European University Institute

DEPARTMENT OF ECONOMICS

Macro-Financial Linkages and the Role of Unconventional Monetary and Macroprudential Policy

Kristina Bluwstein

Thesis submitted for assessment with a view to obtaining the degree of Doctor of Economics of the European University Institute

Florence, 20 December 2017

European University Institute
Department of Economics

Macro-Financial Linkages and the Role of Unconventional
Monetary and Macroprudential Policy

Kristina Bluwstein

Thesis submitted for assessment with a view to obtaining the degree of
Doctor of Economics of the European University Institute

Examining Board

Prof. Fabio Canova, EUI, Supervisor
Prof. Evi Pappa, EUI
Dr. Roberto M. Billi, Sveriges Riksbank
Prof. Mathias Trabandt, Freie Universität Berlin

Researcher declaration to accompany the submission of written work

I, Kristina Bluwstein, certify that I am the author of the work "Macro-Financial Linkages and the Role of Unconventional Monetary and Macroprudential Policy" I have presented for examination for the PhD thesis at the European University Institute. I also certify that this is solely my own original work, other than where I have clearly indicated, in this declaration and in the thesis, that it is the work of others.

I warrant that I have obtained all the permissions required for using any material from other copyrighted publications.

I certify that this work complies with the *Code of Ethics in Academic Research* issued by the European University Institute (IUE 332/2/10 (CA 297).

The copyright of this work rests with its author. [quotation from it is permitted, provided that full acknowledgement is made.] This work may not be reproduced without my prior written consent. This authorisation does not, to the best of my knowledge, infringe the rights of any third party.

Statement of inclusion of previous work (if applicable):

I confirm that chapter 1 was jointly co-authored with Fabio Canova and I contributed 50% of the work and it draws upon an earlier article published as "Beggar-thy-neighbor? The international effects of ECB unconventional monetary policy" (2016). International Journal of Central Banking, Vol.12(3), pp.69-120.

I confirm that chapter 3 was jointly co-authored with Julieta Yung and I contributed 50% of the work.

I confirm that chapter 2 draws upon a working paper "Asymmetric Macro-Financial Spillovers," Working Paper Series 337 (2017), Sveriges Riksbank, which was partially written during my internship at the Sveriges Riksbank.

Signature and Date: 27 July 2017

Abstract

***

This thesis investigates the relationship between the macroeconomy and the financial sector. As shown by the Financial Crisis, large shocks in the financial system can have a significant impact on the real economy. In response, policy makers have adopted new and unprecedented tools to stabilise financial markets, e.g. unconventional monetary and macroprudential policies.

The first chapter, joint with Fabio Canova, examines the international spillovers from unconventional monetary policy measures by the European Central Bank. We use a novel Bayesian mixed-frequency Structural Vector Autoregressive technique to show how unconventional monetary policy disturbances can generate important domestic and international fluctuations through real and financial channels. We find that international spillovers are larger in countries with more advanced financial systems and a larger share of domestic banks.

The second chapter investigates the asymmetry of macro-financial linkages. Using a Markov-Switching Vector Autoregressive model, I show that financial booms tend to be less procyclical than financial busts. To identify the sources of asymmetry, I estimate a non-linear DSGE model with a heterogeneous banking sector and an occasionally binding borrowing constraint. The model shows that the borrowers' balance sheet channel accounts for the asymmetry in macro-financial linkages. I show that a counter-cyclical macroprudential policy rule can improve welfare.

The third chapter, joint with Julieta Yung, looks at financial stability and the term risk premium. We develop a dynamic stochastic general equilibrium framework that can account for macroeconomic and financial moments, given (i) Epstein-Zin preferences, (ii) a heterogeneous banking sector, and (iii) third-order approximation methods that yield a time-varying term premium. We find that a risk shock leads to a decrease in output and bank lending. Moreover, an accomodative monetary policy shock leads to a trade-off between output growth and financial stability. Our framework suggests that macroprudential policies can enhance financial stability.

Acknowledgements

"Education is the kindling of a flame, not the filling of a vessel."

— *Socrates*

"There is no end to education. It is not that you read a book, pass an examination, and finish with education. The whole of life, from the moment you are born to the moment you die, is a process of learning."

— *Jiddu Krishnamurti*

Contents

***

Beggar-Thy-Neighbour? The International Effects of ECB Unconventional Monetary Policy Measures

✳✳✳

This is joint work with Fabio Canova and published as "Beggar-thy-neighbor? The international effects of ECB unconventional monetary policy" (2016). International Journal of Central Banking, Vol.12(3), pp. 69-120.

1.1 Introduction

In recent years there has been an unprecedented use of so-called unconventional monetary policy (UMP) measures by central banks of advanced economies. These measures have attracted increasing criticisms from leaders of developing and peripheral countries. Most notably, the United States' tapering policy has led to condemnations from Turkey, India, Brazil and South Africa (Kynge, 2014). In addition, concerns have been voiced that UMP measures could lead to 'beggar-thy-neighbour' effects. Brazilian President Rousseff remarked in 2012: *"Quantitative easing policies (...) have triggered (...) a monetary tsunami, have led to a currency war and have introduced new and perverse forms of protectionism in the world."*

For Europe, where non Euro members are linked to the euro area either through membership in the European Union or significant trade and financial ties, concerns are widespread that recent Quantitative Easing (QE) measures could lead to large appreciation pressures, to increased financial volatility, and to perverse real effects. For example, Riksbank deputy Governor Per

Jansonn states that *"ECB measures (...) create challenges(...) The plan is to make extensive
purchases of financial assets, equivalent to three times Swedish GDP over a period of just one
year(...) In the event of a more tangible and rapid appreciation of the krona, it will be even more
difficult for the Riksbank to attain an inflation rate in line with the target. "* [1]

The economic implications of international spillovers are expected to be severe, as
demonstrated by the recent example of Switzerland, who abandon its floor to the Euro in
January 2015 in anticipation of QE measures, and lost about 50 billion Swiss Francs in foreign
exchange holdings over the first half of the year. Thus, for both academic and policy purposes,
it is crucial to understand if these international spillovers exist, to measure the repercussions for
foreign economies, and to design policies which can contain their negative consequences.

This paper sheds light on these issues using an empirical model, which combines slow-moving
monthly macroeconomic variables, weekly monetary policy variables, and fast-moving daily
financial variables. To handle the frequency mismatch we employ a Bayesian mixed-frequency
Vector Autoregressive model. The setup accounts for macroeconomic–financial linkages without
any of the time-aggregation biases, which are present when lower-frequency data are used,
and it enables us to give a structural interpretation to the international spillovers. Such an
interpretation is not possible when only high-frequency data is used.

We focus on three sets of questions. (1) Do European Central Bank (ECB) UMP measures
generate important financial and real spillovers in European countries not adopting the Euro?
If so, does the exchange rate regime play a role? (2) Does the degree of financial integration
matter? In particular, is it true that larger international real co-movements in response to
UMP disturbances occur when financial markets are more integrated? (3) Which channel of
international transmission is operative? What is the relative importance of trade and financial
links?

Many papers have analysed the domestic effects of UMP measures (see Cecioni et al., 2011c
for a review). For the euro area, there is evidence that they had positive regional output and
inflation effects (Lenza et al., 2010a; Darracq-Paries and De Santis, 2015), but that real responses
were slower, less significant than those induced by conventional monetary policy measures
(Gambacorta et al., 2014). In addition, high frequency event studies find a reduction in market
spreads (Abbassi and Linzert, 2012; Angelini et al., 2011a; Beirne et al., 2011a), and a fall in
the term premia and government bonds yields following a UMP announcement, especially when
intra-day data are used (see Ghysels et al., 2017).

A number of studies have also began investigating the international consequences of the Fed's
UMP measures for emerging markets and found that QE caused the US dollar to depreciate,
foreign stock prices to rise, and CDS spreads to decrease (see e.g. Neely, 2015; Chinn, 2013a;

---

[1]Minutes of the Monetary Policy Committee meeting of February 11, 2015

Chen et al., 2012; Fratzscher et al., 2017). Moessner (2015) observes that international effects for advanced and emerging countries are similar, while Chen et al. (2012) claims that the impact in emerging countries is stronger (see also Aizenman et al., 2016). Lim et al. (2014) claims that at least 5% of financial inflows to the average developing country between 2000 to 2013 are due to the Fed's UMP. Passari and Rey (2015) find that financial flows to developed countries may also be large.

For euro area UMP measures, Boeckx et al. (2017) show that after a liquidity increase, the countries with less capitalised banks have smaller bank lending and output effects, while Lo Duca et al. (2016) find that confidence and asset prices improve. Since the effects on yields are small, they conclude that UMP policies have limited international impact. However, because of the high-frequency nature of the study, macroeconomic spillovers are not investigated. In this paper, we look at the effects of ECB UMP measures in a structural framework that considers both financial and macroeconomic variables. We also examine the pairwise transmission between the euro area and nine European countries not adopting the Euro. Furthermore, we attempt to disentangle channels of domestic and international transmission of UMP disturbances.

We find that UMP shocks generate important financial market responses in the euro area, sizeable macroeconomic fluctuations, and with no major difference in terms of timing or persistence relative to conventional monetary policy shocks. Interestingly, while UMP disturbances induce significant inflation, conventional monetary policy disturbances primarily affect output. Thus, a combination of conventional and unconventional measures may help to better control output and inflation dynamics. Announcement surprises produce financial market responses, which are similar to those of conventional policy shocks, but output and inflation effects are weak.

International spillovers exist but there is considerable cross-country heterogeneity. The exchange rate regime is not the reason of this heterogeneity. Advanced economies, which tend to be more financially integrated with the euro area and have a larger share of domestic banks, have stronger output and inflation dynamics than those in the euro area. The macroeconomic effects for financially less developed countries, which have a larger share of foreign banks, are varied, but output and inflation responses are the opposite of those of advanced economies. International transmission occurs both via trade (the exchange rate channel) and financial links (wealth, risk and portfolio rebalancing channels). However, the exchange rate does not seem to shape the responses of foreign macroeconomic variables to euro area UMP shocks. This is in contrast to the international transmission of conventional policy shocks, where the exchange rate is crucial to understand foreign dynamics.

Our investigation has important policy implications. Controlling exchange rate movements will not prevent non-euro area countries from importing the unconventional monetary policy

decisions of the ECB (see also Rey, 2015). Since the dynamics of financial flows are crucial and the presence of global banks in the area is important in determining domestic outcomes (see also Cetorelli and Goldberg, 2012), measures indirectly restricting financial flows and bank leverage could be more effective in insulating small open economies from undesired output and inflation fluctuations instead. Devereux et al. (2015) provides the theoretical justification for using such measures.

The paper is structured as follows: Section 2 gives an overview of the channels through which UMP measures may induce domestic and international adjustments. Section 3 describes the estimation methodology, the identification strategy, and the data. Section 4 presents domestic responses. Section 5 discusses international spillovers. Section 6 investigates why international macro-financial linkages are heterogeneous. Section 7 examines the robustness of the results. Conclusions are provided in Section 8. The Appendices present an overview of the unconventional monetary policy actions by the ECB, the details of the mixed frequency algorithm we use, and additional results.

1.2   Channels of International Transmission

There is substantial literature that analyses the mechanics of domestic monetary policy transmission (see e.g. Krishnamurthy and Vissing-Jorgensen, 2011a). As far as conventional monetary policy is concerned, the expectation, the exchange rate, and the interest rate channels have been emphasised (e.g. Russell, 1992). Basic to the idea that monetary policy affects the economy is the notion that central bank decisions influence: (a) price level expectations and thus the domestic aggregate supply via price and wage settings; (b) expectations of future short-term interest rates, which feed into long-term interest rates. As long-term interest rates matter for investment and consumption, the domestic aggregate demand is also altered.

Both aggregate demand and aggregate supply effects could be reinforced, when monetary policy alters the value of the domestic currency. Exchange rates variations influence the quantity and the price of imports and exports and thus both the aggregate supply and aggregate demand. Monetary policy may also tilt the term structure of interest rates and thus consumption and investment decisions. The interest rate channel is considered the main transmission mechanism for conventional monetary policy in Europe before the introduction of the Euro (Angeloni, 2012).

When discussing UMP, two other channels become potentially relevant. UMP measures may alter asset prices if they change the user cost of capital (*wealth channel*), and they may reduce uncertainty and financial risk perceptions (*confidence channel*). The latter purpose of stabilisation has been heavily emphasised during the recent financial crisis.

Figure 1.1: Channels of International Unconventional Monetary Policy Transmission
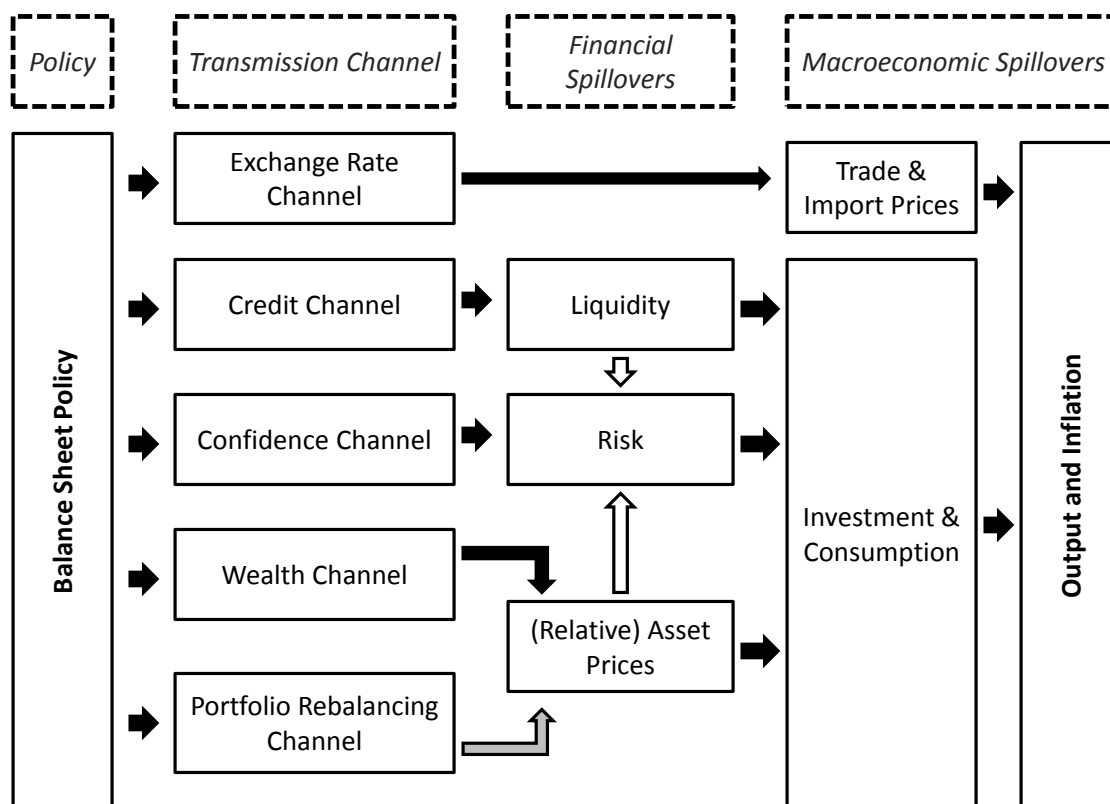
Note: The grey arrow indicates an indirect effect. The white arrows indicate contemporaneous effects.

Figure 1.1 depicts the channels of international transmission that are found relevant when discussing UMP measures. UMP measures may alter the bilateral nominal (real) exchange rate, which affects net trade and import prices for the partner country (*exchange rate channel*). In turn, these variations affect foreign prices, production, and consumption. The relative magnitude of the changes in both foreign inflation and output depends on substitution and income effects (Mishkin, 2001).

There has been an increased interest in the financial channels of international transmission since the onset of the financial crisis. The *credit channel* comprises the bank lending and the balance sheet sub-channels. The *bank lending channel* refers to the effect that UMP measures have on bank reserves when the amount of market liquidity changes (recall that banks are the main financial institutions in the euro area). The *balance sheet channel* refers to variations in the net worth of banks (and firms) due to changes in the value of cash flows and collateral. These two sub-channels alter credit conditions by affecting both the quantity and quality of loans. In economies, which are financially integrated, global credit conditions may also be affected.

UMP measures may change the relative cost of capital. This may have an effect on the

relative price of stocks, bonds, houses, and land, which in turn may lead to international capital flows (*wealth channel*). Both the wealth and the credit channels feed into financial risk, investment, and consumption decisions. While these channels are also present when conventional monetary policy actions are undertaken, unconventional policy, hence an expansion or change in the composition of the balance sheet of the central banks, activates the *portfolio rebalancing channel* (Krishnamurthy and Vissing-Jorgensen, 2011a). It has been argued that balance sheet policies may reduce private portfolio's duration risk (e.g. Bernanke, 2010a; Gagnon et al., 2011a). Thus, yields on long-term securities should decline with long-term borrowing increasing. As a consequence, aggregate demand and financial risk should be altered. Besides a duration (temporal) effect, the *portfolio rebalancing channel* could lead to an international (spatial) rebalancing between UMP and non-UMP countries, as investors seek higher yields or lower risk (see Passari and Rey, 2015). Finally, the *confidence channel* influences perceptions of uncertainty and risk. Changes in liquidity and asset prices may also have an indirect effect on risk, as they influence the confidence of investors, and thus investment and consumption decisions.[2]

Table 1.1: Timeline of ECB Unconventional Monetary Policy Measures

Date	Tool	Total size in Bn of Euros
Dec. 2007-ongoing	Reciprocal Currency Agreement	271.6
Mar. 2008-May 2010	6-month Long term refinancing operations	66
May–Dec. 2009	12-month Long term refinancing operations	614
Jun. 2009-Jun. 2010	Covered Bond Purchase Programme	45
May 2010-Aug. 2012	Securities Market Programme	195
Aug. 2011	12-month Long term refinancing operations	49.8
Oct. 2011	13-month Long term refinancing operations	57
Nov. 2011-Oct. 2012	Covered Bond Purchase Programme 2	15
Dec. 2011	36-month Long term refinancing operations	489
Feb. 2012	36-month Long term refinancing operations	530
Jul. 2012	Draghi's "Whatever it takes speech"	
Aug. 2012-ongoing	Outright Monetary Transaction	
Jul. 2013	Forward Guidance	

Source: ECB weekly Financial Statements; ECB Statistical Warehouse; Updated from Cecioni et al. (2011).

Table 1.1 lists the programs and the timing of ECB unconventional measures during the sample we consider. A detailed explanation of what each measure involves is in Appendix 1.A. 'Unorthodox' policies fell into two broad categories: liquidity policies and sovereign debt policies. The former were introduced as a reaction to the financial crisis to ease tensions and make the

---

[2]While Figure 1.1 is not mentioning the *signalling channel*, we account for signaling effects in the next few sections.

interbank market function properly. The presumption was that the additional liquidity would be channelled to private borrowers and that real activity would then pick up. If the additional liquidity would become available in global markets and if foreign banks were willing to use it to finance domestic projects, foreign real activity could have also received a boost. The second type of policies were introduced during the sovereign debt crisis to restore confidence in the Euro, to lower long-term yields for troubled economies, and restart normal lending practices.

Thus, while ECB unconventional policies could have had a direct effect on the credit and the confidence channel of international transmission, they may have only indirectly affected the exchange rate and the portfolio of agents, whenever they induced capital flows. In addition, they could have produced global wealth effects if, in response to the additional liquidity, the banking system changed the composition of its portfolio of assets towards more risky activities.

1.3   The Mixed Frequency Methodology

Due to the high-frequency nature of financial variables and the slow reporting of macroeconomic data, applied economists typically face a frequency mismatch when trying to jointly examine macro-financial linkages in response to shocks. The most common solution is to aggregate high-frequency data into a lower-frequency, but valuable information is lost in the process and this influences the conclusions one obtains (see Rogers et al., 2014 and Ghysels et al., 2017). Alternatively, one may discard low-frequency data and focus on event studies that look at financial variables movements around policy announcement dates (see Krishnamurthy and Vissing-Jorgensen, 2011a). This approach is also sub-optimal since it ignores the real effects of UMP measures. In addition, because high frequency data is volatile, noise may drive the conclusions.

In this paper, we provide a mixed-frequency compromise (see Foroni and Marcellino, 2013a for a survey of mixed-frequency methods): key macro variables are converted from monthly to weekly-frequency using an augmented Gibbs sampler technique; financial variables are aggregated from daily to weekly frequency by taking averages. Because ECB unconventional policy data is reported weekly, a weekly frequency balances the desire to smooth some of the noise without discarding too much information. The empirical model we consider is

$$y_t = \mathbf{A} y_{t-1} + \mathbf{B} \omega_t + \epsilon_t, \;\; \epsilon_t \sim N(0, \Sigma), \tag{1.1}$$

where $\omega_t = [\mathbf{1}, \omega_\mathbf{t}^*]$ is a vector of control variables, $y_t = (z_t, \, x_t)$ is a vector of endogenous variables containing the low frequency, z_t, and the high frequency data, x_t. z_t has missing observations

since we only observe a mid-month average or end-of-the-month value, z_t^i.

1.3.1 Mixed Frequency with Irregular Spacings

Researchers trying to combine weekly with monthly data face an additional problem, fairly neglected in the literature. Because of the irregular nature of weeks (some months contain four, others five weeks), the Gibbs sampler, which is typically used to predict missing values, can not be used mechanically and needs to be augmented by an additional step that draws the missing, irregularly spaced observations. The approach we employ is similar to Eraker et al. (2015) and Qian (2013), uses a Bayesian setting, and differs from the usual Kalman filter approach (Carter and Kohn, 1994) employed in the literature. In fact, rather than being predicted and smoothed, missing data is sampled directly from a constrained multivariate normal distribution.

Unlike Kalman filter techniques, direct drawing is easily implementable with irregularly spaced data. In addition, while the Kalman filter works sequentially, we can block sample, which significantly increases the computational speed. There are two main drawbacks of the approach: (1) the dependence of the Gibbs draws increases. We avoid this problem by appropriately thinning the chains. (2) The number of nodes at which the distribution needs to be evaluated increases and this affects the tightness of the standard errors.

Apart from having to deal with irregularly spaced weeks, we also need to solve a time aggregation problem. As monthly data is generally reported as a mid-point average, we need to take this into account when drawing missing data. Unlike with end-of-the-period sampling, where one draws the latent variables from an unconstrained multivariate normal distribution, we need to draw all missing variables simultaneously from a constrained multivariate normal distribution, so that the draws satisfy the monthly average. The algorithm we employ to estimate the parameters is described in Appendix 1.B.

To avoid imposing too much a priori information which in unjustified, given our ignorance about the properties of UMP shocks, we will use flat priors on all VAR coefficients.

1.3.2 Identification of UMP shocks

Since the countries we consider are relatively small open economies, they are likely to have little influence on the euro area, while the latter has presumably a larger impact on them. Hence, there is a natural block exogeneity in the system with the euro area block coming first. The block exogeneity assumption has been used quite a lot in the empirical international literature (e.g. Cushman and Zha, 1997; Mackowiak, 2007 ; Dungey and Pagan, 2009). It is stronger than the one employed by Kim and Roubini (2000), where block exogeneity is only imposed on the

contemporaneous matrix. The estimates we compute are equivalent to those obtained with the two steps approach of Canova (2005a).

For each country pair we consider, the structural system is

$$\mathbf{A_{0,11}}y_{1t} = \mathbf{A_{1,11}(L)}y_{1t-1} + \mathbf{B_1}\omega_t + \epsilon_{1t}, \; \epsilon_{1t} \sim N(0, \Sigma_1) \tag{1.2}$$

$$\mathbf{A_{0,21}}y_{1t} + \mathbf{A_{0,22}}y_{2t} = \mathbf{A_{1,21}(L)}y_{1t-1} + \mathbf{A_{1,22}(L)}y_{2t-1} + \mathbf{B_2}\omega_t + \epsilon_{2t}, \; \epsilon_{2t} \sim N(0, \Sigma_2) \tag{1.3}$$

The endogenous variables of the small open economy are $y_{2t} = [IP_t, \pi_t, e_t, sp_t, l_t, risk_t]'$, while the endogenous variables of the euro area are $y_{1t} = [IP_t^*, \pi_t^*, UMP_t^*, sp_t^*, l_t^*, risk_t^*]'$. The control variables are $\omega_t^* = [News_t, i_{t-1}, i_{t-1}^*, PC_t]$. $IP_t(IP_t^*)$ is a real activity measure, $\pi_t(\pi_t^*)$ is inflation, UMP_t^* is the unconventional monetary policy variable, e_t, is the nominal exchange rate, $sp_t(sp_t^*)$ is stock prices, $l_t(l_t^*)$ is a measure of liquidity, and $risk_t(risk_t^*)$ is a measure of risk. $News_t$ is a dummy variable capturing UMP announcements; the conventional monetary policy tool (the interest rate) is denoted by $i_{t-1}(i_{t-1}^*)$. Finally, PC_t is the first Principal Component of a number of control variables and it is described in more detail in the next subsection. It is important to have both the conventional monetary policy tool and the UMP announcements as controls to avoid confounding their effects with those of the shocks of interest.

The variables included in the VAR are chosen so as to be able to examine the transmission channels discussed in Section 2. The exchange rate channel is operative if UMP shocks generate significant exchange rate movements; significant responses of the liquidity variable, on the other hand, would indicate that credit channel is important; a strong and significant response of stock prices would suggest the presence of a wealth channel; finally, a strong and significant response of the risk variable would indicate that the confidence channel matters.

Because theory is silent regarding the features of UMP shocks, we identify them in an agnostic way. We assume that output and inflation matter for UMP decisions within a week, but that the UMP variable reacts to financial variables only with a week delay. Note that these restrictions have to hold only for a week and are therefore weaker than similar restrictions imposed on a monthly or a quarterly VAR.

The assumption that unconventional monetary policy reacts to financial factors with a delay of at least a week is satisfied for the Long Term Refinancing Operation programs (LTRO) that make up the largest proportion of UMP measures in our sample. However, for the Security Market program (SMP), it may be less appropriate since Lo Duca et al. (2016) pointed out that some of the decisions were taken at a daily frequency. The ordering of the variables within the financial block is arbitrary. We have stock prices before the liquidity spread, since we assume they react more slowly to monetary policy than liquidity in the interbank market due to transaction costs. The risk variables appear last, since risk perceptions react fast and take all

available information into account. In Section 7 we examine the robustness of the conclusions
when different identification assumptions are employed.

1.3.3 Data

All data comes from Datastream and the ECB. The sample spans from 18th December 2008
until 10th May 2014. The starting and ending dates have been chosen in order to (a) avoid
major structural breaks, (b) avoid the high volatility period following the Lehman crisis, (c)
have a time period where UMP were frequently used, (d) skip the era of negative interest rates,
applied on bank deposits by the ECB in June 2014. Excluding the first six months of the sample
and starting the estimation in June 2009 does not change the essence of the results we present.

We focus on nine European countries, some of which are EU members and some, which are
not. Since they have the largest trade and financial linkages with the euro area, they are the
most likely candidates to be influenced by the ECB's policies. The majority of countries have
floating currency regimes (Czech Republic, Hungary, Poland, Romania, and Sweden, Norway).
Denmark and Bulgaria are instead pegged to the Euro, while Switzerland is a hybrid case, since
it switched from a floating regime to an exchange rate floor in September 2011. Rey (2015)
has argued that when cross border flows and leverage of global institutions matter, monetary
policy is transmitted globally even under floating exchange rate. Thus, our sample allows us
to examine how important the exchange rate regime is for the transmission of unconventional
monetary policy internationally. Also, it allows us to analyse whether policies targeted to affect
liquidity and leverage have different impact than conventional measures.

In the baseline exercises, the monthly Industrial Production index is used as real activity
measure and the monthly Consumer Price Index is used for inflation. The policy variable is
calculated summing up LTRO, SMP and Covered Bond Purchase Programmes (CBP) (I and
II). The daily financial variables are the bilateral nominal exchange rate, the liquidity spread,
measured by the difference between the 3-month and overnight interbank rates (e.g. EURIBOR-
EONIA for euro area), stock market indices, and CDS spreads. The CDS for the euro area are
computed weighting individual Euro members' CDS using Eurostat weights. The announcement
dummy, $News_t$, sums up the event dummies for LTROs, collateral changes, SMP, CBP I and
II [3]. Implicit in this setup is the assumption that only surprises orthogonal to the monetary
information present at $t-1$ and to the announcement news at t are considered. Changing the
timing of the conditioning variables (announcement surprises at $t+1$, and interest rates at t)
does not change the conclusions we obtain. Thus, the possibility that UMP measures were taken

---

[3]When we examine the role of conventional monetary policy shocks, we switch the role of interest rates and of
the balance sheet variable. When we examine announcement surprises, we keep the nominal interest rates as
predetermined and use the balance sheet variable at $t-1$ as a control variable.

as a substitute or as a complement to conventional surprises is statistically weak.

Apart from using the nominal interest rate and the announcement dummy of euro area UMP measures, we use a principal component (PC) indicator as control variable for global factors. This PC is computed using US and UK (conventional and unconventional) policy variables, global real economy indicators, oil prices, Eastern European and EU (excluding EA) financial indicators, global trade price, and global equity indicators. This also enables us to filter out dynamics, which could be spuriously attributed to UMP measures, but are in fact due to e.g. oil price shocks, global business cycle variations, or monetary policy decisions taken outside the euro area.

Since VAR data is used as conditioning set to draw the latent variables, it is essential that all variables (and in particular the higher-frequency ones) exhibit an approximate normal distribution. All macroeconomic variables, UMP, asset prices, and CDS enter the VAR in log-growth rates. We use first differences for the liquidity spread, and interest rates remain in level. The financial data transformed this way shows less skewness and almost no kurtosis. Note that, while long run relationships will be lost, our transformation helps to have the data on a similar scale, making the Gibbs sampler more efficient, and economic interpretation easier.

Since we have some latitude in choosing the unconventional monetary variable and the risk measure, we have conducted a number of robustness experiments. In particular, we examined euro area responses when an excess liquidity variable is used instead of a balance sheet unconventional monetary variable. This variable is computed using the difference between the current account and reserve requirements plus the net of the deposit and marginal lending facilities. We furthermore split the balance sheet variable into liquidity measures and sovereign measures. We checked using aggregated daily and weekly data at the monthly frequency, and substituted the VIX index for CDS risk, when possible. The next sections comments on the results and Appendix 1.C plots the responses we obtain.

1.4   Domestic Transmission

We first present the dynamics produced by UMP shocks in the euro area, as can be seen in the first column of Figure 1.2. We plot this to compare our results with those present in the literature, and to provide a benchmark to understand international dynamics. Figure 1.2 also reports the responses obtained following an expansionary conventional monetary policy shock (second column) and a UMP announcement (third column).

A few features of the dynamics are note worthy. First, following a UMP shock inflation significantly and persistently increases, while real activity responses are negative on impact and

Figure 1.2: Responses of euro area variables to shocks
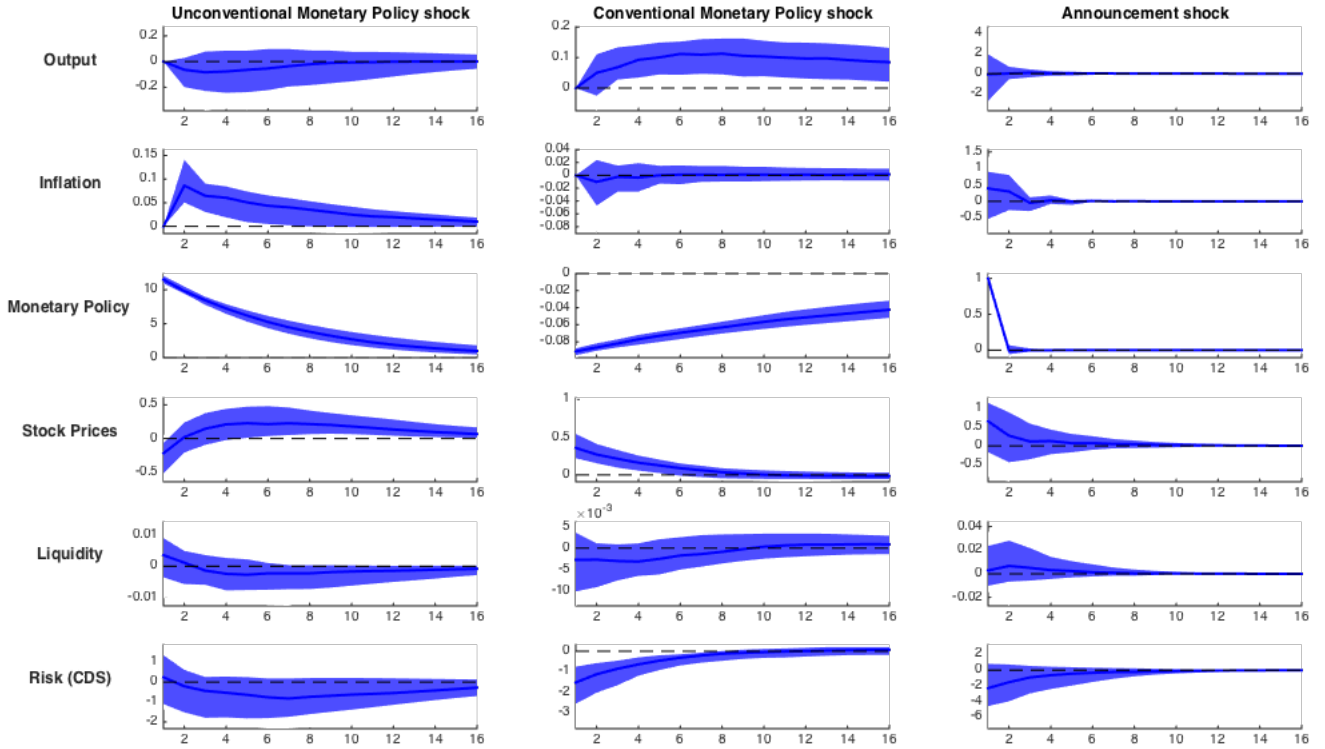
Note: The shaded regions report point-wise 68% credible intervals. The horizontal axis reports weeks; the vertical axis monthly growth rates for all variables but the liquidity spread, the interest rate (for conventional monetary policy) and the announcement dummy.

then insignificant. This latter pattern is in contrast to what researchers have found for the US and UK. However, while central banks in these countries engaged in large asset purchase programs to drive up yields and aggregate demand, euro area UMP measures were aimed mainly at providing liquidity for the interbank market. In order for output effects to materialise, the additional liquidity needed to reach the real economy via bank lending and there is little evidence that this has happened (Borstel et al., 2015). In addition, since euro area members differ substantially in their bank lending responses, failure to observe positive aggregate real activity responses may be due to regional heterogeneities (Santis and Surico, 2013; Altavilla et al., 2016a).

To understand whether the lack of positive real activity responses depends on particular features of the empirical model, we have re-run the analysis (i) with aggregated monthly variables, (ii) with an excess liquidity measure as indicator of unconventional monetary policy, (iii) splitting liquidity from sovereign bond unconventional policies (see Appendix 1.C). Real activity responses are still insignificant at all horizons in the monthly VAR, and disturbances to excess liquidity variable produce the same pattern of real activity and inflation responses as in the baseline case. This lets us conclude that the use of mixed frequency data and of the balance sheet variable

as a measure of UMP are not responsible for our conclusions. However, aggregating liquidity and sovereign debt programs may not be ideal if the task is to measure the real effectiveness of UMP measures. In fact, while liquidity disturbances lead to the same pattern of output and inflation responses as in the baseline case, sovereign debt disturbances produce small medium term positive real activity responses and negative inflation responses.

Second, the responses of financial variables are in line with expectations. Stock prices initially fall and then persistently increase and the responses are generally significant; liquidity spread responses are positive but insignificant on impact and turn significantly negative in the medium run; the responses of the risk variable are generally negative but insignificant. Thus, while the liquidity and the wealth channels are operative, at least in the medium run, the confidence channel seems weak.

Third, as in Gambacorta et al. (2014), we find that real activity responses are stickier and less significant than those obtained after a conventional monetary policy disturbances. In particular, conventional monetary policy disturbances seem to have a persistent positive effect on output -the largest effect occurs after 8-10 weeks - but an insignificant effect on inflation. Hence, jointly using conventional and unconventional monetary tools may help to better control output and inflation dynamics in the area.

Fourth, risk perceptions persistently decrease following a conventional monetary policy disturbance, and stock prices increase for up to 8 weeks while the liquidity spread is not significantly affected. The dynamics of these three financial variables are both quantitatively and qualitatively in line with what is known in the euro area (see e.g. Christoffel et al., 2008). The weak response of inflation and the strong decrease in risk are a feature of our sample period, which only starts in 2008, and includes both the financial and the European sovereign debt crises.

Finally, a UMP announcement surprise does not have measurable effects on output or inflation. The responses of financial variables, although less significant, resemble those produced by a conventional policy disturbance (see also Szczerbowicz, 2015). Altavilla et al. (2016b) have shown that OMT announcements have significant effects on output of Mediterranean countries. Our results are not necessarily in contrast with theirs. First, while they find that output positively reacts in Spain and Italy, no effect is found in France and Germany. Hence, the aggregate effects they find may be insignificant. Second, they consider only the announcement of one program, while we examine the effects of announcements of all UMP programs. Third, their methodology is different: while they use the persistent financial responses that announcements induce as measure for announcement effects in the VAR, we use a dummy approach. Finally, as Ghysels et al. (2017) and Rogers et al. (2014) argued, to measure the effects of announcements, higher-frequency data, ideally intra-daily, should be used. Hence, our announcements effects

could be underestimated.

1.5 International Transmission

Figure 1.3 shows the median posterior responses of the variables of the nine foreign economies to a euro area UMP shock, in deviations from the responses obtained in the euro area (except for the exchange rate which is plotted in level). Positive and significant responses of real activity would indicate that a UMP shock generates foreign output responses which are significantly larger than those obtained in the euro area. For representation purposes, responses are grouped into different country groups: (a) Advanced countries - Sweden, Norway, Denmark and Switzerland, (b) Central Eastern European countries (CEE) - Poland and the Czech Republic, and (c) Southern Eastern European countries (SEE) - Hungary, Romania and Bulgaria. Figure C.1 in the Appendix reports group average responses with the associated posterior credible sets.

Output responses to euro area UMP shocks are quite heterogeneous. While in advanced countries, responses are persistently positive and significantly larger than in the euro area after two weeks, those in the CEE countries are insignificant, and those in SEE countries are persistently negative and significantly smaller than in the euro area after about two weeks. Inflation responses are also heterogeneous: they are positive for CEE and SEE countries, generally after about 2 or 3 weeks, and negative for advanced economies.

Why are macroeconomic responses so different across countries? One possibility is that certain countries are insulated from foreign shocks while others are not because of different exchange rate regimes. Such an explanation does not seem to hold up with both peggers and floaters being part of the advanced countries group. As is pointed out in Rey (2015), having floating exchange rates does not necessarily insulate a country from importing euro area monetary policy decisions. A related explanation could be that different real exchange rate dynamics lead to different trade gains across country groups. Again, this explanation seems incapable to account for the heterogeneities we find: real exchange rate responses are all negative (the local currency appreciate versus the Euro).[4] Lo Duca et al. (2016) and Fratzscher et al. (2017) also find a (nominal) appreciation using an event study approach and much higher-frequency data. Therefore, while the exchange rate channel is activated following UMP shocks, differential exchange rate dynamics do not explain the pattern of macroeconomic responses we obtain.

Gopinath (2015) suggest that similar currency appreciations do not necessarily lead to similar dynamics of exports and imports, if firms behave in non-competitive pricing and alter

---

[4]The exchange rate for Denmark and Bulgaria only reports the price level differential, as the exchange rate is pegged to the Euro.

Figure 1.3: Responses to a euro area UMP shock, foreign countries
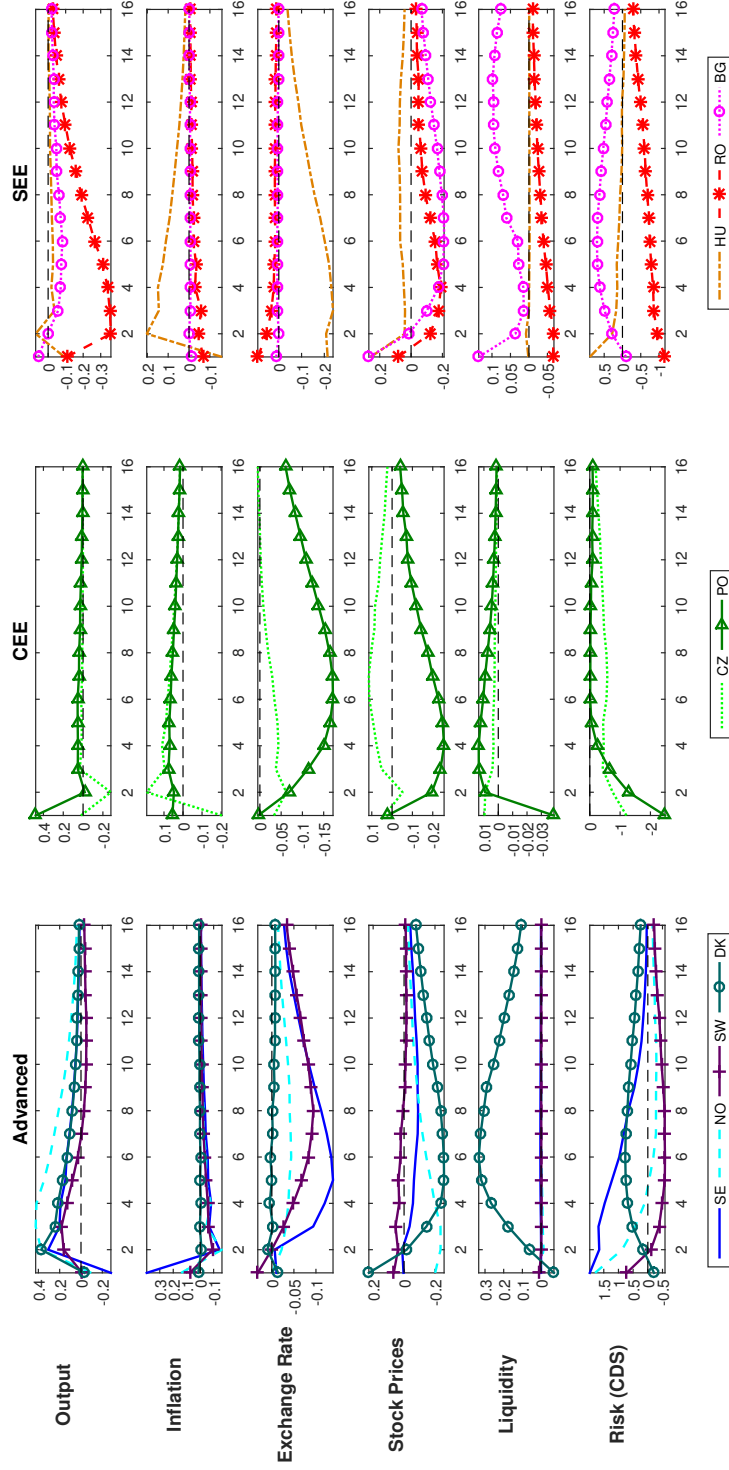
Note: The lines report the point-wise posterior median responses in deviations from euro area responses. The horizontal axis reports weeks, the vertical axis monthly growth rates for all variables but the liquidity spread. The size of the shock is 10% of UMP.

mark-ups following a nominal appreciation. Therefore, if countries have different levels of non-competitiveness, similar appreciations of the currency may lead to different inflation responses across countries. While the inflation dynamics we present are prima-facie consistent with this explanation, it is hard to see how differential non-competitive behaviour may lead to the variety of output responses that we obtain.

