_{bt}/R_t. From the path of the liquidity shock ω_t we see that the shock hits its lower bound during two episodes. The filling for bankruptcy of Lehman Brothers in 2008q3 as well as the intensification of the European Sovereign Debt Crisis after 2011 had a strong impact on the interbank market which in our model results in $\omega_t = 0$. As our model faces this limitation regarding the liquidity shock, it does not perfectly fit the two spikes in the interbank spread during these two episodes.[23] This, however, does not seem to be detrimental to capture the transmission of the shock through the banking sector which is apparent from the bank lending spread R_{kt}/R_t. Compared with the data, the model-implied liquidity injection by the ECB rises already after a year to levels seen later on in 2011 and 2012. The ECB actually introduced its different non-standard policy actions successively as policy makers had to learn the impact of these measures over time. Furthermore, between 2007 and 2008 the goal of the ECB was to keep its balance sheet from increasing by reabsorbing excess liquidity. Only with the introduction of the fixed-rate-full-allotment policy in October 2008 the ECB moved away from this goal. Our simple non-standard policy function (3.41) is not

[21] For the spreads as well as the ECB's liquidity operations, these pre-crisis values are averages over the period 2000q1–2007q2. For the two non-stationary series output and investment, we take the values of 2007q2.

[22] The latter approach is also taken by Christiano *et al.* (2015).

[23] Allowing ω_t to fall below zero, which implies that debtors could loose more than the amount of credit they supplied, does not significantly improve the fit of the model.

