Loan Supply Shocks During the Financial Crisis: Evidence for the Euro Area from a Panel VAR with Sign Restrictions *

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Abstract

This paper employs a panel vector autoregressive model for the member countries of the Euro Area to explore the role of banks during the slump of the real economy that followed the financial crisis. In particular, we seek to quantify the macroeconomic effects of adverse loan supply shocks, which are identified using sign restrictions. We find that loan supply shocks significantly contributed to the evolution of the loan volume and real GDP growth in all member countries during the financial crisis. However, concerning both, the timing and the magnitude of the shocks our results also indicate that the Euro Area was characterized by a considerable degree of cross–country heterogeneity.

JEL classifications: C33, E32, E51

Key words: Euro Area, panel vector autoregressive model, sign restrictions, loan supply shocks

1 Introduction

In the Euro Area, banks were severely affected by the global financial crises that erupted in 2007. Large credit losses borne by banks increased financial stress in the credit markets, which figured prominently in the commentary on the slump of the real economy that followed (Adrian and Shin, 2009). Bank lending decreased sharply. The annual growth rate of loans granted to non–financial corporations fell from 15 percent at the beginning of 2008 to –3 percent at the beginning of 2010. Although the drop in bank loan growth coincided with the economic downturn, it cannot be ruled out that loan–supply effects in addition to loan–demand effects were present (European Central Bank, 2009).

This paper employs a panel vector autoregressive (VAR) model for the member countries of the Euro Area to explore the role of banks during the slump of the real economy that followed the financial crisis. In particular, we seek to quantify the macroeconomic effects of adverse loan supply shocks. Following Uhlig (2005), Canova and de Nicolo (2002) and Peersman (2005), we identify the loan supply shocks by imposing sign restrictions.

Recent work on DSGE models has emphasized the role of banks in business cycle fluctuations. Curdia and Woodford (2010), Gerali et al. (2010), Gertler and Karadi (2009) or Atta-Mensah and Dib (2008) are examples. Meanwhile, banks are seen as issuers of shocks that drive the boom–bust cycle, instead of being only passive players that transmit macroeconomic policy shocks neutrally.[1] Shocks caused by banks trigger economic disturbances due to credit frictions, and may result from various sources, such as increases in loan losses, an unexpected destruction of bank capital or changes in the willingness to lend. Evidence collected from simulation exercises shows that the economic effects of such shocks can be sizable.

As Bernanke and Gertler (1995), Oliner and Rudebusch (1996) and Peek et al. (2003) point out, empirical research faces the difficulty to disentangle movements of bank loans into shocks to loan supply and loan demand.[2] In order

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[1]In the standard DSGE model, banks usually do not play a particular role, except perhaps as a passive player that the central bank uses as a channel to implement monetary policy (Adrian and Shin, 2009).

[2]Movements in loan demand are frequently also related to shocks to aggregate demand.

to cope with this identification problem recent papers using VAR models have followed two different strategies. Ciccarelli et al. (2010) use survey data from the bank lending survey as proxy for loan supply and demand. They trust the bankers' judgement about changes in credit standards and credit demand and identify the economic mechanisms underlying the development of bank loans by imposing zero restrictions on the contemporaneous impact of shocks. Alternatively, Bean et al. (2010), De Nicolò and Lucchetta (2010), Helbling et al. (2010) and Busch et al. (2010) use sign restrictions to identify the shocks, which renders possible *a priori* theorizing. Typically, a decline in bank loans is related to an adverse loan supply shock if the loan rate simultaneously rises, whereas it is triggered by an adverse loan demand shock if the loan rate simultaneously falls.

We analyze the evolution of bank loans during the financial crisis by using macroeconomic data, which cover the period from 2003Q1 to 2010Q2. The identification of the shocks is set–up according to the following two main principles. First, in addition to loan supply shocks, we also account for aggregate supply shocks, monetary policy shocks and aggregate demand shocks. The restrictions imposed to uniquely identify the shocks ensure that the set of sign restrictions is mutually exclusive *ex ante*. Second, we refer to the insights derived from DSGE models with financial frictions to ensure that the restrictions are consistent with what would be theoretically expected.

Our results show that: (i) movements of the loan volume in the member countries of the Euro Area were significantly affected by loan supply shocks during the financial crisis; (ii) in all member countries a sizable part of the drop in national real GDP growth can be attributed to loan supply shocks; and, finally (iii) the member countries of the Euro Area are characterized by a considerable degree of heterogeneity, which is reflected by the timing as well as the magnitude of the shocks. In a counterfactual exercise we find that in some countries, e.g. Austria, Finland or Italy, the dampening effects of loan supply shocks were particularly relevant in the course of 2008, while in other countries, e.g. Germany, Spain or France, they predominantly emerged during 2009 and 2010. At least partly, this dichotomy across countries can be explained by the time pattern of equity increases by the national banking sectors.

The remainder of the paper is organized as follows. In Section 2 we set out the panel VAR model applied. Additionally, we provide a detailed discussion on the identification of the shocks, which includes a survey of the existing literature on this issue. Section 3 summarizes our results that are derived from impulse response analysis, a decomposition of the forecast error variance and a historical decomposition. Section 4 examines the robustness of our results. In Section 5 we provide concluding remarks.

2 Panel VAR with sign restrictions

2.1 Panel VAR

Consider a panel VAR model in reduced form:

$$X_{i,t} = c_i + \sum_{j=1}^{p} A_j X_{i,t-j} + \varepsilon_{i,t}, \tag{1}$$

where $X_{i,t}$ is a vector of endogenous variables for country i, c_i is a vector of country–specific intercepts, A_j is a matrix of autoregressive coefficients for lag j, p is the number of lags and $\varepsilon_{i,t}$ is a vector of reduced–form residuals. The vector $X_{i,t}$ consists of five variables

$$X_{i,t} = [y_{i,t} \;\; p_{i,t} \;\; s_{i,t} \;\; r_{i,t} \;\; l_{i,t}]', \tag{2}$$

where $y_{i,t}$ denotes real GDP, $p_{i,t}$ is the overall price level, measured by the GDP deflator, $s_{i,t}$ is the nominal short–term interest rate, which serves as the policy instrument of the central bank, $r_{i,t}$ is the loan rate and $l_{i,t}$ is the loan volume. For each variable, we use a pooled set of $M \cdot T$ observations, where M denotes the number of countries and T denotes the number of observations corrected for the number of lags p. The reduced–form residuals $\varepsilon_{i,t}$ are stacked into a vector $\varepsilon_t = [\varepsilon'_{1,t} \ldots \varepsilon'_{M,t}]'$, which is normally–distributed with mean zero and variance–covariance matrix Σ.

We use quarterly data that are taken from the Eurostat and the ECB databases covering the period from 2003Q1 to 2010Q2.[3] The beginning of the

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[3]See the Appendix for a detailed description of the data.

sample is determined by the loan market variables, which are available from the ECB's harmonized MFI interest rate statistics only since 2003. The loan volume is measured by the outstanding amount of loans to non–financial corporations in nominal terms; the loan rate is the corresponding interest rate. Concerning the ECB's monetary policy instrument we use the EONIA, which is the average of overnight rates for unsecured interbank lending in the Euro Area. Ciccarelli et al. (2010) argue that even during the financial crisis the EONIA rate is a sensible measure of the ECB's monetary policy. Since the ECB reacted to the crisis by implementing various non–standard measures in its liquidity management, the EONIA currently reflects much better the actual monetary policy stance than the official main refinancing rate.

Since the sample is short, we follow Ciccarelli et al. (2010)[4] and use a panel of 11 Euro Area countries, comprising Austria (AUT), Belgium (BEL), Finland (FIN), France (FRA), Germany (DEU), Greece (GRC), Ireland (IRL), Italy (ITA), the Netherlands (NLD), Portugal (PRT) and Spain (ESP). The main advantage of using a panel approach is that it increases the efficiency of the statistical inference, which would otherwise suffer from a small number of degrees of freedom when the VAR is estimated at the country or the Euro-area level. While this comes at the cost of disregarding cross–country differences by imposing the same underlying structure for each cross–section unit, Gavin and Theodorou (2005) emphasize that the panel approach allows to uncover common dynamic relationships. In fact, the panel approach commits the same error as any empirical approach that uses aggregate Euro–area data and thereby treats the Euro Area as a homogenous entity.

Real GDP, the price level and the loan volume are in logs, while the interest rates are expressed in percent. All variables are linearly de–trended over the sample period. The matrix of constant terms c comprises individual country dummies that account for possible heterogeneity across the units. The panel VAR model is estimated with Bayesian methods using a Normal–inverted Wishart prior, 500 draws and a lag order of $p = 2$.

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[4]They estimate a panel VAR for the Euro Area over the period 2002Q4 to 2009Q4 and argue that this period covers at least one complete business cycle.