Another reason for why output and inflation responses could be different is that euro area UMP shocks occur at the same time as e.g. oil shocks, and that hence our responses are potentially spurious. Again, this explanation does not seem to be relevant for two reasons: (1) We have conditioned on oil prices (via PCs) in the VAR. (2) The only oil producing country of our sample (Norway) displays large output responses but also negative stock price responses, which are hard to rationalise if the UMP shocks proxied for oil shocks.

Cross-country heterogeneities of output and inflation responses could be generated if euro area UMP disturbances hit countries at different stages of the business and the financial cycles. As Figures C.7 and C.8 show, this hypothesis can be rejected, since both the business and the financial cycles of the nine countries are closely synchronised.

Another possibility one can consider to account for the international macroeconomic heterogeneities is that some countries conducted their own UMP measures at the same time as the ECB engaged in non-conventional policies, while others did not. While lack of detailed information prevents us directly linking monetary decisions to existing heterogeneities, we have one country - Sweden - where liquidity policies were conducted from October 2008 until December 2010, but not thereafter. Thus, comparing the responses in the two sub-samples, we can check whether the presence of domestic UMP measures makes a difference. Figures C.5 and C.6 report the absolute impulse responses following a UMP shock in the euro area. They indicate that when liquidity measures were in place, output responses were positive and inflation responses were insignificant; when they were not output responses were insignificant and inflation responses were positive. However, since the second sub-sample roughly corresponds to the period when the ECB implemented sovereign debt policies, it is difficult to reliably attribute these differences to the presence of domestic UMP measures. We discuss our favourite explanation in Section 6.

Stock prices responses are significantly different from those obtained in the euro area. They initially increase for all countries but Norway, and then fall for up to 8 weeks with Denmark as the exception. Note that the responses in CEE and SEE countries are slightly more persistent than in advanced countries. Positive international stock price responses have also been found in event studies such as Lo Duca et al. (2016) and Fratzscher et al. (2017) and are consistent with the presence of both wealth and portfolio rebalancing channels: at least on impact stock prices increase significantly more than in the euro area. In the medium run, stock prices of all countries either increase by less than in the euro area or fall.

There is considerable heterogeneities in the responses of the risk spread: consistent with the finding of Fratzscher et al. (2017), it declines relative to the euro area for CEE and SEE countries (with the exception of Hungary), while it increases for advanced countries. Note that risk responses are large in absolute value, even though we are using CDS spreads to infer risk. Given that country risk usually serves as a floor for domestic financial risk, the true risk effects may be even larger.

The credit channel, on the other hand, seems to be weak. Except for Romania and perhaps Poland, the liquidity spread is not responding significantly to euro area UMP disturbances. This is in line with Williams and Taylor (2009), who find that the LIBOR-OIS spread did not react to the FED's QE1.

In sum, the financial market responses we obtain are in line with those found in high-frequency event studies. Hence, aggregating daily financial data does not entail a significant loss of information regarding the international transmission of UMP measures. Interestingly, our analysis shows that macroeconomic responses to UMP disturbances are very much country specific, even when financial market responses are similar.

1.5.1   A Counterfactual

To quantify the relative importance of financial vs. trade channels in transmitting UMP disturbances we perform a counterfactual exercise: we trace out the dynamics of the foreign variables to a euro area UMP shock holding either stock prices, liquidity and risk spreads, or the exchange rate constant. Thus, in the former case international links are generated via the exchange rate, while in the latter case only financial transmission takes place. Figure 1.4 presents the results of our exercise. In the first panel, we report the benchmark output and inflation responses we had in Figure 1.3, in the second, the responses obtained switching off the exchange rate channel, and in the third, the responses obtained switching off the financial channels.

Eliminating the exchange rate channel slightly alters the magnitude but does not change the shape of the responses. Overall, exchange rate movements seem to slightly reduce output responses and slightly amplify inflation responses. Hence, the trade effects that exchange rate variations may induce are minor in the case of UMP disturbances. In contrast, shutting off financial channels has major effects on foreign output and inflation responses: output responses are now insignificant except on impact and display no persistence, and inflation now drops on impact, because the currency generally appreciates and imported inflation falls. Note also that output and inflation responses are now more homogenous. To conclude, cross-country differences in financial-macro linkages are likely to be the reason for the cross-country heterogeneity of the output and inflation responses.

Figure 1.4: Counterfactual responses to a euro area UMP shock, foreign countries
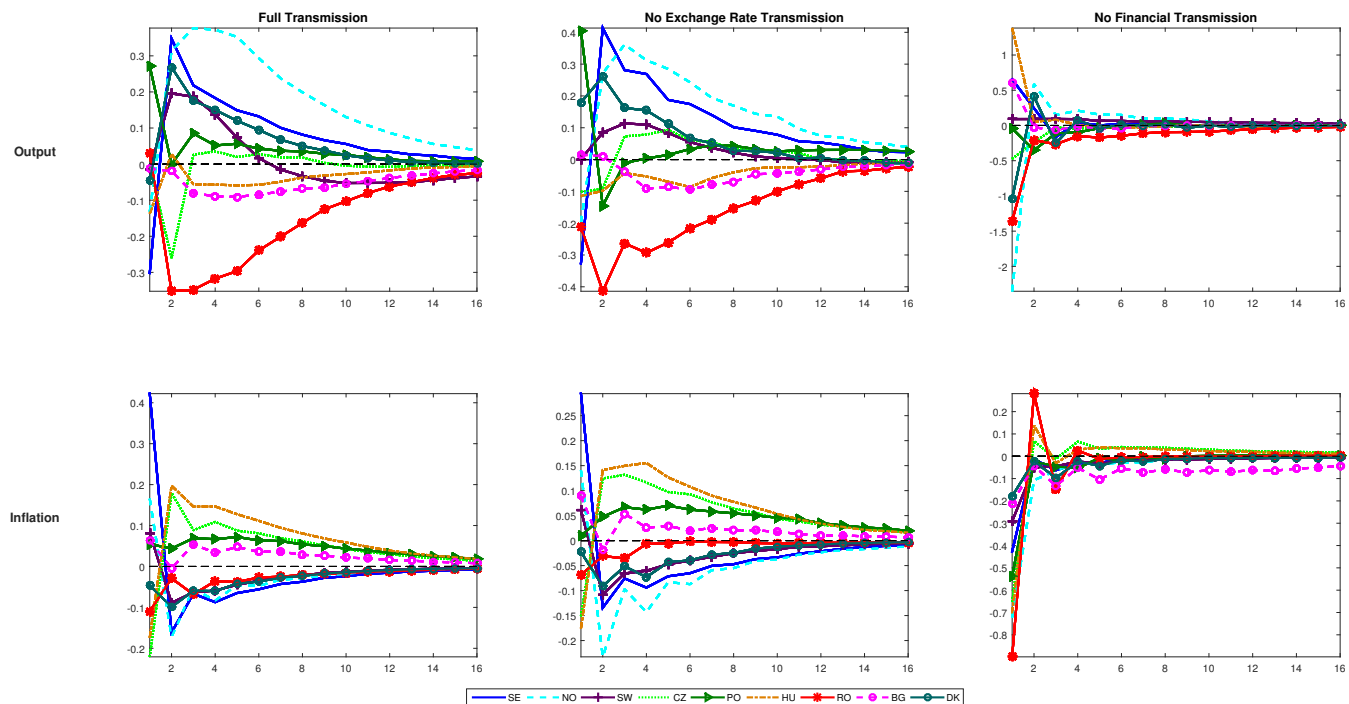
Note: The lines report the point-wise posterior median impulse responses in deviations from the euro area responses. The horizontal axis reports weeks, the vertical axis monthly growth rates.

1.5.2 International Effects of Conventional Monetary Policy and Announcement Surprises

In Appendix 1.C we present the international responses obtained when conventional monetary policy shocks and announcement surprises are considered.

Conventional monetary policy shocks induce very heterogeneous international dynamics. For advanced countries, the exchange rate temporarily appreciates relative to the Euro, but there is very little difference with euro area as far as output and inflation responses are concerned and this occurs despite the fact that both the liquidity and the risk spreads are quite heterogeneous across countries. For CEE countries, the exchange rate depreciates relative to the Euro, but output falls and stock prices increase while the risk spread eventually decreases. Finally, for SEE countries, the local currency generally depreciates, and output temporarily increases, while stock prices fall and the risk spreads increase.

Announcement surprises produce macroeconomic responses, which are similar to those obtained in the euro area for many advanced and SEE countries. The exchange rate and the

financial responses resemble those obtained with a conventional monetary policy shock with Denmark being the exception. However, exchange rate responses are far less persistent. Also, SEE seem to be the countries whose financial markets benefit most from ECB unconventional measures: stock prices increase while the liquidity and the risk spread decrease.

In sum, the evidence suggests that the exchange rate, wealth, risk and portfolio rebalancing channels spill euro area UMP shocks to foreign countries. Advanced economies tend to have output and inflation dynamics, which resemble those of the euro area, even though output effects are larger and inflation effects smaller. For the remaining countries the macroeconomic consequences differ. The exchange rate channel does not seem to shape the responses of foreign macroeconomic variables. In fact, the financial channels are very important for the international transmission of UMP disturbances. This is in sharp contrast with the international transmission of conventional monetary policy shocks, where exchange rate movements drive foreign output and inflation dynamics.

1.6 Why are foreign macroeconomic responses heterogeneous?

As we have seen, positive financial spillovers from UMP disturbances do not necessarily translate into positive real transmission. In addition, even in countries where financial market responses are somewhat similar, real responses are heterogeneous. In this section, we examine the reasons behind this heterogeneity.

The IMF (2013a) states that between 70-90% of assets in CEE and SEE countries is held by foreign banks and claims that these assets amount to, at least, 50% of domestic GDP. Since foreign banks, which in the countries under consideration are mostly from the euro area, have access to the cheap ECB liquidity, they may invest into foreign financial markets what they borrow from the ECB rather than lend it to domestic agents. This would positively affect foreign asset prices, reduce foreign risk, but would not lead to positive real spillovers, as foreign loans would not be affected by the additional liquidity banks obtain. Hence, if countries are heterogeneous in the composition of their banking sector, similar financial market responses may lead to different real effects. In particular, in countries featuring a large share of foreign banks, global liquidity increases should have the smallest pass-through to the real economy.

Figure 1.4 reports the average responses for countries with low foreign bank share (at least 2/3 of banks are domestic) and high foreign ownership. Confirming our intuition, we find no significant difference in the dynamics of the liquidity spread in the two groups, but we observe a

Figure 1.5: Comparative Impulse Responses to a UMP shock
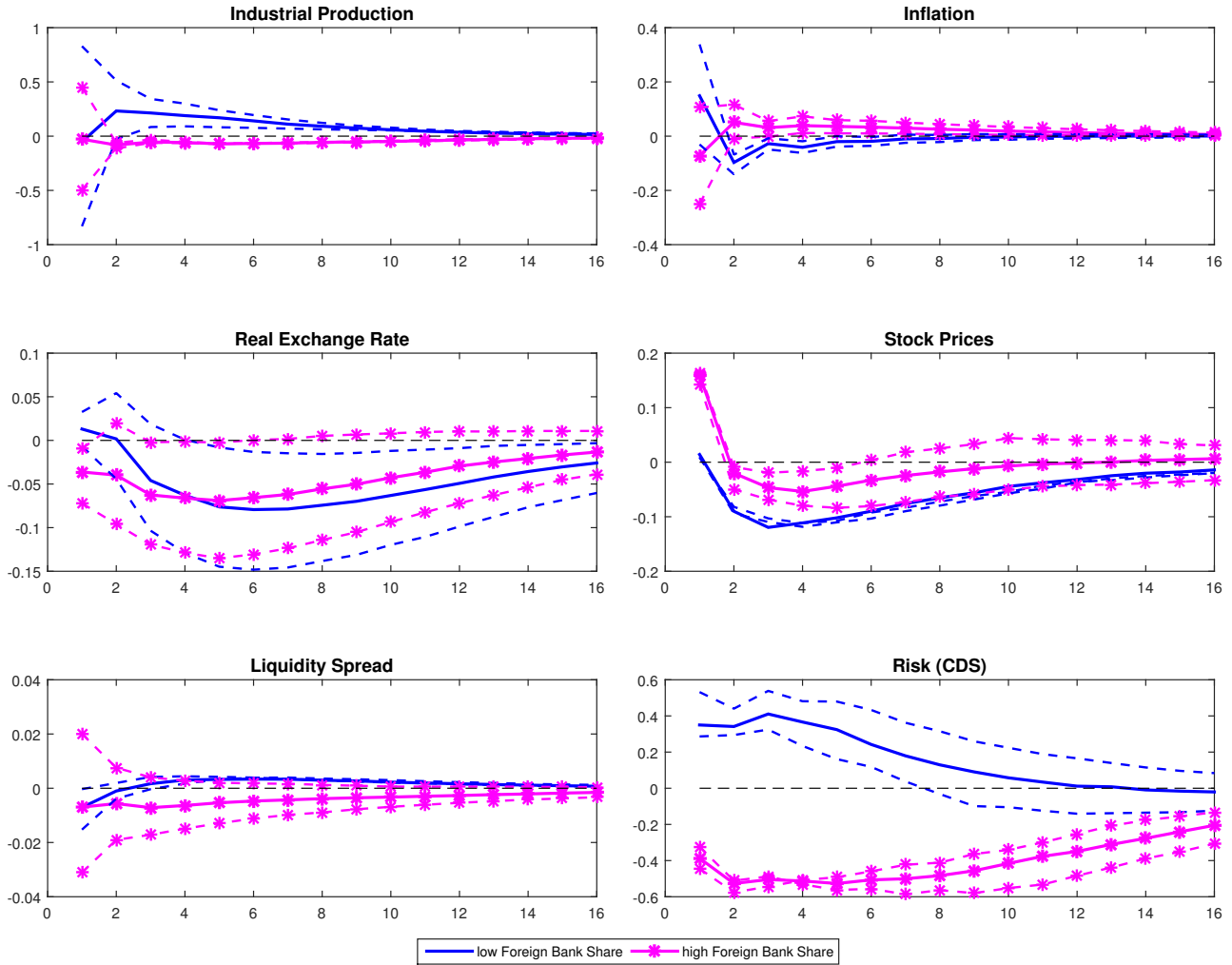
Note: The lines report the point-wise average posterior median responses in deviations from the euro area responses. The dotted line represents the 68% point-wise credible sets. Low foreign bank share countries are Sweden (52%), Norway (58%), Poland (63%) and Denmark (61%); high foreign bank shares countries are Switzerland (72%), Czech Republic (92%), Hungary (100%), Romania (72%) and Bulgaria (81%). Data on foreign bank shares comes from the Bank of International Settlement and is for 2012.

stark difference in the response of stock prices and risk. Countries with high share of foreign bank ownership experience an increase in stock prices and a reduction in risk relative to the euro area; countries with a lower share of foreign banks, feature declining stock prices and increasing risk. In addition, while the former display falling relative real output growth, the latter show a significant relative output increase a few weeks after the euro area UMP shock.

To provide further evidence that the structure of domestic financial markets is crucial to

understand the international transmission of UMP disturbances, we group countries according to the level of financial development (as provided in Schwab, 2012) and the credit-to-GDP ratio. With these two alternative classifications, the groups remains unchanged except for Poland and Switzerland, which switch groups. The financially advanced, high credit-to-GDP ratio countries (Sweden, Norway, Denmark) behave like the low foreign bank share countries, while the less financially advanced, low credit-to-GDP economies (CEE and SEE) show the same responses as the high foreign bank share countries. These results agree with Aizenman et al. (2015), who claim that higher levels of financial development can mitigate the negative effects of a foreign UMP shock and that financially more open but potentially less developed small economies are more sensitive to foreign UMP shocks. They also agree with Dedola et al. (2017), who shows that spillovers of US monetary shocks are largest for emerging economies whose level of financial development is generally low, and with Ongena et al. (2015) who point out that local lending in foreign currencies, which is common among high foreign bank share countries, leads to a stronger international bank lending channel and weaker domestic monetary transmission.

1.7   Robustness

The results presented so far are derived under the identification assumption that a UMP shock has no weekly effect on output and inflation and that the UMP variable does not respond within a week to financial variables. While the first assumption is hard to dispute, the second could be debatable. Furthermore, the ordering of variables within the financial block is arbitrary. In this section we discuss what happens when we alter identification assumptions. The responses for these cases are in Appendix 1.C.

1.7.1   Changing the Ordering of Euro Area Financial Variables

We considered three alternative orderings of the variables of the euro area block; two where financial variables are permuted (R1: output, inflation, UMP, liquidity, stock prices, and risk; R2: output, inflation, UMP, risk, stock prices, and liquidity); and one where the policy variable reacts within a week to macro and financial variables, meaning that the ECB monitored financial markets on a weekly basis when deciding UMP which, as mentioned, seem to have occurred with the Securities Market Programme - roughly 10% of the UMP in our sample (R3: output, inflation, stock prices, liquidity, risk and UMP).

No major differences are noticeable between the baseline and the R1 and R2 schemes except for the kink in the liquidity spread responses for Romania. Thus, the order of the variables

within the financial block is inconsequential for the transmission properties of UMP shocks.

Some changes appear when the R3 scheme is used. The responses for euro area variables
are qualitatively similar, even though stock prices and risk responses are less significant.
Internationally, the most notable change is in the dynamics of peggers countries: the responses
of inflation and of the liquidity spread are now stronger; those of stock prices and of risk are
weaker. Thus, the relative importance of the wealth and portfolio channels may depend on
whether we allow the UMP variable to react to financial variables or not.

1.7.2 Identification of UMP via Sign and Zero Restrictions

While the identification scheme that we have used for euro area UMP shocks with weekly data
imposes relatively weak restrictions, we also examined the dynamics with an identification scheme,
which mixes sign and zero restrictions. In particular, we still assume that output and inflation
do not react to UMP shocks within a week, but impose that a positive UMP shock increases
the UMP variable and makes the liquidity spread non-positive for one period. Restrictions of
this type have been used by Gambacorta et al. (2014) and Carrera et al. (2015a), and seem
reasonable since the main goal of several UMP measures was to increase the liquidity of financial
markets.

Since this scheme identifies a set rather than a point in the space of contemporaneous
matrices, responses are generally more uncertain. Qualitatively speaking, the responses for the
exchange rate, the liquidity spread, and risk are as in the baseline, while the response of stock
prices is, on average, more negative. Interestingly, the dynamic responses of output and inflation
are similar to those of the R3 scheme for most countries. Thus, the idea that unconventional
monetary policy may react to liquidity on a weekly basis finds additional support.

1.7.3 Identification via Heteroskedasticity

The use of higher-frequency data makes us less sensitive to the issue of policy endogeneity but
still imposes some restrictions on financial variables. As a further check on the robustness of
our conclusions, we use volatility changes to identify UMP shocks as in Rigobon (2003). The
method requires that there are at least two regimes with different volatilities (e.g. low and high),
assumes that shocks are uncorrelated, and that the contemporaneous impact matrix and the
parameters of the VAR are stable. While the restrictions such an identification scheme imposes
are weak, one should also remember that regimes are often arbitrarily chosen and that shocks
identified this way have very little economic interpretation (Kilian, 2013).

We check for the presence of different regimes/structural breaks in the reduced form VAR

residuals informally. There is a decrease in volatility in a number of the equations roughly corresponding to Mario Draghi's famous 'whatever it takes' speech on the 26th July 2012. This decrease is marked in the liquidity and UMP equations for the euro area, and in the exchange rate, liquidity, and risk equations for some countries.

To estimate the system, we condition the Gibbs sampler on the variances for the two regimes as Kulikov and Netsunajev (2013a). We divide the sample in pre-Draghi speech, s_1, and post-Draghi speech state, s_2 and assume that the variance of the structural errors is state-dependent

$$\varepsilon_t(s_j)|s_t \sim Normal(0, \mathbf{D}(s_t)). \tag{1.4}$$

The diagonal matrix, $\mathbf{D}(s_2)$, is employed to determine the short-run run matrix, $\mathbf{A_0}$, once posterior variances are computed using $\mathbf{\Sigma^{-1}}(1) = \mathbf{A_0'A_0}$, $\mathbf{\Sigma^{-1}}(2) = \mathbf{A_0'D(s_2)^{-1}A_0}$, where $D(s_1) = I$.

Since not all countries display volatility changes around the chosen breakpoint, general conclusions are difficult to draw. While responses are not very significant, the basic conclusions we have obtained are unchanged: output responses vary across countries with advanced countries displaying strong positive responses while responses in CEE and SEE countries are negative; the real exchange rate appreciates for most countries; the credit channel is weak.

1.8 Conclusion

This paper examined the international transmission of euro area UMP disturbances. We contributed to the literature in three ways: (1) From a methodological point of view, we provide a way to combine low-frequency macroeconomic data with high-frequency financial data, minimising time-aggregation and policy endogeneity biases. (2) From an economic point of view, we shed light into the effect of unconventional ECB measures using a framework where macro-financial linkages are properly accounted for and an international perspective is adopted. (3) From a policy perspective, we provide new evidence on the role of exchange rate regime in internationally transmitting monetary policy decisions in a world where cross border flows and leverage matter.

Moreover, we answered our three questions in the introduction: First, do European Central Bank UMP measures generate important macroeconomic effects in European countries not adopting the Euro? We document that UMP shocks generate important euro area financial market responses, sizeable macroeconomic fluctuations, and are similar to conventional monetary policy shocks in terms of timing and persistence relative. Interestingly, while UMP disturbances

induce significant inflation, conventional monetary policy disturbances primarily affect output. This means that a combination of conventional and unconventional measures may help to better control output and inflation dynamics. Announcement surprises produce financial market responses, which are similar to those of conventional policy shocks, but output and inflation effects are weak.

Second, does the degree of financial integration matter? In particular, is it true that larger financial market integration led to more significant international real co-movements in response to UMP disturbances? International spillovers exist but there is considerable cross-country heterogeneity. The exchange rate regime is not the reason of this heterogeneity. Advanced economies, which are more financially integrated with the euro area and have a larger share of domestic banks, tend to have output and inflation dynamics, which are qualitatively similar but generally stronger than those in the euro area. The macroeconomic effects for financially less developed countries, which have a larger share of foreign banks, are varied, but output and inflation responses are the opposite of those of advanced economies. Third, which channel of international transmission is operative? What is the relative importance of trade and financial spillovers in propagating UMP shocks? International transmission occurs both via trade (the exchange rate channel) and financial links (wealth, risk and portfolio rebalancing channels). However, the exchange rate rate does not seem to shape the responses of foreign macroeconomic variables to euro area UMP shocks. This is in contrast to the international transmission of conventional policy shocks, where the exchange rate is crucial to understand foreign dynamics.

Our results have important policy implications. In our sample of countries, the exchange rate regime is unimportant to explain cross-country differences in the dynamics of real activity and inflation. Exchange rate movements are closely watched by policymakers and, as the quotes from the introduction suggest, are considered crucial for the international propagation of UMP decisions. However, when financial channels are dominant and capital flows important, controlling exchange rate movements will not prevent non-euro area countries from importing the unconventional monetary policy decisions of the ECB (see also Rey, 2015). Since the dynamics of financial flows are crucial and the presence of global banks in the area is important in determining domestic outcomes (Cetorelli and Goldberg, 2012), policies that indirectly restrict financial flows and bank leverage could be more effective in insulating the small open economies in our sample from undesired output and inflation fluctuations. Devereux et al. (2015) provide the theoretical justification for using such measures.

The current work can be extended in various ways. One could study announcement effects in more detail. While we controlled for them in the estimation, we did not consider any potential anticipatory effect that announcements can generate. Taking expectations into account might increase the significance of the credit channel. We could also extend the sample of countries

and include the recent QE measures in the analysis. Finally, we have assumed that structural parameters are stable. Ciccarelli et al. (2013) suggested that time variations could play an important role in international policy transmission. Investigations of this type can improve our understanding of how UMP measures are transmitted and give policymakers a more solid ground to decide which policy to implement.

References

Abbassi, P. and Linzert, T. (2012). The effectiveness of monetary policy in steering money market rates during the financial crisis. *Journal of Macroeconomics*, 34(4):945–954.

Aizenman, J., Binici, M., and Hutchison, M. M. (2016). The Transmission of Federal Reserve Tapering News to Emerging Financial Markets. *International Journal of Central Banking*, 12(2):317–356.

Aizenman, J., Chinn, M. D., and Ito, H. (2015). Monetary Policy Spillovers and the Trilemma in the New Normal: Periphery Country Sensitivity to Core Country Conditions. NBER Working Paper 21128, National Bureau of Economic Research, Inc.

Altavilla, C., Canova, F., and Ciccarelli, M. (2016a). Mending the Broken Link: Heterogeneous Bank Lending and Monetary Policy Pass-Through. SSRN Scholarly Paper ID 2910931, Social Science Research Network, Rochester, NY.

Altavilla, C., Giannone, D., and Lenza, M. (2016b). The Financial and Macroeconomic Effects of the OMT Announcements. *International Journal of Central Banking*, 12(3):29–57.

Angelini, P., Neri, S., and Panetta, F. (2011a). Monetary and macroprudential policies. Temi di discussione (Economic working papers) 801, Bank of Italy, Economic Research and International Relations Area.

Angeloni, I. (2012). *Monetary policy transmission in the Euro area: a study by the Eurosystem Monetary Transmission Network*. Cambridge University Press, Cambridge.

Beirne, J., Dalitz, L., Ejsing, J., Grothe, M., Manganelli, S., Monar, F., Sahel, B., Sušec, M., Tapking, J., and Vong, T. (2011a). The impact of the Eurosystem's covered bond purchase programme on the primary and secondary markets. Occasional Paper Series 122, European Central Bank.

Bernanke, B. S. (2010a). Opening remarks: the economic outlook and monetary policy. *Proceedings - Economic Policy Symposium - Jackson Hole*, pages 1–16.

Boeckx, J., Dossche, M., and Peersman, G. (2017). Effectiveness and Transmission of the ECB's Balance Sheet Policies. *International Journal of Central Banking*, 13(1):297–333.

Borstel, J., Eickmeier, S., and Krippner, L. (2015). The interest rate pass-through in the euro area during the sovereign debt crisis. *Bundesbank Discussion Paper*, 10/2015.

Canova, F. (2005a). The transmission of US shocks to Latin America. *Journal of Applied Econometrics*, 20(2):229–251.

Carrera, C., Forero, F. P., and Ramirez-Rondan, N. (2015a). Effects of U.S. Quantitative Easing on Latin American Economies. Working Paper 2015-35, Peruvian Economic Association.

Carter, C. K. and Kohn, R. (1994). On Gibbs Sampling for State Space Models. *Biometrika*, 81(3):541–553.

Cecioni, M., Ferrero, G., and Secchi, A. (2011c). Unconventional Monetary Policy in Theory and in Practice. Questioni di Economia e Finanza (Occasional Papers) 102, Bank of Italy, Economic Research and International Relations Area.

Cetorelli, N. and Goldberg, L. S. (2012). Banking globalization and monetary transmission. *The Journal of Finance*, 67(5):1811–1843.

Chen, Q., Filardo, A. J., He, D., and Zhu, F. (2012). International Spillovers of Central Bank Balance Sheet Policies. SSRN Scholarly Paper ID 2185394, Social Science Research Network, Rochester, NY.

Chinn, M. D. (2013a). Global spillovers and domestic monetary policy. BIS Working Paper 436, Bank for International Settlements.

Christoffel, K., Coenen, G., and Warne, A. (2008). The New Area-Wide Model of the euro area: a micro-founded open-economy model for forecasting and policy analysis. Working Paper Series 0944, European Central Bank.

Ciccarelli, M., Maddaloni, A., and Peydró, J.-L. (2013). Heterogeneous transmission mechanism: monetary policy and financial fragility in the eurozone. *Economic Policy*, 28(75):459–512.

Cushman, D. O. and Zha, T. (1997). Identifying monetary policy in a small open economy under flexible exchange rates. *Journal of Monetary Economics*, 39(3):433–448.

Darracq-Paries, M. and De Santis, R. A. (2015). A non-standard monetary policy shock: The ECB's 3-year LTROs and the shift in credit supply. *Journal of International Money and Finance*, 54(C):1–34.

Dedola, L., Rivolta, G., and Stracca, L. (2017). If the Fed sneezes, who catches a cold? Working Paper Series 2050, European Central Bank.

Devereux, M. B., Young, E. R., and Yu, C. (2015). A New Dilemma: Capital Controls and Monetary Policy in Sudden Stop Economies. Working Paper 21791, National Bureau of Economic Research.

Dungey, M. and Pagan, A. (2009). Extending a SVAR Model of the Australian Economy. *The Economic Record*, 85(268):1–20.

Eraker, B., Chiu, C. W. J., Foerster, A. T., Kim, T. B., and Seoane, H. D. (2015). Bayesian Mixed Frequency VARs. *Journal of Financial Econometrics*, 13(3):698–721.

Foroni, C. and Marcellino, M. (2013a). *Mixed frequency structural models identification, estimation, and policy analysis*. Norges Bank, Oslo.

Fratzscher, M., Lo Duca, M., and Straub, R. (2017). On the International Spillovers of US Quantitative Easing. *The Economic Journal*, (July).

Gagnon, J., Raskin, M., Remache, J., and Sack, B. (2011a). Large-scale asset purchases by the Federal Reserve: did they work? *Economic Policy Review*, (May):41–59.

Gambacorta, L., Hofmann, B., and Peersman, G. (2014). The Effectiveness of Unconventional Monetary Policy at the Zero Lower Bound: A Cross-Country Analysis. *Journal of Money, Credit and Banking*, 46(4):615–642.

Ghysels, E., Idier, J., Manganelli, S., and Vergote, O. (2017). A High-Frequency assessment of the ECB Securities Markets Programme. *Journal of the European Economic Association*, 15(1):218–243.

Gopinath, G. (2015). The International Price System. Working Paper 21646, National Bureau of Economic Research.

International Monetary Fund (2013a). Central, Eastern and Southeastern Europe-Financing Future Growth: The Evolving Role of Banking Systems in CESEE.

Kilian, L. (2013). Structural vector autoregressions. In *Handbook of Research Methods and Applications in Empirical Macroeconomics*, pages 515–554. Edward Elgar Publishing.

Kim, S. and Roubini, N. (2000). Exchange rate anomalies in the industrial countries: A solution with a structural VAR approach. *Journal of Monetary Economics*, 45(3):561–586.

Krishnamurthy, A. and Vissing-Jorgensen, A. (2011a). The Effects of Quantitative Easing on Interest Rates: Channels and Implications for Policy. *Brookings Papers on Economic Activity*, 43(2 (Fall)):215–287.

Kulikov, D. and Netsunajev, A. (2013a). Identifying monetary policy shocks via heteroskedasticity: a Bayesian approach. Bank of Estonia Working Paper 2013-9, Bank of Estonia.

Kynge, J. (2014). 'Fragile Five' falls short as tapering leaves more exposed. *Financial Times*.

Lenza, M., Pill, H., and Reichlin, L. (2010a). Monetary policy in exceptional times. *Economic Policy*, 25:295–339.

Lim, J. J., Mohapatra, S., and Stocker, M. (2014). Tinker, taper, QE, bye ? The effect of quantitative easing on financial flows to developing countries. Policy Research Working Paper Series 6820, The World Bank.

Lo Duca, M., Fratzscher, M., and Straub, R. (2016). ECB Unconventional Monetary Policy Actions: Market Impact, International Spillovers and Transmission Channels. IMF Economic Review Volume 1 Issue 1.

Mackowiak, B. (2007). External shocks, U.S. monetary policy and macroeconomic fluctuations in emerging markets. *Journal of Monetary Economics*, 54(8):2512–2520.

Mishkin, F. S. (2001). The Transmission Mechanism and the Role of Asset Prices in Monetary Policy. Working Paper 8617, National Bureau of Economic Research.

Moessner, R. (2015). International spillovers from US forward guidance to equity markets. *Applied Economics*, 47(42):4549–4560.

Neely, C. J. (2015). Unconventional monetary policy had large international effects. *Journal of Banking & Finance*, 52:101–111.

Ongena, S., Schindele, I., and Vonnak, D. (2015). In Lands of Foreign Currency Credit, Bank Lending Channels Run Through? SSRN Scholarly Paper ID 2507688, Social Science Research Network, Rochester, NY.

Passari, E. and Rey, H. (2015). Financial Flows and the International Monetary System. *The Economic Journal*, 125(584):675–698.

Qian, H. (2013). Vector Autoregression with Mixed Frequency Data. Technical Report 47856, University Library of Munich, Germany.

Rey, H. (2015). Dilemma not Trilemma: The global Financial Cycle and Monetary Policy Independence. NBER Working Papers 21162, National Bureau of Economic Research, Inc.

Rigobon, R. (2003). Identification Through Heteroskedasticity. *The Review of Economics and Statistics*, 85(4):777–792.

Rogers, J. H., Scotti, C., and Wright, J. H. (2014). Evaluating Asset-Market Effects of Unconventional Monetary Policy: A Cross-Country Comparison. International Finance Discussion Papers 1101, Board of Governors of the Federal Reserve System (U.S.).

Russell, S. (1992). Understanding the term structure of interest rates: The expectations theory. *Federal Reserve Bank of St. Louis Review*, 74(4):36–50.

Santis, R. A. and Surico, P. (2013). Bank lending and monetary transmission in the euro area. *Economic Policy*, 28(75):423–457.

Schwab, K. (2012). The Financial Development Report. Insight Report, World Economic Forum.

Szczerbowicz, U. (2015). The ECB unconventional monetary policies: have they lowered market borrowing costs for banks and governments? *International Journal of Central Banking*, forthcoming.

Trichet, J.-C. (2009). *ECB: The ECB's enhanced credit support.*

Williams, J. C. and Taylor, J. B. (2009). A Black Swan in the Money Market. *American Economic Journal: Macroeconomics*, 1(1):58–83.

Appendix

***

1.A   Timeline of ECB Unconventional Measures

According to Trichet (2009) ECB's unconventional toolbox included five liquidity policy measures to aid the interbank market. The first of these tools was introduced in October 2008 - the new fixed-rate full allotment tender procedure - and designed to ensure that the high demand for liquidity, which reached a peak of 95 billion Euros during the crisis, could be met. The policy allows credit institutions to acquire an unlimited amount of Euros in an auction at a fixed rate. The second, also introduced in October 2008, expanded the list of assets that were accepted as collateral. These two tools together ensured an almost unlimited refinancing to the 2200 credit institutions, which had access. The third tool allowed lengthening of the maturities of the longer term refinancing operations (LTROs) from three months to up to three years. In March and July 2008, the first six-month full allotments were announced and twelve-month LTROs were introduced in June 2009. In December 2011 and then again in February 2012, LTROs with a maturity of three years were introduced to provide more long-term liquidity and to ease interbank market tensions. The fourth tool ensured enough liquidity of foreign currency, particularly of the US Dollar. This was conducted through a direct swap line with the Federal Reserve. The final measure, covered bond purchases (CBPs), introduced in 2009, allowed the ECB to purchase of debt securities issued by banks. This allowed banks to have even longer-term funding than through refinancing operations following the complete shut down of the covered bond market during the financial crisis [5]. In November 2011, a second round of CBPs was introduced. These

---

[5]CBPs are different from asset backed securities. The risk associated with covered bonds stays with the originator, so that the ECB was not necessarily subjected to more risk and the issuing institution still had an incentive to constantly evaluate credit risk. This is in contrast to the US and the UK, where the Fed started buying asset-backed securities, commercial papers and direct obligation of mortgage backed securities and the BoE introduced an asset purchase facility, to ease the non-bank credit market. Since banks are the biggest holders of covered bonds in Europe, such a measure was designed to improve interbank market conditions.

five tools make up what we term (in-) direct liquidity policy.

As far as sovereign debt policy is concerned, a measure was introduced in May 2010 that allowed the ECB to purchase public and private debt securities - the Security Market Programme (SMP). The official objective of the SMP is to provide more liquidity to 'dysfunctional' market segments to ensure that transmission channels for monetary policy are properly operating. The ECB conducted sterilising operations to re-absorb the excess liquidity. The composition of the SMP consisted of 47% Italian debt, 22% Spanish, 16% Greek and the remaining percent on Irish and Portuguese debt. The final measure was announced in August 2012, when the SMP was aborted - the Outright Monetary Transactions (OMT). Similarly to the SMP, the OMT is the sterilised purchase, conditional on certain domestic economic conditions, of 1 to 3 year maturing government debt.

1.B   Mixed Frequency Algorithm

This appendix describes the algorithm used to draw sequences for the posterior distribution of the missing variables and of the parameters - see also Qian (2013).

Let $z_{\searrow t}$ be the vector of all missing observations and let (z, x) represent all recorded observations. The algorithm works as follows:

1. Define a matrix of data Y (missing observations are indicated by NaN).

2. Analyse the aggregation structure (if data comes as sum, average, end-of-period) and define a matrix, M, indicating which observations are missing. For example, if we have two variables, one monthly average which we observe once in the final week, and one weekly which we observe four times, we construct $\overrightarrow{M}$, vectorising $\underset{kxT}{M}$ column by column, so that $\overrightarrow{M} = [0, 0, 0, 1, 1, 1, 1, 1]'$.

3. Transform the averaged data into summed data, where the average is $\overline{z}_{a,b} \equiv \frac{1}{b-a+1} \sum_{t=0}^{b-a} \hat{z}_{\searrow t+a}$, and the sum $z_b = (b - a + 1)\overline{z}_{a,b}$.

4. Specify a normal prior for the coefficients, A, B, and an inverted Wishart prior the variance Σ.

5. Draw initial values for the coefficients, A, B, and for the variance Σ.

6. Specify initial values for the latent data by substituting missing values with sums computed from Step 3.

7. Construct the matrix $\underset{Tk \times Tk}{T}$ that will account for time-aggregation. In our case $T = 262$ and $k = 12$. Initially, $\underset{3144 \times 3144}{T}$ is an identity matrix. Using the matrix M, we scan each row,i, and column,j, for missing values, m. In the previous example, we have $m = 1, 2, 3$ in $i = 1$ right before $j = 4$. We add one for every missing variable to the transformation matrix in row $(j - 1)k + i$ and column $(j - 1)k + i - mk$. The transformation matrix is

then:

$$
\underset{8\times8}{T} =
\begin{pmatrix}
1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\
1 & 0 & 1 & 0 & 1 & 0 & 1 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 1
\end{pmatrix}.
\tag{1.5}
$$

8. Transform the data using $\overrightarrow{M}Y$, so that we have both, a latent disaggregated block and an observed block.

9. Start the Gibbs sampler:

   (a) Estimate the VAR coefficients and draw parameter estimates from $f(A^i, B^i | \hat{Y}^i, \Sigma^{i-1})$.

   (b) Estimate the variances of the VAR and draw the variance estimates from $f(\Sigma^{i-1} | \hat{Y}^i, A^i, B^i)$.

   (c) Compute the covariance matrix of the VAR using draws for the coefficients, $\hat{A}, \hat{B}$, and the variance $\hat{\Sigma}$.

   (d) Constrain the multivariate normal (MVN) distribution using the transformation matrix A, so that $y_t \sim MVN(A\eta, A\Omega A') = MVN(\mu, \Sigma)$. The distribution for the latent variables is

   $$
   z_{\searrow t} | z, x \sim MVN(\mu_0 + \Sigma_{01}\Sigma_{11}^{-1}((z,x)' - \mu_1), \Sigma_{00} - \Sigma_{01}\Sigma_{11}^{-1}\Sigma_{10}),
   \tag{1.6}
   $$

   where Σ_{01} is a submatrix of Σ representing the covariances between the missing and the observed observations. Σ_{00} is the variance of the missing observations and Σ_{11} is the variance of the observed data.

   (e) Sample missing data from the conditional constrained MVN described in Step 9.d (in blocks). That is, for all $t = 1, .., T$, we draw missing data from $f(\hat{z}_t^i | x, \hat{z}_{\searrow t}^{i-1}, A^i, B^i, \Sigma^i)$.

   (f) Repeat steps (a) through (e).

10. Examine convergence using e.g. CUSUM statistics.

The results we present are based on 12500 draws: we discard the first 2500 as burn-in, and retain every 20th draw to reduce serial correlation. Inference is based on 500 saved draws.