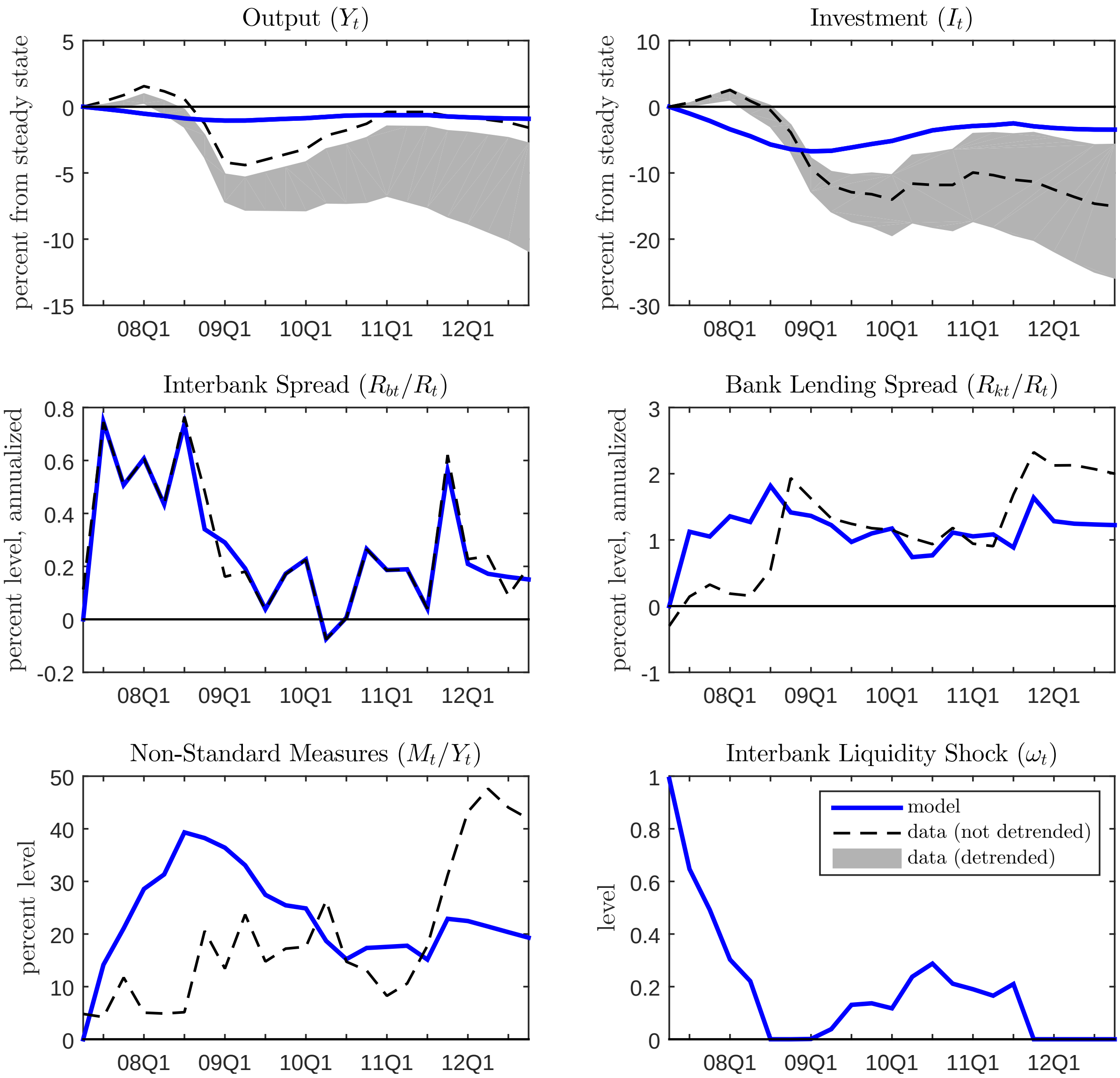

Figure 3.8: Simulation of the Financial Crisis 2007–2012

able to capture such different episodes of policy actions and, thus, determines the average response to the market disturbances.

Given this good fit of the dynamics of lending rates, we can now assess the liquidity shock's implications on aggregate investment and output. The fall in investment is sizable. Investment starts edging down already during the financial turmoil in 2007 and then falls persistently down to a trough of 7 percentage points. All in all, our model accounts for a sizable share of the actual drop in investment. Depending on the different assumptions about trend investment, the share varies between one third and two thirds. This confirms the hypothesis that the financial crisis was a major determinant of the Great Recession. One reason why the recession in our model is not as severe as in the data may be the absence of an explicit residential as well as a public sector. Since some countries experienced a large boom-bust cycle in housing, the drop in investment in the euro area was to a large extent driven by the weakening in residential as well as public investment.[24] Another possibility is that the financial crisis was accompanied by other shocks like an adverse demand shock.

Compared with investment, our model captures a much smaller part of the fall in output. According to its simulated path, output already decreases during the financial turmoil in 2007 and stays very persistently one percentage point below the initial level of 2007q2. This is contrary to the data where output declines sharply between 4 and 8 percent with the Lehman bust, but recovers quickly afterwards. Since our model overpredicts the liquidity injections by the ECB particularly for the period around the Lehman bust, our simulation does not account for such a pronounced contraction in output.

We can conclude that our simple model, which includes a financial sector consisting of a corporate lending and an interbank lending market, is able to replicate well the spillovers of money market tensions on lending conditions during the crisis. The model suggests that the increase in lending rates explained a sizable portion of the fall in investment that occurred during the Great Recession.

3.5.4 What if the ECB had not intervened?

We now want to use the simulations of the financial crisis to ask again what would have been the macroeconomic impact of the liquidity shock if the ECB had not implemented its non-standard policy. As in the previous section, we set to zero all monetary injections implied by equation (3.41). Figure 3.9 shows that the recession in the euro area would have been much more severe without the ECB's non-standard measures. Money market spreads would have been 500 basis point higher around the Lehman bust, which would have translated into an increase in lending spreads of equal size. Compared with the seven percentage points drop in the benchmark, investment would have fallen by over 15 percentage points in the absence of the ECB intervention. For output, the recession would have more than doubled: instead of falling by one percentage point, output would have fallen by almost three percentage points. All in all, our results suggest that the non-standard measures implemented by

[24] For this reason, the theoretical framework used in chapter 4, which analyzes the coordination of monetary and macroprudential policy, includes a housing sector.