2.2 Identification of Structural Shocks

Based on the VAR model (1) we generate impulse responses of the variables to structural shocks η_t. As in Canova and de Nicolo (2002), Peersman (2005) and Uhlig (2005) the shocks are identified by imposing sign restrictions. The reduced–form residuals ε_t are related to the structural shocks η_t according to $\eta_t = (U\Omega^{1/2}Q)^{-1}\varepsilon_t$, where $U\Omega^{1/2}$ is the Cholesky factor, $\Sigma = U\Omega U'$, of each draw and Q is an orthogonal matrix, $QQ' = I$, generated from a QR decomposition of some random matrix W, which is drawn from an $N(0,1)$ density. For each of the 500 Colesky factors resulting from the Bayesian estimation of the VAR model, the draws of the random matrix W are repeated until a matrix Q is found that generates impulse responses to η_t, which satisfy the sign restrictions. For all variables the time period over which the sign restrictions are binding is set equal to two quarters. The restrictions are imposed as $\leq$ or $\geq$.[5]

Our identification scheme is set–up according to the following principles. First, in addition to a loan supply shock we also impose restrictions on three further types of shocks: an aggregate supply shock, a monetary policy shock and an aggregate demand shock. The reason is that it has been shown that increasing the number of identified innovations can help to uncover the correct sign of the impulse response functions (Paustian, 2007). Most importantly, the restrictions uniquely identify the four shocks, in the sense that the set of sign restrictions imposed is mutually exclusive *ex ante*. Furthermore, the simultaneous identification of the three additional disturbances, besides the loan supply shock, ensures that the latter indeed captures exogenous shifts of the credit supply curve rather than any endogenous reaction of loan supply to one of the other shocks. Moreover, the literature considers monetary shocks as well as shocks to aggregate supply and aggregate demand to be the most important driving forces of the business cycle. Finally, the restrictions are consistent with what would be suggested by dynamic stochastic general equilibrium (DSGE) models. Thus, for each shock we will briefly summarize the existing evidence.

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[5] The estimation of the Bayesian VAR and the identification of the structural shocks is performed in MATLAB, using the codes `bvar.m`, `bvar_chol_impulse.m` and `bvar_sign_ident.m` provided by Fabio Canova (http://www.crei.cat/people/canova/).

2.2.1 Aggregate Supply, Monetary Policy and Aggregate Demand Shock

For an aggregate supply shock we assume that output and prices move in the opposite direction. The central bank reacts to an adverse aggregate supply shock by increasing the nominal interest rate (see e.g. Peersman, 2005, and Fratzscher et al., 2009, for similar restrictions in VARs, and Peersman and Straub, 2006, and Canova and Paustian, 2010, for evidence from standard DSGE models). Restrictions on the two loan market variables are not imposed, implying that the data will determine the sign of these responses.

A contractionary monetary policy shocks leads to an unexpected rise of the money market rate and has a non–positive effect on output and prices (see again Peersman, 2005, and Fratzscher et al., 2009, for similar restrictions in VARs, and Peersman and Straub, 2006, and Canova and Paustian, 2010, for evidence from standard DSGE models). The fall in the GDP deflator ensures that the monetary policy shock is different *ex ante* from an adverse aggregate supply shock. The responses of the loan market variables are not restricted.

For an aggregate demand shock we assume that output and prices move in the same direction. The central bank reacts to a negative aggregate demand shock by lowering the nominal interest rate (see again Peersman, 2005, and Fratzscher et al., 2009, for similar restrictions in VARs, and Peersman and Straub, 2006 for evidence from a standard DSGE model). While these restrictions are sufficient to separate the aggregate demand shock from an aggregate supply or a monetary policy shock, we need an additional restriction on the response of the loan rate to distinguish the aggregate demand shock from a loan supply shock (see Section 2.2.3). Here we assume that the loan rate falls following a negative aggregate demand shock. This assumption can be motivated as follows. On the one hand, a negative aggregate demand shock is likely to cause loan demand to fall as part of a decrease in aggregate income. The fall in loan demand should come along with a fall in loan rates. On the other hand, there is large empirical evidence that a reduction of the central bank's interest rate is passed–through (albeit only imperfectly) to the loan rate (de Bondt, 2005).

2.2.2 Loan Supply Shocks in the Literature

Before deriving the restrictions related to the loan supply shock, we first take a closer look at both, the existing empirical VAR literature and the theoretical DSGE literature. Empirical approaches using aggregate time series data have typically been criticized for not having adequately isolated loan supply shocks from loan demand shocks. In fact, as Bernanke and Gertler (1995) and Oliner and Rudebusch (1996) argue, when the economy is hit by a negative shock, it is often impossible to distinguish whether the usual deceleration in bank lending stems from a shift in demand or supply. On the one hand, the corporate sector may be demanding less credit because fewer investments are undertaken; on the other hand, it could be that banks are less willing to lend and, therefore, charge higher interest rates or decline more credit applications.

Due to this severe identification problem most researchers have been reluctant to use aggregate time series and thus, have resorted to micro–(often bank–level) data. We are only aware of two recent macro–data VAR studies that identify loan supply shocks traditionally – by imposing zero restrictions on the contemporaneous or long–run impact of shocks (Groen, 2004; Musso, Neri, and Stracca, 2010). However, with the advent of the sign restrictions approach a new tool for disentangling loan supply from loan demand disturbances on a macro–level has become available. In the context of loan supply shocks, however, empirical studies using sign restrictions are still scarce, all dating from 2010. These papers assume that innovations to loan supply drive the loan rate and the loan volume in different directions, which is a sufficient condition for separating them from exogenous shifts in loan demand. While Bean et al. (2010)[6] and De Nicolò and Lucchetta (2010)[7] only impose these two

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[6]Bean et al. (2010) estimate two VARs with seven variables, one for the US and one for the UK. In each VAR they identify seven structural shocks using a combination of ordering assumptions and theoretical sign restrictions on the impulse responses.

[7]De Nicolò and Lucchetta (2010) estimate a factor–augmented VAR for the G–7 countries, including a large number of indicators of real activity and variables describing the conditions on equity and credit markets. They identify four structural shocks (aggregate supply, aggregate demand, loan supply and loan demand) by only imposing restrictions on two keys variables (price and quantity) for each shock.

restrictions, Helbling et al. (2010) and Busch et al. (2010) argue that some additional restrictions are needed in order to properly identify shocks originating in the banking or financial sector (see Table 1 for a summary of the restrictions imposed).

Table 1: Sign restrictions in VAR models

	Loan volume	Loan rate	Other variables
Bean et al. (2010)	growth rate ↓	credit spread ↑	—
De Nicolò and Lucchetta (2010)	growth rate ↓	change ↑	—
Helbling et al. (2010)	level ↓	credit spread ↑	productivity ↑
			default rates ↓
Busch et al. (2010)	level ↓	level ↑	real GDP ↓
			consumer prices ↓
			money market rate ↓

Notes: The credit spread in Bean et al. (2010) and Helbling et al. (2010) is measured by the corporate bond spread, i.e. the spread of investment–grade corporate bonds over government bonds (Bean et al., 2010) or the the yield differences between Moody's Seasoned Baa and Aaa corporate bonds (Helbling et al., 2010).

Helbling et al. (2010) use a factor–augmented VAR for the G–7 countries to examine the role of credit supply and productivity shocks in explaining the global and U.S. business cycle. In order to distinguish a restrictive credit supply shock from an adverse aggregate supply shock (where the response of the credit spread is unclear and hence left to the data), they put restrictions on productivity and default rates. These restrictions ensure that an adverse credit shock reflects a credit supply contraction as opposed to an endogenous decline in credit due to lenders reducing credit in response to expectations of an increase in future default rates and/or a decline in future productivity.

Busch et al. (2010) estimate a VAR for the German economy with six variables (real GDP, consumer prices, money market rate, loan rate, loan volume, corporate bond spread) over the period 1991Q1 to 2009Q2. They identify two structural shocks, a monetary policy shock and a loan supply shock. For a restrictive loan supply shock they assume that loan rates and the loan volume move in opposite directions over the first three quarters. For the remaining variables they impose a specific timing on the effectiveness of the restrictions, which they derive from the estimated DSGE model of Gerali et al. (2010) that analyzes the macroeconomic effects of shocks originating in the banking sector.

While output immediately falls and remains negative over the first three quarters, a decline in prices and the money market rate is imposed after the second and third quarter respectively.[8] This procedure ensures particularly that a restrictive loan supply shock is *ex ante* different from a contractionary monetary policy shock, after which the money market rate is assumed to be positive for the first three quarters.