1.C   Additional Results

Figure C.1: Euro area responses to UMP shocks: monthly VAR
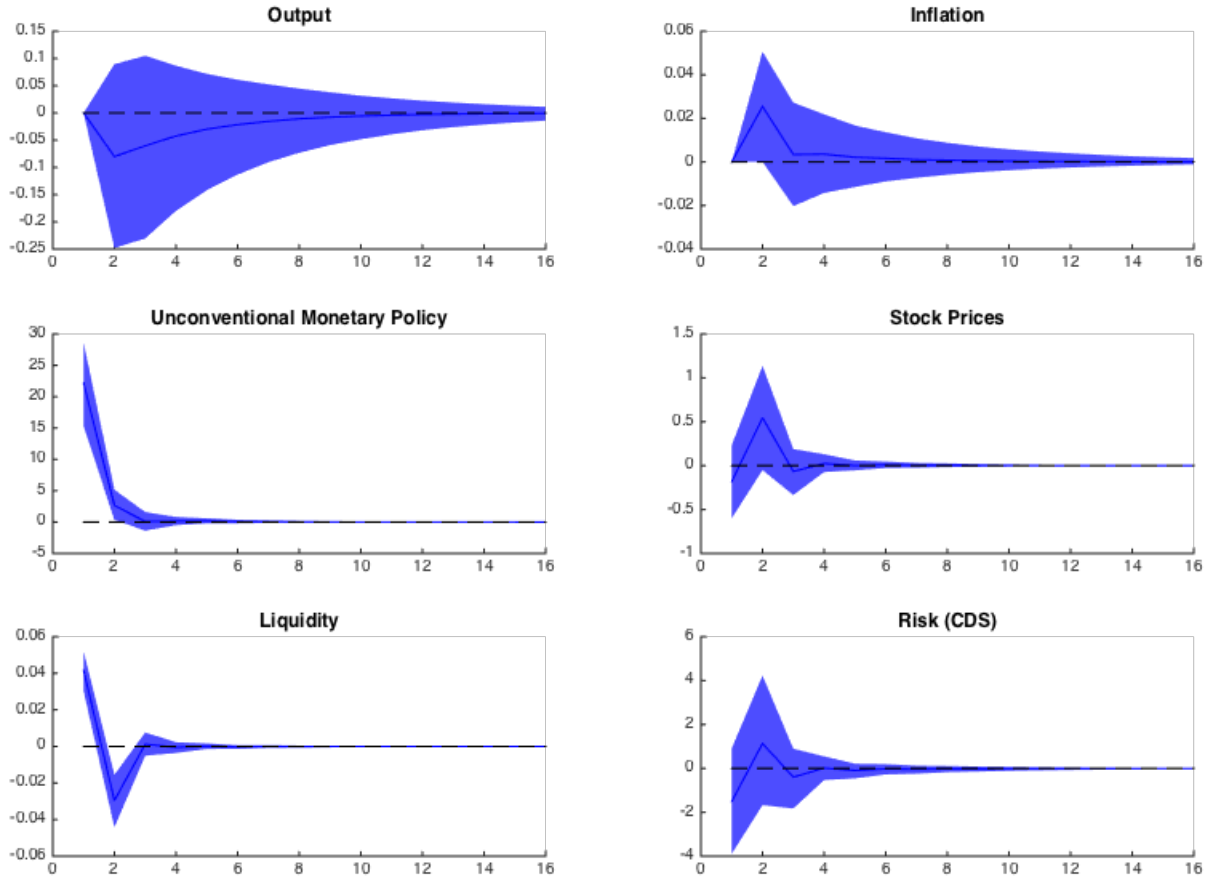
Note: The shaded regions report point-wise 68% credible intervals. The horizontal axis reports weeks; the vertical axis monthly growth rates for all variables but the liquidity spread.

Figure C.2: Euro area responses UMP shocks: Excess liquidity as a measure of UMP.
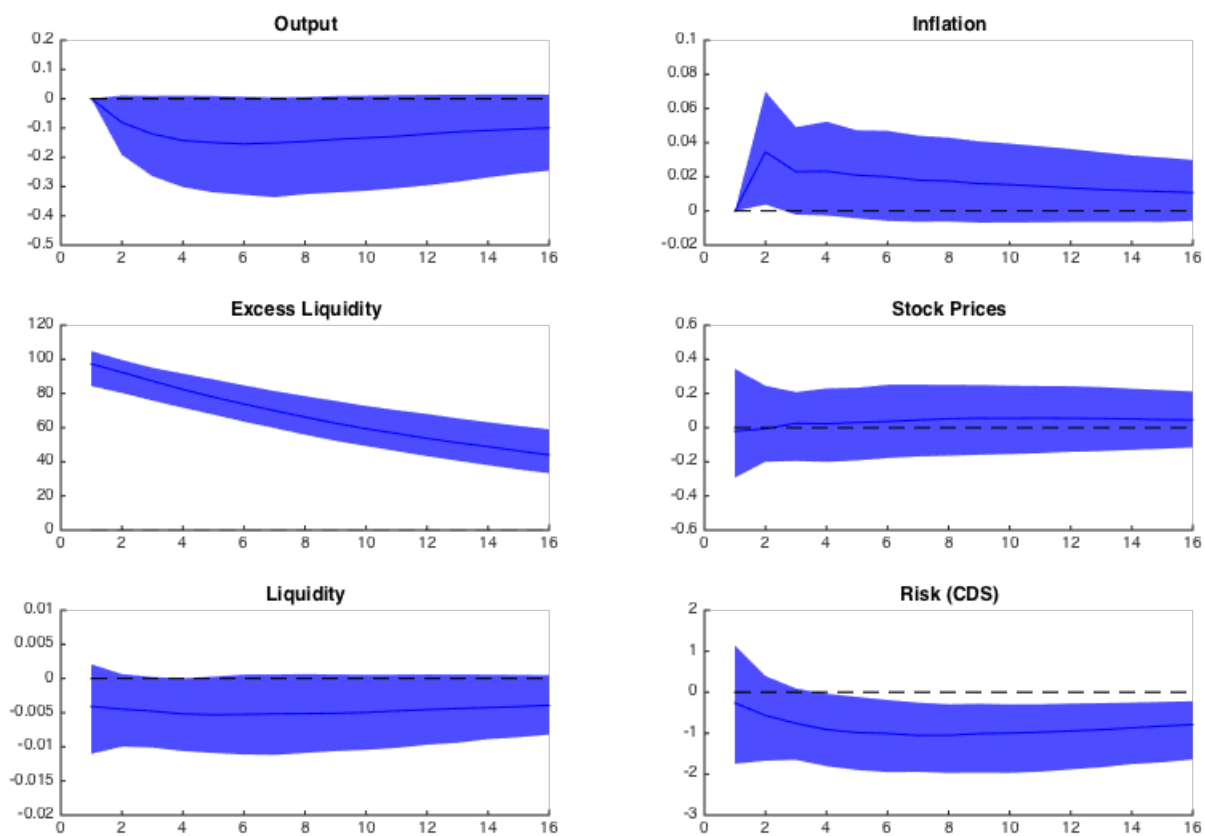
Note: The shaded regions report point-wise 68% credible intervals. The horizontal axis reports weeks; the vertical axis monthly growth rates for all variables but the liquidity spread and excess liquidity.

Figure C.3: Euro area responses UMP shocks: Shocks to UMP liquidity variable.
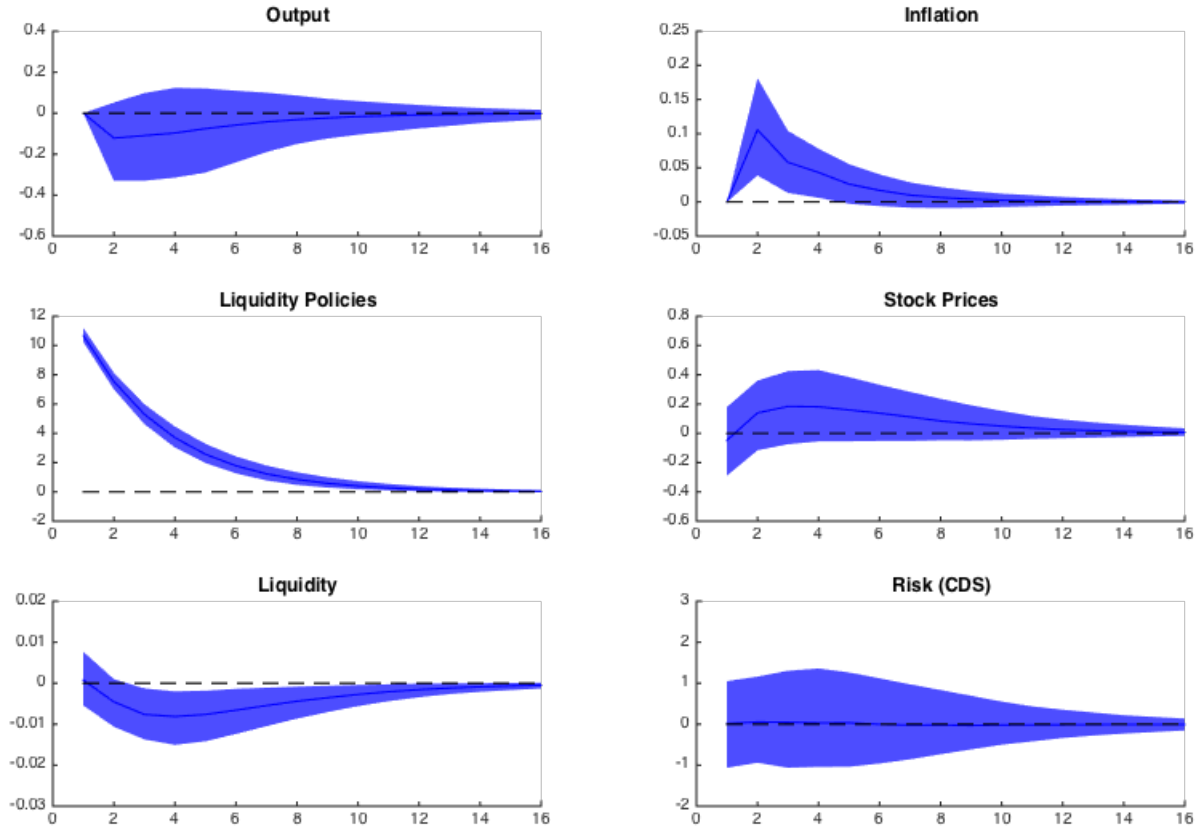
Note: The shaded regions report point-wise 68% credible intervals. The horizontal axis reports weeks; the vertical axis monthly growth rates for all variables but the liquidity spread.

Figure C.4: Euro area responses UMP shocks: Shocks to UMP sovereign bond variable.
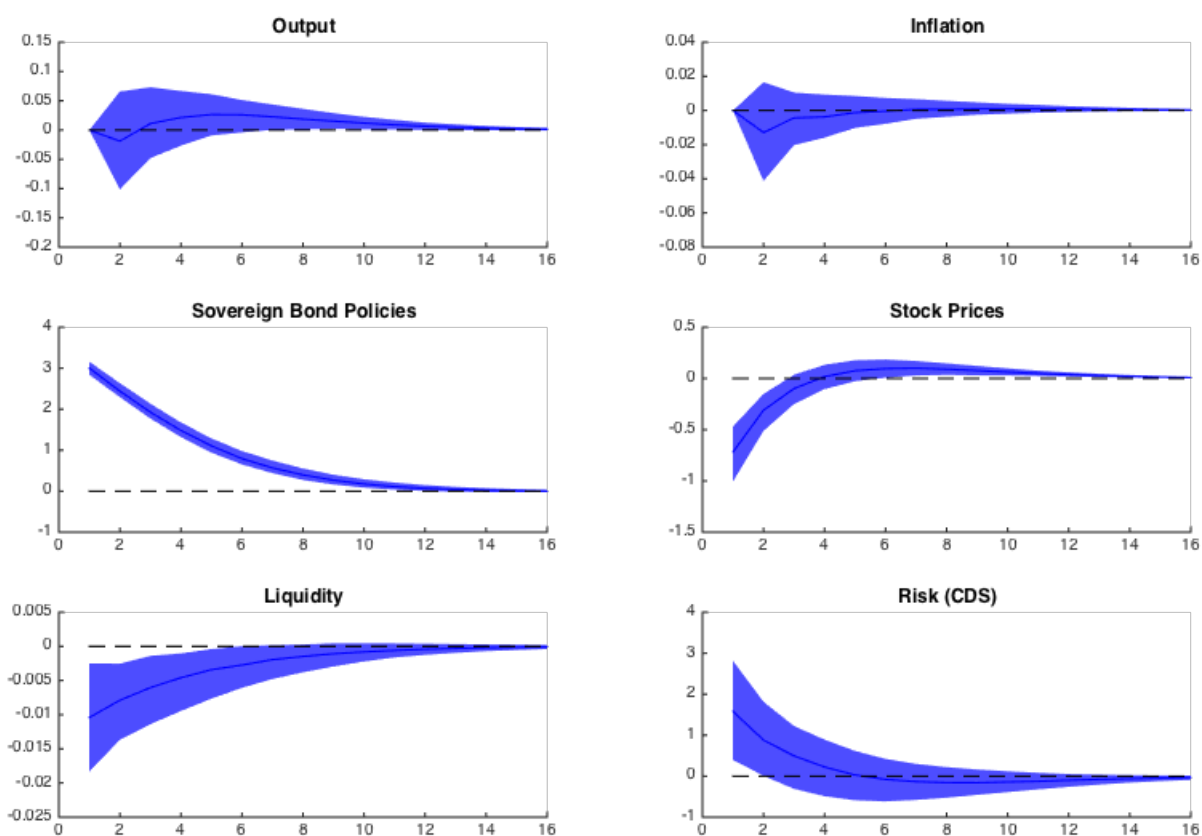
Note: The shaded regions report point-wise 68% credible intervals. The horizontal axis reports weeks; the vertical axis monthly growth rates for all variables but the liquidity spread.

Figure C.5: Swedish responses to UMP shocks, sample with Sweden UMP measures.
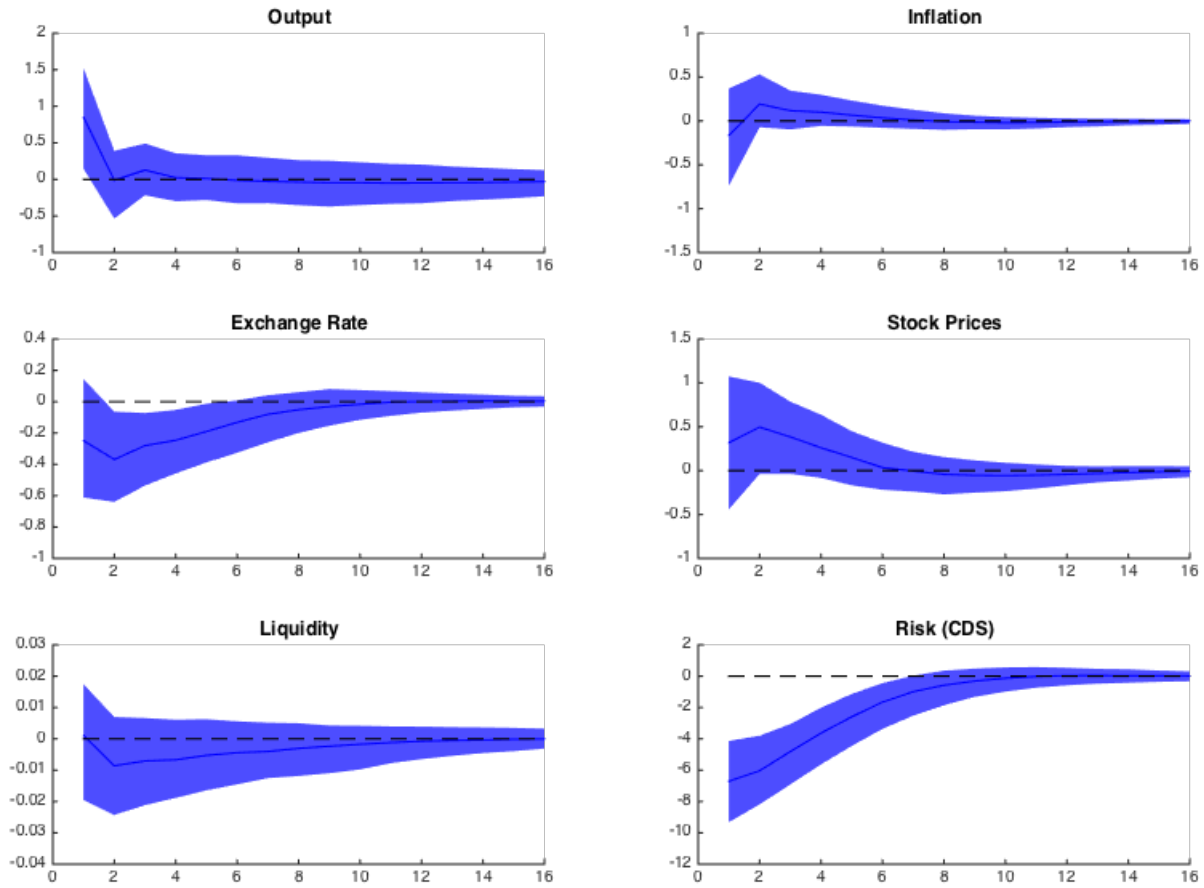
Note: The shaded regions report point-wise 68% credible intervals. The horizontal axis reports weeks; the vertical axis monthly growth rates for all variables but the liquidity spread in absolute terms.

Figure C.6: Swedish responses to UMP shocks: sample without Sweden UMP measures
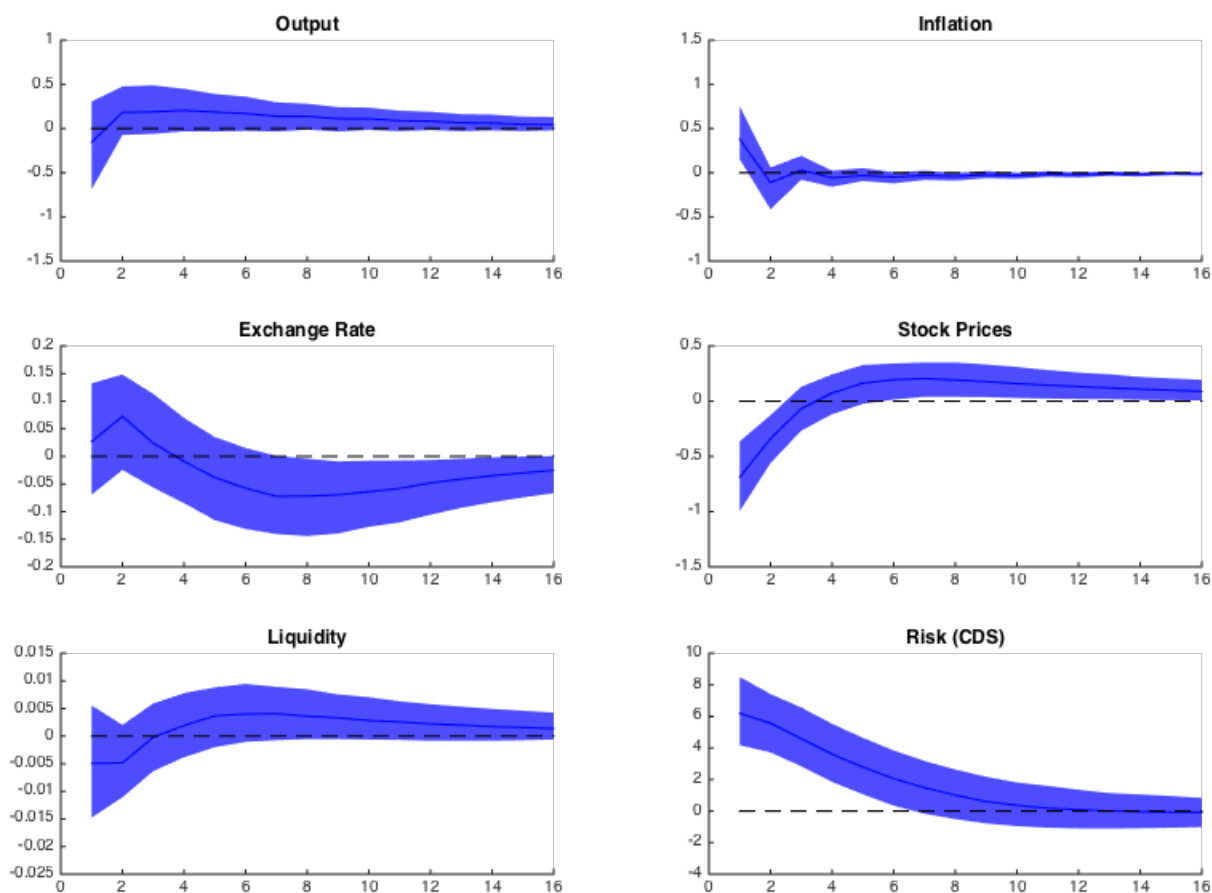
Note: The shaded regions report point-wise 68% credible intervals. The horizontal axis reports weeks; the vertical axis monthly growth rates for all variables but the liquidity spread in absolute terms.

Figure C.7: Real activity dynamics in the nine countries
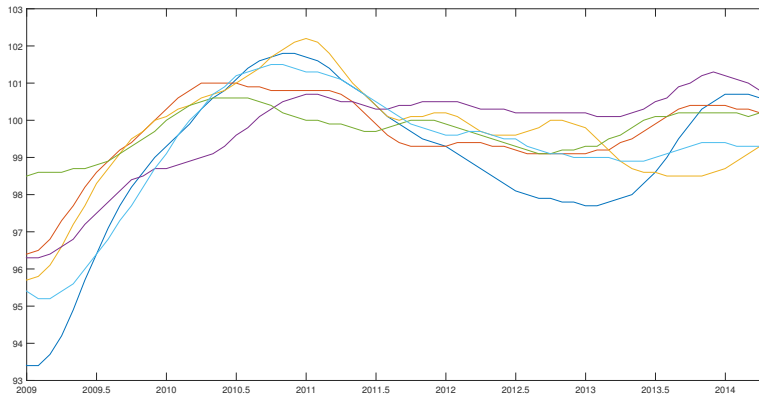
Note: The horizontal axis reports time; the vertical axis the level of the IP index.

Figure C.8: Financial dynamics in the nine countries
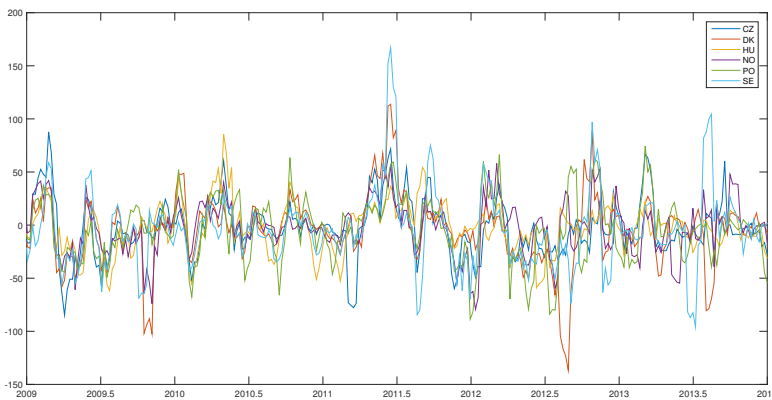
Note: The figure reports the dynamics of the first principal component of stock prices, liquidity and risk spreads. The horizontal axis reports time; the vertical axis monthly growth rates.

Figure C.9: Group responses to euro area UMP shocks
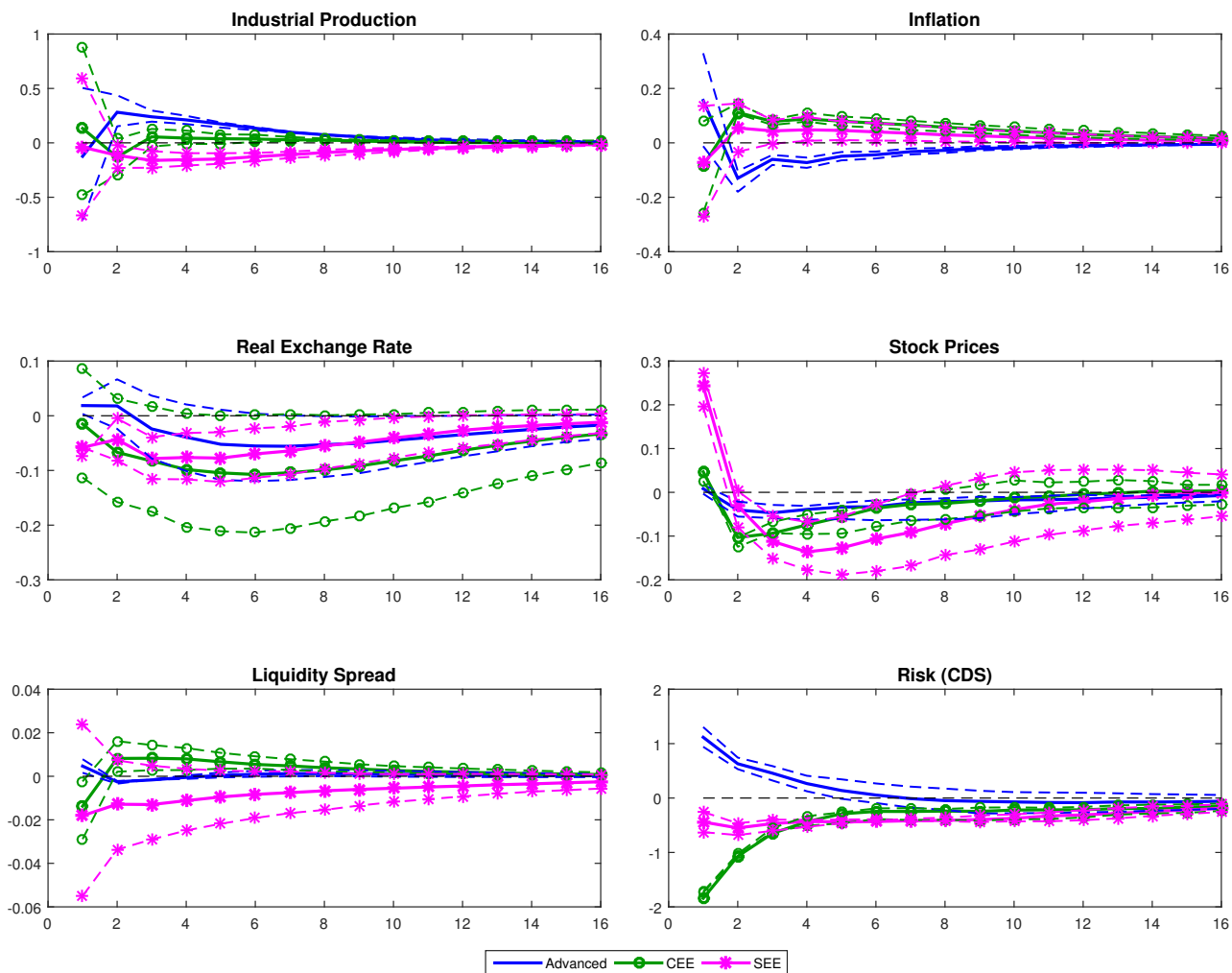
Note: The solid lines report point-wise average posterior median responses in deviations from euro area responses. The dotted lines point-wise 68% credible intervals. The *x*-axis reports weeks, while the *y*-axis monthly growth rates for all variables but the liquidity spread.

Figure C.10: Foreign responses to conventional euro area interest rate shocks
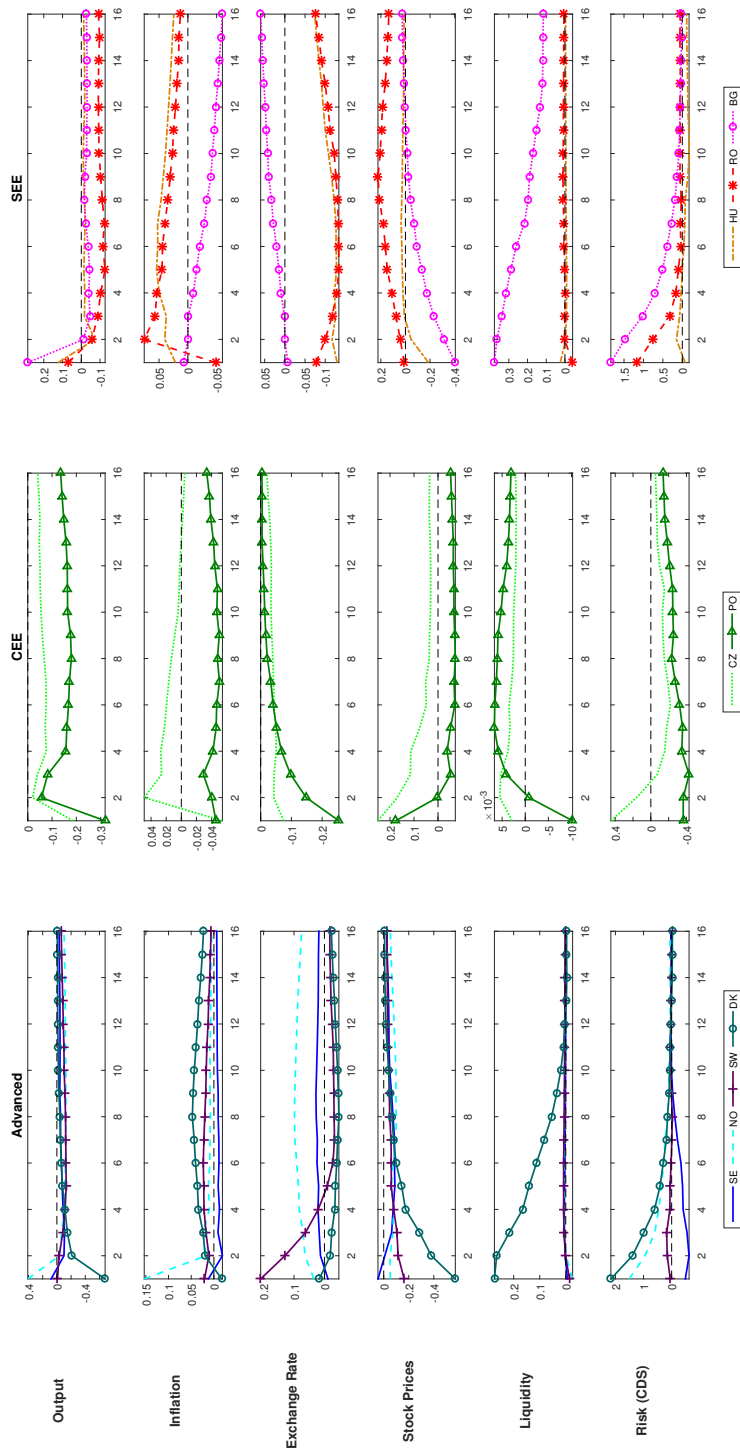
Note: The lines report point-wise posterior median responses in deviations from euro area responses. The *x*-axis reports weeks, the *y*-axis monthly growth rates for all variables but the liquidity spread. The size of the shock corresponds to 10 monthly basis points.

Figure C.11: Foreign responses to euro area announcement shocks
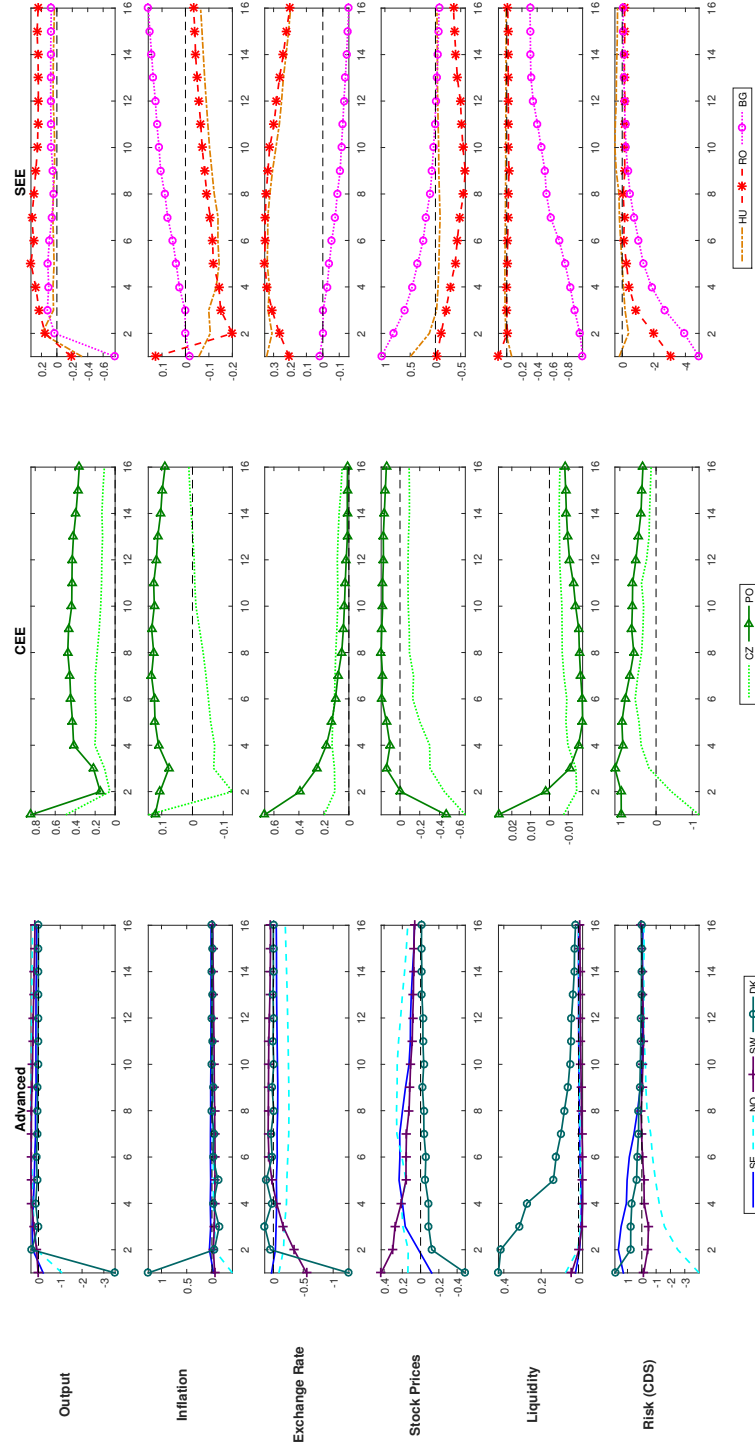
Note: The lines report point-wise posterior median responses in deviations from euro area responses. The *x*-axis reports weeks, the *y*-axis monthly growth rates for all variables but the liquidity spread. The size of the shock is one policy announcement.

Figure C.12: Foreign responses to euro area UMP shocks: Identification R1

Note: The lines report point-wise posterior median responses in deviations from euro area responses. The *x*-axis reports weeks, the *y*-axis monthly growth rates for all variables but the liquidity spread. The size of the shock is one standard deviation of UMP growth (a 10% monthly increase in the quantity of UMP).

Figure C.13: Foreign responses to euro area UMP shocks: Identification R2

Note: The lines report point-wise posterior median responses in deviations from euro area responses. The *x*-axis reports weeks, the *y*-axis monthly growth rates for all variables but the liquidity spread. The size of the shock is one standard deviation of UMP growth (a 10% monthly increase in the quantity of UMP).

Figure C.14: Foreign responses to euro area UMP shocks: Identification R3

Note: The lines report point-wise posterior median responses in deviations from euro area responses. The x-axis reports weeks, the y-axis monthly growth rates for all variables but the liquidity spread. The size of the shock is one standard deviation of UMP growth (a 10% monthly increase in the quantity of UMP).

Figure C.15: Foreign responses to euro area UMP shocks: Identification via zero and sign restrictions
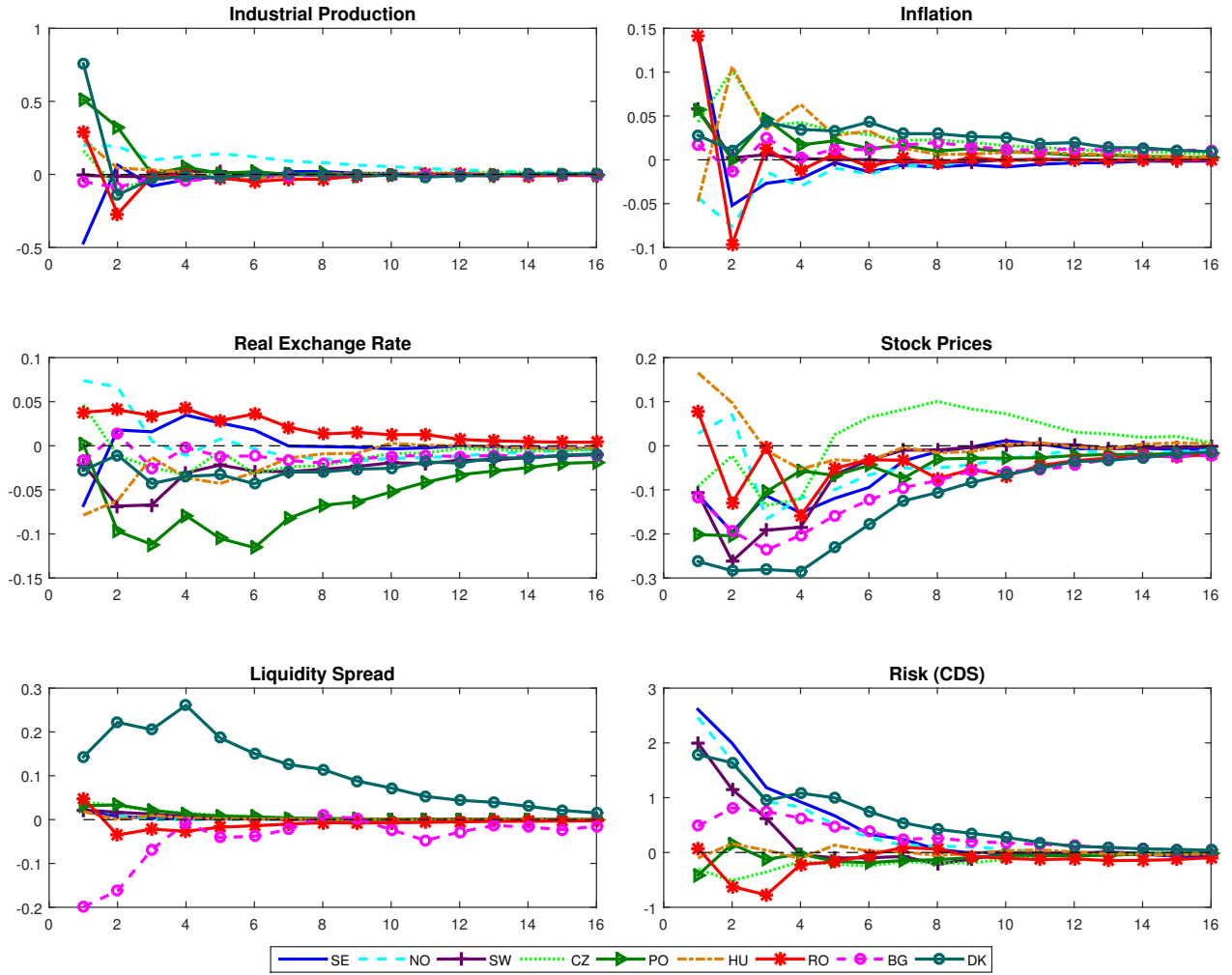
Note: The lines report point-wise posterior median responses in deviations from euro area responses. The *x*-axis reports weeks, the *y*-axis monthly growth rates for all variables but the liquidity spread. The size of the shock is one standard deviation of UMP growth (a 10% monthly increase in the quantity of UMP).