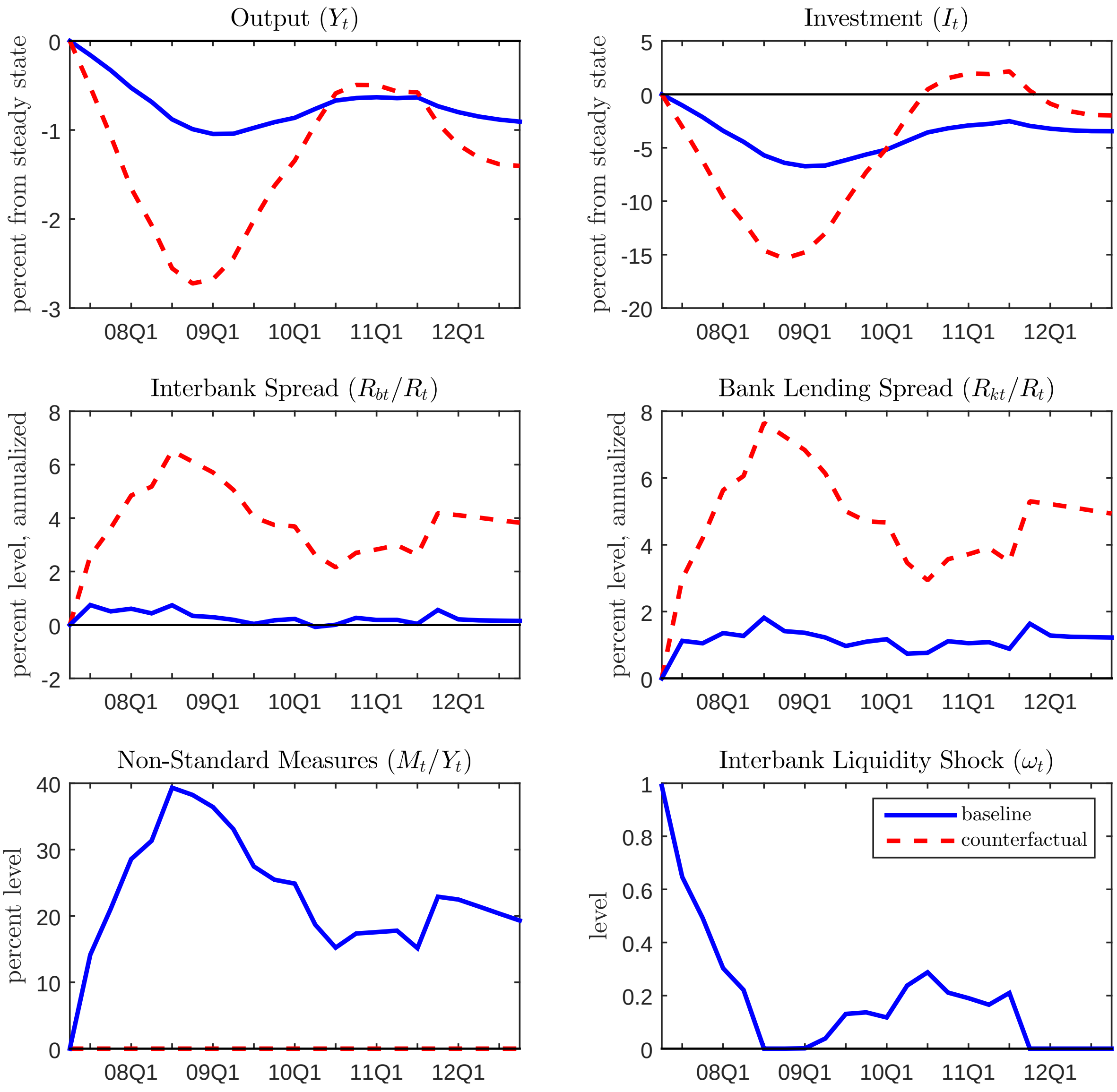

Figure 3.9: Simulation of the Counterfactual No-Policy Scenario

the ECB had a powerful role in attenuating the real consequences of the financial crisis, possibly more powerful than suggested by other studies. For example, Fahr *et al.* (2013) also evaluate the impact of the non-standard measures using a DSGE model. Differently from our approach, they focus jointly on all structural shocks which can account for developments over 2008–2010. Moreover, Fahr *et al.* (2013) concentrate on some specific ECB measures, namely the fixed-rate-full-allotment policy and the long-term refinancing operations. Finally, their counterfactual scenario is implemented in terms of the implications it produces on the standard rule for the policy interest rate. Given all these differences, Fahr *et al.* (2013) find that due to the fixed-rate-full-allotment policy annual real GDP growth had been -6 percent instead of -7 percent during the recession of 2009.

Other available studies rely on a reduced-form framework. Lenza *et al.* (2010) compute a counterfactual analysis within a Bayesian VAR through a conditional forecast, where the conditioning assumption is that money market spreads would have stayed at the elevated levels observed in October 2008. By compressing bank lending spreads, the non-standard measures had a positive effect on the macroeconomy, but only with a delay of several months. According to the authors, the intervention by the ECB improved the annual growth rate of industrial production by a maximum of 2.5 percent. This compares to 20 percent maximum fall (annualized) in euro area industrial production (excluding construction) during the Great Recession. Giannone *et al.* (2012) confirm these results. They show that the non-standard measures had a large impact on the wholesale funding opportunities of financial institutions. These policies eased funding conditions also for institutions that do not have direct access to central bank liquidity (like insurance companies, pension funds, and money market funds).

3.6 Conclusion

In this chapter we have presented an analysis for the euro area of the Global Financial Crisis of 2008–09 based on shocks to interbank liquidity. We have found that a widening of interbank spreads due to increases in liquidity risk was met by an increase in the amount of central bank liquidity. Nevertheless, it led to larger lending spreads and thus to a tightening of lending conditions for the private sector and to a reduction in economic activity, especially in investment. As a widening of interbank spreads during the financial crisis has not only been caused by increases in liquidity risk but went along with a general increase in overall uncertainty, in a first step, we have identified the component of interbank spreads which were orthogonal to the contemporaneous increase in uncertainty. In order to compute the counterfactual no-policy scenario, in which the ECB would not have implemented its non-standard measures, we have used these empirical findings to calibrate a structural general equilibrium model. Our structural model is based on a fairly standard New Keynesian model which we have augmented with financial frictions and an explicit characterization of the interbank market. We assume that the tightening of the interbank market friction in the structural model corresponds to the liquidity shock we have identified before.