The bulk of the DSGE models featuring financial frictions and a non–trivial role of credit markets also predicts that negative loan supply shocks induce a contraction in loan volume accompanied by an increase in the lending rate and a drop in aggregate economic activity (see Table 2). By contrast, as Curdia and Woodford (2010), Gerali et al. (2010), Gertler and Karadi (2009), Gilchrist et al. (2009) and Atta-Mensah and Dib (2008) show, the implications regarding the response of inflation and the policy (money market) rate seem to be quite ambiguous across theoretical models.[9] Table 2 summarizes the main findings.

Table 2: Macroeconomic effects of a restrictive loan supply shock

	Real GDP	Inflation	Money market rate	Loan rate	Loan volume
Curdia and Woodford (2010)	↓	↓	↓	↑	↓
Gertler and Karadi (2009)	↓	↓	↓	↑	↓
Gilchrist et al. (2009)	↓	↓	↓	↑	↓
Gerali et al. (2010)	↓	↑	↑	↑	↓
Atta-Mensah and Dib (2008)	↓	↑	↑	↑	↓

Notes: Curdia and Woodford (2010), Gertler and Karadi (2009) and Gilchrist et al. (2009) report the adjustment of the interest spread to a restrictive loan supply shock. The reaction of the loan rate can be identified by accounting for the response of the money market rate.

As shown by Curdia and Woodford (2010), inflation falls after a restrictive loan supply shock, which induces the monetary authority to decrease the policy rate while the loan rate rises.[10] Gertler and Karadi (2009) and Gilchrist et al. (2009) document similar results. In turn, Gerali et al. (2010) and Atta-

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[8]The response of the corporate bond spread is left unrestricted.

[9]Monetary policy is usually modeled by means of a reaction function, which relates the policy rate to the inflation rate and the output gap.

[10]Notice that Curdia and Woodford (2010) consider different policy reactions functions. Here, we refer to the case in which the policy rate is set only in response to inflation and the output gap.

Mensah and Dib (2008) show that inflation rises in response to a restrictive loan supply shock, which causes an increase in the policy rate that is accompanied by a rising loan rate. The increase in inflation is somewhat puzzling. Gerali et al. (2010) argue that firms cut investment after a contraction in lending and increase capital utilization, since relative costs decline and capital is less useful as collateral (Gerali et al., 2010, p. 135). Simultaneously, firms increase their labor demand, which pushes up wages. Accordingly, inflation rises due to a shift in marginal costs. Atta-Mensah and Dib (2008) assume that firms borrow funds only in order to pay for intermediate good inputs, which implies that marginal costs are directly affected by the loan rate.[11] Consequently, inflation is pushed up after an increase in the loan rate that follows a restrictive loan supply shock.

Notwithstanding the line of argumentation in Gerali et al. (2010) and Atta-Mensah and Dib (2008), we should keep two important points in mind. First, the use of a broad loan aggregate – that comprises total credit to firms – implies that firms borrow also to fund investment activities, instead of only financing intermediate good inputs. Second, in the recent financial crisis conditions on labor markets deteriorated rather than improved almost worldwide.[12]

2.2.3 Sign Restrictions for a Loan Supply Shock

From the discussion in the previous Section we conclude that in the case of a loan supply shock the loan rate and the loan volume should move in opposite directions. For a restrictive loan supply shock the increase in the loan rate ensures that this shock is different *ex ante* from an adverse aggregate demand shock, which comes along with a fall in the loan rate. Consistent with a contraction in the loan volume, real GDP declines after the shock. However, these restrictions are not sufficient to disentangle the loan supply shock from contractionary aggregate supply and monetary policy disturbances, which may also induce a temporary decline in the loan volume and a simultaneous increase

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[11]This assumption is related to the idea of the cost channel. See Barth and Ramey (2000) for a discussion.

[12]Gerali et al. (2010) address this issue by stating that their simulation "considers only one shock and disregards others that could be used to capture the surge and fall in commodity prices and the fall of aggregate demand in 2008" (Gerali et al., 2010, p. 137).

in the loan rate. To overcome this problem, the central bank is assumed to react to the downturn induced by negative loan supply shock by cutting the short–term nominal interest rate. Since contractionary aggregate supply and monetary policy shocks are both accompanied by an increase in the short–term interest rate, this assumption allows us to uniquely identify exogenous credit supply shifts. Moreover, as the discussion in the previous Section suggests, the theoretical evidence derived from DSGE models, albeit somehow ambiguous, is more consistent with a decrease rather than an increase of the money market rate after a negative loan supply shock. Restrictions on the GDP deflator are not imposed for two reasons. On the one hand, the restrictions on the other variables are sufficient to discriminate the loan supply shock from the other structural shocks. On the other hand, the DSGE literature is ambiguous about the effects of shocks originating in the banking sector on prices and inflation.

Generally, exogenous shifts in the credit supply curve typically represent linear combinations of components originating solely in the banking sector, such as sudden changes in the financing conditions or in the degree of competition faced by banks, as well as components reflecting the quality of borrowers, such as the value and the degree of riskiness of collateral or borrowers' liquidity position. However, the sign restrictions described above do not allow us to disentangle these sub–components of the loan supply shock. The restrictions only enable us to identify general exogenous changes in the supply of credit as opposed to endogenous reactions of bank lending to other types of shocks. In the current paper, we do not make an attempt to decompose the loan supply shock into two or more structural disturbances and leave this issue for future research.

Since our VAR model consists of five variables, there is a fifth structural shock, which will, however, not be identified structurally. The interpretation of this shock is that it acts as a residual shock, which captures the remaining variation in the data that is not explained by the four identified shocks (Eickmeier, Hofmann, and Worms, 2009, use a similar approach).

The sign restrictions for the four identified shocks are summarized in Table 3.

Table 3: Sign restrictions

| Shock	Real GDP	GDP deflator	Money market rate	Loan rate	Loan volume
Aggregate supply	↓	↑	↑		
Monetary policy	↓	↓	↑		
Aggregate demand	↓	↓	↓	↓	
Loan supply	↓		↓	↑	↓

Notes: Restrictions are imposed for two quarters.

3   Results

3.1   Impulse responses

Figure 1 shows the impulse responses of the variables to the loan supply shock. The impulse response of the remaining structural shocks are shown in Appendix B. For every variable the solid lines depict the median of the impulse responses, while the shaded areas are the 68% confidence intervals.[13]   Additionally, we report the impulse responses for the credit spread, which are calculated as the difference between the reactions of the loan rate and the money market rate. The simulation horizon covers 20 quarters.

After an adverse loan supply shock the loan volume declines and the loan rate initially rises. While the reduction of the loan volume significantly persists for the first two years, the significant increase in the loan rate can only observed for the first two quarters and hence for the period imposed for identifying the shock. Thereafter, the loan rate quickly falls below its steady state and remains significantly negative for about four quarters, probably due to the central bank's interest rate cuts. Real output falls after the tightening of credit conditions. Likewise the price level decreases, although the reduction is not significant. To counteract the slump of the economy, the central bank's monetary policy becomes expansionary, which leads to a decrease in the money market rate for at least five quarters. As a result, the credit spread significantly increases.

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[13]Notice that the median and the quantiles were computed from all impulse responses that satisfy the sign restrictions, which means that the confidence intervals not only reflect sampling uncertainty, but also modeling uncertainty stemming from the non–uniqueness of the identified shocks.

Figure 1: Impulse response of a loan supply shock
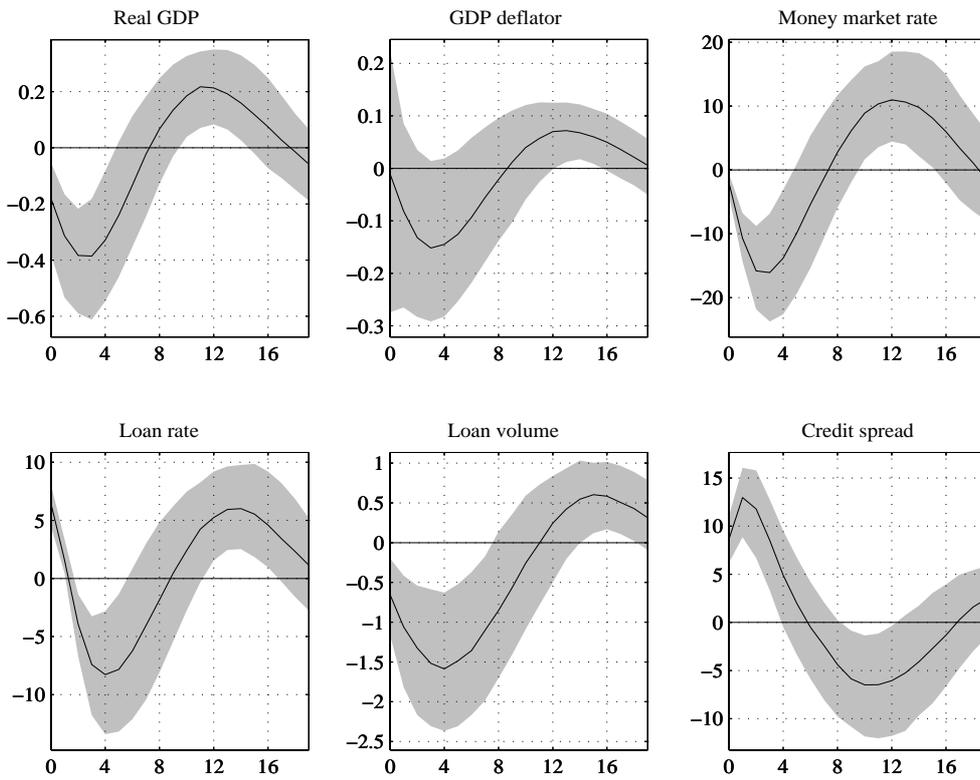
Notes: The solid lines denote the median of the impulse responses, which are estimated from a Bayesian vector-autoregression with 500 draws. The shaded areas are the related 68% confidence intervals. Real GDP, the GDP deflator and the loan volume are expressed in percent terms, while the money market rate, the loan rate and the credit spread are expressed in basis points. The impulse responses are normalized to an adverse one–standard deviation shock. The horizontal axis is in quarters.