Figure C.16: Foreign responses to euro area UMP shocks: Identification via heteroskedasticity
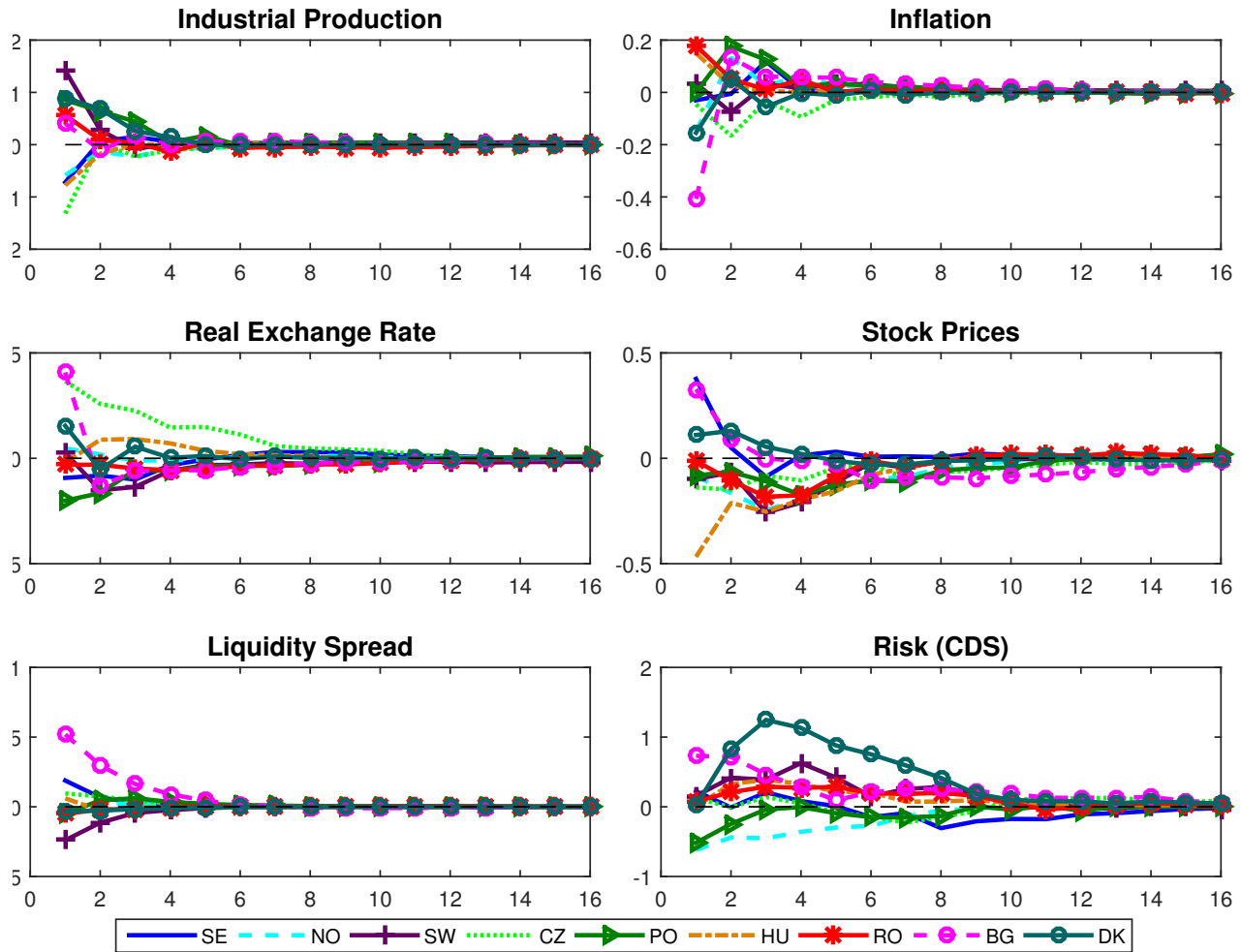
Note: The lines report point-wise posterior median responses in deviations from euro area responses. The *x*-axis reports weeks, the *y*-axis monthly growth
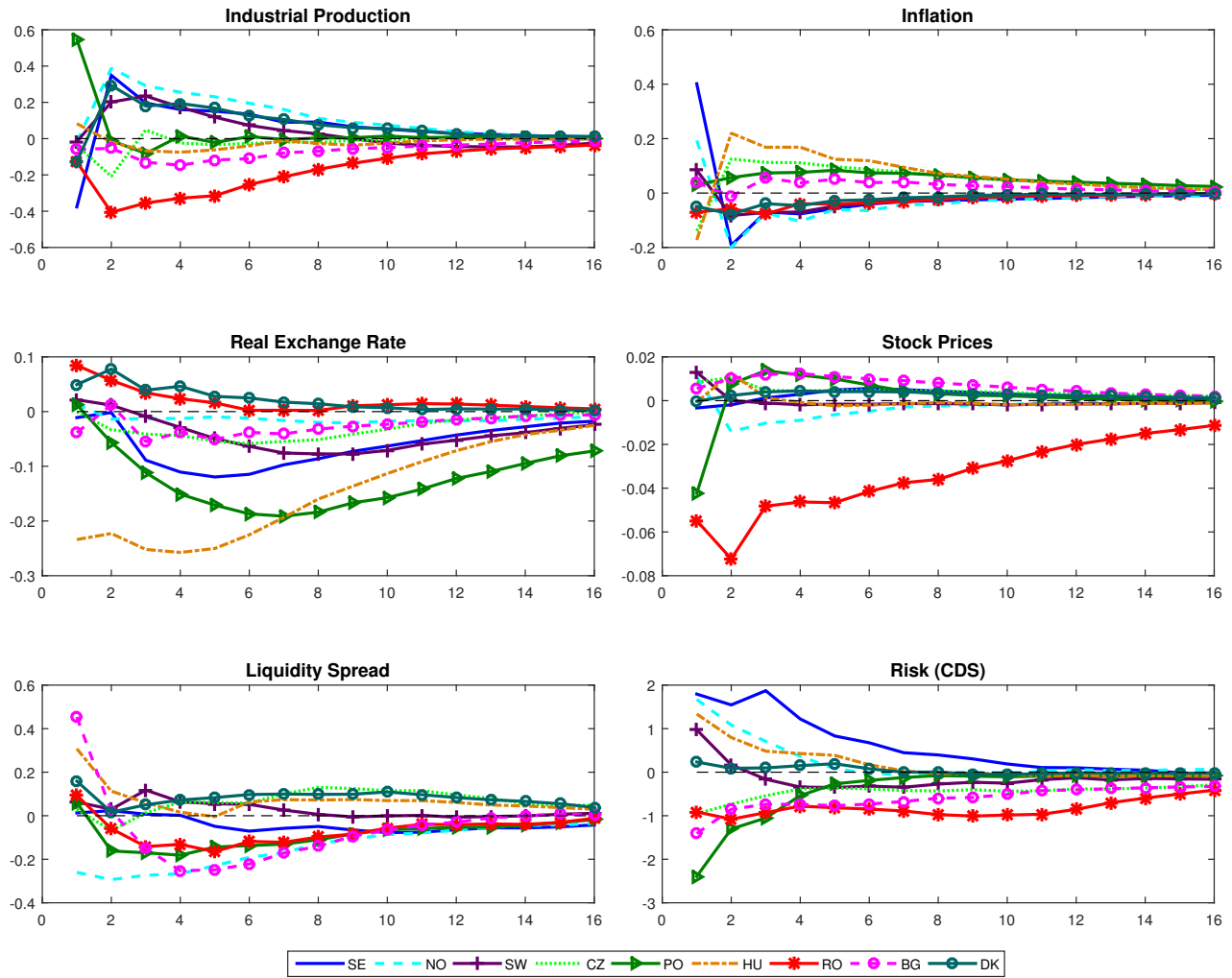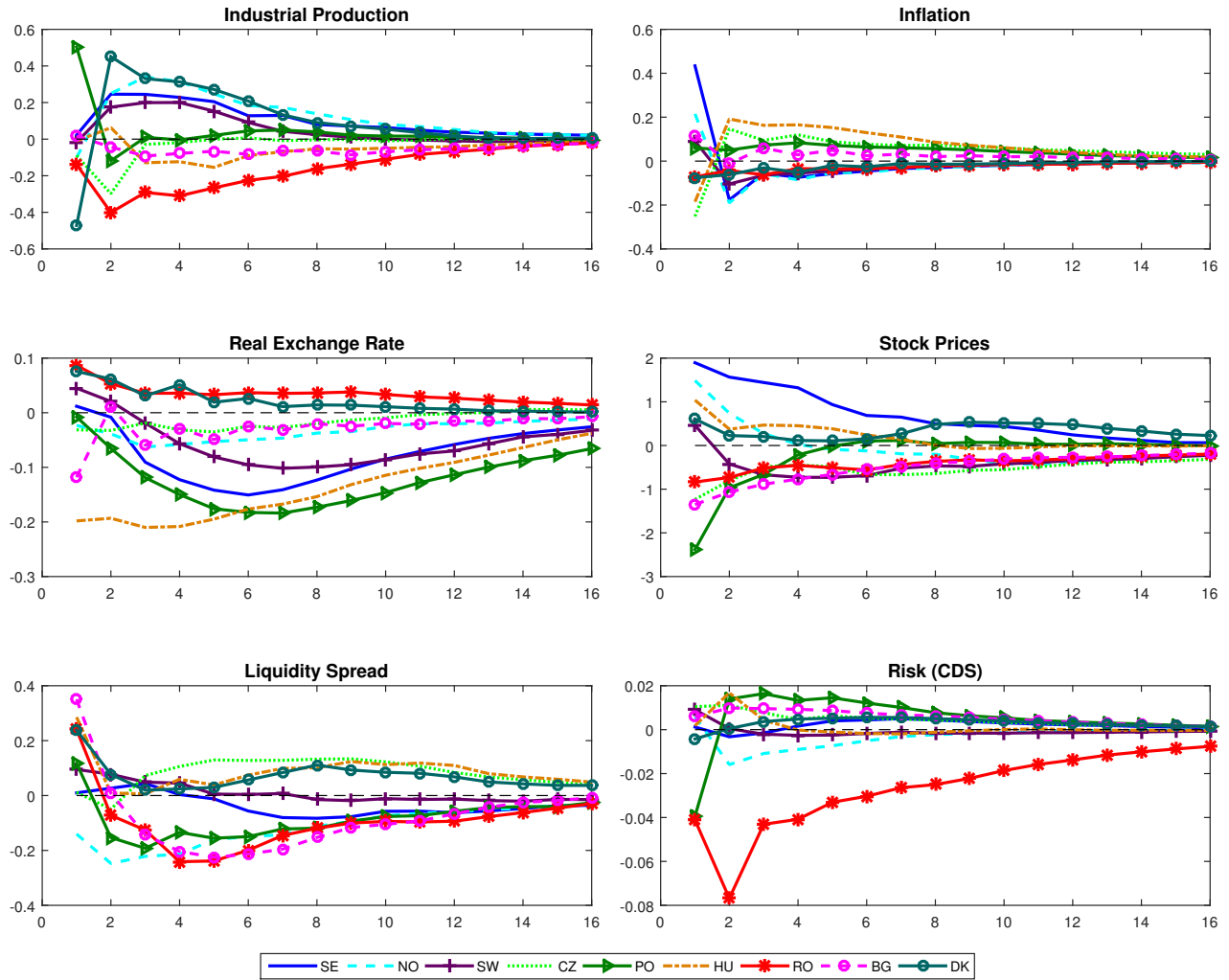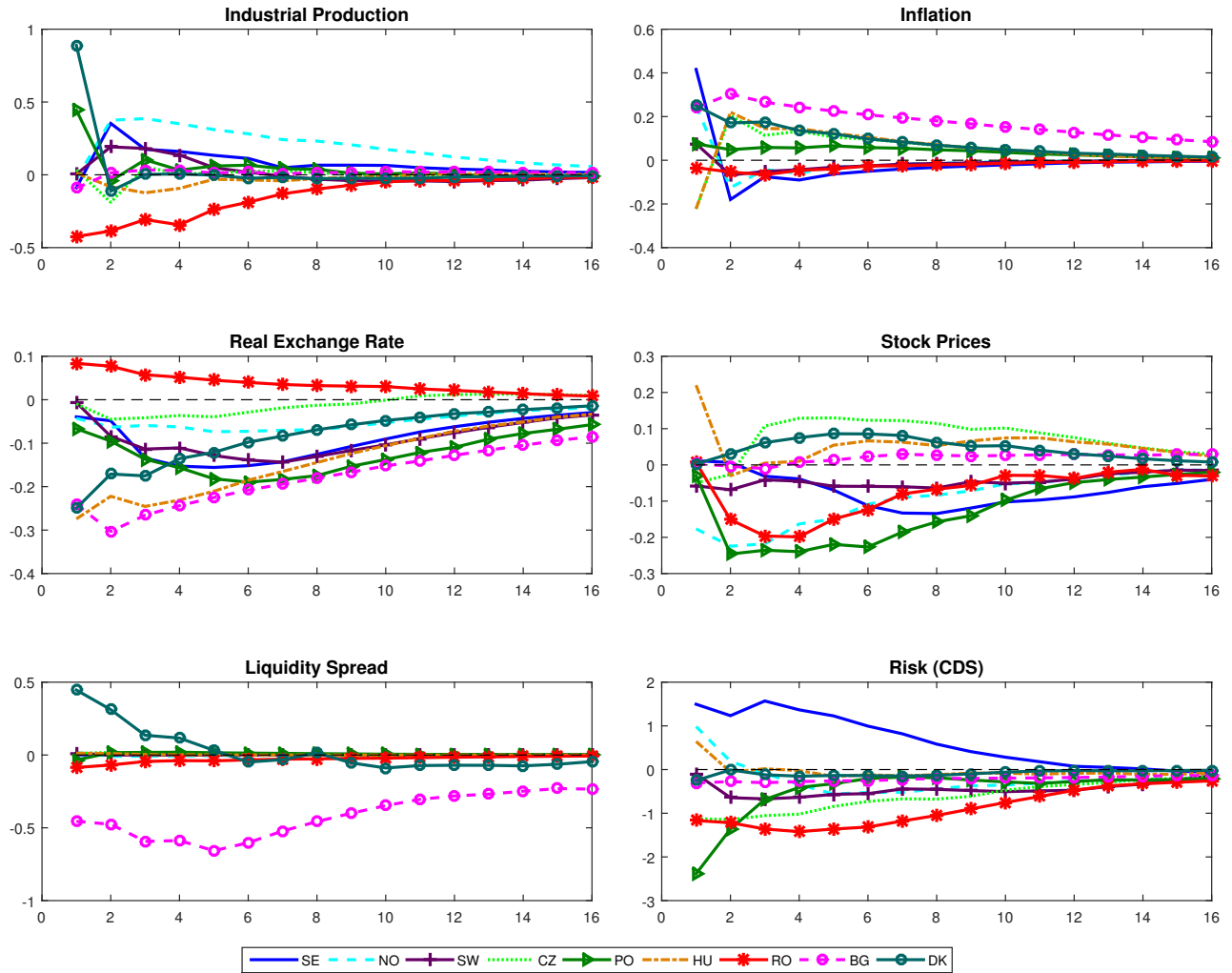
rates for all variables but the liquidity spread. The size of the shock is one standard deviation of UMP growth (a 10% monthly increase in the quantity of UMP).

Asymmetric Macro-Financial Spillovers

✳✳✳

This paper is currently available as "Asymmetric Macro-Financial Spillovers," Working Paper Series 337 (2017), Sveriges Riksbank.

2.1   Introduction

It is commonly assumed that financial cycles are procyclical and accelerate business cycle fluctuations (see e.g. Borio, 2014). It is more disputed whether the relationship between financial and real cycles is symmetric. Symmetry would imply that financial booms strengthen business cycle booms to the same extent as financial busts intensify recessions. While the financial crisis in 2008 has shown that a downturn in the financial sector can cause a long and deep recession, there is growing evidence to suggest that financial sector upturns do not reinforce business cycle booms in the same way (see e.g. Del Negro and Schorfheide, 2013 and Lindé et al., 2016).

The nature of the procyclicality is particularly interesting for the euro area, as the financial sector plays a special role for the real economy. Unlike the US, the European financial sector consists mostly of banks, and corporate debt financing is largely conducted via bank loans rather than debt securities. This creates a strong feedback loop between the banking sector and the real economy.[1] The financial sector adds on average only 5% of gross value added to the GDP of the euro area. Despite this seemingly small contribution, the dynamics of both the business and financial cycles are very similar. As shown in Figure 2.1, which displays cyclical and financial indicators that are constructed from GDP and asset price data[2], the turning points

---

[1]The share of corporate financing in the US is 80% via debt securities and 20% via bank loans, while in the euro area the share is 16% debt securities and 84% bank loans (based on the ECB flow of funds and the FED financial account data).

[2]The financial indicator is similar to Borio et al. (1994). It includes both private property and equity prices for private sector wealth. I use the private property index provided by the ECB, and the Euro Stoxx 50 as a measure for equity. The weights of the two factors are given in the ESA 2010 survey by Table 26 and Table 7,

in the business and financial cycles are strongly correlated. Furthermore, in agreement with Jordà (2014); Borio (2014), financial cycles tend to lead business cycles and are more volatile. Also note that while the overall correlation between the two cycles is positive and large with a correlation coefficient of 0.77, the positive correlation for booms disappears after 2010 indicating that the procyclicality might indeed be asymmetric.

Figure 2.1: The Financial and Business Cycle in the Euro Area
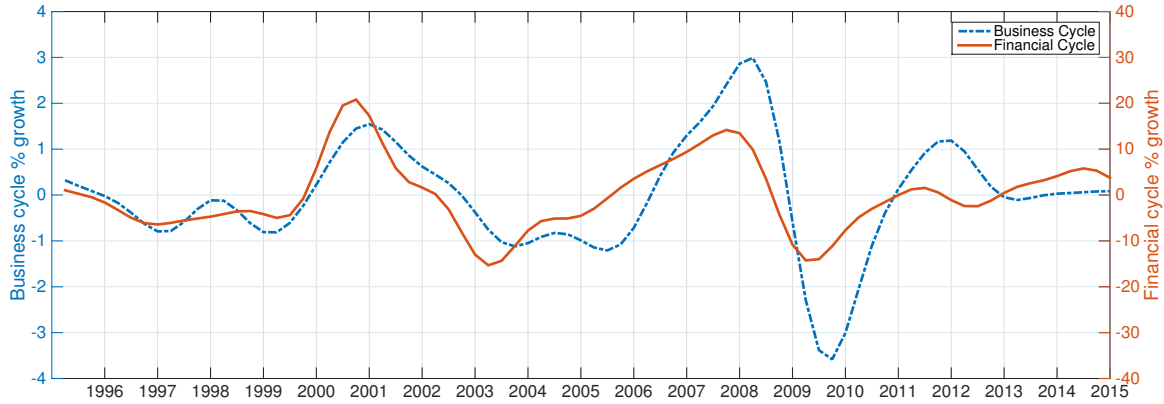
Note: The blue, dashed line indicates the business cycle, and the red, solid line shows the financial cycle. I follow Drehmann et al. (2012) and characterise the business and financial cycles using the Band-Pass Filter. The business cycle is constructed on real GDP data, while I use a composite asset price indicator with house prices and equity prices as measures of private financial wealth. Note the different scales on the axes for the business and financial cycle indicators.

In this paper, I explore whether macro-financial linkages are asymmetric and, if so, what generates these asymmetries.

I contribute to the existing literature in three ways. Firstly, I provide evidence suggesting that financial shocks have an asymmetric effect on real variables. I construct a Bayesian Markov-Switching VAR (MS-VAR) and compare the effects of a positive financial shock in normal times to a negative shock during credit constrained periods using euro area data. Secondly, using a structural model, I explore the reasons behind the asymmetric macro-financial transmission. The model features a heterogeneous banking sector as in Gerali et al. (2010) and an occasionally binding borrowing constraint as in Guerrieri and Iacoviello (2015a). By including a banking sector and occasionally binding borrowing constraints on the side of entrepreneurs, I match the empirical characteristics of the euro area financial sector more closely. Importantly, it also allows me to distinguish between the borrowers' balance sheet channel and the bank balance sheet channel. I use the method of Guerrieri and Iacoviello (2015a) to solve and estimate the non-linear model. Finally, I study whether countercyclical monetary and macroprudential policies could

respectively. As in Borio et al. (1994), I assume that the building to land ratio is roughly 2:1.

be welfare improving, once the observed non-linearities are accounted for. While studies have shown that these policies can be costly in boom times (see e.g. Adrian and Liang, 2014 and Svensson, 2014), this might not necessarily hold true in a non-linear framework.

I find that the output response to a positive shock in unconstrained times is three times smaller than a negative shock during constrained episodes. The MS-VAR also shows that loans fall significantly during constrained periods, but respond little to a positive shock in normal times. Inflation is mostly unaffected by financial shocks and is independent of the state of the economy. The structural model closely matches the stylised facts, which were detected by the MS-VAR and indicates that the asymmetric transmission of financial shocks is mainly due to the borrowers' balance sheet channel. In addition, I find that countercyclical capital buffers can be welfare improving and more effective in increasing the consumption welfare of households than comparable 'leaning-against-the-wind'-type Taylor rules (LATW).

While the links between the financial sector and the real economy have been closely scrutinised in recent years, there are only a few studies that have looked at non-linearities in the macro-financial relationship.

The first part of this paper is closely related to work by Hubrich et al. (2013) and Hartmann et al. (2015). Both papers explore the relationship between financial shocks and the macroeconomy in the euro area, and find evidence in favour of non-linearities in a regime-switching VAR with a financial stress indicator. In addition to using a larger sample period, my paper differs by allowing the switching to take place based upon the different states of the credit cycle, rather than upon the financial stress regimes. Credit conditions were also used in Calza and Sousa (2006) to determine regimes in a threshold VAR. Using a sample that ends in 2002, they find stronger financial spillover effects for credit cycle downturns than upturns. These effects are shown to be more pronounced in the US than in the euro area.

The structural model is closely linked to Guerrieri and Iacoviello (2015a), which however focuses on housing shocks and household borrowing in the US. In my model, the presence of an explicit banking sector, credit supply friction, and capital creates additional feedback loops between the real economy and the financial sector.[3] The asymmetric role of financial frictions are also investigated in Del Negro and Schorfheide (2013) and Lindé et al. (2016). Whereas the former paper evaluates the individual forecast performance of the basic Smets-Wouters model versus the same model augmented with financial frictions, the latter paper estimates a non-linear, regime-switching DSGE model. Both papers find that financial frictions become more important, once the economy has entered a stress state. Relative to the latter paper, I introduce an occasionally binding constraint, which allows me to endogenise the switch between normal and credit constrained times.

---

[3]For an extensive review of the literature on macro-financial linkages in DSGE models, see Gerke et al. (2013).

This chapter is organised as follows. Section 2 empirically analyses whether the macro-financial relationship is asymmetric using a MS-VAR. Section 3 briefly describes a structural model with financial frictions and occasionally binding constraints, the solution and estimation methods, and studie the fit of the model to the euro area data. Section 4 uses the estimated structural model to examine asymmetries in the macro-financial linkages. Section 5 studies the welfare properties of countercyclical macroprudential and monetary policy rules. Section 6 concludes.

2.2 Empirical Model

In this section, I use a Markov-Switching SVAR to investigate whether the transmission of financial shocks is asymmetric. For simplicity, I assume that there are two states of the world: (i) a normal state where households and firms are able to freely borrow and (ii) a credit constrained state in which credit to households and firms is limited, possibly because of binding borrowing constraints.

The VAR includes five variables: output growth, y_t, inflation, π_t, interest rate, i_t, loans to private sector growth, b_t, and asset price growth, q_t. Loans to the private sector capture the credit channel.

All data is monthly and collected from the ECB Statistical Warehouse for the euro area. Industrial production and the Harmonised Index of Consumer Prices (HICP) measure output and inflation, respectively. I use the EONIA (Euro OverNight Index Average) rate as a proxy for interest rates. The EONIA rate is the rate at which banks provide loans to each other for the duration of one day. It is a more useful measure of the interest rate than the main refinancing rate, as it moves closely with the main refinancing rate in normal times, but has the added benefit of also responding to changes in liquidity moves, when unconventional monetary policy measures are implemented. In addition, unlike the main refinancing rate, the EONIA can enter into negative territory, which it does at the end of the sample. The loan growth rate to euro area non-monetary financial institutions measures credit growth in the private sector. The Euro Stoxx 50 represents asset prices. Output, the HICP, loans, and asset prices are reported in annual growth rates and the interest rate in first differences. The sample spans the period from September 1999 until April 2016.

2.2.1 Model Specification and Estimation

The model is estimated using Bayesian methods (see Krolzig, 1997). All coefficients are assumed to be regime-variant. Regime-dependent intercepts, A_{0s}, are important to inspect the average differences depending on the state of the credit cycle, while regime-variant autoregressive coefficients, $A_{i,s}$, can track differences in the transmission channels. I also allow for Markov-Switching in the variance, ε_t, to account for the likely increase in variance of financial variables during the credit constrained state, which could otherwise bias my coefficient estimates. The states are $s_t = \{N, C\}$, where N is a normal state, and C a credit constrained state. To identify the states, I restrict the level of credit growth to be larger in the normal state than in the credit constrained state, i.e. $\frac{A_{o,N}}{1-\sum_{i=1}^{p} A_{i,N}} > \frac{A_{o,C}}{1-\sum_{i=1}^{p} A_{i,C}}$ for the credit growth variable, where p is the number of lags. The transition probabilities between the states are assumed to be constant, so that the model is represented by

$$
y_t = \begin{cases} A_{0N} + \sum_{i=1}^{p} A_{i,N} y_{t-i} + \sum_{N}^{\frac{1}{2}} \varepsilon_t \\[2mm] A_{0C} + \sum_{i=1}^{p} A_{i,C} y_{t-i} + \sum_{C}^{\frac{1}{2}} \varepsilon_t \end{cases}.
\tag{2.1}
$$

To keep the model parsimonious, I use $p = 1$ for the autoregressive annual rates, and a constant in terms of deterministic variables. I estimate the model by employing a 4-step Gibbs sampler procedure, in which I first compute the states and then draw for the transition probabilities, the coefficients, and the variance. The algorithm I use is the following:

1. Use a filter-smoothing algorithm to determine the states $s^l|y, A^{l-1}$ (Frühwirth-Schnatter, 2006).

2. Draw transition probabilities $p^l|s^l$ from a Dirichlet distribution.

3. Draw regime dependent intercepts and constant coefficients $A_s^l|y, s^l, p^l, \sum_s^{l-1}$ from a Normal distribution.

4. Draw regime dependent covariance matrices $\sum_s^l|y, s^l, p^l, A_s^l$ from an Inverse Wishart distribution.

l is the number of sample draws, and y the data. The priors for the parameters are stated in each step of the algorithm. The initial 1000 draws are discarded as burn-in and the remaining chain is thinned by recording only every 25th draw to avoid excessive autocorrelation between the draws, which would otherwise slow down the convergence to the posterior distribution.

I initialise the algorithm by assuming that credit growth is positive in the normal state $a_{0,4}^N > 0$, and the initial transition probability of remaining and switching states is given by 0.9

and 0.1, respectively. This makes the states themselves persistent, and comparable with the results of the structural model. I report the identified states and the first two moments of the variables in the two states in Figure A.1 and Table A.1. The credit constrained state is identified around the year 2000 to 2004, after the dot-com collapse, and then again from 2008 to 2014 during the financial and sovereign debt crises. As expected, the mean of each variable during the constrained state is significantly lower than during the normal state, and the variance for each variable is more than twice as large.

My main interest is to examine whether the credit channel (proxied by loans to the private sector) is weaker and the real economy less affected, when financial markets are booming and credit is expanding, than it would be the case when financial conditions are deteriorating. In other words, I want to examine how the financial sector passes-through positive financial shocks to the real economy in normal times relative to negative financial shocks in credit constrained times.

I identify financial shocks by applying a recursive identification scheme on the contemporaneous coefficient matrix. I divide variables into fast and slow moving, in which asset prices belong to the first group and the macroeconomic variables belong to the second group. The interest rate, as a monetary policy proxy, reacts both to output and inflation contemporaneously. Loans are assumed to be slower than asset prices, since banks' credit conditions need time to adjust. Hence, the order of the variables follows: output, inflation, interest rate, loans, and asset prices. The shock of interest is an unexpected, exogenous shock to asset price growth. The exogeneity assumption holds well, as many of the financial shocks in this sample originated from the outside the euro area (e.g. the dot-com bubble, Financial Crisis in 2008 emerged from the US).

2.2.2   The Results

To examine the dynamics across states, I report the impulse responses and the contribution of asset price growth shocks to the forecast error variance of output. I compare the responses of a positive shock in a normal state to a negative shock in a constrained state. The reason for looking at these specific shocks is that financial booms usually occur, when credit is easily available and the financial sector is hit by positive surprises, while financial busts coincide with a tightening of credit supply and negative, unexpected shocks to financial markets.

Because the model is non-linear, impulse responses are constructed using conditional forecasts. I apply the methodology of Koop et al. (1996) in which the responses are computed by subtracting the forecast that is conditional only on the history of the model, $\mathcal{F}_{t-1}$, from the forecast which

is also conditional on the sign of the shock, ϵ_t, and the state of the model,

$$\Phi_y^+(\mathcal{F}_{t-1}, \epsilon_t, s_t, \tau) = E(y_{t+\tau}|\mathcal{F}_{t-1}, \epsilon_t > 0, s_t = N) - E(y_{t+\tau}|\mathcal{F}_{t-1}),$$
$$\Phi_y^-(\mathcal{F}_{t-1}, \epsilon_t, s_t, \tau) = E(y_{t+\tau}|\mathcal{F}_{t-1}, \epsilon_t < 0, s_t = C) - E(y_{t+\tau}|\mathcal{F}_{t-1}).$$

This methodology is particularly suited to compute impulse responses in my case, as they allow for non-linear effects due to the sign or the magnitude of the shock. I calculate conditional forecasts 50 times per draw and then average the impulse response, Φ, over the repetitions and compute the credible set using the 16th and 84th percentile of the Monte Carlo draws. Figure 2.2 shows the results for a normalised financial shock that lasts for one period.

Most variables move as expected. Output, inflation, the interest rate, loans and asset prices all rise following a positive financial shock (in blue), and fall following a negative financial shock (in red).

Figure 2.2: Impulse Responses to a Financial Shock
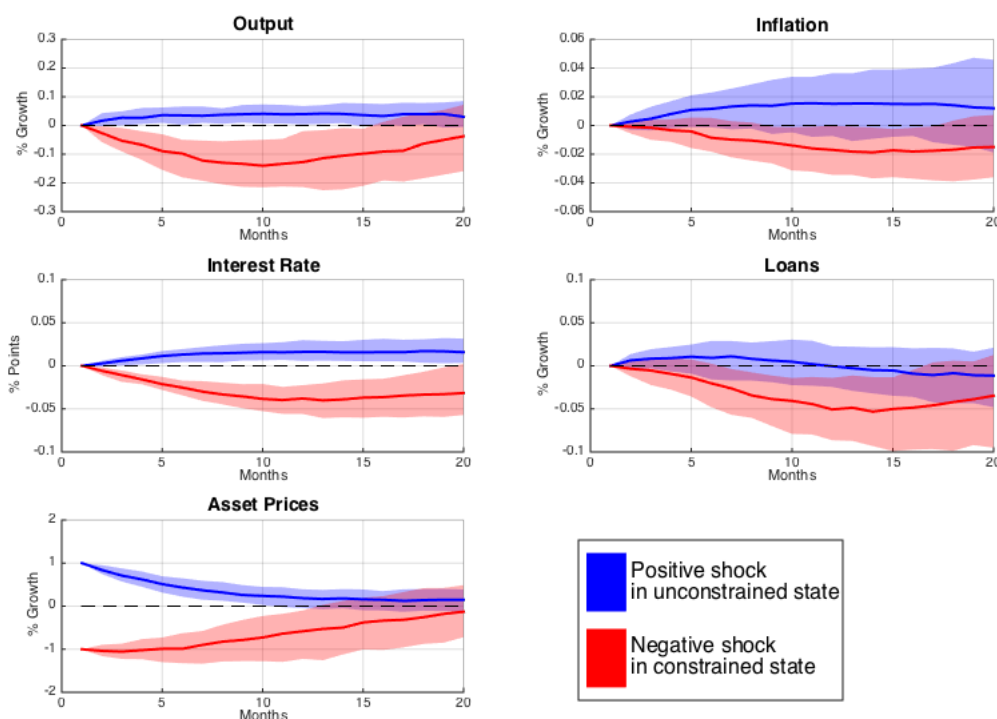
Note: The shaded regions report point-wise 68% credible sets. The financial shock is normalised to 1% of asset price growth and imposed for one period.

The figure shows clear asymmetry both in the financial market and in the macroeconomic responses. For example, the negative shock on asset prices in credit constrained times persists more than the equivalent positive shock during normal times. This asymmetry is also evident in

the responses of loans. When credit conditions are slack, a positive shock does little to increase loan growth. However, when credit is already restricted, a negative shock causes loans to fall significantly and persistently. Thus, it seems that the credit channel, represented here by the dynamics of loans, only operates significantly in the credit constrained scenario for the negative shock.

The macroeconomic responses show a similar pattern. Output falls more than three times as much as it rises, indicating a very strong and significant asymmetric behaviour of the macro-financial linkages. Inflation dynamics do not seem to differ significantly in the two scenarios, and are affected by a large degree of uncertainty in the responses. The effect on the interest rate is significantly negative and persistent in the negative scenario. In the normal state, the interest rate rises, although by a smaller amount.

To sum up, there seems to be evidence of asymmetries in the responses of financial markets to positive and negative shocks, and in the transmission to the real economy, making financial booms smaller than financial busts.

The weaker role of the financial sector during normal times is confirmed by looking at the forecast error variance decomposition. Table 2.1 reports the variance decomposition in the normal state and the constrained state (in italics) for output growth. The most striking difference is between the medium-term effects of financial shocks on output. In the normal state, financial shocks only explain roughly 10% of output growth over the 1-5 year horizon. However, in the credit constrained state, financial shocks explain almost one third of output growth variation highlighting again the asymmetry of macro-financial linkages.

Table 2.1: Forecast Error Variance Decomposition in normal (left) and constrained (right) state for output growth

Periods	y_t (Demand)		π_t (Supply)		i_t (Monetary)		b_t (Loans)		q_t (Financial)	
1 month	100	*100*	0	*0*	0	*0*	0	*0*	0	*0*
2 months	96.69	*99.05*	0.80	*0.04*	1.41	*0.06*	0.23	*0.07*	0.60	*0.70*
1 year	52.84	*61.50*	21.15	*1.35*	7.35	*2.27*	2.92	*1.95*	11.05	*30.62*
2 years	28.63	*51.17*	42.52	*3.04*	6.33	*2.38*	3.88	*5.89*	11.77	*32.13*
5 years	15.53	*49.32*	48.83	*4.72*	6.92	*3.34*	5.56	*7.18*	10.34	*31.92*

Note: The left hand side number of the column represents the variance decomposition in the normal state, the right hand side number in italics displays the results for the constrained state. The values are in percentages and represent the median draw of the Gibbs sampler.

Limitations: Disentangling the Credit Channel As the VAR only includes loans and thus only allows us to look at the aggregate movement of credit, it is difficult to understand

the exact transmission mechanism in the data. The credit channel can be disentangled into two components (a) the borrowers' balance sheet channel, and (b) the bank balance sheet channel. The borrowers' balance sheet channel typically arises due to the asymmetric information problem and the unenforceability of contracts between lenders and borrowers which gives rise to an external finance premium (Bernanke et al., 1999) and collateral requirements (Kiyotaki and Moore, 1997). In contrast, the bank balance sheet channel is related to banks' inability to buffer their loan supply in times of adverse shocks and dependence of borrowers on these loans.

Figure 2.3: Credit Indicator
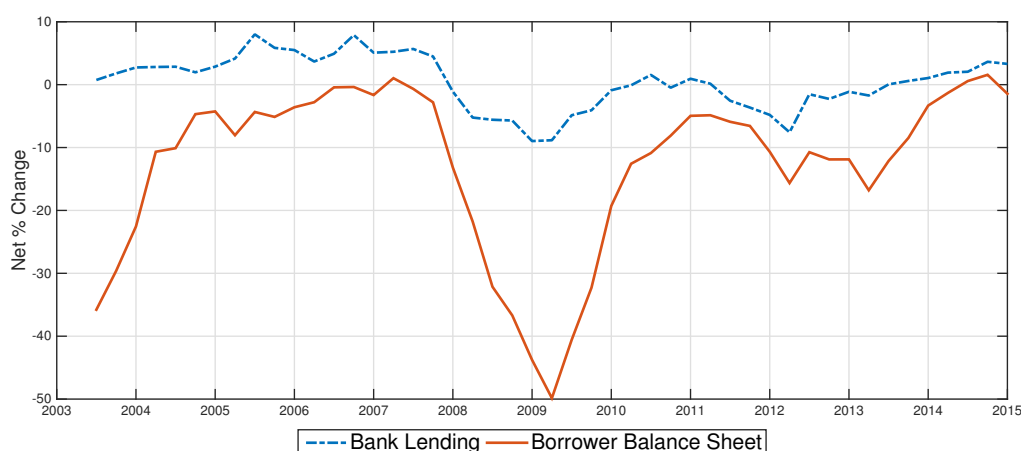
Source: Ciccarelli et al. (2014) and author's own calculations based on the ECB's quarterly Bank Lending Survey of Professional Forecasters. The *y*-axis represents the difference between the net percentage of forecasters responding that conditions with regard to supply lending (bank lending) and borrower's quality (balance sheet) have tightened to the ones who respond that credit conditions have eased. The blue, dotted line represents the bank lending indicator, and the red, solid line indicates the balance sheet indicator.

For policy purposes, it is useful to understand which of these channels plays a greater role in the transmission of financial shocks to the real economy. Survey data can provide an initial clue about the relative importance of the two channels over time. I use the quarterly Bank Lending Survey of the ECB to split the qualitative responses of financial institutions to changes in their loan supply into answers regarding bank lending versus balance sheet conditions. I then construct two indicators by measuring the difference between the net percentage of forecasters that have responded that conditions regarding lending supply (bank lending) and borrowers' quality (borrowers' balance sheet) have tightened versus eased as in Ciccarelli et al. (2014). Figure 2.3 shows the two indicators. While both indicators run relatively in parallel during normal times, the borrowers' balance sheet indicator falls faster and is clearly more negative during more credit constrained episodes than the bank lending indicator. As this corresponds

to the asymmetric response of loans in Figure 2.2, presumably, the borrowers' balance sheet seems to play a greater role for the observed asymmetry in the macro-financial transmission. However, it should be noted that due to the self-reporting by banks, banks are more likely to over-emphasise the borrower channel and potentially skew the survey results in their favour. The structural model I use in the next section provides firmer evidence that it is indeed the borrowers' balance sheet channel which is more important.

2.3   DSGE Model

To understand the asymmetric transmission of financial shocks in financial markets and the real economy, I use a structural model. The model has two main features: (i) an occasionally binding borrowing constraint to allow for different states of the world, and (ii) a detailed financial sector that allows me to distinguish between the borrower and the bank balance sheet channel. The model is an extension of the work by Gambacorta and Signoretti (2014), which in turn builds upon the banking model of Gerali et al. (2010). The financial sector in the model has two main characteristics: (i) a target leverage ratio and quadratic adjustment costs for banks, which gives rise to credit supply frictions, and (ii) a borrowing constraint for entrepreneurs which requires them to provide capital as a collateral, and thus creates credit demand frictions. The borrowing constraint is the crucial link between the financial sector and the real economy, as it introduces the 'financial accelerator' mechanism into the model: when a negative financial shock occurs, capital income falls, so that capital is less worth as a collateral. As a consequence, borrowers have to reduce their borrowing which causes investment and output to fall.

The model I use is to a large extent similar to Gambacorta and Signoretti (2014) except for two key changes. Firstly, I allow for the borrowing constraint of the entrepreneurs to be occasionally binding. As in the empirical model, there are two states of the world: one state in which the borrowing constraint is binding and credit conditions are tight, and another state in which the constraint is slack and agents can borrow unlimitedly.

Secondly, I consider a larger number of shocks to analyse the effects of disturbances in the financial sector and estimate the model. In addition to a standard technology and a cost-push shock, I introduce a monetary policy shock and two financial shocks: (i) a shock to the loan-to-value (LTV) ratio of entrepreneurs, and (ii) a net worth (default) shock. A shock to the LTV ratio is often described as a credit squeeze or risk perception shock. A positive shock (an increase in the loan-to-value ratio) allows entrepreneurs to borrow more for the same amount of collateral and vice versa. A net worth shock instead redistributes wealth between borrowers and lenders. The shock enters the budget constraint of both entrepreneurs and banks. Both of

these shocks are modelled to be exogenous from conditions in the Euro Area to capture the idea that they represent global shocks (originating e.g. from the US) which however still affect the balance sheet and risk perceptions of European firms and banks.

2.3.1 Description of the Model

The model contains several agents: patient households, impatient entrepreneurs, retailers, wholesale and retail banks, capital goods producers, and a central bank. There is one type of households, which are patient and provide labour to impatient entrepreneurs. The entrepreneurs produce intermediate goods that are sold to retailers competitively. These retailers differentiate the intermediate goods and sell them with a mark-up to households, who also own the retailers and keep their profits. Banks have two branches: a wholesale and a retail branch. Wholesale banks take deposits from households and operate under perfect competition. Retail banks are monopolistic and give out loans to entrepreneurs for a mark-up. In addition, they take and monitor collateral from the entrepreneurs given an LTV ratio. There is also a central bank that sets the policy rate and determines the capital-asset ratio for banks, which is fixed. Finally, in order to derive a price for capital, there are capital producers who buy undepreciated capital from entrepreneurs and re-sell it for a new price back to entrepreneurs taking into account quadratic adjustment costs. The borrowers' balance sheet channel is captured by the borrowing constraint of the entrepreneurs and affects credit conditions via the net worth of the borrower. The bank balance sheet channel describes credit supply on the lenders' side via the leverage ratio that accounts for both bank lending, as well as bank capital.

Households

Households maximise

$$\max_{c_t^P, l_t, d_t} \mathbb{E}_0 \sum_{t=0}^{\infty} \beta_P \left[\log(c_t^P) - \frac{l_t^{1+\phi}}{1+\phi} \right], \tag{2.2}$$

where c_t^P is consumption, l_t is labour supply, β_P is the patient discount factor. They deposit savings at wholesale banks, for which they receive a risk-free return. They also own retail firms, which are monopolistic and generate a profit, so that they are subject to the budget constraint

$$c_t^P + d_t \leq w_t l_t + (1 + r_{t-1}^{ib}) d_{t-1} + J_t^R, \tag{2.3}$$

61

where d_t are bank deposits, w_t is the real wage, and r_t^{ib} is the short term policy rate. J_t^R are the profits of the retail sector and ϕ is the elasticity of labour. The first-order condition yields the standard consumption Euler equation

$$\frac{1}{c_t^P} = \mathbb{E}_t \frac{\beta_P(1 + r_t^{ib})}{c_{t+1}^P}. \tag{2.4}$$

Households also provide labour to the entrepreneurs for the production of intermediate goods, which follows the usual labour supply schedule

$$l_t^\phi = \frac{w_t}{c_t^P}. \tag{2.5}$$

Entrepreneurs

Entrepreneurs need to borrow from banks and hold capital, but also produce goods, employ households and consume. They form the link between the real economy and the banking sector and are thus important for generating a feedback loop between the financial and macroeconomic side of the model. The entrepreneurs maximise

$$\max_{c_t^E, l_t^d, b_t^E} \mathbb{E}_0 \sum_{t=0}^{\infty} \beta_E \log(c_t^E). \tag{2.6}$$

with respect to their consumption, c_t^E, labour demand, l_t^d, and bank loans, b_t^E. The optimisation problem is subject to a budget constraint, which is

$$c_t^E + (1 + r_{t-1}^b)b_{t-1}^E + w_t l_t^d + q_t^k k_t^E \leq \frac{y_t^E}{x_t} + b_t^E + q_t^k(1 - \delta^k)k_{t-1}^E + \epsilon_t^b, \tag{2.7}$$

where r_t^b is the interest rate on bank loans, k_t^E is the entrepreneurs stock of capital, q_t^k is the price of capital, and y_t^E is the intermediate output produced by entrepreneurs. $\frac{1}{x_t} = \frac{P_t^W}{P_t}$ is the relative competitive price of the intermediate good produced by the entrepreneur, and δ^k is the depreciation rate of capital. The net worth shock, ϵ_t^B, enters the budget constraint of the

entrepreneurs by altering their income. It follows an AR(1) process with an i.i.d shock ε_t^b and a variance σ^b. The entrepreneurs are also subject to an occasionally binding borrowing constraint

$$b_t^E \leq \frac{m_t^E q_{t+1}^k k_t^E (1 - \delta^k)}{1 + r_t^b}, \tag{2.8}$$

where m_t^E is the stochastic LTV ratio which follows an AR(1) process with an i.i.d shock ε_t^{me} and variance σ^{me}. A high LTV ratio implies that banks can lend more for the same amount of collateral and vice versa. The borrowing constraint determines how much entrepreneurs can borrow from banks. For small enough shocks, $\beta_P > \beta_E$ ensures that the borrowing constraint is binding and credit is constrained in the economy. However, with larger shocks the constraint becomes slack.