Through the eyes of our structural model, we have focused on the large fall in aggregated investment after the Global Financial Crisis of 2008–09 and have shown that the tensions in the money market were a major determinant of the Great Recession in the euro area. The surge in liquidity risk accounted for a sizable share of the observed fall in investment after 2008–09. The liquidity injected by the ECB played an important role in attenuating the macroeconomic impact of the shock. Without this intervention, interbank spreads would have been at least 100 basis points higher and their adverse impact on investment would have been twice as severe.

Our study does not deny the importance of other shocks in explaining the crisis. In fact, the model falls short in explaining the repercussions of the interbank market shock on inflation as in our model lending spreads have no impact on households' consumption. Our findings therefore suggest that other shocks have also played a role during the Great Recession. We leave it for future research to capture all of these effects in a more complex framework that can merge the arguments of this chapter with those brought forward in other studies.

Bibliography

Bassett, W. F., Chosak, M. B., Driscoll, J. C. and Zakrajšek, E. (2014). Changes in Bank Lending Standards and the Macroeconomy. *Journal of Monetary Economics*, **62**, 23–40.

Bloom, N. (2009). The Impact of Uncertainty Shocks. *Econometrica*, **77** (3), 623–685.

Boeckx, J., Dossche, M. and Peersman, G. (2014). *Effectiveness and Transmission of the ECB's Balance Sheet Policies*. Ghent University Working Paper of the Faculty of Economics and Business Administration 14/887.

Cahn, C., Matheron, J. and Sahuc, J.-G. (2014). *Assessing the Macroeconomic Effects of LTROs*. Banque de France Working Paper 528.

Calvo, G. (1983). Staggered Prices in a Utility-Maximizing Framework. *Journal of Monetary Economics*, **12** (3), 383–398.

Christiano, L., Eichenbaum, M. and Evans, C. (2005). Nominal Rigidities and the Dynamic Effects of a Shock to Monetary Policy. *Journal of Political Economy*, **113** (1), 1–45.

—, — and Trabandt, M. (2015). Understanding the Great Recession. *American Economic Journal: Macroeconomics*, **7** (1), 110–167.

—, Rostagno, M. and Motto, R. (2010a). *Financial Factors in Economic Fluctuations*. ECB Working Paper 1192.

Christiano, L. J., Trabandt, M. and Walentin, K. (2010b). Models for Monetary Policy Analysis. In B. M. Friedman and M. Woodford (eds.), *Handbook of Monetary Economics*, vol. 3, San Diego and Amsterdam: North-Holland, pp. 285–367.

Ciccarelli, M., Maddaloni, A. and Peydró, J.-L. (2015). Trusting the Bankers: Another Look at the Credit Channel of Monetary Policy. *Review of Economic Dynamics*, **18** (4), 979–1002.

Del Negro, M., Eggertsson, G., Ferrero, A. and Kiyotaki, N. (2011). *The Great Escape? A Quantitative Evaluation of the Fed's Liquidity Facilities*. Federal Reserve Bank of New York Staff Reports 520.

European Central Bank (2014). *The Determinants of Euro Area Sovereign Bond Yield Spreads During the Crisis*. ECB Monthly Bulletin May, 67–83.

Fahr, S., Motto, R., Rostagno, M., Smets, F. and Tristani, O. (2013). A Monetary Policy Strategy in Good and Bad Times: Lessons from the Recent Past. *Economic Policy*, **28** (74), 243–288.

Gertler, M. and Karadi, P. (2011). A Model of Unconventional Monetary Policy. *Journal of Monetary Economics*, **58** (1), 17–34.

— and — (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** (1), 5–53.

— and Kiyotaki, N. (2010). Financial Intermediation and Credit Policy in Business Cycle Analysis. In B. M. Friedman and M. Woodford (eds.), *Handbook of Monetary Economics*, vol. 3, San Diego and Amsterdam: North-Holland, pp. 547–599.

Giannone, D., Lenza, M., Pill, H. and Reichlin, L. (2012). The ECB and the Interbank Market. *Economic Journal*, **122** (564), F467–F486.

Lenza, M., Pill, H. and Reichlin, L. (2010). Monetary Policy in Exceptional Times. *The Economic Policy*, **25** (4), 295–339.

Peersman, G. (2011). *Macroeconomic Effects of Unconventional Monetary Policy in the Euro Area*. ECB Working Paper 1397.

Smets, F. and Wouters, R. (2003). An Estimated Dynamic Stochastic General Equilibrium Model of the Euro Area. *Journal of the European Economic Association*, **1** (5), 1123–1175.