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Our impulse responses are qualitatively in line with those obtained in most related studies. For example Busch et al. (2010), Bean et al. (2010) and Ciccarelli et al. (2010) find that adverse loan supply shocks trigger a persistent drop in output, the price level, the loan volume and the policy rate. The responses remain significant for about 4 to 8 quarters after the shock. Similarly to Busch et al. (2010) and unlike the other studies, our analysis suggests that the reaction of the GDP deflator, albeit negative, is not statistically significant.

The only two studies drawing qualitatively different conclusions are Helbling et al. (2010) and De Nicolò and Lucchetta (2010). Since Helbling et al. (2010) assume that adverse loan supply shocks have a positive impact on productivity and a negative impact on default rates, real GDP, although insignificantly, initially increases and remains above average for more than four years. In contrast De Nicolò and Lucchetta (2010) conclude for the G–7 countries that aggregate demand shocks are the main drivers of the real cycle, and bank credit demand shocks are the main drivers of the bank lending cycle, while loan supply shocks are almost irrelevant.

3.2 Variance decomposition

In order to understand the quantitative importance of the structural shocks we compute the forecast error variance decomposition, which in contrast to the impulse response analysis takes into account the estimated magnitude of the shocks. Table 4 reports the median of the forecast error variance shares of each variable due to the four structural shocks at the 1– to 5–year forecast horizon. The final column shows that the identified structural shocks explain between 50 and 60% of the variations in the endogenous variables. While aggregate supply shocks only seem to play a minor role for explaining fluctuations over the period from 2003 to 2010, aggregate demand shocks account for the bulk of variations in real GDP and the interest rates. The monetary policy shock has the largest contribution to the forecast error of the GDP deflator and the loan volume.

The variable most strongly affected by the credit supply shock is loan volume. About 15% of its forecast error variance over all horizons can be attributed to shocks originating in the banking system. With a share between 6 and 10% these

Table 4: Forecast error variance decomposition (in percent)

	Year	Loan supply shock	Aggregate demand shock	Aggregate supply shock	Monetary policy shock	Sum of all shocks
Real GDP	1st	6	38	4	5	53
	2nd	9	31	5	13	58
	3rd	9	29	6	15	59
	4th	10	29	6	14	59
	5th	10	28	6	15	59
GDP deflator	1st	9	12	16	20	57
	2nd	9	18	10	23	60
	3rd	9	16	9	24	58
	4th	10	17	9	23	59
	5th	11	18	10	22	61
Money market rate	1st	5	39	6	6	56
	2nd	8	35	6	6	55
	3rd	8	32	8	7	55
	4th	9	33	8	9	59
	5th	10	31	8	11	60
Loan rate	1st	7	40	5	3	55
	2nd	4	43	4	4	55
	3rd	5	38	6	7	56
	4th	7	37	6	8	58
	5th	7	36	6	9	58
Loan volume	1st	14	9	7	15	45
	2nd	17	15	6	20	58
	3rd	16	17	6	23	62
	4th	15	17	7	23	62
	5th	15	19	7	22	63

shocks also explain some of the fluctuations of output and the GDP deflator. Thus, exogenous shifts in credit supply are at least as important as aggregate supply shocks for explaining movements in real GDP and prices. Nevertheless, as would have been expected in the context of the financial crisis and the related global recession, aggregate demand and monetary policy shocks have the largest explanatory power for macroeconomic fluctuations in the Euro Area.

3.3 Historical contribution of loan supply shocks

While the forecast error variance decomposition sheds some light on the quantitative importance of the structural shocks over the entire sample period, a

historical contribution allows to figure out the relevance of a shock for a specific sub–period. In this Section we are interested in the role of loan supply shocks during the world financial crisis. The historical decomposition is performed in two steps (Burbidge and Harrison, 1985). First, we transform the reduced–form residuals ε_t for each time period t into the structural residuals η_t, while in the second step we compute the quantitative contribution of the loan supply shock to the growth rate of some of the variables in VAR.

Evolution and variability of loan supply shocks

Figure 2 shows the evolution of the median loan supply shock for each country over time. For most of the countries the variability of the shock has increased from 2008 on, which indicates that loan supply shocks have played a larger role during the financial crisis.

An interesting issue, in particular in the context of a monetary union, is the cross–country correlation of the shock. An indicator of heterogeneity across Euro Area countries is the cross–sectional standard deviation of the loan supply shock, which has increased from on average 0.5 over the period from 2003Q3–2007Q2 to on average 0.8 over the period of the financial crisis, which comprises 2007Q3–2010Q2. This result per se points to a higher degree of heterogeneity of the magnitude of loan supply shocks during the financial crisis. In order to get a more comprehensive picture of the cross–country distribution of loan supply shocks, Figure 3 shows boxplots for each quarter of the sample period. While the increase in the height of the boxes during the crisis period confirms the previous finding of a rise in the cross–sectional standard deviation, the fact that, over the entire sample period, the boxes embrace both, positive as well as negative values, is an indicator of a substantial asynchronicity of the loan supply shocks not only in the time before but also during the crisis. A notable exception is the fourth quarter 2008 in which almost all Euro Area countries were hit by a large adverse shock.

Figure 2: Loan supply shock
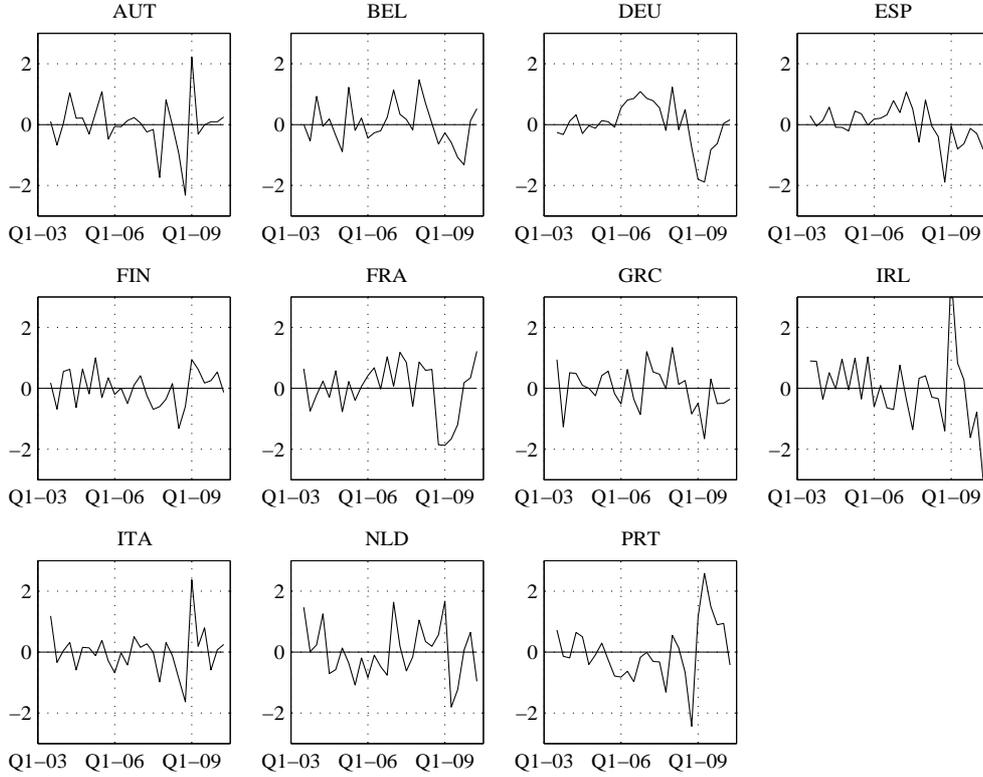
Notes: The loan supply shock is computed as median of the η'_ts of the 500 draws. Positive (negative) values indicate a favorable (adverse) loan supply shock.