Entrepreneurs do not work but use capital and labour in the production of intermediate goods. As in Kiyotaki and Moore (1997), capital has many functions in this model and thus establishes another important feedback mechanism between the real economy and the financial sector. Capital is used (i) in the production of intermediate goods, (ii) as a collateral for the entrepreneurs, and (iii) as a source of funds for investment. The production function for intermediate goods follows a standard Cobb-Douglas form

$$y_t^E = A_t^e (k_t^E)^\alpha (l_t^d)^{(\alpha-1)}, \tag{2.9}$$

where α denotes the capital share, and A_t^e technology. A_t^e is stochastic and follows an AR(1) process with an i.i.d. technology shock ε_t^a with variance σ^a. Entrepreneurs operate under perfect competition. Their optimal consumption Euler equation is

$$\frac{1}{c_t^E} - \lambda_t^E = \mathbb{E}_t \frac{\beta_E (1 + r_t^b)}{c_{t+1}^E}. \tag{2.10}$$

This is similar to the households' Euler equation but differs by the Lagrange multiplier on the borrowing constraint, λ_t^E, which represents the marginal value of one unit of additional borrowing. Another difference is that entrepreneurs, unlike households, discount at a higher rate and face the higher bank loan rate, r_t^b, rather than the risk-free rate, r_t^{ib}. The labour demand schedule is

$$\frac{(1-\alpha)y_t^E}{l_t^d x_t} = w_t. \tag{2.11}$$

The investment Euler equation equalises the marginal benefit with the marginal cost of saving capital. As capital also serves as collateral, the equation also depends on the Lagrange multiplier of the borrowing constraint and the LTV ratio. It follows

$$\frac{\lambda_t^E m_t^E q_{t+1}^k (1-\delta^k)}{1+r_t^b} + \frac{\beta_E}{c_{t+1}^E}\left[q_{t+1}^k(1-\delta^k) + r_{t+1}^k\right] = \frac{q_t^k}{c_t^E}, \tag{2.12}$$

where r_t^k is the return to capital which is defined by the marginal product of capital as

$$r_t^k \equiv \alpha\frac{A_t^E(k_t^E)^{(\alpha-1)}(l_t^d)^{(1-\alpha)}}{x_t}. \tag{2.13}$$

Banks

The banking sector is divided into a perfectly competitive wholesale and a monopolistic retail sector. The wholesale sector maximises bank profits by optimising the net interest margin between the loan and deposit rate subject to the quadratic adjustment costs of deviating from a target leverage ratio ν

$$\max_{b_t, d_t} R_t^b b_t - r_t^{ib} d_t - \varepsilon_t^b - \frac{\theta}{2}\left(\frac{K_t^b}{b_t} - \nu\right)^2 K_t^b. \tag{2.14}$$

To simplify, I set the deposit rate equal to the risk-free rate set by the central bank. Wholesale banks are subject to a balance sheet constraint that can also be interpreted as a capital adequacy constraint. Loans have to be backed up by sufficient bank capital and deposits at the beginning of the period before any losses from the net worth shock have been realised

$$b_t - \mathbb{E}_t[\epsilon_{t+1}^b] = d_t + K_t^b. \tag{2.15}$$

Leverage generates a feedback between the interest rate spread and the real economy. ε_t^b is the same net worth shock as in (2.7) that transfers wealth between entrepreneurs and banks. It is modelled as in Iacoviello (2015).

K_t^b is the banks' capital and θ is the parameter for capital adjustment cost for banks. Combining (2.14) and (2.15), the first-order condition of the wholesale bank is

$$R_t^b = r_t^{ib} - \theta \left(\frac{K_t^b}{b_t} - \nu \right) \left[\frac{(b_t - d_t)^2 - b_t \mathbb{E}_t[\epsilon_{t+1}^b] + \mathbb{E}_t[\epsilon_{t+1}^b]^2}{b_t^2} \right]. \qquad (2.16)$$

The retail bank on the other hand, repackages the wholesale loans and charges a mark-up, $\overline{\mu}^b$, on the wholesale loan rate, so that the retail loan rate becomes

$$r_t^b = R_t^b + \overline{\mu}^b. \qquad (2.17)$$

The retail banks have market power, which helps them to adjust their lending in response to shocks or cycles. Another crucial determinant for the feedback loop between the banking sector and the real economy is bank capital. Bank capital accrues from past capital and retained earnings, J_t^B,

$$K_t^b = K_{t-1}^b(1 - \delta^b) + J_{t-1}^B. \qquad (2.18)$$

Since it is procyclical, bank capital worsens, when output declines due to decreasing banks' profits. The latter is defined as the sum of both the retail and wholesale sector profits on loans and deposits, respectively, and depends on the condition of the macroeconomy

$$J_t^B = r_t^b B_t - r_t^{ib} D_t - \frac{\theta}{2} \left(\frac{K_t^b}{b_t} - \nu \right)^2 K_t^b. \qquad (2.19)$$

Retailers and Capital Good Producers

The monopolistic retailers are differentiating the intermediate goods produced by the entrepreneurs at no cost and sell them with a mark-up, x_t. However, retailers face quadratic price

adjustment cost, which causes prices to be sticky. The parameter κ_P represents the parameter for price stickiness.

The first order condition of the retailers generates the classic New Keynesian Philip's curve

$$1 = \frac{mk^y}{mk^y - 1} + \frac{mk^y}{mk^y - 1} mc_t^E - \kappa_P(\pi_t - 1)\pi_t + \beta_P \mathbb{E}_t \left[\frac{c_t^P}{c_{t+1}^P} \kappa_P(\pi_{t+1} - 1)\pi_{t+1} \frac{Y_{t+1}}{Y_t} \right], \qquad (2.20)$$

where the marginal cost are, $mc_t^E \equiv \frac{1}{x_t}$. The firm's mark-up, mk^y, is stochastic and follows an AR(1) process with the autocorrelation coefficient ρ_{mk} and an i.i.d. mark-up shock, ε_t^{mk}, with variance σ_{mk} .

Capital good producers are perfectly competitive and their main task is to transform the old, undepreciated capital from entrepreneurs to new capital without any additional costs. They then resell the new capital to the entrepreneurs in the next period at price P_t^k, so that the real price of capital is $q_t^k \equiv \frac{P_t^k}{P_t}$. In addition, capital producers 'invest' in the final goods bought from retailers, which are not consumed by household, and also transform these into new capital. The final goods to capital transformation is subject to quadratic adjustment costs that are parameterised by κ_i, the investment adjustment cost parameter. The first-order condition of capital good producers is

$$1 = q_t^k \left[1 - \frac{\kappa_i}{2} \left(\frac{I_t}{I_{t-1}} - 1 \right)^2 - \kappa_i \left(\frac{I_t}{I_{t-1}} - 1 \right) \frac{I_t}{I_{t-1}} \right] + \beta_E \mathbb{E}_t \left[\frac{c_t^E}{c_{t+1}^E} q_{t+1}^k \kappa_i \left(\frac{I_{t+1}}{I_t} - 1 \right) \left(\frac{I_{t+1}}{I_t} \right)^2 \right],$$
$$(2.21)$$

with capital evolving according to

$$K_t = (1 - \delta^k) K_{t-1} + \left[1 - \frac{\kappa_i}{2} \left(\frac{I_t}{I_{t-1}} - 1 \right)^2 \right] I_t. \qquad (2.22)$$

Monetary Policy

Monetary policy follows a standard Taylor rule, so that the policy rate is set according to

$$1 + r_t^{ib} = (1 + r^{ib})^{(1-\rho_{ib})} (1 + r_{t-1}^{ib})^{\rho_{ib}} \left(\frac{\pi_t}{\pi} \right)^{\phi_\pi(1-\rho_{ib})} \left(\frac{y_t}{y} \right)^{\phi_y(1-\rho_{ib})} (1 + \varepsilon_t^r). \qquad (2.23)$$

where ρ_{ib} is the autoregressive coefficient, and ϕ_π and ϕ_y are the monetary policy parameter. ε_t^r is an i.i.d monetary policy shock with variance σ^r. The monetary policy authority is also responsible for setting a target leverage ratio for banks to avoid an over-leveraging of the economy similar to the real world Basel capital ratios.

Market Clearing and Aggregation

Goods and labour markets clear. The resource constraint of the economy is

$$Y_t = C_t + I_t, \tag{2.24}$$

as it is a closed economy with no government intervention.

2.3.2 Solving and Estimating the Model

Because the entrepreneurs' borrowing constraint is occasionally binding, I need to apply non-standard solution and estimation methods. Disregarding non-linearities in the borrowing constraint, as is often done in the literature, would lead to a symmetric transmission mechanism and symmetric feedback from financial variables over the credit cycle. If we were to assume that borrowing constraints were always binding, we would also need to believe that the discount factor of impatient agents is higher than the discount factor of patient agents, and that shocks are so small, that the economy does not move too far from its steady state level. This assumption is often violated in practise, since financial shocks can wipe out a large percentage of asset prices in a very short time.

Solution Method

I use the method of Guerrieri and Iacoviello (2015b) which uses a piece-wise linear approach to approximate the global solution. The idea behind the method is to treat the binding and non-binding scenario as two separate regimes for which a first-order approximation can be used. One of the requirements for this method to work accurately is that the system is always expected to return to the initial regime in finite time. As we have seen with in Section 2, this requirement is not particularly restrictive, as state switching between the constrained and unconstrained credit regimes is relatively common in the data. Also, it is consistent with the notion that credit constrained periods are expected to proceed times of credit expansions. While the method is

unable to capture any anticipatory effects, it has some key advantages over fully fledged global methods: It is computationally fast and can be applied to non-linear models with a large number of state variables, for which global methods would otherwise be infeasible. Moreover, Guerrieri and Iacoviello (2015b) show that the difference between the piecewise-linear solution method and a global solution method is quantitatively small in selected examples and that the solutions are very accurate for models with occasionally binding constraints.

Data

To estimate the model, I use five observable variables, which are related to $[y_t^{obs}, \pi_t^{obs}, r_t^{ib,obs}, b_t^{obs}, q_t^{obs}]$ of the model. The data is reported quarterly from 1999Q1 until 2016Q2. I use euro area GDP for Y_t, inflation based on the HICP for π_t, the EONIA rate for r_t^{ib}, an index for the notional stock of loans to the private sector for b_t, and the EURO STOXX 50 equity price index for asset prices, q_t. The data is detrended using a one-sided Hedrick-Prescott filter, except for the interest rate and inflation, which are demeaned and divided by 400% to express quarterly rates.[4] The smoothing parameter is set to $\lambda = 1600$ to compute the quarterly business cycle component.

Calibration and Priors

Not all parameters of the model are estimated. Those that are calibrated are reported in Table A.2. It is important to properly calibrate the two discount factors, as they are crucial for the dynamics of the model with an occasionally binding borrowing constraint. The more impatient the entrepreneurs are relative to the patient households (the smaller β_E), the more they discount future consumption and value an additional unit of borrowing, thus the larger the Lagrange multiplier on borrowing λ_t^E. The increase in the Lagrange multiplier in turn causes the borrowing constraint to become more binding and makes it less likely for it to become slack unless very large shocks occur. For the impatient discount factor, I use a value of $\beta_E = 0.975$ based on Iacoviello (2005) and a slightly higher patient discount factor of $\beta_p = 0.9943$ based on Gerali et al. (2010). The latter is computed by matching the mean, monthly deposit rate on M2 in the euro area.

I calibrate the target capital-to-loans ratio, $\nu = 0.09$ in line with the Basel Accords. I follow Gerali et al. (2010) for the entrepreneur's steady state LTV ratio, $m_{ss}^E = 0.35$ which is in line with the values for non-financial corporations in the euro area (firms' LTV ratio is significantly lower than households), and use their estimated value for the bank capital adjustment cost of $\theta = 11$. The other calibrated parameters for labour elasticity, the steady state values for marginal costs

---

[4]The one-sided filter has the advantage that it is strictly backward-looking, so that only past information is used to separate the trend and cyclical component without changing the timing of information and of the shock.

and mark-up, the capital share, and the deprecation rate of capital are set to standard values in the literature for the euro area (see e.g. Gambacorta and Signoretti, 2014). To model the macro-financial transmission channels as close as possible to the data, I estimate the parameters for price stickiness, the investment adjustment cost, the monetary policy parameters, and the shock parameters.

Estimation

For the estimation, I use relatively non-informative prior values for the chosen parameters as reported in Table 2.2. To construct the likelihood I follow Guerrieri and Iacoviello (2015a) and use the piecewise-linear solution from the previous step. The Bayesian estimation follows a random walk Metropolis-Hastings algorithm in which the likelihood is computed by solving for the errors recursively. The main advantage of this method is that it is computationally faster and more feasible for a larger state space than (i) the Kalman filter approach or (ii) particle filter methods.

The first step is to recursively solve for the errors, $\varepsilon_t = \{\varepsilon_t^a, \varepsilon_t^{mk}, \varepsilon_t^r, \varepsilon_t^{me}, \varepsilon_t^b\}$, which are drawn drawn from a multivariate Normal distribution, given the past unobserved components, X_{t-1} and the current realisation of Y_t. Due to the unobserved components, the filter requires initial values for X_0 that represent the steady state values of the model. For that purpose, I use the first ten observations. Once the filtered errors are computed, the next step is to evaluate the log-likelihood

$$\log(f(Y^T)) = -\frac{T}{2}\log(\det(\Sigma)) - \frac{1}{2}\sum_{t=1}^{T}\varepsilon_t'(\Sigma^{-1})\varepsilon_t - \sum_{t=1}^{T}\log(|\det\frac{\partial\varepsilon_t}{\partial Y_t}|). \qquad (2.25)$$

I can use a short-cut in the computation of the Jacobian matrix, $\frac{\partial\varepsilon_t}{\partial Y_t}$. From the piecewise-linear solution, we implicitly get $\frac{\partial\varepsilon_t}{\partial Y_t} = (\mathbf{H}_t\mathbf{Q}(X_{t-1},\varepsilon_t))^{-1}$ and the local linearity of the solution guarantees the invertibility of the Jacobian matrix during the implicit differentiation step. By combining prior information with the likelihood and maximising it using a random walk Metropolis-Hastings algorithm, I get the posterior parameter estimates.

The advantages of this method are two-fold: On the one hand, the method only requires an initial guess whether the constraint in the model is binding or not, so that convergence is easier achieved than having to guess the path of all endogenous variables. On the other hand, the algorithm is comparatively fast, since the Jacobian matrix that is needed to compute the likelihood is already provided as a by-product of the solution method.

I restrict the choice of parameters for estimation to the parameter for price stickiness, κ_P, investment adjustment cost, κ_i, the monetary policy parameters, ϕ_π, ϕ_y, the autoregressive

coefficients, $\rho_A, \rho_{ib}, \rho_{mk}, \rho_{me}, \rho_B$, and the five standard errors of the shocks, $\sigma_A, \sigma_r, \sigma_{mk}, \sigma_{me}, \sigma_B$. In particular κ_i is important to estimate rather than calibrate, as it determines the feedback loop between asset prices and output. As can be seen from Eq. (2.21), the smaller κ_i is, the more responsive are capital good producers to changes in asset prices. Previous calibration values of this parameter are very imprecise and diverge by a factor of 100 (Gambacorta and Signoretti, 2014), so that estimation can provide valuable information. To improve the efficiency of the algorithm, I estimate the model with a strictly binding borrowing constraint using standard Bayesian methods first and use these values as starting values for the algorithm. The results are reported in Table 2.2.

Table 2.2: Estimated Parameters

Parameters	Description	Prior Mean	Posterior Mean	Posterior std	Prior shape	Prior std
κ_p	Price stickiness	20.00	85.9940	0.0056	Gamma	10.00
κ_i	Investment adj. cost	5.00	11.2019	0.0039	Gamma	2.50
ϕ_π	Taylor rule on π	2.00	6.0229	0.0004	Gamma	1.00
ϕ_y	Taylor rule on y	0.10	0.1905	0.0018	Normal	0.15
AR Coefficients						
ρ_A	Technology	0.80	0.9896	0.0006	Beta	0.10
ρ_{mk}	Mark-up	0.80	0.8359	0.0007	Beta	0.10
ρ_{ib}	Taylor rule	0.75	0.6082	0.0008	Beta	0.10
ρ_{me}	LTV ratio	0.80	0.8164	0.0009	Beta	0.10
ρ_B	Net worth	0.80	0.9167	0.0005	Beta	0.10
Standard Errors						
σ_A	Technology	0.01	0.0157	0.0003	Inv.Gamma	0.50
σ_{mk}	Mark-up	0.01	0.0646	0.0005	Inv.Gamma	0.50
σ_r	Taylor rule	0.01	0.0248	0.0010	Inv.Gamma	0.50
σ_{me}	LTV ratio	0.01	0.0225	0.0007	Inv.Gamma	0.50
σ_B	Net worth	0.01	0.0198	0.0001	Inv.Gamma	0.50

Note: The posterior statistics are based on 50 000 draws from the random walk Metropolis-Hastings algorithm. Starting values were chosen based on the estimated parameters of the model with a permanently binding borrowing constraint. The first 50% of draws are discarded as burn-in.

The parameters seem reasonably well identified and mostly driven by the likelihood component of the posterior distribution. The parameter for investment adjustment cost is similar to what has been found in Gerali et al. (2010) ($\kappa_i = 10.26$). However, the price stickiness parameter is notably larger than in the previous literature. One explanation for the high κ_p is the lack of

wage stickiness in the model, so that κ_p is soaking up the additional stickiness that is present in the data. Since I use the EONIA rate as the observable interest rate, the Taylor parameter on inflation, ϕ_π, reacts more strongly to movement in prices. Overall, the estimates of the standard parameter are in line with what is known in the literature. In addition, I can now also provide a more precise value of the investment adjustment cost parameter that is crucial in determining macro-financial spillovers.

2.3.3 Validation

To assess the theoretical model, I evaluate its ability to (i) capture asymmetries, and (ii) reproduce the macro-financial transmission described in Section 2.

For the asymmetries, I compare how well the DSGE model manages to identify the credit constrained and unconstrained state. Figure A.1 reports the probability of being in the credit constrained state both in the MS-VAR and in the DSGE model. The identified states in both models are almost identical. Both models identify an unconstrained state approximately between 2004 and 2008 and then again for a period starting in 2014. A credit constrained episode is identified from 2000 to 2004, from 2008 to 2014 in the period of the financial and sovereign debt crises, and in the last few periods of the sample. It appears that the regimes identified by the MS-VAR proceeds the states identified in the model by one or two months and are marginally more persistent for the unconstrained state. Overall, the model performs well along this dimension.

For the macro-financial transmission, I compare the monthly VAR impulse responses with the VAR impulse responses based on simulated data from my model. As the model is estimated using quarterly data, I need to re-calibrate the time-varying parameters to a monthly frequency before simulating the data.[5] I draw errors for the five shocks from a normal distribution with zero mean and the estimated standard deviation of the shocks. I then simulate the observable variables of the model, $[y_t^{obs}, \pi_t^{obs}, r_t^{ib,obs}, b_t^{obs}, q_t^{obs}]$, 100 times and feed the averaged data into the same MS-VAR algorithm as in Section 2. Figure A.2 reports the results. The model performs well in matching the response of output, asset prices, and loans. The credible sets of the responses with the simulated data fully include the responses of the model with the real data. The only dimension for which the model seems to be unsuccessful is in replicating the response of inflation and as a consequence interest rates: both are insignificant with the simulated data. Note however that this was also the case for the empirical responses of the annual inflation and given how

---

[5]The time-varying parameters in the model are the discount factors, the AR coefficients of the error processes, the depreciation rate, and the price and investment adjustment costs. To convert these parameters to a monthly frequency, I take the discount rates and AR coefficients to the power of one third, divide the deprecation rate by three and multiply the adjustment costs times three (Pfeifer, 2013).

quantitatively small the responses are, this failure is of little consequence for the macro-financial transmission.

Overall, the results of the DSGE model are largely consistent with the empirical results of the MS-VAR, and both asymmetries, as well as macro-financial transmission are well accounted for.

2.4   The Transmission of Financial Shocks

Using the estimated model, I study the transmission properties of two financial shocks: an LTV ratio shock, ε_t^{me} and a net worth shock, ε_t^b. Both shocks affect the entrepreneurs' ability to borrow. However, they differ significantly in the way they impact loans. The LTV shock affects the supply of loans that banks can give to entrepreneurs via the LTV ratio, m_t^E, as seen in (2.8). Instead, the net worth shock affects the demand and supply of loans via the budget constraints of both entrepreneurs and banks.

The advantage of using the model is in the ability to dissect the credit channel into its two components: the borrower and the bank balance sheet channels. The bank balance sheet channel works through the leverage ratio of banks, $lev_t = \frac{K_t^b}{b_t}$. The balance sheet channel functions through the net worth of entrepreneurs,

$$NW_t = q_t^k(1 - \delta^k)K_{t-1} - (1 + r_{t-1}^b)B_{t-1} + \alpha \frac{Y_t}{x_t}. \tag{2.26}$$

The question is which of these channels is dominant in producing asymmetries between the financial system and the real economy in different states.

2.4.1   LTV Ratio Shock

Figure 2.4 shows the response of the model to a one standard deviation shock to the entrepreneurs' LTV ratio. A positive shock (with a slack borrowing constraint) is in blue, and a negative shock (with a binding borrowing constraint) is the dotted, red line. The left column reports the responses of the macroeconomic variables, output, Y_t, consumption, C_t, and the Lagrange multiplier on the borrowing constraint, λ_t^E, while the right column represents the responses of the financial sector. In particular, the general response of loans, b_t, is further broken up into (i) the response of the leverage ratio of banks, lev_t, and (ii) the response of the net worth of entrepreneurs, NW_t.

A positive shock to the LTV ratio causes the borrowing constraint in (2.8) to become slack, as entrepreneurs can borrow more for less collateral. As banks can now supply more loans, total

loans increase. The ability to borrow more for less capital leads to an increase in the entrepreneurs' net worth. Also, since banks do not back up the additional loans with an equivalent amount of bank capital, their leverage ratio decreases. On the macroeconomic side, current consumption and production increase. Entrepreneurs are able to consume more, and have more capital to invest. The additional consumption drives up the production of intermediate goods, the demand for labour, and, in turn, consumption and employment of households increase. Overall, total consumption and output in the economy rise.

The opposite holds true for a negative LTV shock: with entrepreneurs having to provide more collateral for the same amount of loans, an additional unit of borrowing becomes more expansive and loans decrease, leading to the opposite reaction and a fall in the macroeconomic variables.

Figure 2.4: Responses to an LTV Financial Shock
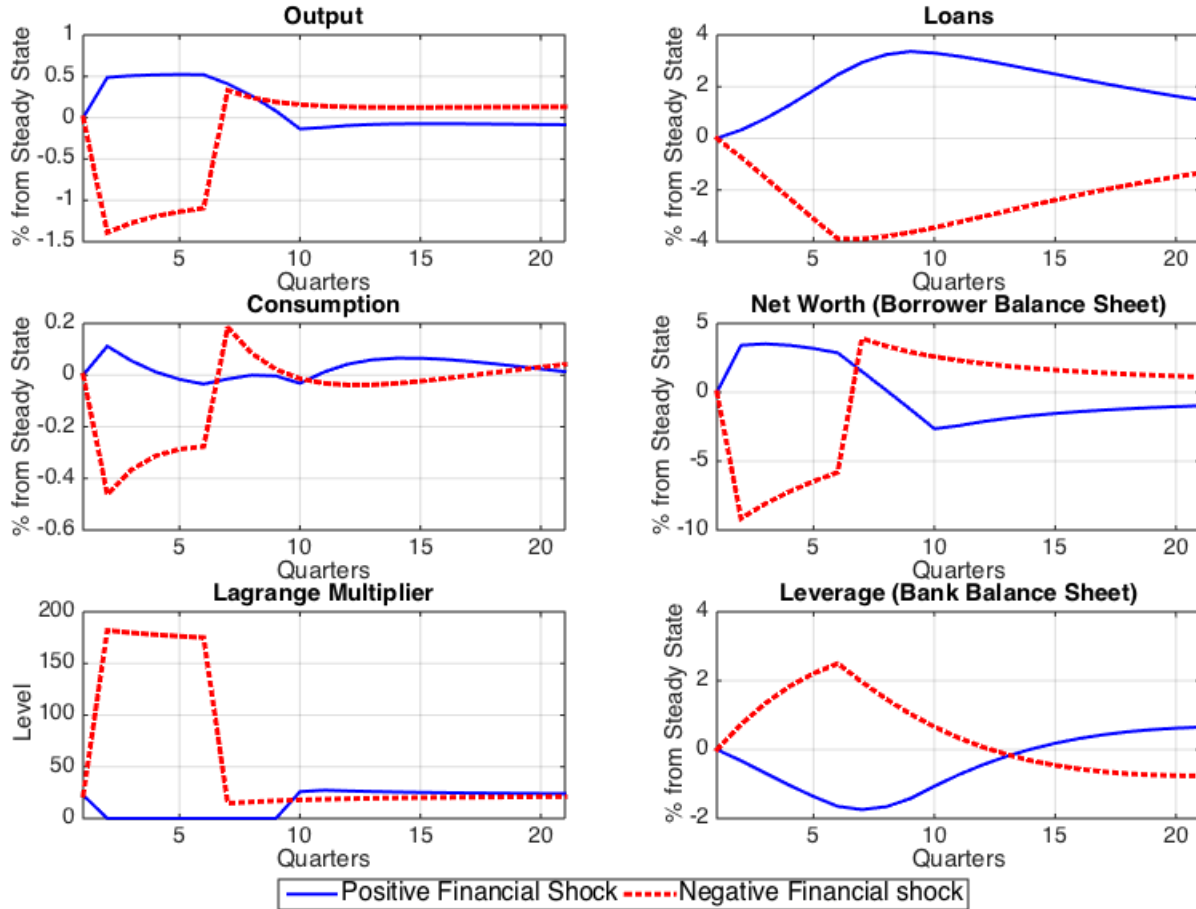
Note: The blue line indicates a positive shock, while the red dotted line represents a negative shock. The financial shock is a one standard deviation shock to the LTV ratio, which raises the LTV ratio by 2.2 percentage points. The parameters and standard error are set to the posterior mean. The shock is induced for 5 periods, after which the series reverts back to its steady state.

While the left-hand side of the figure looks similar to the one reported following an LTV shock, the right-hand side and, particularly, the reaction of loans is different. The LTV shock increases the LTV ratio and leads to an increase in loans. The net worth shock on the other hand acts more like a shock to the demand of loans. When the borrowing constraint is binding and a negative net worth shock hits he economy, entrepreneurs want to borrow more given their increased marginal utility of borrowing, but can only borrow up to when the borrowing constraint becomes binding.

As is apparent from Figure 2.4, the responses of the variables following a positive and negative shock are clearly asymmetric due to the occasionally binding borrowing constraint. When the constraint is binding, one additional unit of borrowing is associated with positive marginal utility, $\lambda_t^E > 0$. In contrast, a slack constraint that follows from a positive financial shock causes households to consume more today without the need to borrow, so that the marginal utility of borrowing, λ_t^E, is zero. The agents are allowed to borrow more, but there is no additional utility from borrowing. This is why loans increase by less for the positive scenario than they fall for the negative case. With less demand for loans, the leverage ratio of banks also decreases slightly less relative to the decrease from a negative shock, as banks are deleveraging faster in a credit constrained scenario. Note also that the asymmetry in the net worth of entrepreneurs (representing the borrowers' balance sheet channel) is very large with a negative shock causing net worth to fall three times more than it rises for a positive shock. The magnitude of the difference is similar to what we have seen in Figure 2.3.

This asymmetry is reflected in the size and shape of the responses of macroeconomic variables. In terms of size, the responses between a positive and a negative shock differ depending on the state of the world. A slack borrowing constraint following a positive shock causes entrepreneurs to consume more. However, as the marginal utility of borrowing is zero and because of diminishing marginal returns to consumption, their marginal utility of consumption decreases, so that consumption spending increases only by a small amount. As in Section 2, output increases only incrementally following a positive shock and three times less so than for a negative shock. When the constraint is binding, the results differ. Consumption becomes more sensitive to changes in the credit market, as the net worth of entrepreneurs falls more strongly. A negative financial shock increases the marginal utility of borrowing, so that agents adjust their consumption more.

In terms of shape asymmetries, we can observe that the output, consumption, and the net worth of entrepreneurs are less persistent and revert back quicker to the steady state after a negative shock. The quicker response occurs because the multiplier on the borrowing constraint, λ_t^E, reverts back to its steady state value quicker for a negative shock than for a positive shock that causes the constraint to become slack.

In terms of the relative importance of the two transmission channels, even though both credit

channels show some asymmetry, it is the borrowers' balance sheet channel that reacts stronger during a credit constrained regime and is responsible for the asymmetric pass-through to the real economy. To provide further evidence for this claim, I run a simulation in which banks cannot adjust their leverage ratio, therefore effectively switching the bank balance sheet off. Figure A.3 shows the responses, when transmission is taking place exclusively via the borrowers' balance channel. The only noticeable difference is that the response of leverage is zero. For all other variables, the effect of turning the channel off is barely visible. Hence, we can conclude that it is indeed the borrowers' balance sheet channel that is driving the asymmetric macro-financial transmission.

2.4.2 Net Worth Shock

Figure 2.5 shows the response of the model to a one standard deviation shock to the entrepreneur's net worth, ε_t^b. While this type of shock also affects the entrepreneurs' borrowing constraint, it goes through the system differently than the LTV shock.

In contrast, a positive net worth shock increases the wealth of entrepreneurs, so that even when the constraint is slack, they do not need to borrow more to satisfy their current consumption, as is shown in (2.7), and start to deleverage. Banks' leverage ratio increases strongly, as banks need to smooth out the losses caused by ε_t^b with bank capital, as can be seen in the capital adequacy constraint in (2.15). For the net worth shock, the bank balance sheet channel is reacting very strongly, albeit symmetrically.

While there are sizeable differences between the responses of loans from the LTV and the net worth shock, the responses of the macroeconomic variables and net worth are very similar even in terms of magnitude. With a positive financial shock, entrepreneurs are richer, which increases total consumption, and output. The net worth of entrepreneurs still responds very asymmetrically, but the drop for a negative net worth shock is less dramatic than for a negative LTV shock. Consumption is more persistent and the asymmetries are not as strong as with the LTV shock, but they still follow a similar pattern. As the response of leverage is ten times larger for a net worth shock, the bank balance sheet channel is quantitatively more important for macro-financial transmission than under an LTV shock.

Figure 2.5: Responses to a Net Worth Financial Shock
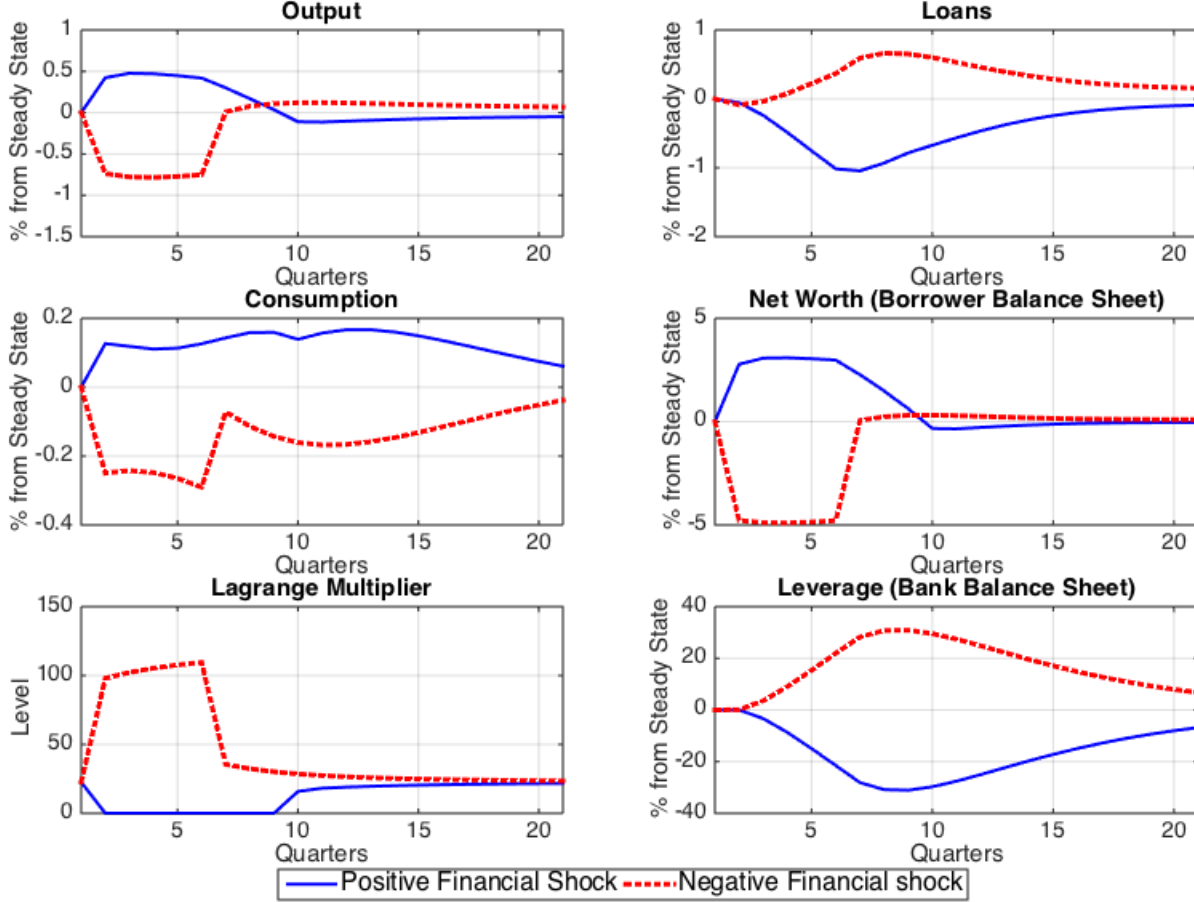
Note: The blue line indicates a positive shock, while the red dotted line represents a negative shock. The financial shock is a one standard deviation shock to the entrepreneurs' budget constraint. The parameters and standard error are set to the posterior mean. The shock is induced for 5 periods, after which the series reverts back to its steady state.

Figure A.4 shows the responses, when the bank balance sheet channel is switched off and only the borrowers' balance sheet channel is responsible for the transmission of the financial shock. The effects are more visible than under an LTV shock. It is apparent that the bank channel has a mitigating yet symmetric role on output volatility.

To sum up, the main driver for the asymmetry in macro-financial spillovers in response to both shocks is the borrowers' balance sheet channel.

2.5   Monetary and Macroprudential Policies: A Welfare Analysis

In this section, I analyse the effects of two countercyclical policy measures: leaning-against-the-wind (LATW) and countercyclical macroprudential capital buffers (CCB). The advantages of these policies are thought to be a reduction in (i) the probability and costs of financial crises, and (ii) the volatility of the credit cycle (and therefore also the volatility of business cycles). However, countercyclical policies have often been found to be too costly to implement, as they can reduce the level of bank lending and output (see e.g. Svensson, 2014 for LATW or Van den Heuvel, 2008, and BIS (2010) for CCB). In this section, I study whether this conclusion still holds, when there are asymmetries in the transmission of financial shocks.

The idea of LATW-type monetary policy is that central banks smooth financial cycles and stabilise asset prices by allowing the interest rate to vary with asset prices. To model it, I extend the monetary policy rule in (2.23) by including an additional term for asset prices, $\left(\frac{q_t}{q}\right)^{\phi_q(1-\rho_{ib})}$, so that the new monetary policy rule follows

$$1 + r_t^{ib} = (1 + r^{ib})^{(1-\rho_{ib})}(1 + r_t^{ib})^{\rho_{ib}}\left(\frac{\pi_t}{\pi}\right)^{\phi_\pi(1-\rho_{ib})}\left(\frac{y_t}{y}\right)^{\phi_y(1-\rho_{ib})}\left(\frac{q_t}{q}\right)^{\phi_q(1-\rho_{ib})}(1 + \varepsilon_t^r). \quad (2.27)$$

The concept behind a CCB is that the capital adequacy ratio is adjusted for a measure of the financial cycle, which affects the lending behaviour of banks throughout the credit cycle and thus also dampens output volatility (Angelini et al., 2015). I follow the Basel III regulation and set the target leverage ratio, ν_t, in (2.14) to be time-varying and follow a countercyclical rule that depends on the credit-to-GDP ratio

$$\nu_t = (1 - \rho_v)\nu + (1 - \rho_v)\chi_v\left(\frac{B_t}{Y_t}\right) + \rho_v\nu_{t-1}. \quad (2.28)$$

For the calibration, of these two rules, I set the value of the autoregressive parameter in (2.28) to be $\rho_v = 0.9$, to make the policy very persistent, once the target leverage for banks is changed. The sensitivity of the capital ratio to the financial cycle is calibrated to $\chi_v = 0.0129$ to match an average deviation of 0-2.5% from the steady state value, as is foreseen by Basel III. To provide a fair comparison between the two policies, I calibrate the parameter of asset-leaning in (2.27), ϕ_q, to match the policy impact effect of the CCB rule on a negative shock on asset prices. This yields $\phi_q = 0.00375$ for the Taylor rule parameter.

To evaluate the welfare effects over the financial cycle, I calibrate the positive shock in an unconstrained state and the negative shock in a constrained credit state to correspond to the magnitude and duration of an average euro area credit cycle. Based on the asset price indicator in Section 1, the average magnitude is 8.3% and -7.3% for a boom and bust, respectively, lasting for roughly 4 years each. I follow Adam and Billi (2008) and Ascari and Ropele (2012) and compute the consumption welfare gain of households, μ^*, as the percentage value that would make the utility without countercyclical policies equivalent to the utility under the alternative policy (indicated by *), i.e.

$$\sum_{t=0}^{T} \beta^t u(c_t(1+\mu^*),\, l_t) = \sum_{t=0}^{T} \beta^t u(c_t^*,\, l_t^*), \tag{2.29}$$

where $\mu^* \geq 0$. Using the utility function from (2.2), and solving for the welfare gain, μ^*, yields

$$\mu^* = \exp[\sum_{t=0}^{T} \beta^t u(c_t^*,\, l_t^*) - \sum_{t=0}^{T} \beta^t u(c_t,\, l_t)] - 1. \tag{2.30}$$

The consumption welfare gain, μ, then represents the percentage of consumption households are gaining over one financial cycle in the euro area by adopting the alternative policy. The welfare gain in household consumption from the monetary policy rule is -0.24%, while the welfare gain from the macroprudential rule is positive, 2.14%.[6] The fact that countercyclical macroprudential policies can be welfare improving even without accounting for the reduction in the probability and costs of potentially prevented financial crises, is crucial for policy making, as the 2.14% can be considered as a lower bound for the actual welfare gain.

The difference in the welfare effects of the two policies is not surprising. Introducing an additional asset-price component into the standard Taylor rule only dampens the response of asset prices and does not affect the shape of the response. The response of the remaining variables in the financial sector is largely unaffected by the modified monetary policy rule and only changes the magnitude of the output and inflation responses. In contrast, adding macroprudential policy alters the steady state of the model and affects the responses of the financial sector as a whole. As banks need to adjust their leverage ratio to meet the time-varying target, the variability of leverage becomes much smaller and the variability of loans and the retail rate increase. This

---

[6]Note that in a linear model, the welfare effects over the cycle would roughly be zero, as the welfare gains in bust times would cancel out the symmetric welfare losses in boom times. The steady state of the baseline model is the same under the new monetary policy rule, while introducing the macroprudential rule alters the steady state level of consumption and labour. Using (2.30), the steady state welfare from CCB is 0.08% smaller than under the baseline model. However, this implies that the transient welfare gain of introducing CCB is 2.14%-0.08% = 2.06%, and still positive.

means that the target leverage ratio increases during a downturn, which causes banks to increase their lending rate and pass-on the higher costs to the consumers. By increasing lending spreads, borrowers reduce their demand for loans, which translates into less real activity. The opposite holds true for an upswing. Quantitatively, the reduction in the lending rate does not spur the same response in real activity.

While both these policies are specifically calibrated to match real life situations and thus not generalisable, the current analysis already provides a valuable insight into how asymmetric macro-financial linkages can be exploited. Policy makers can design countercyclical policy measures to reduce the volatility caused by the financial cycle without risking a substantial reduction in output during boom times. Macroprudential policies are particularly more powerful, as they affect the financial transmission channels directly. This result is consistent with Bruneau et al. (2016) who also find that macroprudential rules are preferred to a Taylor rule augmented for housing.

2.6   Conclusion

I conclude that the macro-financial transmission of financial shocks is asymmetric. The pass-through of a positive shock to the real economy is smaller during normal times than the pass-through of a negative shock during constrained times. This result is obtained both empirically in a MS-VAR, as well as in a structural, estimated DSGE model. In addition, the structural model allows me to distinguish between the two different macro-financial channels, the bank and borrowers' balance sheet channels. I find that in particular the borrower balance sheet channel plays a more dominant role in the asymmetry of the transmission, which is consistent with survey data.

In terms of policy, my analysis shows that the asymmetry in macro-financial linkages can be exploited by using countercyclical policies. Time-varying macroprudential capital buffer rules, as suggested by Basel III, seem more consumption welfare improving than an equivalent LATW policy, and actually constitute a welfare gain for households over the duration of the euro area financial cycle. Given that the model is not even taking into account the added benefits of a reduction in the probability and costs of financial crises, the welfare effects are likely to be larger.

An interesting extension of this paper would be the inclusion of risk and the precautionary savings motive. The risk channel affects the decision of households and firms to delay their consumption and investment. By extending the model with risk, it would be possible to analyse the effects of financial shocks on financial stability and give a more complete picture of macro-financial linkages. It would make it possible to inspect the build-up of risky asset bubbles during

financial booms and the benefits of countercyclical policies for the reduction of crisis probability. Another interesting avenue would be to look at international macro-financial spillovers and the role of domestic macroprudential policies. As financial markets operate globally, imposing regulations can often have spillover effects on other countries.

To sum up, this paper has provided strong evidence that there are asymmetries in the transmission of shocks from the financial sector to the real economy. Neglecting these non-linearities could have sizeable and distortionary effects on policy recommendations, and should therefore be taken into account, when designing monetary and macroprudential policy.

References

Adam, K. and Billi, R. M. (2008). Monetary conservatism and fiscal policy. *Journal of Monetary Economics*, 55(8):1376–1388.

Adrian, T. and Liang, N. (2014). Monetary Policy, Financial Conditions, and Financial Stability. IMES Discussion Paper Series 14-E-13, Institute for Monetary and Economic Studies, Bank of Japan.

Angelini, P., Clerc, L., Cúrdia, V., Gambacorta, L., Gerali, A., Locarno, A., Motto, R., Roeger, W., Heuvel, S. V. d., and Vlček, J. (2015). Basel III: Long-term Impact on Economic Performance and Fluctuations. *Manchester School*, 83(2):217–251.

Ascari, G. and Ropele, T. (2012). Disinflation in a DSGE perspective: Sacrifice ratio or welfare gain ratio? *Journal of Economic Dynamics and Control*, 36(2):169–182.

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

BIS (2010). Assessing the macroeconomic impact of the transition to stronger capital and liquidity requirements - Final report.

Borio, C. (2014). The financial cycle and macroeconomics: What have we learnt? *Journal of Banking & Finance*, 45:182–198.

Borio, C., Kennedy, N., and Prowse, S. (1994). Exploring aggregate asset price fluctuations across countries: measurement, determinants and monetary policy implications. BIS Economic Paper 40, Bank for International Settlements.

Bruneau, G., Christensen, I., and Meh, C. (2016). Housing Market Dynamics and Macroprudential Policy. Staff Working Paper 16-31, Bank of Canada.

Calza, A. and Sousa, J. (2006). Output and Inflation Responses to Credit Shocks: Are There Threshold Effects in the Euro Area? *Studies in Nonlinear Dynamics & Econometrics*, 10(2):1–21.

Ciccarelli, M., Maddaloni, A., and Peydro, J. L. (2014). Trusting the Bankers: A New Look at the Credit Channel of Monetary Policy. *Review of Economic Dynamics*.

Del Negro, M. and Schorfheide, F. (2013). DSGE Model-Based Forecasting. Handbook of Economic Forecasting, Elsevier.