Villa, S. (2016). Financial Frictions in the Euro Area and the United States: A Bayesian Assessment. *Macroeconomic Dynamics*, advance online publication, doi: 10.1017/S1365100514000881.

3.A Solving the Bank Optimization Problem

We need to solve the optimization problem of bankers to relate the marginal value $\mathcal{V}_{st}$ as well as the marginal costs $\mathcal{V}_{bt}$, $\mathcal{V}_{mt}$, and $\mathcal{V}_t$ with the corresponding interest rates $R_{kt}^{hh'}$, R_{bt}, R_{mt}, and R_t. In order to do so, we insert the first-order conditions (3.25)-(3.27) together with the incentive constraint (3.30) into the value function (3.24):

$$V_{jt} = \left[\mathcal{V}_{bt} + \lambda_t^h \left(\mathcal{V}_{bt} - \theta\omega_t\right)\right] N_{jt}^h + \theta \frac{\bar{\lambda}_t - \lambda_t^h}{1+\bar{\lambda}_t} \omega_t D_{jt}.$$

This can be used to rewrite the Bellman equation (3.23) as:

$$\begin{aligned}
& V_{jt-1}\left(S_{jt-1}^h, B_{jt-1}^h, M_{jt-1}^h, D_{jt-1}\right) \\
= \;& E_{t-1}\Lambda_{t-1,t} \sum_{h'=i,n} \gamma^{h'} \left\{ (1-\sigma) N_{jt}^{h'} + \sigma \left[\left[\mathcal{V}_{bt} + \lambda_t^{h'} \left(\mathcal{V}_{bt} - \theta\omega_t\right)\right] N_{jt}^{h'} + \theta \frac{\bar{\lambda}_t - \lambda_t^{h'}}{1+\bar{\lambda}_t} \omega_t D_{jt} \right] \right\} \\
= \;& E_{t-1}\Lambda_{t-1,t} \sum_{h'=i,n} \gamma^{h'} \left[(1-\sigma) + \sigma \left[\mathcal{V}_{bt} + \lambda_t^{h'} \left(\mathcal{V}_{bt} - \theta\omega_t\right)\right]\right] N_{jt}^{h'} \\
& + E_{t-1}\Lambda_{t-1,t} \sum_{h'=i,n} \gamma^{h'} \sigma\theta \frac{\bar{\lambda}_t - \lambda_t^{h'}}{1+\bar{\lambda}_t} \omega_t D_{jt}.
\end{aligned} \tag{3.42}$$

Since $\sum_{h'=i,n} \gamma^{h'} \lambda_t^{h'} = \bar{\lambda}_t$, the last term in equation (3.42) drops out. Given the definition of the marginal value of net worth (3.36), the Bellman equation (3.42) at time t simplifies to:

$$V_{jt} = E_t \Lambda_{t,t+1} \sum_{h'=i,n} \gamma^{h'} \Omega_{t+1}^{h'} N_{jt+1}^{h'}.$$

The value of a bank j at the end of period t can thus also be expressed as the expected discounted net worth in the following period. To discount the expression, we make again use of the *augmented stochastic discount factor* $E_t \Lambda_{t,t+1} \sum_{h'=i,n} \gamma^{h'} \Omega_{t+1}^{h'}$. Given the law of motion for net worth (3.19), we can finally express our guess (3.24) as:

$$\begin{aligned}
V_{j,t} &= \mathcal{V}_{st} S_{jt}^h - \mathcal{V}_{bt} B_{jt}^h - \mathcal{V}_{mt} M_{jt}^h - \mathcal{V}_t D_{jt} = E_t \Lambda_{t,t+1} \sum_{h'=i,n} \gamma^{h'} \Omega_{t+1}^{h'} N_{jt+1}^{h'} \\
&= E_t \Lambda_{t,t+1} \sum_{h'=i,n} \gamma^{h'} \Omega_{t+1}^{h'} \left\{ \left[Z_{t+1} + (1-\delta) Q_{t+1}^{h'} \right] S_{jt} - R_t D_{jt} - R_{bt} B_{jt} - R_{mt} M_{jt} \right\}.
\end{aligned}$$

Using the methods of undetermined coefficients will yield the equation (3.32)-(3.35).