Contribution to the growth rate of the loan volume and real GDP

In the second step we are interested in the quantitative contribution of the loan supply shocks to some of the variables in our VAR model. For this reason, we set the loan supply shock to zero during the period of the financial crisis (2007Q3–2010Q2) and simulate a counterfactual scenario that shows how the variables in the VAR model would have evolved without any shocks originating in the banking system. Figure 4 and 5 plot the actual (solid line) and the counterfactual (dashed line) evolution of the quarter–on–quarter growth rates of the loan volume and real GDP for each country in the panel. Concerning the actual evolution some similarities across countries can be observed. The loan

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Figure 3: Cross–country distribution of loan supply shocks
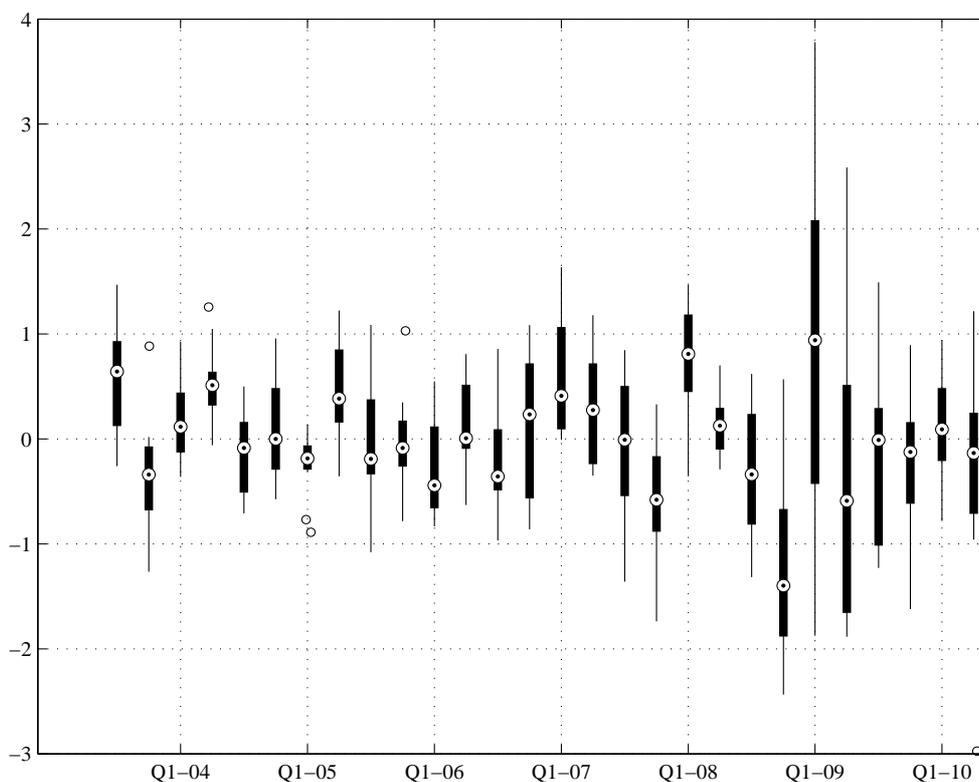
Notes: On each box, the central mark is the median, the edges of the box are the 25th and 75th percentiles, the whiskers extend to the most extreme data points not considered outliers, and outliers are plotted individually.

volume fell in all countries since 2009 at the latest, with Greece being the only country with positive growth rates in 2010. Real GDP growth was also negative in all countries from the second quarter 2008 on and reached its minimum at the end of 2008 or the beginning of 2009, with Greece being again an exception.

The difference between the actual and the counterfactual evolution is then interpreted as the contribution of the loan supply shock. Figures 6 and 7 support our previous finding that the Euro Area was characterized by a considerable degree of cross–country heterogeneity. In the first group, which comprises Austria, Finland, Italy, Portugal and to some extent also Ireland, loan supply shocks dampened the growth rates of both, the loan volume and real GDP, in the first
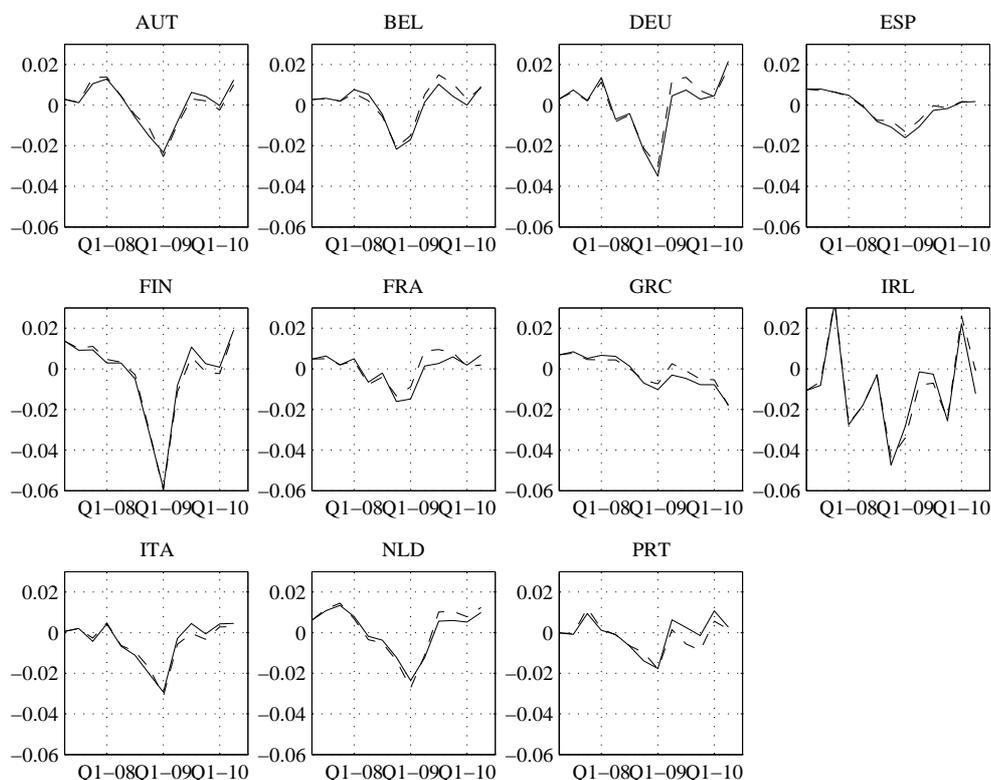
19

Figure 4: Actual and counterfactual evolution of loan–volume growth
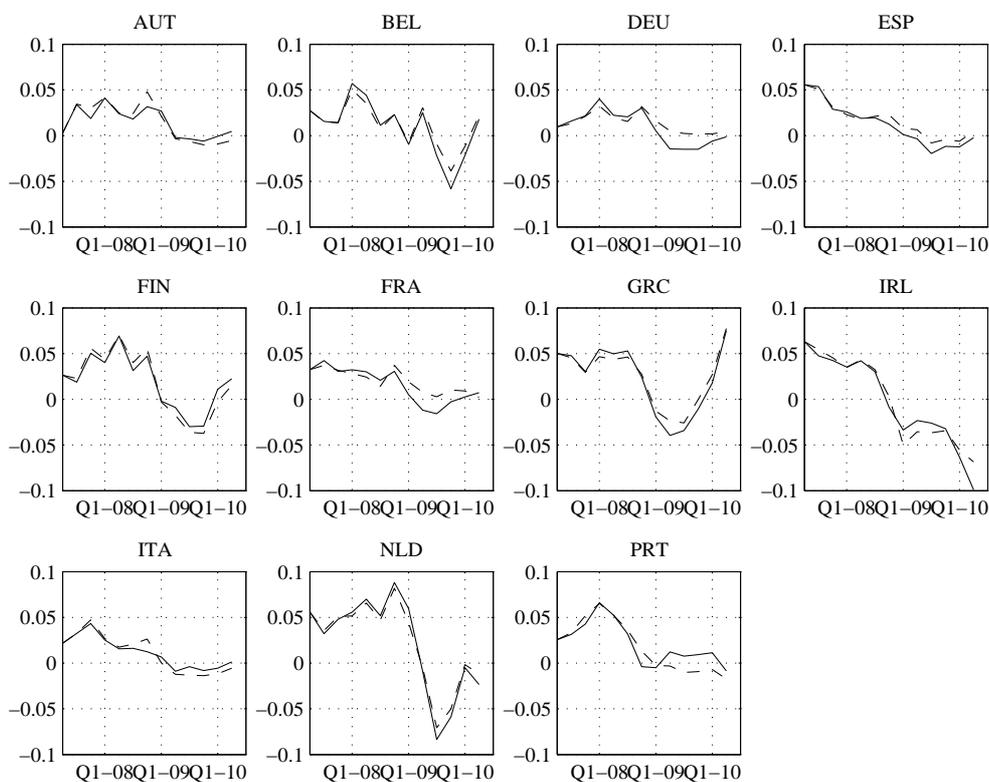
Notes: The lines show the evolution of the quarter–on–quarter growth rates of the loan volume during the crisis period. The solid lines represent the actual growth rate of the loan volume and the dashed lines represent the counterfactual when the loan supply shock is set to zero during the period 2007Q3–2010Q2.