Drehmann, M., Borio, C., and Tsatsaronis, K. (2012). Characterising the financial cycle: don't lose sight of the medium term! BIS Working Paper 380, Bank for International Settlements.

Frühwirth-Schnatter, S. (2006). *Finite Mixture and Markov Switching Models*. Springer Science & Business Media.

Gambacorta, L. and Signoretti, F. M. (2014). Should monetary policy lean against the wind? *Journal of Economic Dynamics and Control*, 43(C):146–174.

Gerali, A., Neri, S., Sessa, L., and Signoretti, F. M. (2010). Credit and Banking in a DSGE Model of the Euro Area. *Journal of Money, Credit and Banking*, 42(s1):107–141.

Gerke, R., Jonsson, M., Kliem, M., Kolasa, M., Lafourcade, P., Locarno, A., Makarski, K., and McAdam, P. (2013). Assessing macro-financial linkages: A model comparison exercise. *Economic Modelling*, 31(C):253–264.

Guerrieri, L. and Iacoviello, M. (2015a). Collateral constraints and macroeconomic asymmetries. National Bank of Poland Working Paper 202, National Bank of Poland, Economic Institute.

Guerrieri, L. and Iacoviello, M. (2015b). OccBin: A toolkit for solving dynamic models with occasionally binding constraints easily. *Journal of Monetary Economics*, 70(C):22–38.

Hartmann, P., Hubrich, K. S., Kremer, M., and Tetlow, R. J. (2015). Melting Down: Systemic Financial Instability and the Macroeconomy. SSRN Scholarly Paper ID 2462567, Social Science Research Network, Rochester, NY.

Hubrich, K., D'Agostino, A., Červená, M., Ciccarelli, M., Guarda, P., Haavio, M., Jeanfils, P., Mendicino, C., Ortega, E., Valderrama, M. T., and Valentinyiné Endrész, M. (2013). Financial shocks and the macroeconomy: heterogeneity and non-linearities. Occasional Paper Series 143, European Central Bank.

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

Iacoviello, M. (2015). Financial Business Cycles. *Review of Economic Dynamics*, 18(1):140–164.

Jordà, Ò. (2014). Assessing the historical role of credit: Business cycles, financial crises and the legacy of Charles S. Peirce. *International Journal of Forecasting*, 30(3):729–740.

Kiyotaki, N. and Moore, J. (1997). Credit Cycles. *Journal of Political Economy*, 105(2):211–48.

Koop, G., Pesaran, M. H., and Potter, S. M. (1996). Impulse response analysis in nonlinear multivariate models. *Journal of Econometrics*, 74(1):119–147.

Krolzig, H.-M. (1997). *Markov-Switching Vector Autoregressions*, volume 454 of *Lecture Notes in Economics and Mathematical Systems*. Springer Berlin Heidelberg, Berlin, Heidelberg.

Lindé, J., Smets, F., and Wouters, R. (2016). Challenges for Central Banks' Macro Models. CEPR Discussion Paper 11405, C.E.P.R. Discussion Papers.

Pfeifer, J. (2013). A guide to specifying observation equations for the estimation of DSGE models. Technical report, Working paper, University of Mannheim, Germany.

Svensson, L. E. O. (2014). Inflation Targeting and "Leaning against the Wind". *International Journal of Central Banking*, 10(2):103–114.

Van den Heuvel, S. J. (2008). The welfare cost of bank capital requirements. *Journal of Monetary Economics*, 55(2):298–320.

Appendix

Table A.1: Mean and standard deviation conditional on states

	Normal State	Constrained State
y	1.8591 (1.6745)	-0.9308 (6.0830)
π	1.4149 (0.9194)	2.0690 (0.8645)
i	0.0491 (0.6443)	-0.3660 (1.3072)
b	1.0345 (1.3501)	-1.8018 (2.594)
q	9.4368 (13.1354)	-7.9783 (26.3424)

Note: The values report the mean value of the variables conditional on the state with the standard deviation reported in brackets.

Table A.2: Calibrated Parameters

Parameters	Description	Value
β_P	Discount factor patient households	0.9943
β_E	Discount factor impatient entrepreneurs	0.975
ϕ	Elasticity of labour	1
mk^{ySS}	Steady state mark up	1.2
α	Capital share in production	0.25
δ_k	Depreciation Rate of Capital	0.050
$mcspread$	Marginal cost spread	0.0050
π^{ss}	Steady state of inflation	1
m_e^{ss}	Steady state Loan-To-Value ratio	0.35
θ	Bank capital adjustment cost	11
ν	Target capital-to-asset ratio	0.09

Figure A.1: State Identification based on MS-VAR and DSGE model
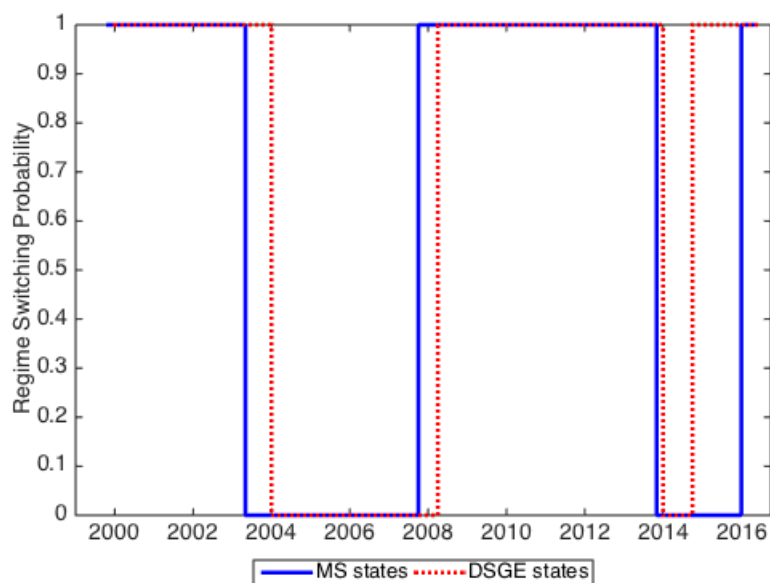
Note: The blue, solid line represents the states identified by the MS-VAR, while the red dotted line indicates the states identified by the non-linear, estimated DSGE model. The y-axis shows the probability of being in a credit constrained state.

Figure A.2: MS-VAR impulse response comparison real vs. simulated data
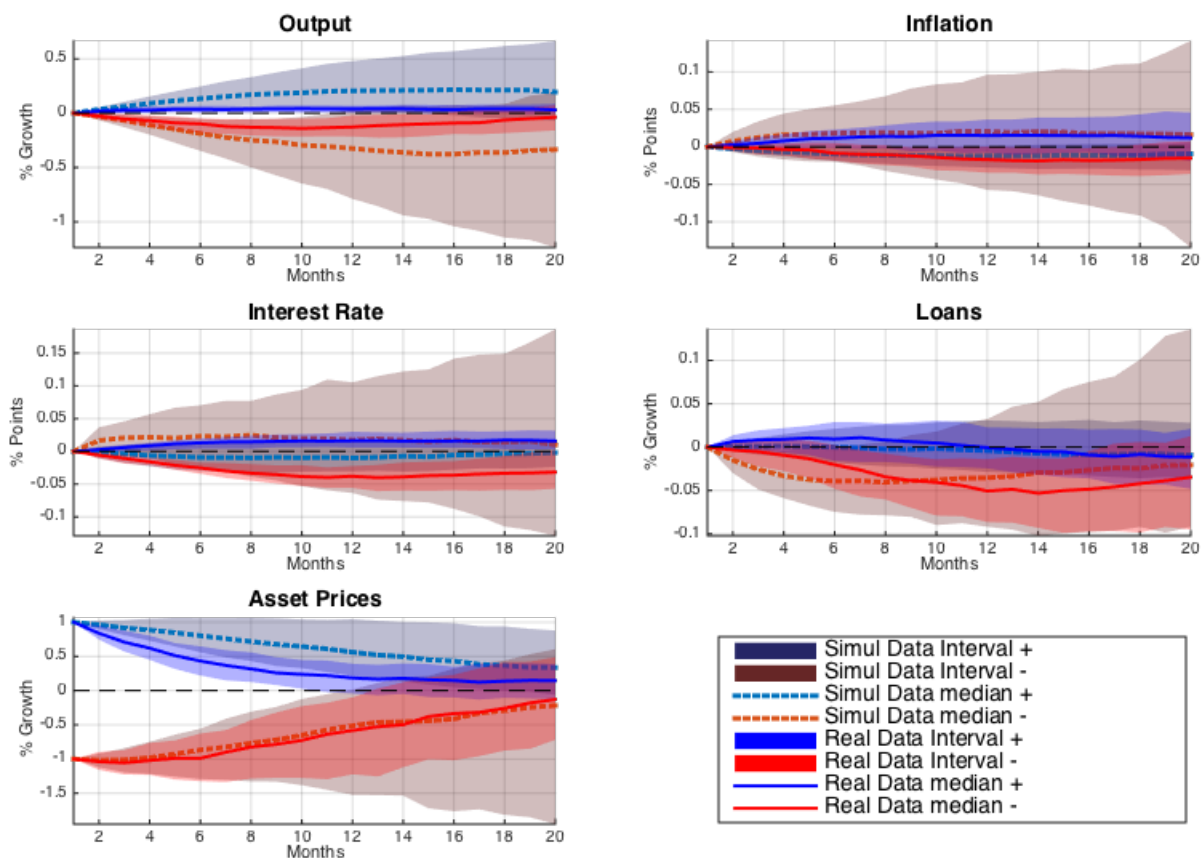
Note: The shaded regions report point-wise 68% credible sets. The coloured regions report the credible sets for the real data, while the grey, transparent interval represents the credible set based on the model with simulated data. The solid lines show the median response for the model with the real data, and the dashed lines report the median for the simulated data.

Figure A.3: LTV shock without bank balance sheet channel
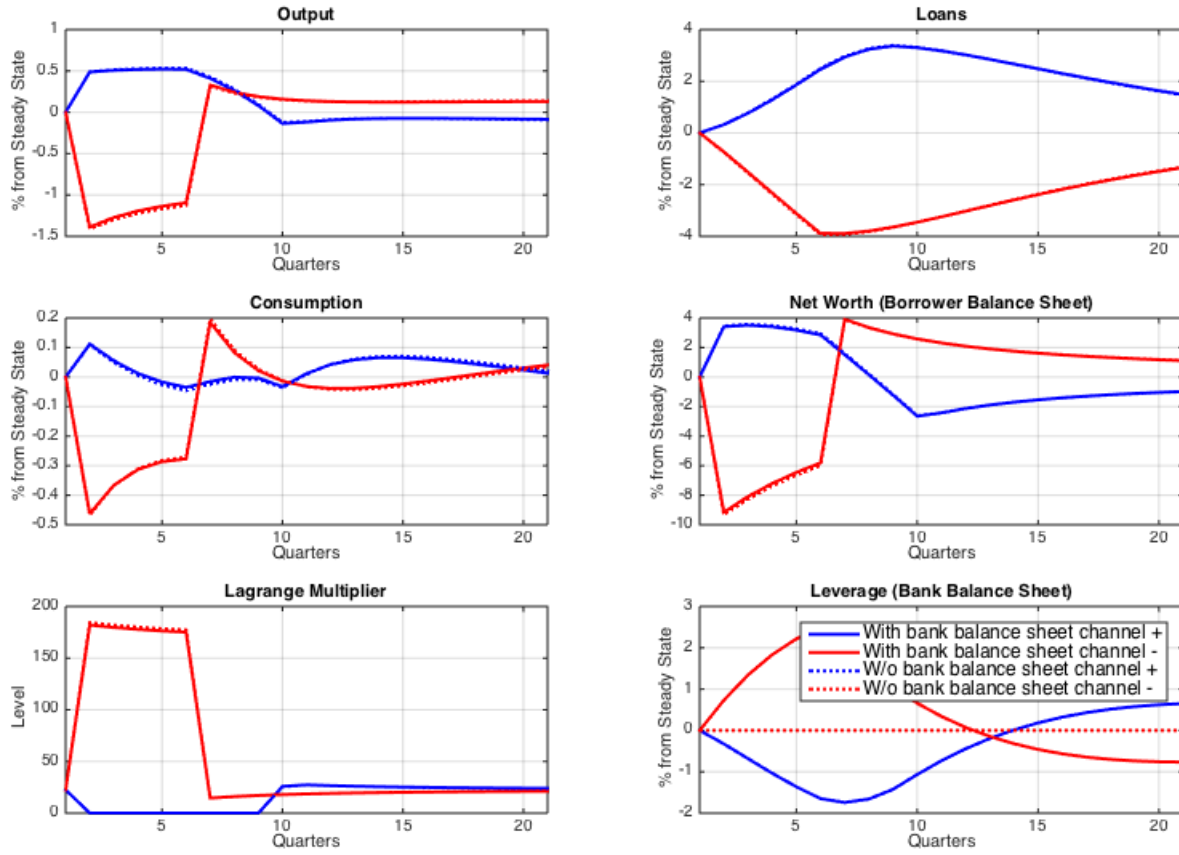
Note: The blue line indicates a positive shock, while the red line represents a negative shock. The solid line is the baseline model, while the dotted line is the model without a bank balance sheet channel. The parameters and standard error are set to the posterior mean. The shock is induced for 5 periods, after which the series is left to revert back to its steady state.

Figure A.4: Net worth shock without bank balance sheet channel
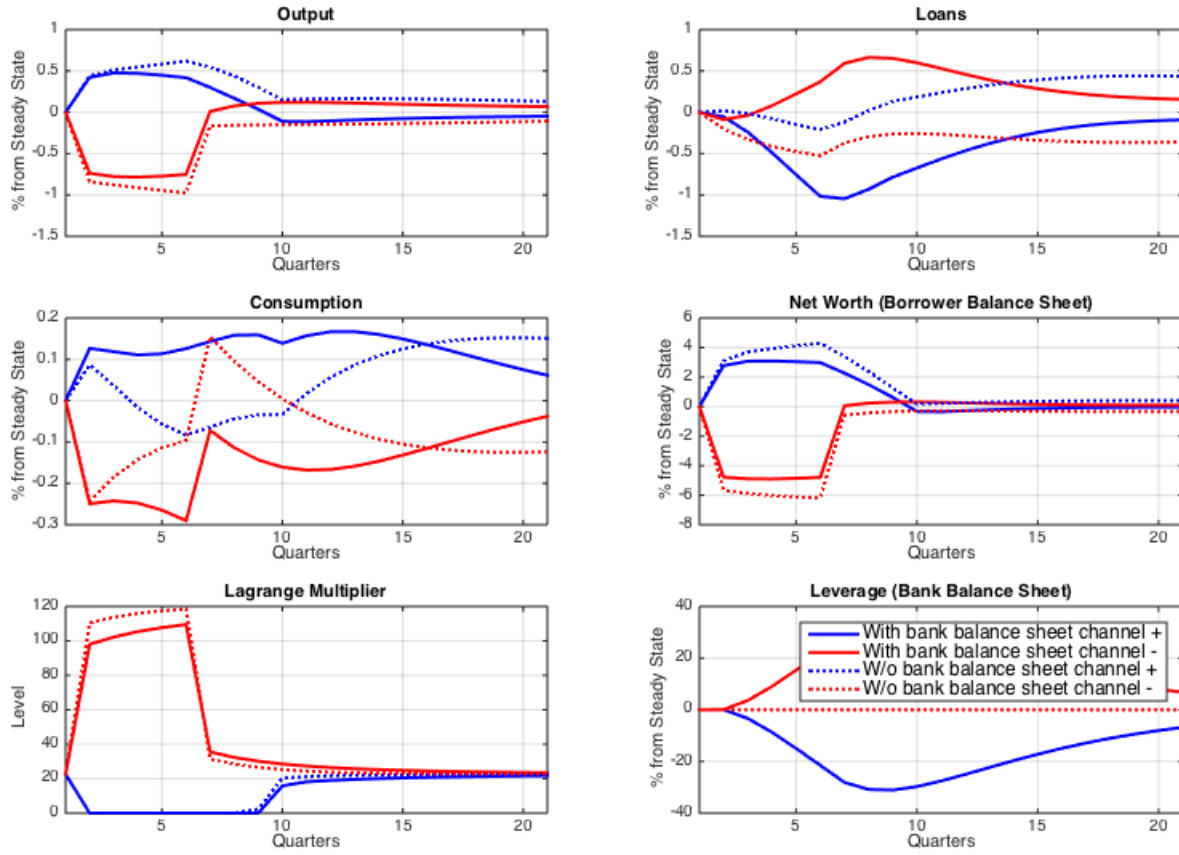
Note: The blue line indicates a positive shock, while the red line represents a negative shock. The solid line is the baseline model, while the dotted line is the model without a bank balance sheet channel. The parameters and standard error are set to the posterior mean. The shock is induced for 5 periods, after which the series is left to revert back to its steady state.

Financial Stability and the Term Premium

***

This chapter is jointly written with Julieta Yung.

3.1 Introduction

Many central banks have adopted new measures to target financial stability and mitigate effects of risk shocks on the real economy and financial markets. From the Brexit referendum to the increase in uncertainty during the Financial Crisis, policy makers have been forced to respond to a wide range of events that have increased perceived risk in financial markets, as well as the macroeconomy as a whole. Risk and uncertainty are used interchangeably in this paper, as both of these terms describe unexpected events that increase volatility in financial markets. However, they are technically different. 'Risk' is defined as an event occurring with measurable probability, while 'uncertainty' describes when the likelihood of future events is indefinite or incalculable (Knight, 1921). However, measuring risk and its transmission through the financial system to the real economy is challenging.

While there have been many empirical studies employing a wide array of indicators trying to measure the effects of risk shocks, empirical studies alone cannot be used to study the structural role of these shocks and specific transmission mechanisms. For that purpose, Dynamic Stochastic General Equilibrium (DSGE) models have been emerging that have slowly started to introduce risk into standard New Keynesian models. Nevertheless, a caveat of these models is that they often assume a specific form of the type of shock (i.e. a macroeconomic second-moment demand shock) and say very little about the role on bank lending and financial stability. Instead, we propose to measure the effects of risk on the financial sector through the term premium. In this paper, we will investigate the role of risk shocks on the macroeconomy, as well as the banking sector and financial stability. We will investigate two policy questions: (i) does monetary policy affect risk premia? And if so, does accommodative monetary policy lead to a build-up of risk?

And (ii) does macroprudential policy reduce financial instability in the economy?

We contribute to the literature in four ways. Firstly, we introduce a feedback mechanism between the macroeconomy, the banking sector, and the term premium. By doing so, we combine two strands of literature: the term structure literature, which has focussed on how the macroeconomy affects the term premium, and the uncertainty literature, which has primarily looked at the effects of risk on the macroeconomy. On top of being able to look at the effects of macroeconomic changes on the term premium and vice versa, the introduction of a banking sector allows us to analyse how financial risk affects bank lending and financial stability.

Secondly, our model is able to match basic macro and term premia moments observed in the data. However, in contrast to previous studies which required a very high constant risk aversion coefficient (CRRA), we achieve this with a remarkable low CRRA, which is more consistent with macroeconomic studies (Havranek et al., 2015).

Thirdly, we do not have to make any specific assumptions about the type of risk in the model. Risk, as expressed by the time-varying term premium, arises naturally in the model due to the risk-averse preferences of households, which require higher compensation for long-term bonds than short-term bonds. Any exogenous shock to the term premium can then be interpreted as a truly unpredictable event. We can hence remain agnostic in our modelling approach of whether the shock acts as a demand or supply shock. More so, it allows us to proxy different type of risk shocks. As Andreasen (2012) points out rare disasters increase the level of the term premium, while uncertainty (measured by stochastic volatility and GARCH) increases the variance of the term premium.

Finally, our model allows us to investigate whether a) accommodative monetary leads to a short-term reduction in risk premia but a long-term increase in financial instability, and b) the effectiveness of several macroprudential policies in mitigating and safeguarding the economy from the negative consequences of financial risk.

In particular, we are interested in how risk affects bank lending and investment. As a first step, we look at the empirical responses of an exogenous shock to the term premium in a Structural Vector Autoregressive (VAR) model using zero and sign restrictions. The empirical exercise confirms that a shock to the term premium behaves very similarly to other risk shocks identified in the literature (e.g. Bloom, 2009). We find that there is indeed a strong short-lived, negative macroeconomic response with output decreasing and a less significant contraction in private sector loans. After confirming that a term premium shock can be used to proxy conventional risk shocks, we construct a DSGE model with heterogeneous banking (Gerali et al., 2010; Gambacorta and Signoretti, 2014) and extend it with a government sector, asset pricing, time-varying risk premia and Epstein-Zin preferences similar to Rudebusch and Swanson (2012). We calibrate it to the US economy and solve it using third-order approximations. We find that

the term premium shock has large, temporary, negative effects on the macroeconomy and affects the lending behaviour of banks by reducing the volume of loans and investment. We can confirm that expansionary monetary policy would indeed lead to a reduction in the risk premium, and an increase in financial instability as stated in Adrian and Liang (2016). Also, we conclude that macroprudential policies targeting the loan-to-value ratio of borrowers can be very effective in mitigating some of the negative consequences of risk shocks on the economy. without having any of the negative effects of increasing the capital/asset ratio

Our papers relates to two strands of literature: a) the macro-finance literature in term structure models, and b) the macro literature on risk shocks. The literature on macro-finance term structure models is still evolving. While early studies were mostly limited to endowment economies, there has been a slow surge of models integrating the term structure into non-linear DSGE models. Earlier literature has shown that term premia can vary significantly over time (Piazzesi and Schneider, 2007). Our paper relates to the term premium literature which also uses third-order approximations to generate a time-varying risk premium and uses Epstein-Zin preferences to match finance moments (Rudebusch and Swanson, 2012; Rudebusch et al., 2007; Van Binsbergen et al., 2012; Caldara et al., 2012). However, in addition to these papers, we introduce a banking sector to be able to measure the effects of risk on lending and investment, and importantly, build in a feedback loop so that changes to the term premium have effects on the macroeconomy. Another advantage of our approach is that we also account for the reverse causality from the term premium to the macroeconomy. Favero et al. (2005) and Hamilton and Kim (2002) find indeed some reduced from evidence that the term premium is not just influenced by macro factors, but can also influence the real economy in itself. As suggested by New Keynesian models and empirical evidence in Rudebusch et al. (2007), a decrease in the term premium should cause an increase in output growth, which would render the term premium counter-cyclical.

The term premium shock has a large scope of interpretation, as it affects long-term risk expectations of households. As such, it is related to several strands of macroeconomic literature: a) 'Animal spirit' shocks (e.g. Azariadis, 1981; Grauwe, 2011) that affect the expectations of investors and skew it toward being optimistic or pessimistic, and b) Uncertainty shocks (e.g. Bloom, 2009; Christiano et al., 2014) which model uncertainty shock as a second moment shock to Total Factor Productivity (TFP). The advantage of our model is that we do not need to make any specific assumption about whether the risk shock is behaving like a demand or supply shock (i.e. uncertainty shock). By using the term premium and solving it using a third-order approximation, we explicitly allow there to be a constant level of baseline risk, as the steady state level of the risk premium is positive even in the absence of shocks. We also do not need to make any assumption about specific agents' beliefs, as is necessary to incorporate an animal

spirit shock into a DSGE model. Modelling a term premium shock allows for a straight-forward way to test for the effects of shocks to long-term risk perceptions in a relatively standard DSGE framework.

The paper is structured as follows: Section 3.2 provides intuition on what movements in the term premium represent as it captures investors' perception of long-term risk. Section 3.3 provides an empirical framework to study the impact of a risk shock on macroeconomic variables using a Bayesian vector autoregressive approach. Section 3.4 describes the main assumptions and mechanisms behind the DSGE model that links the real economy and the financial sector via the term premium. We also provide details about the calibration and solution methods. Section 3.5 presents the model-implied macroeconomic implications of a risk shock along with the term premium's response to classic macroeconomic shocks. We also study the effects of monetary policy shocks as they relate to the term premium and financial stability. Section 3.5.2 explores the impact of macroprudential policies on mitigating the effects of risk shocks. Finally, Section 3.6 concludes.

## 3.2   The Term Premium as a Measure of Risk

The term premium, or bond risk premium, is the compensation that investors require in order to hold a long-term bond instead of a series of short-term bonds during the same horizon. As such, a high term premium reflects a perceived increase in financial risk over the life of a bond. This compensation for risk varies throughout time as investors update their beliefs about the future path of the economy, including changes in expected inflation, the course of monetary policy, and their tolerance for risk, among other factors.[1]

The evolution of the ten-year term premium from 1961 to 2017 is shown in Figure 3.1 along with the ten-year U.S. Treasury yield. In December 2013, for example, a ten-year U.S. Treasury bond earned a 2.90 percent annualised yield. More than half of this return, 1.73 percentage points, reflected the compensation risk-neutral investors at that time would require in order to be exposed to long-term risk, i.e. the term premium. As can be observed from the figure, the term premium is substantial –around 1.63% for the past six decades– and varies significantly

---

[1]The term premium is not the same as the term spread. The term spread is the difference between long- and short-term bonds, also known as the slope of the yield curve, and can be decomposed into two components: the expectations term and the term premium component. It is well established in the literature that the term spread is a leading indicator for recessions, from Estrella and Hardouvelis (1991) and Estrella and Mishkin (1998) to Ang et al. (2006) and Liu and Moench (2016). The intuition behind the predictive power of the term spread is that, since the expectation hypothesis poses that long-term rates are determined by future expected short-term rates, an increase in the expectations term implies that future monetary policy is likely to tighten, anticipating a recession in the future. Whereas the term spread also incorporates variation in short-term expectations, the term premium is primarily governed by expectations of long-term risk to the economic outlook.

over time –ranging from -0.65% to 4.79%. Moreover, it has been around zero for the past two years.

Figure 3.1: Ten-Year Treasury Yield and the Term Premium (1961-2017)
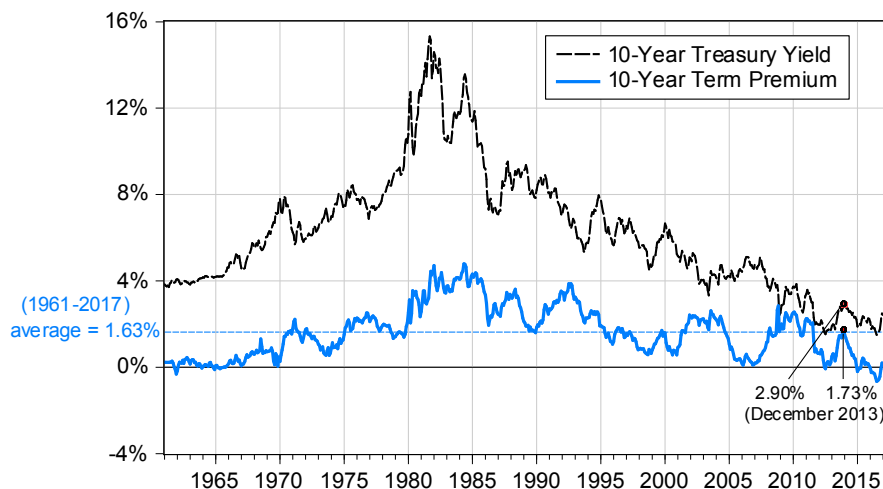
At least part of the decline in the ten-year yield since the early 1980's can be attributed to a lower term premium. However, in reality, the term premium is unobservable and as such, needs to be estimated or inferred from the term structure of interest rates and its expected path. Several techniques have been proposed to proxy for investors' expectations of future economic conditions, often yielding differing patterns, for which it is important to provide further intuition of what movements in the term premium represent.[2]

From a traditional finance perspective, the term premium is driven by uncertainty about future short-term rates. Forward-looking agents, however, expect the future path of policy rates to be shaped by macroeconomic forces (e.g., inflation, labor market conditions, growth, etc.), as policy-making is contingent on the state of the economy. Therefore, a macro-finance approach to understanding the term premium implies that macroeconomic uncertainty is the underlying driver of expectations about the path of short-term rates, and hence should be embedded in the term premium.

To provide economic intuition of what movements in the term premium represent, we compare

---

[2]Swanson (2007), Rudebusch et al. (2007), and Li et al. (2017) compare different estimates of the term premium and provide excellent overviews of the challenges faced when measuring the long-term expectation of short rates. Li et al. (2017) conclude that the most important factor in accounting for differences across estimates is whether the chosen methodology employs surveys of market participants or not. For this paper, we utilise the ACM term premium measure developed by the Federal Reserve Bank of New York. For a short summary of the methodology and an overview of how it compares to other measures, refer to Adrian et al. (2014).

its evolution to several economic variables, including different measures of uncertainty. Figure 3.2(a) displays the term premium along with the unemployment rate. As it has been established in the literature, the term premium is counter-cyclical –rising along with unemployment during economic downturns and falling during economic upswings. This counter-cyclicality suggests that the term premium should be negatively correlated with output and consumption; therefore, as household's marginal utility of consumption is high, the term premium should rise. In fact, the correlation between the term premium and year-over-year changes in personal consumption expenditures is –44%.[3] This interpretation is also consistent with the empirical evidence in Ludvigson and Ng (2009), indicating that agents seek compensation for macroeconomic risks associated with recessions that account for variation in the term premium.

We use the Merrill Lynch MOVE Index, which summarises options-implied expected volatility of Treasury yields, in order to capture investors' uncertainty about future interest rates in Figure 3.2(b). During the overlapping period, the correlation between these two series is 50 percent.[4]

Finally, as can be observed in Figures 3.2(c) and 3.2(d), the term premium is associated with fluctuations in economic policy (57% correlation) and inflation uncertainty (48% correlation), as measured by different components from the Baker et al. (2016) Uncertainty Index. Baker et al. (2016) estimate the dispersion among economic forecasters in the consumer price index (CPI) as a measure of inflation uncertainty, and also in the purchase of goods and services by state, local and the federal government.[5]

We therefore expect the term premium to be high when investors are more risk averse; the marginal rate of consumption is high; output is low; or there is more uncertainty about the future economic outlook (i.e. the path of interest rates, inflation, monetary policy).[6] In the next

---

[3]Monthly estimates of market-based Personal Consumption Expenditures are available from 1988/01 to 2017/04 from the Bureau of Economic Analysis. The term premium is also negatively correlated with monthly Industrial Production year-over-year changes from the Federal Reserve Board during the 1962/02–2017/04 period (-32%) and quarterly GDP year-over-year changes from the Bureau of Economic Analysis from 1962-Q3 to 2017-Q1 (-32%).

[4]Adrian et al. (2014) also show that the term premium is correlated with the disagreement about the level of the federal funds rate four quarters ahead (as measured by the average forecast of the highest ten responses minus that of the lowest ten responses in the Blue Chip Financial Forecasts survey) from 1982 to 2013. The correlation between the term premium and the quarterly dispersion of professional forecasters 3-month T-bill rate estimates four quarters ahead is 53% during the 1981–2017 period.

[5]The term premium is also correlated with the Jurado et al. (2015) monthly (one-year ahead)macroeconomic uncertainty index (46%) and the quarterly dispersion of professional forecasters CPI estimates over the next ten years (64%). Moreover, Mallick et al. (2017) developed a structural vector autoregressive model and find that a quarterly VIX shock is followed by a higher U.S. term premium between quarters 5 and 10 and that a quarterly shock to implied bond volatility has a statistically significant positive (although short-lived) impact on the term premium.

[6]There are, of course, other explanations for movements in the term premium, such as the recent central bank purchases of bonds under Quantitative Easing, the use of explicit forward-rate guidance to reduce uncertainty about the future path of monetary policy, and the possible flight-to-quality flows that reflect preference for certain class of assets.

sections, we further explore the effects of risk shocks on the economy via the term premium, both empirically and in the context of a DSGE model.

Figure 3.2: Term Premium and Uncertainty
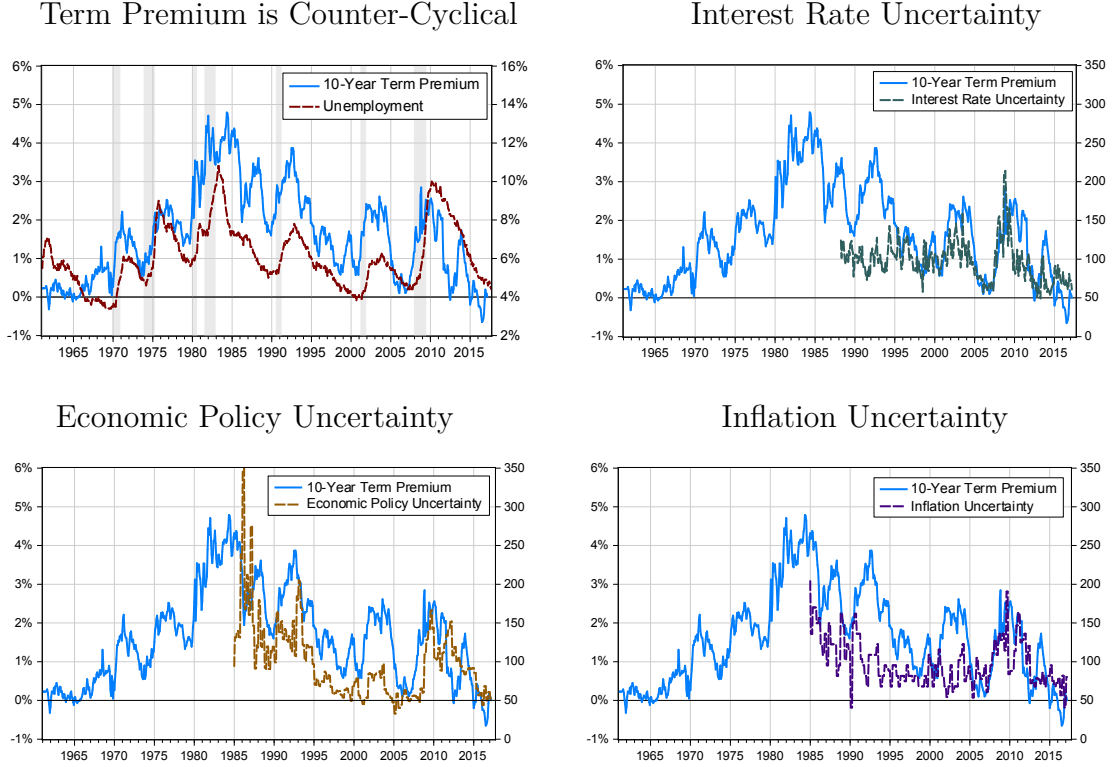
Notes: Term premium is the ACM series from the Federal Reserve Bank of New York, as in Adrian et al. (2013), from January 1961 to March 2017. Unemployment rate is from the Bureau of Labor Statistics, and shaded areas indicate NBER recession periods. Interest Rate Uncertainty is proxied by the Merrill lynch Option Volatility Estimate (MOVE) Index. Economic Policy and Inflation Uncertainty are obtained from the Baker et al. (2016) Uncertainty Index. All data are monthly. Refer to Appendix 3.A.1 for details.

3.3 The Impact of a Risk Shock: Empirical Approach

As a first step, we want to understand the role of the term premium on both the macroeconomy and financial variables in an empirical Vector Autoregressive (VAR) model. This allows us to obtain a benchmark from which we can evaluate the theoretical DSGE responses in the later section. Also, it provides us with an initial idea of the quantitative effects and persistence of a term premium or risk shock. The structural Bayesian VAR(12) follows

$$\mathbf{A_0 x_t = A_1 x_{t-1} + e_t} \tag{3.1}$$

95

where $\mathbf{A_0}$ and $\mathbf{A_1}$ are the matrices of structural coefficients, and $\mathbf{e_t}$ is an orthogonal vector of structural innovations. The vector $\mathbf{x_{t-1}}$ also includes a constant. We use monthly U.S. data from 1961 until 2017 for output, inflation, the shadow federal funds rate, bank loans to the private sector, and the term premium (see Appendix 3.A.2 for a detailed description of the data). We choose the shadow federal funds rate to account for monetary policy during the zero lower bound period constraining the policy rate from below. Output and bank loans enter the model in log growth rates, while the remaining variables are in levels. We choose an independent Normal-Wishart prior and a lag length of 12 months.

3.3.1   Identification

We follow Canova and Nicolo (2002) and employ sign restrictions ex post on the impulse responses to structurally identify a term premium shock in the data. The advantage of the term premium shock is that it can be interpreted as any type of unanticipated movement capturing a change in investors' perception of long-term financial risk or uncertainty. There is a multitude of potential real life occurrences of such shocks (e.g. political events, new regulation, trade agreements), so that understanding the effect of a term premium shock on the economy has important policy implications that we want to later interpret in the context of our model.

As the data frequency is monthly, sign restrictions allow us to account for the fact that a term premium or risk shock affects other financial variables simultaneously. A shock that raises the term premium (tp_t) implies that long-term risk in financial markets is increasing and that financial uncertainty is worsening. The contemporaneous sign restrictions are reported in Table 3.1. We restrict financial risk to be negatively correlated with output growth (y_t), consistent with the counter-cyclical properties of the term premium shown in the previous section.[7] Another key identification assumption is that monetary policy mainly influences the short-term rate (i_t), so that the term premium has no contemporaneous effect on the short term interest rate. To impose a combination of zero and sign restrictions, we use the algorithm of Binning (2013).

While we are only interested in a risk shock per se, we need to ensure that the shock is fully identified and cannot be mis-specified as another shock in the model. We explicitly identify a demand, supply, monetary policy, and a credit shock in the data to avoid mistaking the financial risk shock with other shocks in the model. We use standard sign restrictions on output and inflation (π_t): a demand shock increases output and inflation simultaneously, while a supply

---

[7]Rudebusch et al. (2007) show that in response to a monetary policy or a technology shock, a rise in the term premium is associated with current and future weakness in output and that a decline in the term premium is associated with stimulus to the economy. However, for a government spending shock, a rise in the term premium is associated with current and future output strength, thus finding that the correlation between output and the term premium depends on the nature of the shock itself.

Table 3.1: Sign Restrictions

| Variable/Shock	Demand	Supply	Monetary Policy	Credit	Financial Risk
y_t	> 0	< 0	< 0	0	< 0
π_t	> 0	> 0	< 0	0	
i_t	> 0	> 0	> 0		0
b_t				> 0	
tp_t					> 0

shock increases inflation, but decreases output (Kilian and Lütkepohl, 2017). As inflation rises in both cases, so does the interest rate. A contractionary monetary policy shock (hence an increase in the interest rate), leads to a decline in both output and inflation. Finally, a credit shock, being a pure financial shock, increases the volume of loans (b_t) but has no effect on macroeconomic variables contemporaneously. This set of identification restrictions is thus necessary and sufficient to ensure we identify a shock to the term premium. To remain as agnostic as possible, we impose these restrictions only contemporaneously upon impact of the shock.

3.3.2   Results

Figure 3.3 shows the impulse responses of a one standard deviation positive shock to the term premium. From the left column, we can see that a shock to the term premium of 2,000 basis points has a short-lived, yet very sizeable effect on the economy. Output declines by 2% and returns back to the steady state after five years. This confirms that the term premium is indeed counter-cyclical as shown in Section 3.2. The response of inflation and the interest rate is not very strong and zero is included in the credible set. Loans decline and exhibit more persistent effects than output, with the median response only returning to the steady state after roughly 10 years. To confirm that the term premium is indeed capturing financial uncertainty, we perform the same analysis but use the junk-bond spread instead of the term premium to capture financial risk (see Appendix 3.A.2 for a description of the data). A widening of the junk-bond spread, an indicator of the overall creditworthiness of the private sector, is often a signal of higher perceived risk in the financial markets. If the term premium is a good measure of financial uncertainty, we should expect a similar behaviour of macroeconomic responses for a shock to the junk-bond spread, as we observe for the term premium shock. We linearly detrend the junk-bond spread and use the same BVAR structure and identification restrictions. The right column of Figure 3.3 reports the results for a one-standard deviation shock to the junk-bond spread. Similarly to the term premium shock, output and loans decline significantly. Also, inflation increases, yet insignificantly, while interest rate decreases persistently. In contrast to the term premium shock,

the effects of a junk-bond spread shock seem to be quantitatively larger. A possible explanation for this difference is that the junk-bond spread relates more closely to corporate short-term risk and is thus more volatile. Importantly, we find that banks reduce loans to the private sector as a consequence of a risk shock and thus established empirically that there is indeed a link between risk and loan allocation that renders further investigation.

Figure 3.3: Impulse Responses to a Term Premium (left) and Junk-Bond Spread (right) Shocks
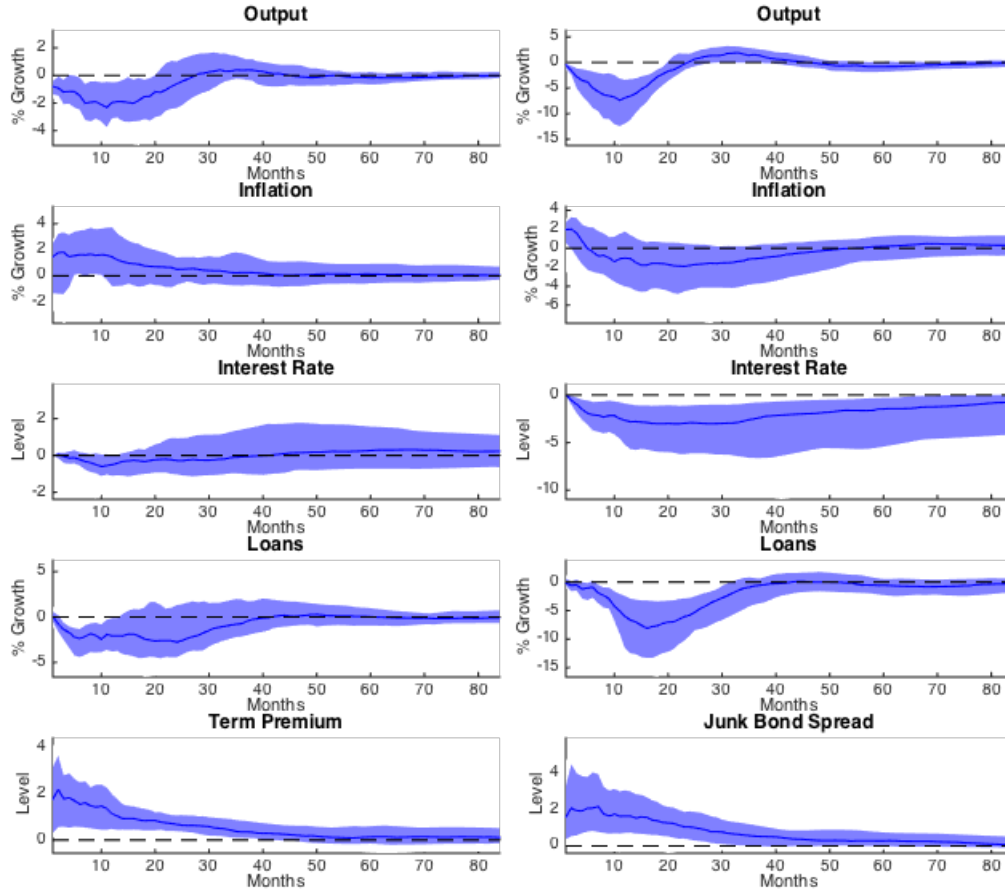
Notes: The shaded regions report point-wise 68% Monte Carlo credible sets. The solid line shows the median response to a one standard deviation shock to the term premium (left column) and junk-bond spread (right column).