3.B Data Descriptions

Our estimation in section 3.2 is done in two steps. First, we compute a measure of liquidity spreads which is not contaminated by the effects of uncertainty shocks. To do so, we use weekly data ranging from 2007:01:05–2014:12:05. This dataset includes:

interbank spread: difference between the 3-month Euribor and 3-month overnight index swap rate; end-of-period data; Source: ECB

VSTOXX index: measure of implied volatility derived from options on the Dow Jones EURO STOXX 50 Index; end-of-period data; Source: Bloomberg

CDS spreads: *EU Banks CDS* is the median spread between CDS Senior Debt 5-Year and CDS Subordinated Debt 5-Year for the European Union Large Banking Groups; *DE CDS*, *FR CDS*, *ES CDS*, and *IT CDS* are CDS U.S. Dollar Senior Debt 5-Year for Germany, France, Spain, and Italy, respectively; end-of-period data; Source: Thomson Reuters Datastream

In a second step, we estimate a VAR. The quarterly dataset runs from 2001q1-2014q3 and includes:

GDP: gross domestic product; in log; constant prices; seasonally and working day adjusted; euro area (changing composition); Source: Eurostat

consumption spending: final consumption of households and non-profit institutions serving households (NPISH); in log; constant prices; seasonally and working day adjusted; euro area (changing composition); Source: Eurostat

investment spending: gross fixed capital formation; in log; constant prices; seasonally and working day adjusted; euro area (changing composition); Source: Eurostat

core inflation: quarterly gross inflation rate; Harmonized Index of Consumer Prices (HICP); all items excluding energy and unprocessed food; seasonally adjusted, not working day adjusted; euro area (changing composition); Source: ECB

bank lending spread: difference between bank lending rate and 3-month overnight index swap rate: bank lending rate given by interest rates on loans to non-financial corporations (new business) for loans over EUR 250.000 and up to EUR 1 million, maturity: over 3 month and up to 1 year; end-of-period data; Source: ECB

ECB liquidity injections: sum of two items from the Eurosystem balance sheet, relative to quarterly GDP: lending to euro area credit institutions related to monetary policy operations and securities held for monetary policy purpose; neither seasonally nor working day adjusted; end-of-period data; Source: ECB

liquidity spread: as explained in the text, this spread is equal to the Euribor-OIS spread for the period 2001–2006 and equal to the measure of liquidity spread computed in the first step from 2007 onwards

3.C Conditioning of Variables

In general, we want to condition the path of a sub-set of endogenous model variables and study its effect on the remaining variables. We first solve the model by doing a first-order Taylor approximation to the equilibrium conditions around the deterministic steady state of the model and applying a generalized Schur decomposition. The solution can then be expressed in first order state-space form:

$$\mathbb{Y}_t = \mathbb{A}\mathbb{Y}_{t-1} + \mathbb{B}\mathbb{U}_t, \tag{3.43}$$

with $\mathbb{Y}_t$ containing all endogenous variables and $\mathbb{U}_t$ being a vector of structural shocks. The matrices $\mathbb{A}$ and $\mathbb{B}$ are functions of the structural parameters of the model. We will partition the vector of endogenous variables:

$$\mathbb{Y}_t = \begin{bmatrix} \mathbb{Y}_t^C \\ \mathbb{Y}_t^U \end{bmatrix},$$

with $\mathbb{Y}_t^C$ being a vector of m variables whose realizations can be used to back out m shocks $\mathbb{U}_t$ and $\mathbb{Y}_t^U$ containing all other endogenous variables. We condition the path of $\mathbb{Y}_t^C$ for T periods starting from $t = 0$. For the start period $t = 0$ we assume that all variables are at their steady state.

Define the path of realizations of $\mathbb{Y}_t^C$ at times $\tau \in (1; T)$ as $\mathbb{X}$, where at any point in time $\mathbb{X}_\tau$ is a vector of size m. At any point in time, define $\mathbb{U}_{\tau|\mathbb{X}}$ as the path of $\mathbb{U}_t$, given $\mathbb{X}_\tau$. Using the first order state-space representation (3.43) of the model, we can derive $\mathbb{U}_{\tau|\mathbb{X}}$ as:

$$\mathbb{U}_{\tau|\mathbb{X}} = \tilde{\mathbb{B}}^{-1}\left[\mathbb{X}_\tau - \widetilde{\mathbb{A}\mathbb{Y}}_{\tau-1|\mathbb{X}}\right]. \tag{3.44}$$

The matrix $\tilde{\mathbb{B}}$ is a submatrix with the first $(m \times m)$ elements of $\mathbb{B}$. We define $\mathbb{Y}_{\tau-1|\mathbb{X}}$ as the path of endogenous variables at time $\tau - 1$ induced by the path $\mathbb{X}$. The vector $\widetilde{\mathbb{A}\mathbb{Y}}_{\tau-1|\mathbb{X}}$ includes only the first m elements from the product $\mathbb{A}\mathbb{Y}_{\tau-1|\mathbb{X}}$.