half of the crisis period (2007Q3–2008Q4). If the shock had been absent, these growth rates would have been larger by up to 1.7 percentage points in the case of the loan volume and up to 0.4 percentage points in the case of real GDP. However, in the second half of the crisis period (2009Q1–2010Q2), a sequence of mostly favorable loan supply shocks helped stimulating the economies through higher loan volume growth. If the shocks had been absent, GDP and loan volume growth would have been lower by up to 0.8 and 1.9 percentage points, respectively. In contrast to the other members of this group, in Ireland this sequence abruptly became negative by the end of 2009, due to some large adverse

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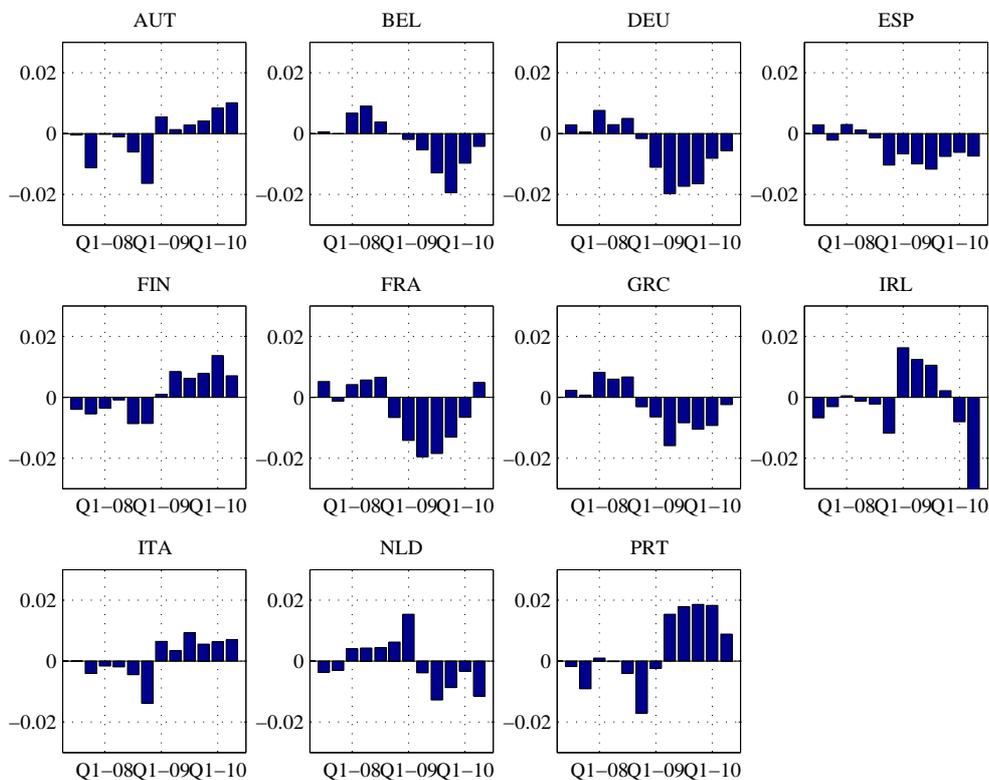Figure 5: Actual and counterfactual evolution of real GDP growth

Notes: The lines show the evolution of the quarter–on–quarter growth rates of real GDP during the crisis period. The solid lines represent the actual GDP growth rate and the dashed lines represent the counterfactual when the loan supply shock is set to zero during the period 2007Q3–2010Q2.

loan supply shocks in 2009 and 2010 (see Figure 2).

The second group consists of Belgium, Germany, Spain, France, Greece and the Netherlands. In these countries the contribution of loan supply shocks to loan volume growth and real GDP growth was inverse compared to that of the first group. While both, the loan volume and real GDP were stimulated by the loan supply shocks in the first half of the crisis period with contributions of up to 1.5 and 0.4 percentage points, respectively, the banking sector aggravated the recession of the year 2009 in these euro area countries. If the shock had been absent, the growth rate the loan volume in this second period would have

Figure 6: Contribution of the loan supply shock to loan–volume growth

been larger by up to 2 percentage points and that of real GDP by up to 0.8 percentage points.

In sum, these results suggest that the banking system was not only a passive transmitter of mostly aggregate demand and monetary shocks during the financial crisis, but rather acted as an additional source of substantial economic disturbances. Further, the time profile of credit supply shocks displays a high degree of heterogeneity across Euro Area countries, with two country groups emerging.

At least partly, this dichotomy in the evolution of loan supply shocks can be

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Figure 7: Contribution of the loan supply shock to real GDP growth
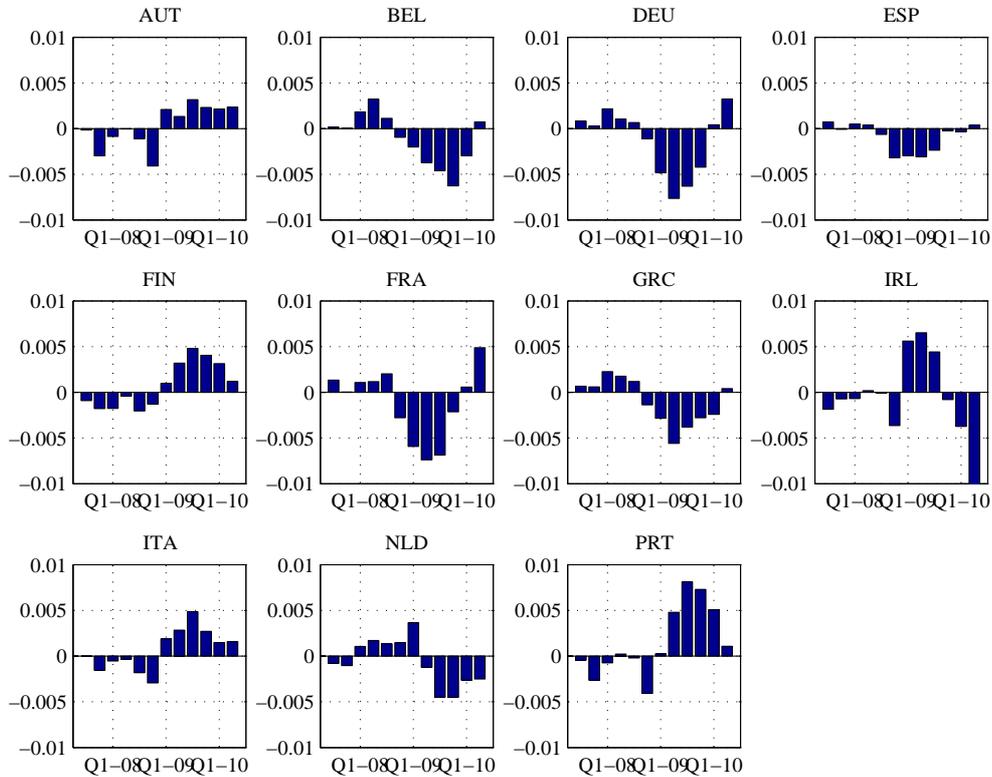
Notes: The bars show the difference between the actual and the counterfactual GDP growth rates when the loan supply shock is shut down during the crisis period. A positive (negative) bar at each period captures how the change in real GDP would have been lesser (greater) in the absence of the shock.

explained by the country–specific time pattern of equity increases by the banking sector. Indeed, the bulk of the additional funds raised by European banks during the crisis years 2008 and 2009 was the result of direct capital injections provided by national governments, as a part of a broader range of non–standard policy measures for stimulating the local economies.[14] Since these capital injections can be considered widely exogenous, the induced improvement in banks' equity share is completely unrelated to changes in credit demand conditions and thus,

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[14]We thank Hans–Werner Sinn for providing us the data on capital injections. See Sinn (2010) for further discussion.