To check the robustness of the results, we estimate alternative specifications. Figure 3.B.1 in the Appendix reports the results for a one-standard deviation shock to the term premium excluding the financial crisis (left column) and focussing only on the period of the Great Moderation (right column). Excluding the financial crisis (January 1961–July 2007) has no effect on either the quantitative nor qualitative results. Looking only at the time of the Great Moderation (January 1986–July 2007) does not change the results qualitatively, but increases the credible sets around the median response due to the decrease in data volume. As a further robustness check to show that our model is well specified, we report the responses of a monetary

policy shock in Figure 3.B.2 in the Appendix. In line with economic theory, a contractionary monetary policy shock causes output and inflation to fall on impact, and the term premium to increase –only slowly converging back to zero. Finally, we report the responses to a VIX shock in Figure 3.B.3 in order to investigate the effects of short-term risk rather than long-term risk. As the CBOE VXO/VIX is only available from July 1986, the credible sets are wider than for the term premium model due to the reduced sample size. The responses are qualitatively similar. However, the responses for the VIX shock are less persistent than for a term premium shock. The reduction in the persistence of the macroeconomic responses is consistent with the assumption that short-term risk, as captured by the VIX, would have less persistent effects than changes in long-term risk, as measured by the term premium.

Next, we develop a structural model to further analyse the relationship between the term premium and the macroeconomy.

3.4   DSGE Model

In this section, we construct a New-Keynesian DSGE model that can generate a positive and time-varying term premium to structurally analyse the effects of a long-term risk shock on the macroeconomy, the banking sector, and financial stability.[8] There are two key features that help match term premium moments: Epstein-Zin preferences and third-order solution methods. Firstly, Epstein and Zin (1989) preferences have the advantage that risk aversion can be modelled independently from the intertemporal elasticity of substitution (IES). Intuitively, Epstein-Zin preferences imply that households are not just concerned with smoothing their consumption once sudden shocks are realised in the short term, but also with medium- and longer-term changes in consumption, allowing long-term risk to play a role in households' decision-making process. As Epstein-Zin preferences yield the same results using first-order approximations as standard utility functions, the model is still able to match macroeconomic moments. However, by allowing an additional parameter, α_{EZ}, the risk aversion of households can now be amplified to match the empirical features of bond moments, as well.

Secondly, using higher order solution methods generates heteroskedasticity in the stochastic discount factor, which creates an endogenously determined time-varying term premium. First-order solutions would imply that the expectation hypothesis holds and hence for the term premium to be zero. Second-order solutions can improve upon this by generating a positive, yet constant term premium. Only by using third-order solutions, we manage to capture a

---

[8]The advantage of the New Keynesian model over a Real Business Cycle model is that inflation and inflation expectations are taken into account which is crucial for the determination of the yield curve and thus, the term premium.

time-varying term premium and match empirical bond moments.

In this setup, asset prices become relevant for real behaviour, giving the term premium a key role as a feedback mechanism between financial markets and the macroeconomy. Importantly, this framework allows us to structurally study the implications of a term premium shock for financial stability in a general equilibrium context and thus understand the mechanisms by which long-term risk affects the macroeconomy.

3.4.1   Model Description

As in Gerali et al. (2010) and Gambacorta and Signoretti (2014), the model contains several agents: patient households, impatient entrepreneurs, retailers, wholesale and retail banks, capital goods producers, and a monetary policy authority. We modify their baseline model by introducing non-defaultable long-term bonds that are issued by a fiscal authority to finance government spending. Long-term bonds are determined by standard asset pricing rules that allow for a time-varying term premium to arise endogenously in the model and create a feedback loop between the financial sector and the real economy.

Households are patient and provide labor to impatient entrepreneurs. Competitive entrepreneurs produce intermediate goods which are sold to retailers. These retailers differentiate the intermediate goods and sell them with a mark-up to households, who also own the retailers and keep their profits. Banks have two branches: a wholesale and a retail branch. Wholesale banks take deposits from households and can invest in long-term bonds. They operate under perfect competition. Retail banks are monopolistic and give out loans to entrepreneurs charging a mark-up fee. In addition, they take and monitor collateral from the entrepreneurs given a stochastic loan-to-value (LTV) ratio. To sum up, banks can choose between a) keeping deposits which are equivalent to short-term T-Bills, as they pay the risk-free rate, b) give out loans to entrepreneurs and receive profits from the mark-up they charge, or c) invest in long-term bonds which pay a term premium. The remaining profits are invested in bank capital which is monitored by the central bank or monetary policy authority. The monetary policy authority sets the policy rate, determines the capital/asset ratio for banks, and the LTV target ratio for entrepreneurs. The fiscal authority issues long-term government bonds to finance government spending which is modelled exogenously. In addition, there are capital producers who buy undepreciated capital from entrepreneurs and re-sell it for a new price back to entrepreneurs taking into account quadratic adjustment cost. This is necessary to derive a price for capital. Similar to Rudebusch and Swanson (2012), we focus on long-term bonds rather than equity, in order to capture changes in households' perception of long-term risk. Since long-term bonds affect real behaviour and vice versa, the term premium has important policy implications for

the central bank, which we further investigate in Section 3.5.2.

Households

Households maximise their recursive utility function

$$V_t = U(c_t^P, l_t) + \beta_P \left[\mathbb{E}_t(V_{t+1})^{(1-\alpha_{EZ})} \right]^{1/(1-\alpha_{EZ})}, \tag{3.2}$$

where c_t^P is consumption, l_t is labour supply, β_P is the patient discount factor, and α_{EZ} is the Epstein-Zin parameter that measures households' risk aversion. The intra-period utility function is given by

$$U(c_t^P, l_t) = \frac{(c_t^P)^{1-\varphi}}{1-\varphi} - \frac{l_t^{1+\phi}}{1+\phi}.$$

$1/\phi$ is the Frisch elasticity of labour and $1/\varphi$ is the IES. Households deposit savings at wholesale banks, for which they receive a risk-free return. They also own retail firms, which are monopolistic and generate a profit, so that they are subject to the budget constraint

$$c_t^P + d_t \leq w_t l_t + (1 + r_{t-1}^{ib})d_{t-1} + J_t^R, \tag{3.3}$$

where d_t are bank deposits, w_t is the real wage, and r_t^{ib} is the short-term rate set by the monetary policy authority. The central bank has therefore the potential to directly impact the household decision-making process, since an increase in the policy rate would induce households to increase their savings. J_t^R are the profits of the retail sector. The first-order condition yields the standard consumption Euler equation

$$\frac{1}{c_t^P} = \mathbb{E}_t \frac{\beta_P(1 + r_t^{ib})}{c_{t+1}^P}. \tag{3.4}$$

Households also provide labour to the entrepreneurs for the production of intermediate goods, which follows the usual labour supply schedule

$$l_t^\phi = \frac{w_t}{c_t^P}. \tag{3.5}$$

Entrepreneurs

Entrepreneurs need to borrow from banks by providing capital as a collateral, but also produce goods, employ households and consume. They form the link between the real economy and the banking sector and are thus important for generating a feedback loop between the financial and

macroeconomic side of the model. The entrepreneurs maximise

$$\max_{c_t^E, l_t^d, b_t^E} \mathbb{E}_0 \sum_{t=0}^{\infty} \beta_E \log(c_t^E). \tag{3.6}$$

with respect to their consumption, c_t^E, labour demand, l_t^d, and bank loans, b_t^E. The optimisation problem is subject to a budget constraint, which is

$$c_t^E + (1 + r_{t-1}^b)b_{t-1}^E + w_t l_t^d + q_t^k k_t^E \leq \frac{y_t^E}{x_t} + b_t^E + q_t^k(1 - \delta_k)k_{t-1}^E, \tag{3.7}$$

where r_t^b is the interest rate on bank loans, k_t^E is the entrepreneurs stock of capital, q_t^k is the price of capital, and y_t^E is the intermediate output produced by entrepreneurs. $\frac{1}{x_t} = \frac{P_t^W}{P_t}$ is the relative competitive price of the intermediate good produced by the entrepreneur, and δ_k is the depreciation rate of capital. The entrepreneurs are also subject to an occasionally binding borrowing constraint

$$b_t^E \leq \frac{m_t^E q_{t+1}^k k_t^E (1 - \delta_k)}{1 + r_t^b}, \tag{3.8}$$

where m_t^E is the stochastic LTV ratio which follows an AR(1) process with an i.i.d shock ε_t^{me} and variance σ_{me}. A high LTV ratio implies that banks can lend more for the same amount of collateral and vice versa. The borrowing constraint determines how much entrepreneurs can borrow from banks. For small enough shocks, $\beta_P > \beta_E$ ensures that the borrowing constraint is binding and credit is constrained in the economy.

Entrepreneurs do not work but use capital and labour in the production of intermediate goods. As in Kiyotaki and Moore (1997), capital has many functions in this model and thus establishes another important feedback mechanism between the real economy and the financial sector. Capital is used (i) in the production of intermediate goods, (ii) as a collateral for the entrepreneurs, and (iii) as a source of funds for investment. The production function for intermediate goods follows a standard Cobb-Douglas form

$$y_t^E = A_t^e (k_t^E)^{\alpha} (l_t^d)^{(\alpha-1)}, \tag{3.9}$$

where α denotes the capital share, and A_t^e technology. A_t^e is stochastic and follows an AR(1) process with an i.i.d. technology shock ε_t^a with variance σ_a. Entrepreneurs operate under perfect

competition. Their optimal consumption Euler equation is

$$\frac{1}{c_t^E} - \lambda_t^E = \mathbb{E}_t \frac{\beta_E(1 + r_t^b)}{c_{t+1}^E}. \tag{3.10}$$

This is similar to the households' Euler equation but differs by the Lagrange multiplier on the borrowing constraint, λ_t^E, which represents the marginal value of one unit of additional borrowing. Another difference is that entrepreneurs, unlike households, discount at a higher rate and face the higher bank loan rate, r_t^b, rather than the risk-free rate, r_t^{ib}. The labour demand schedule is

$$\frac{(1 - \alpha)y_t^E}{l_t^d x_t} = w_t. \tag{3.11}$$

The investment Euler equation equalises the marginal benefit with the marginal cost of saving capital. As capital serves as collateral, the equation also depends on the Lagrange multiplier of the borrowing constraint and the LTV ratio. It follows that

$$\frac{\lambda_t^E m_t^E q_{t+1}^k (1 - \delta_k)}{1 + r_t^b} + \frac{\beta_E}{c_{t+1}^E} \left[q_{t+1}^k (1 - \delta_k) + r_{t+1}^k \right] = \frac{q_t^k}{c_t^E}, \tag{3.12}$$

where r_t^k is the return to capital which is defined by the marginal product of capital as

$$r_t^k \equiv \alpha \frac{A_t^E (k_t^E)^{(\alpha-1)} (l_t^d)^{(1-\alpha)}}{x_t}. \tag{3.13}$$

Banks

The banking sector is divided into a perfectly competitive wholesale and a monopolistic retail sector. The wholesale sector maximises bank profits by optimising the net interest margin between the loan rate, the long-term bond rate, and the deposit rate subject to the quadratic adjustment costs of deviating from a target capital/asset ratio, ν. As the deposit rate is the same as the risk-free rate, banks' demand for deposits is elastic and the amount of deposits is determined by households. The bank's maximisation problem is

$$\max_{b_t^E, b_t^l} R_t^b b_t^E + r_t^l b_t^l - r_t^{ib} d_t - \frac{\theta}{2} \left(\frac{K_t^b}{B_t} - \nu \right)^2 K_t^b, \tag{3.14}$$

where $B_t = b_t^E + b_t^l$ represents the total assets of the bank. K_t^b is the banks' capital and θ is the parameter for the capital adjustment costs. Monetary policy tightening, i.e. a higher policy rate,

thus lowers bank profits, as households increase their deposits. If lower profits lead banks to increase their holdings of long-term bonds $\left(b_t^l \uparrow\right)$, which puts upward pressure on the price of long-term bonds, then real long-term yields would decline. This price pressure is independent from the expectations of short-term rates in the future; i.e. it's purely a term premium effect. This mechanism implies that monetary policy would then have indirect effects on the long-term yield by lowering the term premium through this portfolio-rebalancing channel.

Wholesale banks are subject to a balance sheet constraint that can also be interpreted as a capital adequacy constraint. Loans and bonds have to be backed up by sufficient bank capital and deposits at the beginning of the period

$$b_t^E + b_t^l = d_t + K_t^b. \tag{3.15}$$

Combining (3.14) and (3.15), the first-order condition of the wholesale bank collapses to

$$R_t^b = r_t^l. \tag{3.16}$$

While the long-term bond rate is determined by the households' stochastic discount factor, the retail bank on the other hand, repackages the wholesale loans and charges a mark-up, $\overline{\mu}_b$, on the wholesale loan rate, so that the retail loan rate becomes

$$r_t^b = R_t^b + \overline{\mu}_b. \tag{3.17}$$

The retail banks have market power, which helps them to adjust their lending in response to shocks or cycles. Notice that, everything else held constant, a term premium shock that increases the long-term rate, also increases the loan rate charged by retail banks, making access to credit more expensive for entrepreneurs. Alternatively, in response to a monetary policy shock that raises the policy rate, the bank can increase its mark-up on the loan rate, affecting the entrepreneurs' ability to finance new projects. Thus both, the term premium and monetary policy shocks, have the potential to indirectly affect the real economy through this credit-access channel. Another crucial determinant for the feedback loop between the banking sector and the real economy is bank capital. Bank capital depreciates at rate δ_b and accrues from past capital and retained earnings, J_t^B,

$$K_t^b = K_{t-1}^b(1 - \delta_b) + J_{t-1}^B. \tag{3.18}$$

Since it is pro-cyclical, bank capital worsens when output declines due to decreasing banks' profits. The latter is defined as the sum of both the retail and wholesale sector profits on loans,

long-term bonds, and deposits, respectively, and depends on the condition of the macroeconomy

$$J_t^B = r_t^b b_t^E + r_t^l b_t^l - r_t^{ib} d_t - \frac{\theta}{2}\left(\frac{K_t^b}{B_t} - \nu\right)^2 K_t^b. \tag{3.19}$$

Retailers and Capital Good Producers

The monopolistic retailers differentiate the intermediate goods produced by the entrepreneurs at no cost and sell them with a mark-up, x_t. However, retailers face quadratic price adjustment cost, which causes prices to be sticky. The parameter κ_P represents the degree of price stickiness. The first order condition of the retailers generates the classic New Keynesian Philip's curve

$$1 = \frac{mk_t^y}{mk_t^y - 1} + \frac{mk_t^y}{mk_t^y - 1}mc_t^E - \kappa_P(\pi_t - 1)\pi_t + \beta_P\mathbb{E}_t\left[\frac{c_t^P}{c_{t+1}^P}\kappa_P(\pi_{t+1} - 1)\pi_{t+1}\frac{Y_{t+1}}{Y_t}\right], \tag{3.20}$$

where the marginal cost is $mc_t^E \equiv \frac{1}{x_t}$, $\pi_t = log\,(P_t/P_{t-1})$, and Y_t is total output. The firm's mark-up, mk_t^y, is stochastic and follows an AR(1) process with the autocorrelation coefficient ρ_{mk} and an i.i.d. mark-up shock, ε_t^{mk}, with variance σ_{mk}.

Capital good producers are perfectly competitive and their main task is to transform the old, undepreciated capital from entrepreneurs to new capital without any additional costs. They then resell the new capital to the entrepreneurs in the next period at price P_t^k, so that the relative price of capital is $q_t^k \equiv \frac{P_t^k}{P_t}$. In addition, capital producers 'invest' in the final goods bought from retailers, which are not consumed by households, and also transform these into new capital.

The final goods to capital transformation is subject to quadratic adjustment costs that are parameterised by κ_i, the investment (I_t) adjustment cost parameter. The first-order condition of capital good producers is

$$1 = q_t^k\left[1 - \frac{\kappa_i}{2}\left(\frac{I_t}{I_{t-1}} - 1\right)^2 - \kappa_i\left(\frac{I_t}{I_{t-1}} - 1\right)\frac{I_t}{I_{t-1}}\right] + \beta_E\mathbb{E}_t\left[\frac{c_t^E}{c_{t+1}^E}q_{t+1}^k\kappa_i\left(\frac{I_{t+1}}{I_t} - 1\right)\left(\frac{I_{t+1}}{I_t}\right)^2\right], \tag{3.21}$$

with capital, K_t, evolving according to

$$K_t = (1 - \delta_k)K_{t-1} + \left[1 - \frac{\kappa_i}{2}\left(\frac{I_t}{I_{t-1}} - 1\right)^2\right]I_t. \tag{3.22}$$

Monetary Policy

Monetary policy follows a standard Taylor rule, so that the policy rate is set according to

$$1 + r_t^{ib} = (1 + r^{ib})^{(1-\rho_{ib})}(1 + r_{t-1}^{ib})^{\rho_{ib}} \left(\frac{\pi_t}{\pi}\right)^{\phi_\pi(1-\rho_{ib})} \left(\frac{y_t}{y}\right)^{\phi_y(1-\rho_{ib})} (1 + \varepsilon_t^r). \qquad (3.23)$$

where ρ_{ib} is the interest-rate smoothing coefficient, $\left\{r^{ib}, \pi, y\right\}$ are the interest rate, inflation and output targets, respectively, and ϕ_π and ϕ_y are the inflation and output monetary policy parameters. ε_t^r is an i.i.d monetary policy shock with variance σ_r.[9]

The monetary policy authority is also responsible for setting a target capital/asset ratio for banks to avoid an over-leveraging of the economy similar to the Basel Tier 1 leverage ratios. Moreover, the central bank also sets the LTV target ratio for entrepreneurs. These two choices, nevertheless, are independent from the monetary policy rule that targets output and price stability, thus allowing for macroprudential policies to simultaneously aim to reduce financial instability.

Asset Pricing Equations

Let $p_t^{(n)}$, the price of a bond at time t maturing at $t + n$, be determined by the risk-adjusted expected valuation of future payoffs,

$$p_t^{(n)} = \mathbb{E}_t[m_{t+1} p_{t+1}^{(n-1)}], \qquad (3.24)$$

where $p_t^{(0)} = 1$ and m_{t+1} is the stochastic discount factor defined as $m_{t+1} = \beta_P \frac{v'(c_{t+1}^P)}{v'(c_t^P)}$. The yield for the n-th period zero-coupon bond, $i_t^{(n)}$, can then be computed as

$$i_t^{(n)} \equiv -\frac{1}{n} \log p_t^{(n)}. \qquad (3.25)$$

---

[9]Fuerst and Mau (2016) point out that the exact monetary policy rule specification is important to generate variability in the term premium in response to macroeconomic shocks. In order to achieve greater variability in the term premium, the monetary authority should respond to the level of output relative to the steady state rather than the output gap (see Rudebusch and Swanson, 2012). As an output level rule means the central bank is committing to a contractionary policy for longer, thus reducing inflation by more, the term premium is more affected than in the case of an output gap rule.

Without loss of generality, we assume that long-term bonds are default-free securities issued by the fiscal authority that pay a geometrically declining coupon every period in perpetuity.[10] The price of the long-term bond in this economy, $\tilde{p}_t^l$, for a one dollar coupon is

$$\tilde{p}_t^l = 1 + \delta_c \mathbb{E}_t[m_{t+1}\tilde{p}_{t+1}^{l-1}] - \mu_t^{tp}, \tag{3.26}$$

where δ_c is the coupon decay rate that controls the duration of the bond. We set the decay rate to match the 10-year maturity benchmark rate for zero-coupon bonds.[11] In order to analyse the effects of an unexpected increase in long-term risk, we introduce a term premium shock, μ_t^{tp}, to the price of long-term securities, which is modelled as an AR(1) shock, where $\mu_t^{tp} = \rho_\psi \mu_{t-1}^{tp} + \varepsilon_t^{tp}$, for $\varepsilon_t^{tp} \sim N(0, \sigma_{tp})$.[12] Notice that a positive term premium shock lowers the price of the long-term bond and therefore increases the yield that investors require in order to be compensated for the higher risk. This exogenous variation in long-term bonds affects the economy like a shock to long-term uncertainty/risk, as it implies a decrease in the long-term bond price that is not reflected in the risk-neutral bond price, so that it must be related to an increase in the compensation that banks require to hold long-term debt due to risk. In practice, various exogenous events could cause an unexpected increase in long-term risk perceptions (e.g. political elections/referendums, new regulation, discovery of additional resources). As Andreasen (2012) points out rare disasters increase the level of the term premium, while uncertainty increases the variance of the term premium, so that our term premium shock can account for both types of events.

From a purely financial decomposition, the price of the bond can be expressed as the risk-neutral present value of the bond, plus the covariance between future payoffs and the stochastic dicount factor of the household that governs the term premium: $\tilde{p}_t^l = \mathbb{E}_t[\tilde{p}_{t+1}^{l-1}]\left(1 + r_t^{ib}\right)^{-1} + cov_t\left(m_{t+1}, \tilde{p}_{t+1}^{l-1}\right)$. In our model, the stochastic discount factor is $m_{t+1} = \beta_P \left(\frac{c_{t+1}^P}{c_t^P}\right)^{-\varphi} \left[V_{t+1}/\left(\mathbb{E}_t\left(V_{t+1}^{1-\alpha_{EZ}}\right)^{1/(1-\alpha_{EZ})}\right)\right]^{-\alpha_{EZ}}$. This implies that the term premium depends on the covariance between future returns and consumption growth, and the covariance between future returns and the utility index of households; i.e. their future prospects. Hence investors

---

[10]This is equivalent to assuming that long-term bonds are infinitely-lived *consol-style* bonds as in Chin et al. (2015). The purpose of this assumption is to reduce the pricing relationship to just one recursive equation in the model, rather than having to solve for each maturity level. As shown in Rudebusch and Swanson (2012) this simplification still generates equivalent results to using ten-year zero-coupon bonds, while significantly reducing the computational burden.

[11]We use an adjusted formula of Macaulay duration $D = \frac{(1+i)}{(1+i-\delta_c)}$ and solve it for δ_c with $D = 40$ periods to mimic a ten-year zero-coupon bond for which duration is equal to maturity. Note that $\delta_c < \beta^{-1}$ is the upper bound that defines an infinite duration bond.

[12]We model the term premium shock as an AR(1) process following the empirical evidence supporting the idea that investors' perceived declines in the term premium are persistent (see Adrian et al., 2013). Moreover, this is consistent with the literature on uncertainty or credit risk shocks being persistent, as in Christiano et al. (2014).

demand a higher term premium when marginal utility of consumption is high and their future prospects have deteriorated, their relative risk aversion increases ($\alpha_{EZ} \uparrow$), they become less patient ($\beta_P \downarrow$), or their ability to smooth consumption across periods diminishes ($\varphi \uparrow$).

By definition, the yield to maturity of the long-term bond, r_t^l, is thus

$$r_t^l \equiv \log \frac{\delta_c \widetilde{p}_t^l}{\widetilde{p}_t^l - 1}. \tag{3.27}$$

An important assumption for a positive term premium is that risk neutrality does not hold, as otherwise m_{t+1} would be equal to the expected future short-term interest rate with the expectations hypothesis holding. Assuming that households are however risk averse, the difference between the long-term rate and the sum of expected future short-term rates is characterised by a time-varying term premium. As guaranteed by the absence of arbitrage in the bond markets, we compute the term premium as the difference between the yield on the long-term bond and the yield on the equivalent risk-neutral bond, which can simply be defined as the expected present value of future payoffs discounted at the risk-free rate rather than the household's stochastic discount factor. The price for the risk-neutral bond, $\hat{p}_t^l$, is therefore

$$\hat{p}_t^l = 1 + \frac{\delta_c}{(1 + r_t^{ib})} \hat{p}_{t+1}^{l-1}. \tag{3.28}$$

Hence the implied term premium, ψ_t^l, is defined as

$$\psi_t^l = \log \frac{\delta_c \widetilde{p}_t^l}{\widetilde{p}_t^l - 1} - \log \frac{\delta_c \hat{p}_t^l}{\hat{p}_t^l - 1}. \tag{3.29}$$

Government Sector

For simplicity, we assume that all government spending, G_t, is financed exclusively via long-term bonds. The budget constraint of the fiscal authority is thus expressed as the ratio of the value of long-term bonds to output $\left(\frac{b_t^l}{Y_t} \right)$,

$$G_t + r_t^l \frac{b_{t-1}^l}{Y_{t-1}} = \frac{b_t^l}{Y_t}. \tag{3.30}$$

Government spending follows a stationary AR(1) process

$$G_t = (1 - \rho_g)G^{SS} + \rho_g G_{t-1} + \varepsilon_t^g, \tag{3.31}$$

where G^{ss} is the steady state value of government consumption, ρ_g captures the degree of correlation in fiscal policy, and ε_t^g is a government spending i.i.d. shock with variance σ_g.

Market Clearing and Aggregation

Goods and labour markets clear. The resource constraint of the economy is

$$Y_t = C_t + I_t + G_t, \tag{3.32}$$

as it is a closed economy.

3.4.2 Solution and Calibration

Since the dimension of the model is relatively high with 14 state variables, our only feasible option to solve the model is through perturbation methods. As the term premium needs to be time-varying, we use third-order solutions to ensure realistic dynamics for the term premium.[13] We apply pruning to cut out unstable higher-order explosive terms. The advantage of using third-order solutions is that the macroeconomic responses remain mostly unchanged, and thus correspond to results in the previous literature, while the responses for the bond markets can be rendered more realistically. As estimation of larger-scale, non-linear models is still difficult, we follow Rudebusch and Swanson (2012) and calibrate our model to fit specific moments for both macroeconomic, as well as financial variables. Table 3.2 reports the values of the calibrated parameters for the baseline model.

Most of these values are standard and based on previous estimates for the U.S. data. For the households, the discount factors are set such that β_P implies an annual inflation rate of 1.6% and $\beta_P > \beta_E$ ensures that entrepreneurs are more impatient. ϕ is based on the inverse of the Frisch elasticity being 2/3. φ is based on the IES being 2/3, in line with previous micro-founded studies which find the IES to be smaller than one (e.g. Vissing-Jørgensen, 2002). We set the Epstein-Zin parameter $\alpha_{EZ} = -6$ to match the term premium moments. Using the constant relative risk aversion (CRRA) formula in Swanson (2010), this number implies an overall CRRA of 2. This

---

[13]Caldara et al. (2012) show that perturbation methods provide equally accurate solutions to models with recursive preferences than Chebychev polynomials and value function iterations, but are considerably faster.

Table 3.2: Calibrated Parameters

Parameters	Value	Parameters	Value	Parameters	Value
Households		Finance		Shocks	
β_P	0.996	θ	11	ρ_A	0.9
β_E	0.975	ν	0.09	ρ_{mk}	0.7
ϕ	1.5	$\overline{\mu}_b$	0.0050	ρ_g	0.9
φ	1.5	δ_c	0.9789	ρ_{me}	0.9
α_{EZ}	-3			ρ_B	0.9
				ρ_ψ	0.9
Production		Monetary policy			
mk^{ySS}	1.2	ϕ_π	1.5	σ_A	0.005
α	0.3	ϕ_y	0.5	σ_{mk}	0.01
κ_P	28.65	ρ_{ib}	0.7	σ_g	0.0025
κ_i	5			σ_{me}	0.01
δ_k	0.050	$\frac{K^{ss}}{4Y^{ss}}$	2.5	σ_r	0.004
π^{ss}	1	$\frac{G^{ss}}{Y^{ss}}$	0.17	σ_ψ	0.002

is a remarkable low result in the macro-finance literature, in which estimates unrealistically range from 30 to 110 (e.g. Rudebusch and Swanson, 2012), while at the same time being very consistent with the low estimates found in the macro literature (see Havranek et al., 2015 for a meta-study).

The production parameters are standard. The price elasticity of demand is assumed to be 6, which implies $mk^{ySS} = 1.2$. The adjustment cost for prices, modelled via Rotemberg pricing, follows the estimated values by Gerali et al. (2010), as do the adjustment cost for investment, κ_i, and the adjustment cost for banks, θ. The capital share is assumed to be 0.3, and the rate of depreciation follows an annual depreciation rate of 20%. The banking parameter, ν, is set to match the Basel capital/asset target ratio of 0.09. The decay rate for consol bonds, δ_c, is set to match the 10-year bond duration. The monetary policy rule parameters reflect that the central bank targets inflation and output, but inflation more heavily. The shock parameters are set to standard values, with the persistence of shocks being 0.9, except for the mark-up shock, which is less persistent. The standard deviations of the shocks are set between 0.2–1 percentage points, depending on the volatility of the respective variable. Finally, the steady state capital/output and government spending/output ratios are set as in Rudebusch and Swanson (2012).

To evaluate the fit of the model, we compare both macroeconomic as well as asset price moments implied by the DSGE model to the data. We use quarterly U.S. data for chained GDP, consumption, investment, and labour. The Hedrick-Prescott filter is used to compute the business cycle component of the log of these macroeconomic variables. For inflation, the

Table 3.3: Comparing Simulated Model Data with Actual Data

Unconditional Moments	U.S. Data, 1961-2016 (1961-2007)	Model Data
$SD[Y]$	1.46 (1.46)	1.40
$SD[C]$	0.85 (0.83)	1.00
$SD[I]$	4.08 (3.95)	1.19
$SD[l]$	2.10 (1.97)	1.62
$SD[\pi]$	2.45 (2.52)	2.66
$SD[r^{ib}]$	3.20 (2.70)	0.71
$\mu[\psi^l]$	1.62 (1.74)	1.63
$SD[\psi^l]$	1.19 (1.20)	1.05

Notes: All variables are reported in quarterly percentage points except for inflation, the interest rate, and the term premium which are converted into annual frequency. For robustness, we compute the unconditional moments for both data from 1961-2016 and data excluding the financial crisis from 1961-2007 in parentheses. The model moments are computed by simulating the data 224 times to be consistent with the duration of the actual data.

interest rate, and the term premium, annualised data are used. The interest rate is the shadow Federal Funds rate, and inflation is calculated using the GDP deflator. The term premium is the ten-year Treasury average term premium from the Federal Reserve Bank of New York (Adrian et al., 2013). Details can be found in the Data Appendix 3.A.3.

Since we use third-order approximations, theoretical moments are more complicated to compute, so that we use simulated moments instead. Table 3.3 shows the results for the baseline calibration. As we can see, the model performs well in matching output, consumption, labour, inflation, and in particular the term premium moments. Unlike previous studies, we are able to match the term premium moments with a very small CRRA of 2, which is more consistent with the macroeconomic literature. It performs less well in matching investment and the interest rate. In both of these cases, the model indicates lower volatility than is found in the data. The volatility of investment is potentially lower, as government spending in our model does not crowd out private investment, so that there is less variability in the model simulated variables than in the data.

After performing some sensitivity analysis, we conclude that in particular, the parameters for the IES, the capital share, the monetary policy parameters, the Epstein-Zin parameter, and the variance for the term premium shock are important to determine the term premium moments. There is a tradeoff in increasing the volatility of the interest rate versus increasing the mean of the term premium, as higher interest rate volatility corresponds to an increase in the term premium. Interestingly, changing the banking or production parameters has very little effect

on the term premium. Instead, it seems that the term premium moments are mostly driven by household parameters. The dynamics of the model are, however, relatively robust to changes in the parameters, as seen in Figure 3.C.1 in Appendix 3.C.

3.5   Results

We begin by analysing how a term premium shock affects the macroeconomy. As in the empirical section, we interpret a term premium shock as a temporary, exogenous change in long-term risk that is immediately priced in the financial markets. Figure 3.4 reports the results. A 10 basis-point term premium shock that raises the long-term interest rate has a clear negative effect on the macroeconomy, with output, consumption, investment, and inflation all falling upon impact. These results are consistent with the idea that an increase in the long-term rate that is orthogonal to the expected path of future short-term rates, reflects higher perceived risk in the economy, inducing households to save more and consume less, prices to go down, and output and investment to contract. While the effect on consumption and investment is more persistent, the effect on output and inflation dissipates quickly, as the monetary policy authority responds with monetary accommodation (lowering the policy rate) to stimulate the economy. The policy rate therefore declines, as the monetary policy rule prescribes lower interest rates in response to a decline in output and inflation. Both consumption and inflation show an initial overshooting but then converge back to their steady states.

To understand the effect of a term premium shock on the financial sector, we look at the response of the loan/deposit ratio, and find that the financial system becomes more leveraged and hence less stable as risk increases.[14] The persistence of the response suggests that a term premium shock has long-term consequences for financial stability. The increase in long-term rates following higher perceived risk, brings about a clear redistribution effect between private and government debt, with private loans decreasing as loan rates go up ($r_t^b \uparrow$) and government debt-to-GDP ratio increasing (as $r_t^l \uparrow$). In an environment with higher financial uncertainty, private lending rates increase, making it less attractive for borrowers to take out loans, which further contributes to a decline in private debt as credit availability becomes constrained.

Overall, the results of the theoretical model are in line with the previous literature on uncertainty shocks (e.g. Leduc and Liu, 2016) in that the term premium shock seems to correspond with a demand shock. Unlike the literature on uncertainty shocks, we do not have to assume persistent shocks to the second moment of TFP to model uncertainty. Instead, we can use a level shock to the term premium to replicate exogenous events that increase investors'

---

[14]Jorda et al. (2017) find that the loan/deposit ratio is a better predictor for financial fragility than other measures (i.e. capital/asset ratios).

long-term risk expectations. The macroeconomic responses to the term premium shock are also consistent with recent findings in the finance literature, in which Joslin et al. (2014) find that both economic activity and inflation significantly decline when a canonical term structure model of interest rates incorporates macroeconomic fundamentals beyond the information spanned by the yield curve. Although not a general equilibrium framework, their model allows bond prices to be influenced by yield curve factors as well as macroeconomic risks, which in turn account for variation in the term premium. Finally, the DSGE model responses to a term premium shock confirm and refine the findings in our empirical section, which predict that a risk shock lowers output, short-term rates, and loans, and has a more muted effect on prices.

Figure 3.4: Impulse Responses to a Term Premium Shock
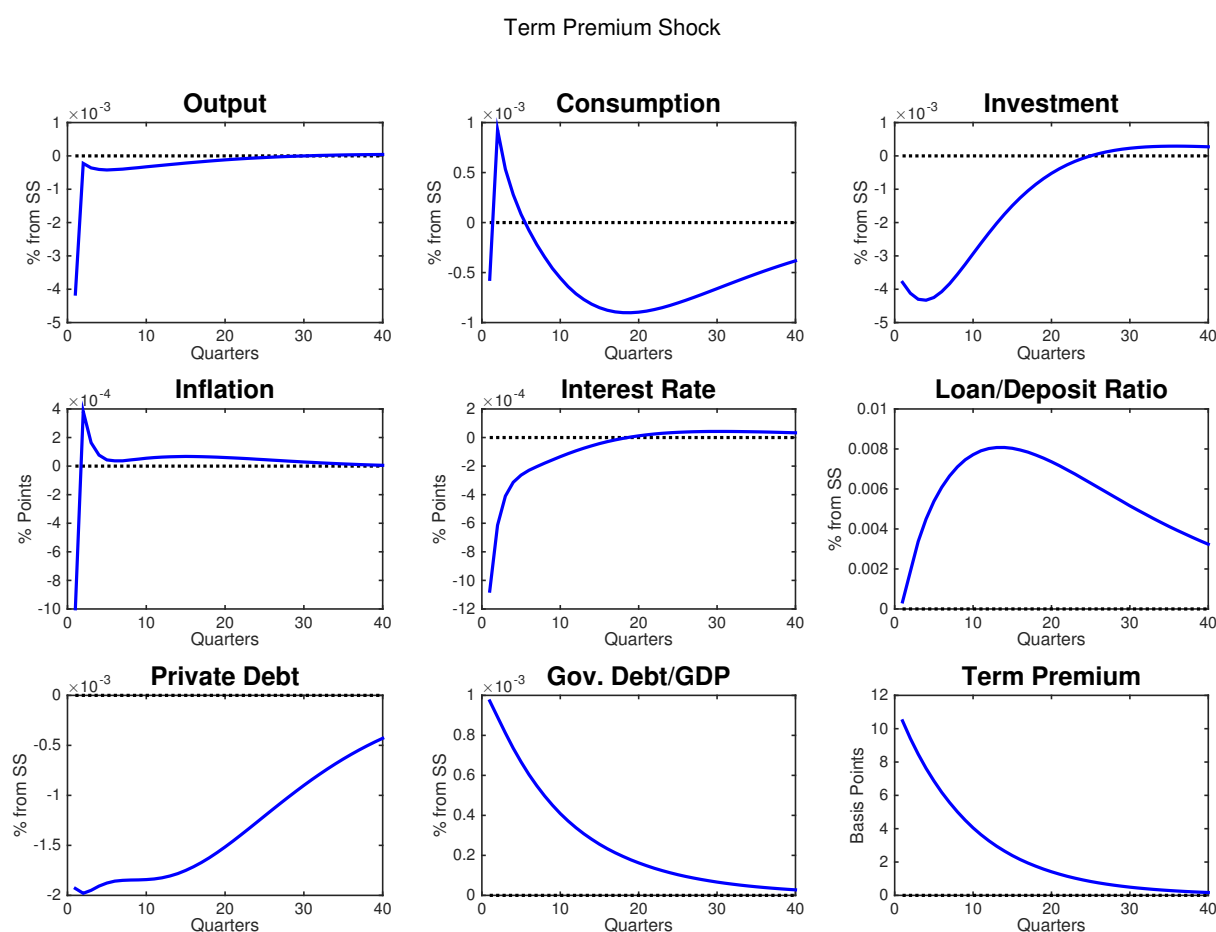
Notes: The blue line represents the impulse responses from the theoretical DSGE model using the baseline calibration. The shock is a 10 basis point shock to the term premium.

### 3.5.1 Monetary Policy and Other Macroeconomic Shocks

Next, we analyse the impulse responses of traditional macroeconomic shocks as well as their effect on the term premium. The responses to a positive, one standard deviation technology, government spending, and monetary policy shocks are reported in Figure 3.5. The left column shows the results for a technology shock, which can also be interpreted as a supply-side shock. As is standard in the literature, a technology shock increases output and lowers inflation and the short-term interest rate. Consistent with the findings outlined in Rudebusch et al. (2007), a technology shock reveals a negative relationship between output and the term premium, which declines as a result of stronger economic activity associated with higher productivity.

In the middle panel, a government spending shock that represents a shock on the demand side, raises both output and inflation, together with the short-term interest rate and the term premium. As in the case of Rudebusch et al. (2007), an increase in government debt that induces output growth, yields a higher term-premium, all else equal. The mechanism behind this result works through the bond-supply channel: As the government increases the supply of long-term bonds to finance higher spending, bond prices go down and bond yields go up, while the risk-neutral yields remain constant, thus increasing the term premium.

The right-hand-side column shows the responses to a positive monetary policy shock, i.e. an increase in the short-term rate. A contractionary monetary policy shock induces less persistent responses and implies, as expected, a decrease in output and inflation. As in Rudebusch et al. (2007) and Rudebusch and Swanson (2012), the term premium increases in response to tighter monetary policy conditions. The intuition behind the increase in the term premium is that tighter monetary policy often leads to increases in risk aversion, so that investors demand a higher compensation to hold long-term bonds.[15]

---

[15]Mallick et al. (2017) investigate the role of monetary policy shocks on the term premium, where pre-2008 they use the Federal funds rate as the main monetary policy instrument and post-2008 they instead use Fed asset purchases and three-month Federal funds futures. Both empirical identification strategies of monetary policy shocks lead to statistically significant effects on the term premium, although through different mechanisms.

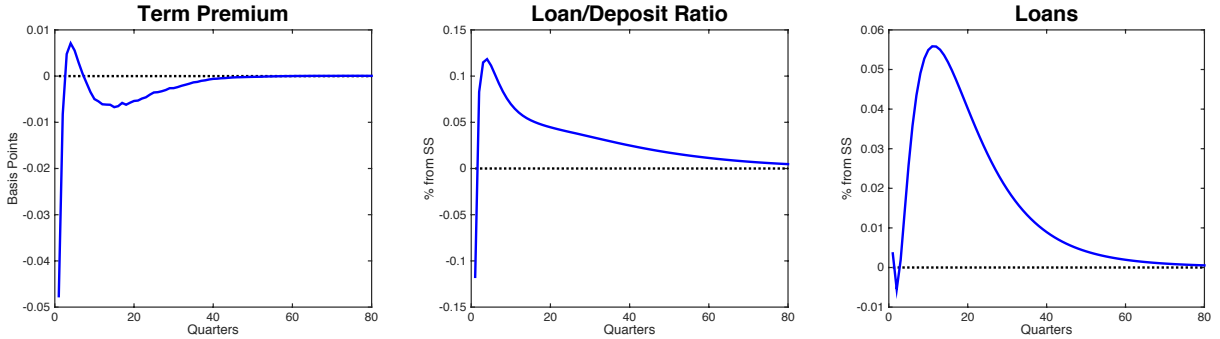Figure 3.5: Impulse Responses to Classic Macroeconomic Shocks
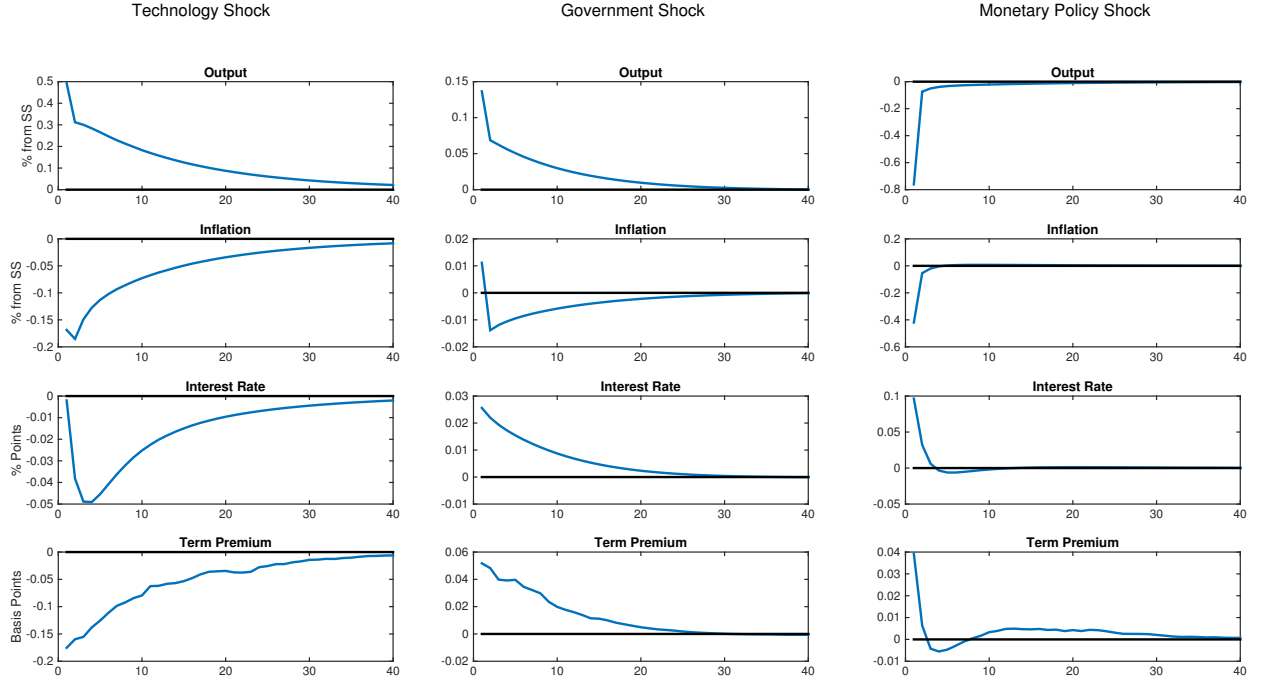
Notes: The blue line represents the impulse responses from the theoretical DSGE model using the baseline calibration. The shock size is a positive one standard deviation shock to the corresponding macroeconomic variable. The *y*-axis represents percentage deviation from steady state with the exception of the interest rate and the term premium, which are presented in quarterly percentage and basis points, respectively. The *x*-axis indicates quarters.