Once we have filtered out the path $\mathbb{U}_{\tau|\mathbb{X}}$ of m shocks, we can compute the contribution of these shocks to the historical realisation of all variables in our model. We simply need to cumulate the impact of these m shocks through equation (3.43):

$$\begin{aligned}
\mathbb{Y}_{1|\mathbb{X}} &= \mathbb{A}\underbrace{\mathbb{Y}_{0|\mathbb{X}}}_{=0} + \mathbb{B}\mathbb{U}_{1|\mathbb{X}} = \mathbb{B}\mathbb{U}_{1|\mathbb{X}}, \\
\mathbb{Y}_{2|\mathbb{X}} &= \mathbb{A}\mathbb{Y}_{1|\mathbb{X}} + \mathbb{B}\mathbb{U}_{2|\mathbb{X}} = \mathbb{A}\mathbb{B}\mathbb{U}_{1|\mathbb{X}} + \mathbb{B}\mathbb{U}_{2|\mathbb{X}}, \\
\mathbb{Y}_{3|\mathbb{X}} &= \mathbb{A}\mathbb{Y}_{2|\mathbb{X}} + \mathbb{B}\mathbb{U}_{3|\mathbb{X}} = \mathbb{A}^2\mathbb{B}\mathbb{U}_{1|\mathbb{X}} + \mathbb{A}\mathbb{B}\mathbb{U}_{2|\mathbb{X}} + \mathbb{B}\mathbb{U}_{3|\mathbb{X}}, \\
&\vdots \\
\mathbb{Y}_{\tau-1|\mathbb{X}} &= \mathbb{A}^{\tau-2}\mathbb{B}\mathbb{U}_{1|\mathbb{X}} + \mathbb{A}^{\tau-3}\mathbb{B}\mathbb{U}_{2|\mathbb{X}} + \ldots + \mathbb{A}\mathbb{B}\mathbb{U}_{\tau-2|\mathbb{X}} + \mathbb{B}\mathbb{U}_{\tau-1|\mathbb{X}}.
\end{aligned} \tag{3.45}$$

Chapter 4

Optimal Monetary and Macroprudential Policy[1]

[1]This Chapter (pp. 119–187) is published as: Quint, D. and Rabanal, P. (2014). Monetary and Macroprudential Policy in an Estimated DSGE Model of the Euro Area. *International Journal of Central Banking*, **10** (2), 169–236, URL: *http://www.ijcb.org/journal/ijcb14q2a8.pdf*.

English Summary

In this thesis three self-contained essays take stock of the policy implemented by the European Central Bank since the introduction of the euro.

Monetary Policy Stress

The ECB's *one size* monetary policy is unlikely to fit all euro area members at all times, which raises the question of how much monetary policy stress this causes at the national level. I measure monetary policy stress as the difference between actual ECB interest rates and Taylor-rule implied rates at the member state level. These rates explicitly take into account the natural rate of interest to capture changes in trend growth. I find that monetary policy stress within the euro area has been steadily decreasing prior to the recent financial crisis. Current stress levels are not only lower today than in the late 1990s, they are also in line with what is commonly observed among U.S. states or pre-euro German Länder.

Liquidity Provision to Banks as a Monetary Policy Tool

We study the macroeconomic consequences of the money market tensions associated with the Global Financial Crisis of 2008–09. We identify a liquidity shock in a structural VAR and then use this shock to calibrate key parameters of a structural model. Our structural model relies on the Smets and Wouters (2003) framework augmented with the banking model of Gertler and Kiyotaki (2010). We highlight two main results. First, the liquidity shock causes a sizable fall in investment: when calibrated to account for the observed increase in euro area interbank spreads, it can account for one third of the observed, large fall in aggregate investment after the financial crisis of 2008–09. Second, the liquidity injected into the market by the ECB played an important role in attenuating the macroeconomic impact of the shock. Without this intervention, interbank spreads would have been at least 100 basis points higher and their adverse impact on investment would have been twice as severe. These effects are somewhat larger than estimated in other available studies.

Optimal Monetary and Macroprudential Policy

We study the optimal mix of monetary and macroprudential policies in an estimated two-country model of the euro area. The model includes real, nominal and financial frictions, and hence both monetary and macroprudential policy can play a role. We find that the introduction of a macroprudential rule would help in reducing macroeconomic volatility, improve welfare, and partially substitute for the lack of national monetary policies. Macroprudential policy would always increase the welfare of savers, but its effect on borrowers depends on the shock that hits the economy. In particular, macroprudential policy may entail welfare costs for borrowers under technology shocks, by increasing the countercyclical behavior of lending spreads.

Deutsche Zusammenfassung

Die vorliegende Dissertation besteht aus drei eigenständigen Aufsätzen, die jeweils die von der Europäischen Zentralbank (EZB) zu verantwortende Politik im Bereich Preis- und Finanzmarktstabilität zum Thema haben. Im Einzelnen werden folgende Fragen beantwortet.