Figure 8: Loan supply shocks and equity injection into the banking system
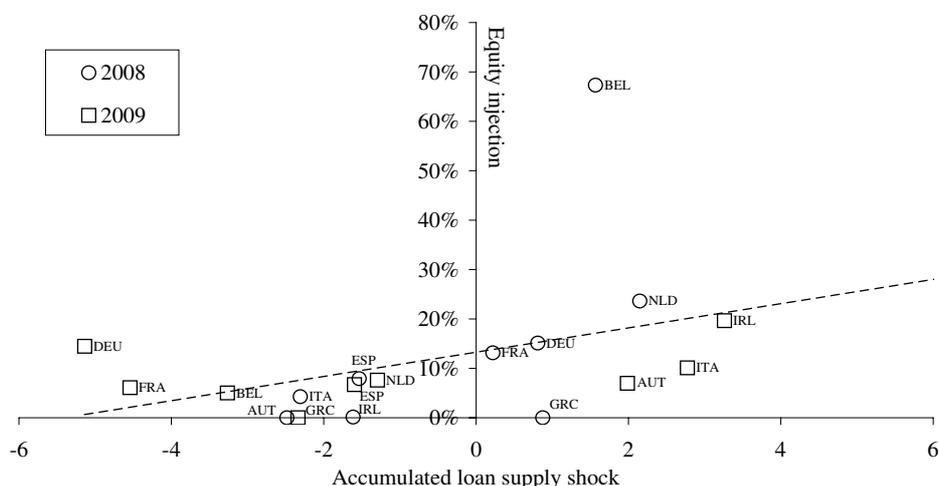
Notes: The accumulated loan supply shock for a specific year is the sum of the four quarterly realizations of the loan supply shocks shown in Figure 2. Positive (negative) values indicate a favorable (adverse) loan supply shock. Equity injection is calculated as the ratio of the total nominal amount of equity raised in year t by the banking sector of country i divided by the average nominal amount of total assets of the national banking system. The data on equity increases is based on the quarterly reports of each country's private banks. The total assets are annual averages of the outstanding amounts of total assets at the end of each month, drawn from the ECB's aggregated balance sheet statistics of national monetary financial institutions (excluding the Eurosystem).

represents an exogenous shift in the loan supply curve. As it turns out, over the course of 2008 and 2009, there were substantial cross–country differences in the raising of new equity. In particular, the amount of new equity in countries belonging to the first group (Austria, Italy, Ireland)[15] was substantially higher in 2009 than in 2008. The opposite was true in the second group (Belgium, Germany, Spain, France, Greece and the Netherlands). This profile is consistent with our sequence of identified disturbances according to which the loan supply shocks hitting the countries of the first group tend to have been negative in 2008 and positive in 2009, while the reverse holds for the Euro Area countries belonging to the second group (Figure 5). This particular relationship between

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[15]Unfortunately, no official data is available for Finland and Portugal.

the equity increases carried through during the crises and the the credit supply shocks occurring over the same period is supported by Figure 8. It plots the country–specific capital increases as a share of total assets in 2008 (circles) and 2009 (squares) against the cumulated country specific loan supply shocks in both years. As can be seen, the figure suggests a positive correlation between the two variables, which continues to hold if the 2008 values for Belgium are excluded.

Nevertheless, it should be kept in mind that this interpretation of the link between capital raises and observable loan supply shocks has some important limitations. First, as we do not disentangle the various potential forces that could lead to a sudden shift in the loan supply curve, it can not be ruled out that the identified loan supply disturbances actually reflect exogenous changes in risk appetite rather than shifts in the capital position of banks. Second, while it is intuitively appealing to view the non–standard policy measures adopted by Euro Area governments during the financial crisis as exogenous, it can still be argued that a non–negligible part of the stimuli represent endogenous reactions to the deteriorating economic situation. Third, due to limited data availability, we are not able to decompose the observed banks' capital increases into an endogenous component, reflecting private banks' decisions, and a true exogenous one, attributable to policy measures.

4   Robustness of the Results

To examine the robustness of the results presented so far, in this Section we estimate a series of alternative VAR specifications in which we deviate along several dimensions from our baseline VAR. We first leave the identification assumptions unchanged and investigate the effect of changes in the data sample by excluding the financial crisis or relaxing the panel structure and resorting to aggregate data for the Euro Area. Second, we take a look at alternative identification schemes by including additional variables and modifying the sign restrictions.

4.1 Baseline Identification

Excluding the financial crisis: To investigate the extent to which our baseline results in general and the relative importance of loan supply shocks in particular are driven by the extraordinary economic collapse during the financial crisis, we exclude this episode from the sample. In particular, we estimate the baseline model by only resorting to the period 2003Q1 – 2007Q4. The median of the corresponding impulse responses to a negative credit supply shock are shown in Figure 9 (dashed lines) along with the 68% credibility bounds of the baseline model. The shortening of the sample period seems to have little effect on the reactions to the shock since they always have the same sign and qualitatively the same pattern as the baseline impulse responses. Furthermore, except in few cases, the dashed lines lie within the credibility intervals of our baseline VAR. Interestingly, excluding the financial crisis increases the relative importance of the loan supply shock as measured by the fraction of forecast error variance it explains. For output, the GDP deflator, the money market rate and the loan rate this measure increases by 5 percentage points. In the case of the loan volume the increase is even larger – from about 15 to more than 25 percent.[16] The likely reason for the higher explanatory power of loan supply shock is that by abstracting from the crisis period one in fact excludes a subsample in which economic developments in the Euro Area were most likely driven by extremely large negative aggregate demand shocks.

Aggregate Euro Area data: As a further robustness check we estimate our baseline VAR by using aggregate Euro Zone data rather than a panel of country-specific series. The median of the impulse responses to an adverse loan supply shock (dotted lines) are again shown in Figure 9. They are also in line with the dynamic pattern implied by our baseline specification and so, provide further support for the results discussed above. Solely with respect to the loan volume and the GDP deflator there are more pronounced deviations from the baseline results: While still being significant and still having the correct sign,

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[16]The results of the forecast error variance decomposition for the VAR estimated over the shorter sample (2003Q1 – 2007Q4) are available upon request.

Figure 9: Loan supply shock (alternative sample)
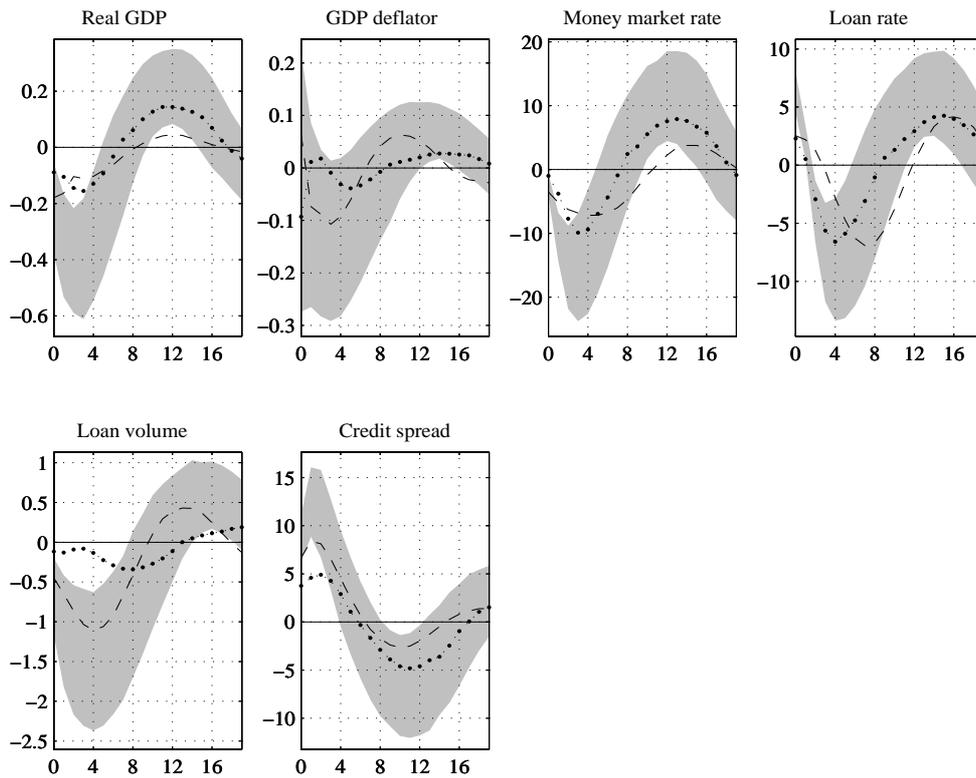
Notes: The shaded areas are the 68% confidence intervals of the impulse responses resulting from the baseline model of Section 3. The dashed lines show the median of the impulse responses from the model that excludes the financial crisis period from the sample. The dotted lines are those from the model that uses aggregate euro area data. All impulse responses are estimated from a Bayesian vector-autoregression with 500 draws. Real GDP, the GDP deflator and the loan volume are expressed in percent terms, while the money market rate, the loan rate and the credit spread are expressed in basis points. The impulse responses are normalized to an adverse one–standard deviation shock. The horizontal axis is in quarters.

the reaction of loan volume to credit supply shocks turns to be much weaker and barely hump-shaped. In contrast to the baseline case, the response of the GDP deflator becomes significantly negative between the third and the sixth quarter after the shock.