We analyse the interaction of monetary policy and the term premium more closely by considering the effects of an expansionary monetary policy shock. There has been a large debate on the effects of monetary policy on financial stability, particularly in the aftermath of the Global Financial Crisis (e.g., Adrian and Liang, 2016). The key problem lies with the risk-return tradeoff between financial stability and general macroeconomic conditions. While low interest rates help to increase the amount of loans and often coincide with a lowering of the term premium –which boosts banks' profits and investment in the short-term–, they also lead to the build-up of risky leverage in the long run (also see Dell'ariccia et al., 2017). This holds particularly true during times when interest rates are already at low levels (Coimbra and Rey, 2017). Our model provides the mechanisms for which this idea can be rationalised in a general equilibrium context in Figure 3.6, showing the effects of an expansionary monetary policy shock. An expansion in monetary policy does indeed lead to a decrease in the term premium and an increase in loans given out to entrepreneurs. The loan/deposit ratio of banks drops initially, as banks are making more profit to invest in bank capital ($J_t^B \uparrow$), before increasing significantly due to the increase in

the amount of loans (b_t^l ↑) and the decline in household savings following the lower return on deposits (d_t ↓). With banks having less deposits to back up their loans, this suggests a worsening of financial stability. Our model suggests that it takes 25 years for banks to converge back to their steady state levels. This would indeed imply that especially a prolonged period of monetary easing could contribute to a positive short-term reduction in the term premium and an increase in investment and loans, at the cost of a slow decline in financial stability as measured by the loan/deposit ratio.[16] We can conclude that our model manages to capture a) both the basic macroeconomic dynamics, as well as the term premium moments, and b) the effects of long-term risk shocks. Unlike previous studies, we achieve these desirable properties without having to increase the CRRA to extraordinary high levels, or having to make any specific assumptions on the type of uncertainty that feeds into households' consumption decisions and how it might affect the macroeconomy. We also show that accommodative monetary policy can indeed lead to a reduction in the term premium in the short run, but also have implications for long-term financial stability.

Figure 3.6: Expansionary Monetary Policy Shock

Notes: The blue line represents the impulse responses from the theoretical DSGE model using the baseline calibration. The shock represents a one standard deviation decrease in the short-term policy rate.

3.5.2   Macroprudential Policy

Given our proposed framework, we investigate different policy actions to deal with an exogenous increase in long-term risk that has destabilising effects in the financial sector. As we have seen in the previous section, even a small term premium shock can have large and long-lasting effects on the macroeconomy. The reduction in private loans that follows a term premium shock contributes

---

[16]It should be noted that our model assumes that loans are not risky and that the premium on loan rates arises due to market power of retail banks rather than endogenous default risk of borrowers. While our model implies that the ratio is capital over non-risky assets, it can be seen as a short-cut for capital/risky assets due to the premium paid on private sector loans, and as such can be seen as a measure of financial vulnerabilities.

to a large and persistent fall in investment. We shall test two specific types of macroprudential policies that the monetary policy authority can implement in order to make the economy more resilient to increases in long-term risk: Macroprudential Policy A (MP-A) relays on increasing banks' required capital/asset ratio, ν; Macroprudential Policy B (MP-B) decreases the steady state of the LTV ratio of entrepreneurs, $m_t^{E,SS}$. We assume a doubling of the capital/asset ratio from 0.09 to 0.18, so that banks are encouraged to have a larger capital buffer with respect to their assets. The LTV target ratio for entrepreneurs decreases from 0.35 to 0.25 implying that entrepreneurs need to back up the same quantity of loans with more collateral than before. Both measures are intended to make the financial system more resilient to risk shocks. Figure 3.7 reports the results for the two macroprudential policies relative to the baseline scenario from the previous section.

MP-A, the increase in the capital/asset ratio, does not seem to improve general macroeconomic conditions, as output, investment and private debt are projected to fall as much as in the baseline scenario. However, the severity of the decline in consumption is mitigated by this policy. Most importantly, the increase in the loans/deposit ratio is substantially lower, indicating that it is indeed a very effective measure to safeguard financial stability as a term premium shock hits the economy. In contrast, MP-B, the reduction in the LTV target ratio, has consistent positive effects on all variables. The severity of the negative responses is reduced for all macroeconomic variables, and in particular prevents a large decline in private debt and investment. It also reduces the loan/deposit ratio, albeit less than MP-A. While MP-A stabilises the economy by reducing loans even further during a risk shock, MP-B effectively mitigates the negative impact of a term premium shock on investment. This counterfactual experiment provides a clear indication that stricter LTV target ratios can help to safeguard the economy from some of the negative consequences of an unanticipated risk shock, whereas higher capital/asset ratios are more effective at directly tackling financial instability. The latter can still be costly, as banks might be incentivised to reduce the number of loans they give to borrowers to meet the higher capital target, which in turn reduces investment in the economy even further. These results are consistent with Altunbas et al. (2017) , who find evidence suggesting that macroprudential tools have a significant impact on bank risk.[17] Overall, we can conclude that the destabilising effects of monetary policy rules that target output and price stability can be at least partially offset by macroprudential policies designed to provide financial stability during times of distress.[18]

---

[17]Refer to Claessens (2015) for an overview on the impact of different macruprudential policies.

[18]Note that our model does not take into account bank failures, which might occur for extreme risk events. In those cases a capital/asset ratio would potentially provide enough buffer to avoid bank failure and thus have very large effects on financial stability.

Figure 3.7: Impulse Responses of a Term Premium Shock under Different Policy Scenarios
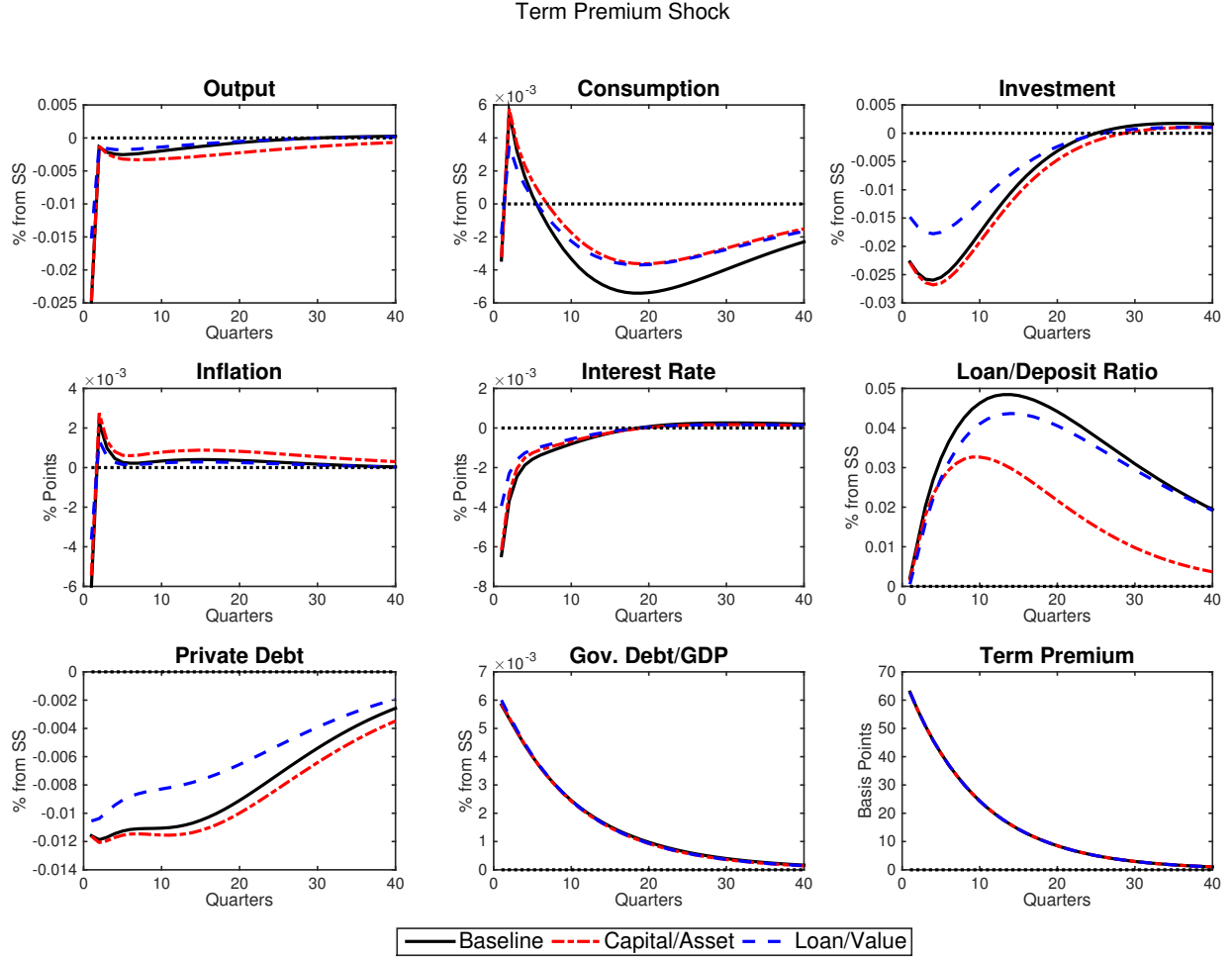
Notes: The blue line represents the impulse responses from the theoretical DSGE model using the baseline calibration. The red dotted line represents scenario under MP-A, a higher capital/asset ratio, whereas the blue dashed line corresponds to scenario under MP-B, a lower LTV ratio. The shock is a 60 basis point shock to the term premium.

3.6 Conclusion

We have shown that a term premium shock can be a good measurement for the effects of long-term uncertainty/risk shocks. Both empirically, as well as in a DSGE model, term premium shocks have real macroeconomic consequences and can affect lending conditions in the financial sector. We construct a model with time-varying term premia, which allows us to match both macro and finance moments without having to assume extreme values for the CRRA coefficient. Our model confirms that risk shocks reduce the volume of private loans in favour of government bonds

temporarily and lead to a more persistent decline in the loan/deposit ratio of banks indicating a potential threat to financial stability. In real terms, the negative financial consequences translate into a decline in investment, as well as consumption and output. We have also provided evidence for two policy hypotheses: a) the assumption that accommodative monetary policy reduces risk premia and increases short-term lending, at the cost of increased risk in the long-term, as shown by a decline in the capital/asset ratio of banks, and b) that macroprudential policies, and in particular stricter LTV ratios for borrowers, can help to mitigate some of the negative consequences of risk shocks.

There are many avenues in which the model can be extended. In terms of the banking sector, one useful addition to make the model more realistic would be to allow for private loans to default endogenously. This would endogenise the premium that is charged on top of private loans based on the relative riskiness of private debt over government debt. Another useful extension would be to introduce a proper government sector that can tax and subsidise households, as this might reduce the supply for long-term government debt, and help to match the volatility of investment more realistically. Finally, an interesting avenue to pursue would be to estimate the model formally. Especially, the household parameters, which are crucial to pin down both the macroeconomic, as well as asset price behaviour, would benefit from an estimation rather than an informal calibration. As methods that allow to estimate a model to the third order (see e.g. Andreasen et al., 2013) are still difficult to implement for high-dimensional models, we shall leave this for future investigation.

References

Adrian, T., Crump, R. K., Mills, B., and Moench, E. (2014). Treasury Term Premia: 1961-Present.

Adrian, T., Crump, R. K., and Moench, E. (2013). Pricing the Term Structure with Linear Regressions. *Journal of Financial Economics*, 110(1):110–138.

Adrian, T. and Liang, N. (2016). Monetary Policy, Financial Conditions, and Financial Stability. SSRN Scholarly Paper ID 2811090, Social Science Research Network, Rochester, NY.

Andreasen, M. M. (2012). On the Effects of Rare Disasters and Uncertainty Shocks for Risk Premia in Non-linear DSGE Models. *Review of Economic Dynamics*, 15(3):295–316.

Andreasen, M. M., Fernández-Villaverde, J., and Rubio-Ramírez, J. (2013). The Pruned State-Space System for Non-Linear DSGE Models: Theory and Empirical Applications. NBER Working Paper 18983, National Bureau of Economic Research, Inc.

Ang, A., Piazzesi, M., and Wei, M. (2006). What Does the Yield Curve Tell Us about GDP Growth? *Journal of Econometrics*, 131:359–403.

Azariadis, C. (1981). Self-fulfilling prophecies. *Journal of Economic Theory*, 25(3):380–396.

Baker, S., Bloom, N., and Davis, S. (2016). Measuring Economic Policy Uncertainty. *Quarterly Journal of Economics*, 131(4):1593–1636.

Binning, A. (2013). Underidentified SVAR Models: A Framework for Combining Short and Long-run Restrictions with Sign-Restrictions. Working Paper 2013/14, Norges Bank.

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

Caldara, D., Fernandez-Villaverde, J., Rubio-Ramirez, J., and Yao, W. (2012). Computing DSGE Models with Recursive Preferences and Stochastic Volatility. *Review of Economic Dynamics*, 15(2):188–206.

Canova, F. and Nicolo, G. D. (2002). Monetary Disturbances Matter for Business Fluctuations in the G-7. *Journal of Monetary Economics*, 49(6):1131–1159.

Chin, M., Filippeli, T., and Theodoridis, K. (2015). Cross-country co-movement in long-term interest rates: a DSGE approach.

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

Claessens, S. (2015). An Overview of Macroprudential Policy Tools. *Annual Review of Financial Economics*, 7(1):397–422.

Coimbra, N. and Rey, H. (2017). Financial Cycles with Heterogeneous Intermediaries. SSRN Scholarly Paper ID 2937756, Social Science Research Network, Rochester, NY.

Dell'ariccia, G., Laeven, L., and Suarez, G. A. (2017). Bank Leverage and Monetary Policy's Risk-Taking Channel: Evidence from the United States. *The Journal of Finance*, 72(2):613–654.

Epstein, L. G. and Zin, S. E. (1989). Substitution, Risk Aversion, and the Temporal Behavior of Consumption and Asset Returns: A Theoretical Framework. *Econometrica*, 57(4):937–969.

Estrella, A. and Hardouvelis, G. A. (1991). The Term Structure as a Predictor of Real Economic Activity. *Journal of Finance*, 46(2):555–576.

Estrella, A. and Mishkin, F. S. (1998). Predicting U.S. Recessions: Financial Variables as Leading Indicators. *Review of Economics and Statistics*, 80(1):45–61.

Favero, C., Kaminska, I., and Söderström, U. (2005). The Predictive Power of the Yield Spread: Further Evidence and a Structural Interpretation. Working Paper 280, IGIER (Innocenzo Gasparini Institute for Economic Research), Bocconi University.

Fuerst, T. S. and Mau, R. (2016). Term Premium Variability and Monetary Policy. SSRN Scholarly Paper ID 2785759, Social Science Research Network, Rochester, NY.

Gambacorta, L. and Signoretti, F. M. (2014). Should Monetary Policy Lean Against the Wind? *Journal of Economic Dynamics and Control*, 43(C):146–174.

Gerali, A., Neri, S., Sessa, L., and Signoretti, F. M. (2010). Credit and Banking in a DSGE Model of the Euro Area. *Journal of Money, Credit and Banking*, 42:107–141.

Grauwe, P. D. (2011). Animal spirits and monetary policy. *Economic Theory*, 47(2-3):423–457.

Hamilton, J. D. and Kim, D. H. (2002). A Reexamination of the Predictability of Economic Activity Using the Yield Spread. *Journal of Money, Credit and Banking*, 34(2):340–360.

Havranek, T., Horvath, R., Irsova, Z., and Rusnak, M. (2015). Cross-Country Heterogeneity in Intertemporal Substitution. *Journal of International Economics*, 96(1):100–118.

Jorda, O., Richter, B., Schularick, M., and Taylor, A. M. (2017). Bank Capital Redux: Solvency, Liquidity, and Crisis. SSRN Scholarly Paper ID 2941520, Social Science Research Network, Rochester, NY.

Joslin, S., Priebsch, M., and Singleton, K. J. (2014). Risk Premiums in Dynamic Term Structure Models with Unspanned Macro Risks. *The Journal of Finance*, 69(3):1197–1233.

Jurado, K., Ludvigson, S. C., and Ng, S. (2015). Measuring Uncertainty. *American Economic Review*, 105(3):1177–1216.

Kilian, L. and Lütkepohl, H. (2017). *Structural Vector Autoregressive Analysis*. Cambridge University Press.

Kiyotaki, N. and Moore, J. (1997). Credit Cycles. *Journal of Political Economy*, 105(2):211–248.

Knight, F. H. (1921). *Risk, Uncertainty and Profit*. Boston, New York, Houghton Mifflin Company.

Leduc, S. and Liu, Z. (2016). Uncertainty Shocks Are Aggregate Demand Shocks. *Journal of Monetary Economics*, 82(C):20–35.

Li, C., Meldrum, A., and Rodriguez, M. (2017). Robustness of Long-Maturity Term Premium Estimates.

Liu, W. and Moench, E. (2016). What Predicts US Recessions? *International Journal of Forecasting*, 32(4):1138–1150.

Ludvigson, S. and Ng, S. (2009). Macro Factors in Bond Risk Premia. *Review of Financial Studies*, 22(12):5027–5067.

Mallick, S. K., Mohanty, M S., and Zampolli, Fabrizio (2017). Market Volatility, Monetary Policy and the Term Premium.

Piazzesi, M. and Schneider, M. (2007). Equilibrium Yield Curves. In *NBER Macroeconomics Annual 2006, Volume 21*, pages 389–472. MIT Press.

Rudebusch, G. D., Sack, B. P., and Swanson, E. T. (2007). Macroeconomic Implications of Changes in the Term Premium. *Federal Reserve Bank of St. Louis Review*, 89(4):241–69.

Rudebusch, G. D. and Swanson, E. T. (2012). The Bond Premium in a DSGE Model with Long-run Real and Nominal Risks. *American Economic Journal: Macroeconomics*, 4(1):105–143.

Swanson, E. T. (2007). What We Do and Don't Know about the Term Premium. *FRBSF Economic Letter*, 07(21):1–3.

Swanson, E. T. (2010). Risk Aversion, the Labor Margin, and Asset Pricing in DSGE Models. 2010 Meeting Paper 138, Society for Economic Dynamics.

Van Binsbergen, J. H., Fernández-Villaverde, J., Koijen, R. S., and Rubio-Ramírez, J. (2012). The Term Structure of Interest Rates in a DSGE Model with Recursive Preferences. *Journal of Monetary Economics*, 59(7):634–648.

Vissing-Jørgensen, A. (2002). Limited Asset Market Participation and the Elasticity of Intertemporal Substitution. *Journal of Political Economy*, 110(4):825–853.

Appendix

<div align="center">***</div>

3.A Data Appendix

3.A.1 Term Premium, Unemployment and Uncertainty Indicators

- The term premium is the ten-year Treasury average term premium from the Federal Reserve Bank of New York, developed by Tobias Adrian, Richard Crump, and Emanuel Moench, which can be downloaded at `https://www.newyorkfed.org/research/data_indicators/term_premia.html`. For details on the methodology refer to Adrian et al. (2013). Data from January 1961 to May 1961 are extended back using the growth rate of the ten-year Treasury note yield at constant maturity from the Federal Reserve Board.

- The civilian unemployment rate for individuals 16 years of age and older is seasonally adjusted and obtained from the Bureau of Labor Statistics.

- The monthly economic policy uncertainty index was developed by Scott Baker and Nicholas Bloom of Stanford University and Steven Davis of the University of Chicago. For more details refer to Baker et al. (2016). Inflation Uncertainty and Economic Policy Uncertainty are proxied by the dispersion in the consumer price index, purchase of goods and services by state and local governments, and purchases of goods and services by the federal government.

- Financial Uncertainty is proxied by the Merrill lynch Option Volatility Estimate (MOVE) Index, which is a yield curve weighted index of the normalised implied volatility on one-month Treasury options which are weighted on the 2, 5, 10, and 30 year contracts.

3.A.2   Empirical Section: Term Premium and Macroeconomic Variables

Monthly from 1961-M01 to 2016-M12, expressed in annual terms.

- Output is the seasonally adjusted annual log change of the industrial production index (2012=100) from the Federal Reserve Bank of St. Louis.

- Inflation is the annual percentage change in the U.S. Consumer Price Index (SA, 1982-84=100) from the Bureau of Labor Statistics.

- The nominal shadow short-term interest rate is computed as the average discount rate from 1961-M01 to 1961-M12; the end-of-period discount rate from the Federal Reserve Bank of New York from 1962-M01 to 1982-M06; the Federal Funds Target rate from 1982-M07 to 2008-M12 and from 2015-M10 to 2016-M12; and the Wu-Xia shadow Federal Funds rate from 2009-M01 to 2015-M09.

- Loans is the annualised log growth of end-of-period loans and leases in bank credit for all commercial banks (SA, Bil.$).

- The junk-bond spread is the Moody's seasoned Baa corporate bond yield (% p.a.) minus the ten-year Treasury note yield at constant maturity (% p.a.) from the Federal Reserve Board.

- The Chicago Board Options Exchange Volatility Index (VIX) from Bloomberg, 1990–2017, reflects a market estimate of future volatility, based on the weighted average of the implied volatilities for a wide range of strikes. 1st & 2nd month expirations are used until 8 days from expiration, then the 2nd and 3rd are used.

3.A.3   DSGE Model: Macroeconomic and Financial Data

Quarterly from 1961-Q1 to 2016-Q4, expressed in annual terms.

1. Consumption*. Real personal consumption is computed as the period-to-period log growth rates of real expenditures of non-durable goods and services (SAAR, Bil.$), averaged using their shares in nominal expenditures. The weighted average growth rate is applied to the sum of nominal expenditures in both categories in 1961-Q1 to produce chained real consumption with a base of 1961-Q1.

2. Investment*. Annualised log growth of the private domestic investment component of chained real GDP is SSAR, Chn.2009$.

3. Labour*. Total hours of production per worker is computed as the amount of aggregate weekly hours of total private production and non-supervisory employees (SA, Thous.), multiplied by the number of weeks in the quarter to produce quarterly hours of labor. Since the data start in 1964-Q1, business sector compensation per hour (SA) from the Bureau of Labor Statistics is used to extend the series backwards to the start of the dataset.

4. Inflation. Inflation is annualised log growth rate of the chain price index of GDP.

5. Output*. Seasonally adjusted annual log growth rate of chained real GDP.

6. Short Rate. The short-term nominal interest rate is computed as the average discount rate from 1961-Q1 to 1961-Q4; the end-of-period discount rate at Federal Reserve Bank of New York from 1962-Q1 to 1982-Q2; the Federal Funds target rate from 1982-Q3 to 2008-Q4 and 2015-Q4 to 2016-Q4; and the Wu-Xia shadow Federal Funds rate from 2009-Q1 to 2015-Q3.

7. Loans*. Annualised log growth of end-of-period loans and leases in bank credit for all commercial banks (SA, Bil.$).

* HP filtered to extract the cyclical component.

Table 3.A.1: Data Sources and Summary Statistics (1961-2016)

Variable	Name	N	Mean	St. Dev.	Min	Max	Source
Quarterly Data							
C_t	Consumption	224	0.00	0.85	-2.00	2.92	Bureau of Economic Analysis
I_t	Investment	224	0.00	4.08	-12.62	9.50	FRB St. Louis
l_t	Labour	224	0.00	2.10	-6.71	4.71	Bureau of Labor Statistics
π_t	Inflation	224	3.42	2.45	-0.62	12.77	Bureau of Economic Analysis
Y_t	Output	224	0.00	1.46	-4.78	3.75	FRB St. Louis
r_t^{ib}	Short Rate	224	4.79	3.51	-2.92	14.00	FRB, FRB Atlanta
ψ_t^l	Term Premium	224	1.64	1.19	-0.59	4.94	Federal Reserve Board
b_t^E	Loans	224	0.00	6.36	-14.16	23.59	Federal Reserve Board
Monthly Data							
y_t	Output	672	1.41	3.85	-15.89	7.44	FRB St. Louis
π_t	Inflation	672	3.85	2.89	-1.96	14.59	Bureau of Labor Statistics
i_t	Short Rate	672	4.77	3.49	-2.99	14.00	FRB, FRB Atlanta
b_t	Loans	672	7.80	4.53	-9.40	20.30	Federal Reserve Board
tp_t	Term Premium	672	1.64	1.19	-0.65	4.79	Federal Reserve Board

Figure 3.A.1: Macroeconomic Variables From 1961 to 2016
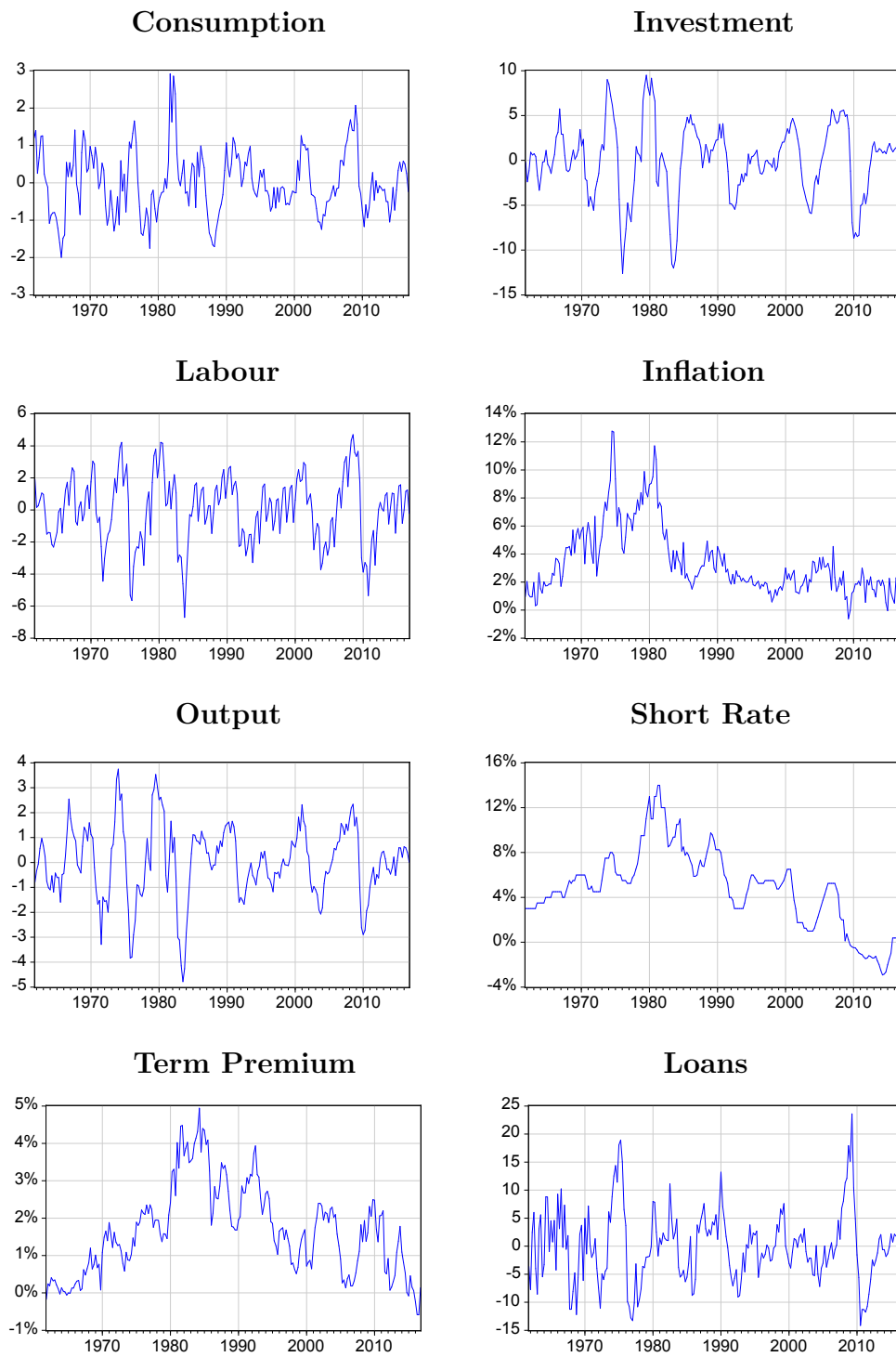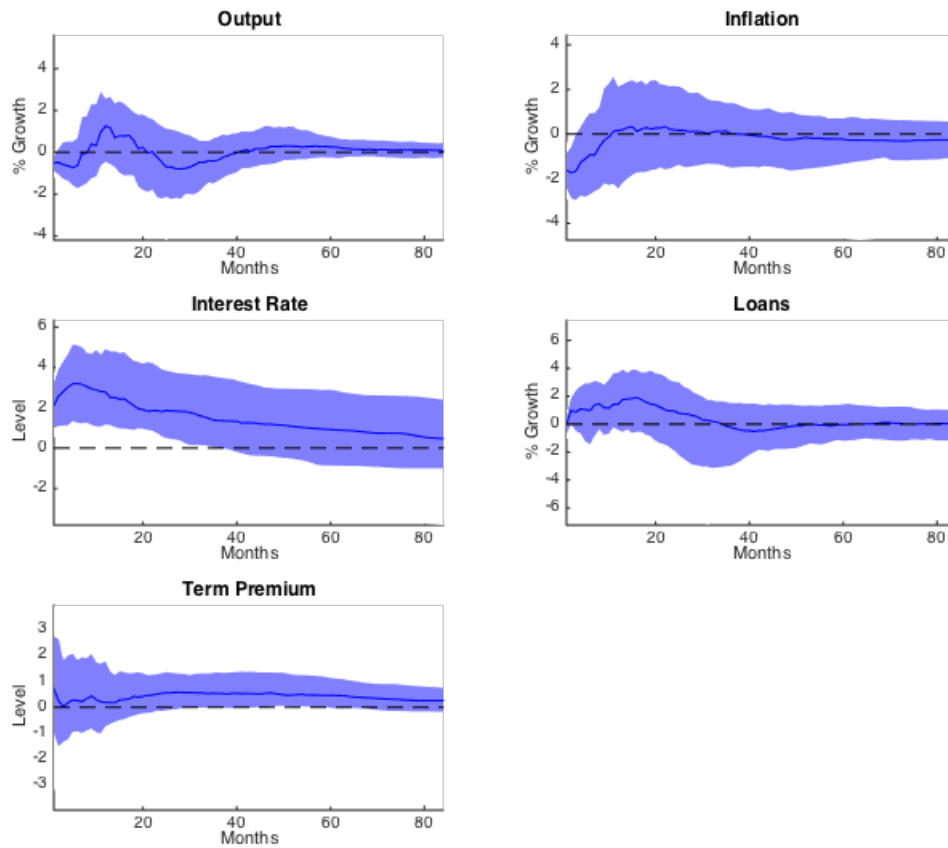
3.B   Empirical Robustness

Figure 3.B.1: Impulse Responses Excluding Financial Crisis (left) and Great Moderation Only (right)
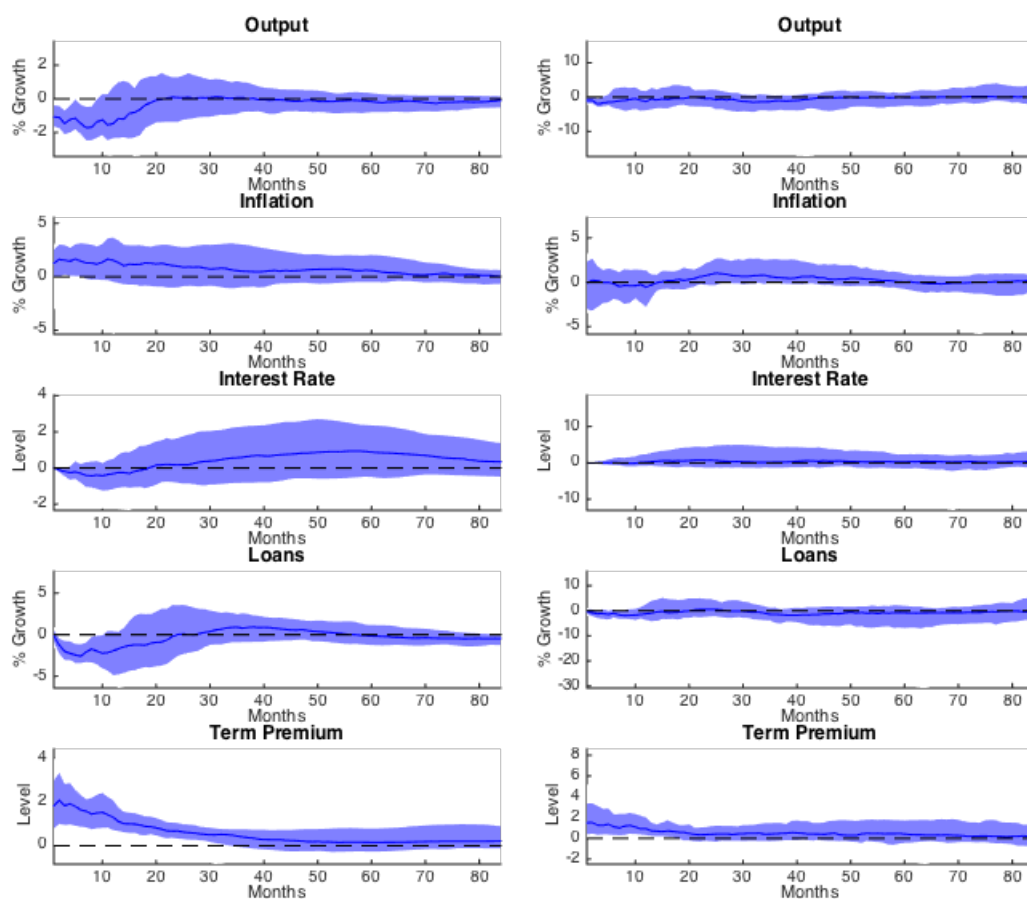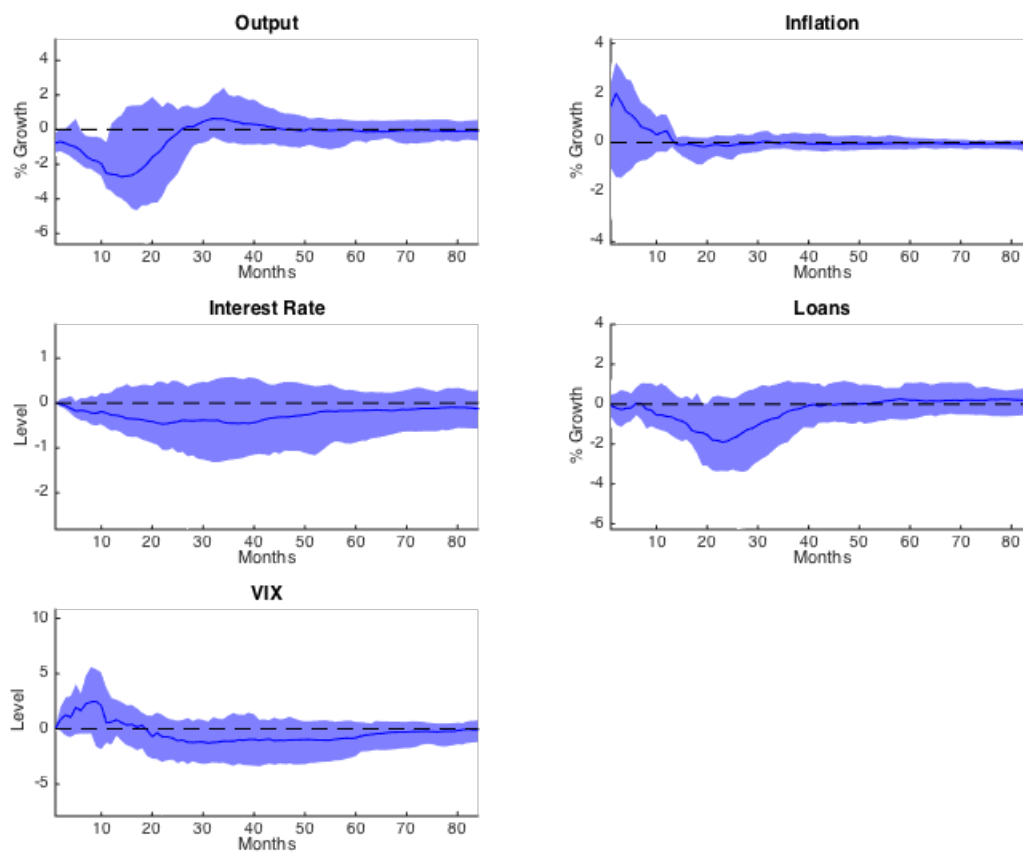

Notes: The shaded regions report point-wise 68% Monte Carlo credible sets. The solid line shows the median response to a one standard deviation shock to the term premium.

Figure 3.B.2: Impulse Responses to a Contractionary Monetary Policy Shock

Notes: The shaded regions report point-wise 68% Monte Carlo credible sets. The solid line shows the median response to a one standard deviation shock to the shadow interest rate.
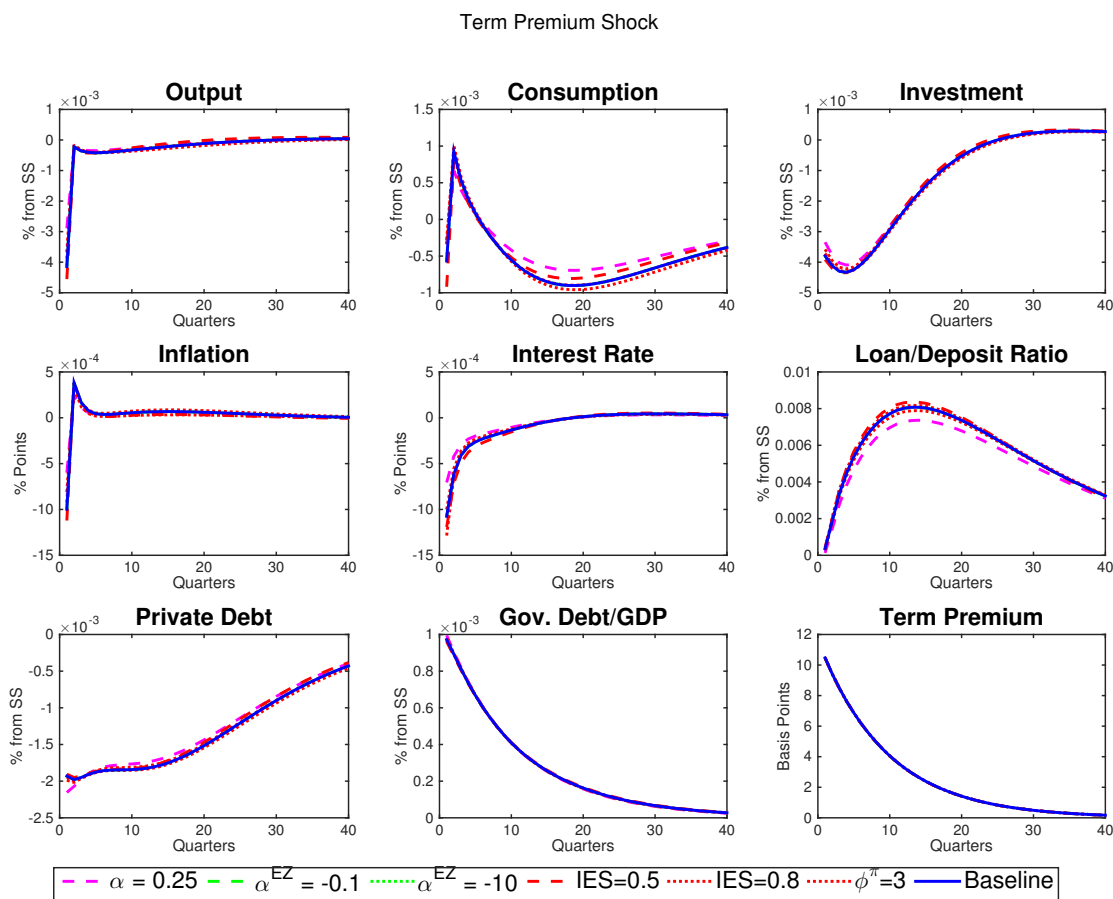
Figure 3.B.3: Impulse Responses to a VIX Shock

Notes: The shaded regions report point-wise 68% Monte Carlo credible sets. The solid line shows the median response to a one standard deviation shock to the VIX.

3.C Model Parameter Sensitivity

Figure 3.C.1: Responses to a Term Premium Shock under different Parameterisation

Notes: The blue line represents the impulse responses from the theoretical DSGE model using the baseline calibration. The shock is a 10 basis point shock to the term premium. The dotted and slash lines represent the median response under different parameterisation as specified in the legend.