Geldpolitischer Stress

Aufgrund der zwischen den Euro-Mitgliedsländern herrschenden Heterogenität kann die einheitliche Geldpolitik der EZB nicht allen Ländern zeitgleich gerecht werden. In diesem Aufsatz wird daher untersucht, wie viel geldpolitischer Stress dies bei den jeweiligen Mitgliedsländern verursacht. Hierbei wird geldpolitischer Stress als Differenz zwischen dem tatsächlichen EZB-Zinssatz und dem auf nationaler Ebene optimalen Zinssatz gemessen. Optimale nationale Zinsen werden mit Hilfe einer Taylor-Regel ermittelt und berücksichtigen explizit den natürlichen Zins, um Veränderungen im Trendwachstum zwischen den Mitgliedsländern zu erfassen. Der Aufsatz gelangt zu dem Ergebnis, dass der geldpolitische Stress innerhalb des Eurogebietes bis zur jüngsten Finanzkrise stetig abgenommen hat. Die derzeitigen Stressniveaus sind nicht nur niedriger als zur Einführung des Euros, sie sind ferner auch vergleichbar mit den Niveaus, die für die U.S.-Bundesstaaten ermittelt werden können, und die für die deutschen Bundesländer vor der Einführung des Euros beobachtbar waren.

Unkonventionelle Geldpolitik

In diesem Aufsatz werden die makroökonomischen Auswirkungen der Spannungen im Interbankenmarkt untersucht, die in der Europäischen Währungsunion durch die Finanzkrise von 2008-09 hervorgerufen wurden. Mit Hilfe eines vektorautoregressiven Modells wird zuerst ein Liquiditätsschock identifiziert, welcher seinen Ursprung im Interbankenmarkt hat. In einem zweiten Schritt wird der Modellrahmen von Smets und Wouters (2003) um das Bankenmodell von Gertler und Kiyotaki (2010) erweitert und mit Hilfe der Schätzung aus dem ersten Schritt kalibriert. Ein zentrales Ergebnis ist, dass der in diesem Aufsatz identifizierte Liquiditätsschock einen Großteil des in Folge der Krise eingetretenen Investitionseinbruchs erklärt. Darüber hinaus zeigt der Aufsatz, dass die von der EZB im Markt bereitgestellte Liquidität eine entscheidende Rolle gespielt hat, die makroökonomischen Effekte dieses Schocks abzufedern. Ohne die Intervention der EZB wären die gesamtwirtschaftlichen Investitionen doppelt so stark gefallen. Die identifizierten Effekte sind somit größer, als dies von anderen Studien bislang belegt wurde.

Geldpolitik und Makropudentielle Regulierung

Dieser Aufsatz befasst sich mit der optimalen Koordinierung zwischen Geldpolitik und makroprudentieller Regulierung in der Europäischen Währungsunion. Es wird ein Zwei-Länder-Modell entwickelt, welches neben nominalen und realen Fiktionen auch Finanzmarktfriktionen abbildet. Damit kann neben der Geldpolitik auch eine makroprudentielle Regulierung eine Stabilisierungsfunktion innehaben. Es wird gezeigt, dass sich durch eine optimale Koordinierung der beiden Politiken Konjunkturzyklen bestmöglich stabilisieren lassen. Eine makroprudentielle Regulierung fungiert demnach auch in gewissem Maße als Substitut für den Wegfall einer eigenständigen Geldpolitik auf nationaler Ebene. Jedoch beeinflusst die makroprudentielle Regulierung die Wohlfahrt von Sparern und Kreditnehmern auf unterschiedliche Weise. Während sie die Wohlfahrt von Sparern grundsätzlich erhöht, kann sie die der Kreditnehmer verschlechtern. Wird die Konjunktur durch Angebotsschocks getrieben, verstärkt eine makroprudentielle Regulierung gegebenenfalls die Volatilität der Zinsspanne zwischen Spar- und Kreditzinsen und senkt damit die Wohlfahrt von Kreditnehmern.

Vorveröffentlichungen

Die folgende Liste enthält alle Vorveröffentlichungen.

Kapitel 2: Monetary Policy Stress

- QUINT, D. (2016). Is it Really More Dispersed?. *International Economics and Economic Policy*, 13(4), 593-621.
- QUINT, D. (2014). *Is it Really More Dispersed? Measuring and Comparing the Stress From the Common Monetary Policy in the Euro Area?*. Freie Universität Berlin School of Business and Economics Discussion Paper 2014/13.

Kapitel 4: Optimal Monetary and Macroprudential Policy

- QUINT, D. and RABANAL, P. (2014). Monetary and Macroprudential Policy in an Estimated DSGE Model of the Euro Area. *International Journal of Central Banking*, **10** (2), 169–236.
- QUINT, D. and RABANAL, P. (2014). *Monetary and Macroprudential Policy in an Estimated DSGE Model of the Euro Area*. Freie Universität Berlin School of Business and Economics Discussion Paper 2014/5.
- QUINT, D. and RABANAL, P. (2013). *Monetary and Macroprudential Policy in an Estimated DSGE Model of the Euro Area*. IMF Working Paper 13/209.