4.2 Alternative Identification Approaches

The crucial restriction enabling us to disentangle aggregate demand disturbances from loan supply shocks is the assumption that the loan rate falls in response to an adverse demand shock. The reason is a downward shift of the credit demand curve since the temporary economic slack caused by a negative aggregate demand shock typically leads to a deterioration of investment opportunities, thus, reducing the amount of credit needed by firms to finance investment. Moreover, the policy rate reduction, usually engineered by the central bank in the face of declining economic activity and decelerating inflation, is passed at least partly through to loan rates.

Albeit appearing intuitive and being supported by many DSGE models, this intuition may still be rather incomplete, missing some general mechanisms characterizing the reaction of banks to economic downturns. As the latter typically imply a deterioration in borrowers balance sheets, a reduction in the value of collateral, more subdued economic prospects and hence, higher borrowers' riskiness, there are little *a priori* reasons for banks not to respond by *increasing* loan rates.[17] In fact, this channel have most likely been at work around the peak of the financial crisis (winter 2008 – 2009) as suggested by skyrocketing risk premia on loan and other lending rates despite unprecedentedly low ECB rates in those months.

Given this potential ambiguity with respect to the sign of the response of the loan rate to aggregate demand shocks we relax the corresponding sign restriction in our VAR model and test the robustness of our results by employing alternative strategies for disentangling loan supply from aggregate demand shocks. In particular, we resort to restrictions on a measure of the "quality" of bor-

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[17]This channel is at the heart of the "financial accelerator mechanism" proposed by Bernanke, Gertler, and Gilchrist (1999).

rowers or, alternatively, impose assumptions on the composition of firms' debt portfolios.

Table 5: Sign restrictions (alternative identification approaches)

Shock	Real GDP	GDP deflator	Money market rate	Loan rate	Loan volume	Model 1 Insolvencies	Model 2 Corporate securities
Aggregate supply	↓	↑	↑				
Monetary policy	↓	↓	↑				
Aggregate demand	↓	↓	↓			↑	↓
Loan supply	↓		↓	↑	↓	0	0

Notes: Sign restrictions are imposed for two quarters. The sign restrictions imposed on *Insolvencies* and *Corporate securities* are strict. A "0" denotes an exact zero restriction on the impact response.

Quality of borrowers: Following the reasoning in Helbling et al. (2010) we assume that an adverse aggregate demand shock induces an immediate worsening in the quality of borrowers *via* increased default probability while borrowers' quality remains unchanged or even improves on impact when negative loan supply shocks occur. The idea lying at the heart of this assumption is quite straightforward: An adverse loan supply shock corresponds to a tightening in credit standards which can not be explained by changes in underlying fundamentals affecting the riskiness of potential borrowers. In other words, in the face of a negative credit supply shock, banks become more restrictive although the firms' situation has not changed or has become even better. In contrast, by triggering a more or less pronounced economic downturn, unfavorable aggregate demand shocks typically induce a worsening of borrowers' situation and an increased default frequency. Hence, the two types of shocks can be disentangled based on the quite distinct behavior of borrowers' quality they are associated with.

We proxy the quality of borrowers by the percentage deviation of the absolute number of corporate insolvencies from its linear trend. We use country-specific data covering the period 2003Q1 – 2010Q2, provided by *Creditreform*

Germany.[18] We assume that a negative aggregate supply shock induces a strict increase in the number of insolvencies in the first two periods while we impose an exact zero restriction upon the impact reaction of insolvencies to a negative loan supply shock. Alternatively, one can assume that the reaction of insolvencies to adverse aggregate demand shocks is non-negative while being non-positive in the case of loan supply shocks. However, this modification of the identifying restrictions has only a negligible effect on the results.[19]

Restrictions on the debt portfolio of firms: In our next robustness check we focus on a model in which the outstanding amount of debt securities issued by firms is additionally included.[20] As in Kashyap, Stein, and Wilcox (1993), we assume that firms regard bank loans and securities as alternative sources of external funds. The idea is that if firms face a limited access to bank loans after an adverse loan supply shock, at least some of them might raise their issuance of debt securities. In turn, an adverse aggregate demand shock triggers a fall in both, bank loans and debt securities, because of a slowdown of economic activity. Accordingly, we identify the shocks by imposing the following restrictions. An adverse loan supply shock is characterized by an immediate drop of the loan volume and an increase in the loan rate, while the reaction of the amount of debt securities outstanding initially remains unchanged. An adverse aggregate demand shock is characterized by an immediate fall of the loan volume that comes along with an immediate drop of the amount of debt securities outstanding.

Results: The impulse responses to loan supply and aggregate demand shocks in the six-dimensional VAR including the number of insolvencies (the outstanding amount of debt securities) are shown by the dashed (dotted) lines in Figures 10 and 11 respectively. They are strikingly similar to that implied by our baseline

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[18]See http://www.creditreform.de/English/Creditreform/About_us/index.jsp . Since *Creditreform Germany* only provides yearly data, we interpolate the series linearly to generate quarterly data.

[19]The results obtained under this identifying assumptions are available upon request.

[20]Data on the outstanding amount of debt securities by corporate issuers is taken from the database of the Bank of International Settlements.

specification and always lie within the 68% credibility intervals of the baseline VAR. Furthermore, the loan supply shocks implied by the extended models are virtually identical to that from the baseline VAR: The country-specific correlations between the shock series derived from the different models lie between 93.4% and 99.9%, which provides further support for the robustness of our baseline results.[21]
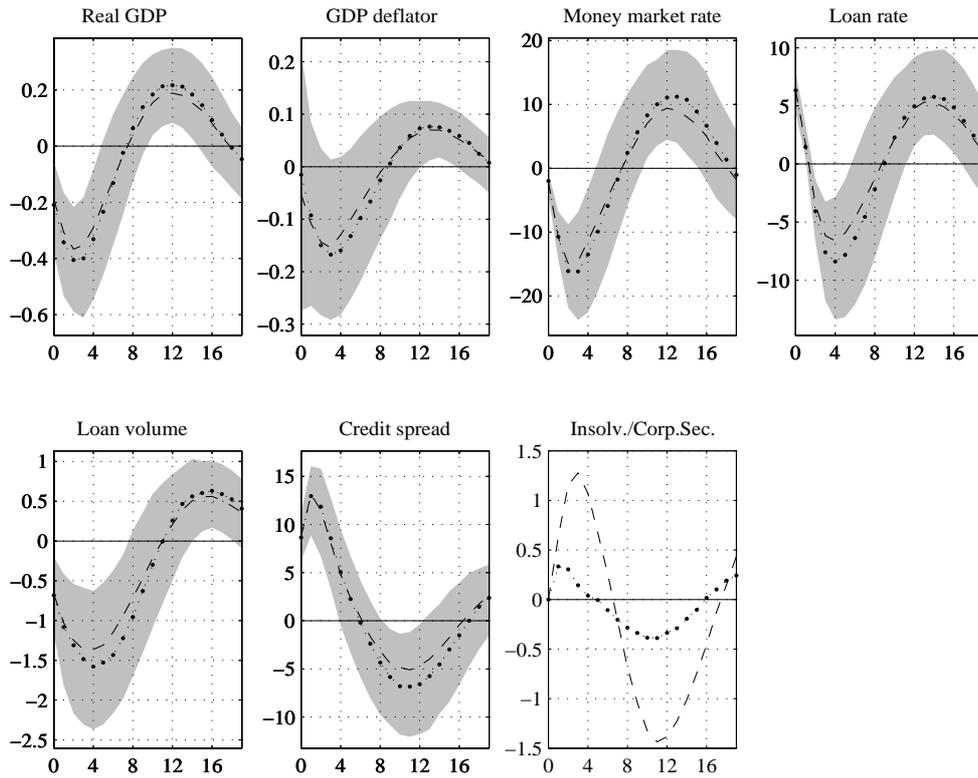
5 Conclusion

We employ a panel vector autoregressive (VAR) model for the member countries of the Euro Area to explore the macroeconomic effects of adverse loan supply shocks during the recent financial crisis. We identify the loan supply shocks by imposing sign restrictions. To ensure a sound identification of the shocks, we additionally account for aggregate supply shocks, monetary policy shocks and aggregate demand shocks.

Our findings indicate that (i) the evolution of bank loans in the member countries of the Euro Area was significantly affected by loan supply shocks in the course of the financial crisis; (ii) in all member countries a remarkable share of the decline in national real GDP growth can be related to loan supply shocks; and, (iii) the Euro Area is characterized by a considerable degree of cross–country heterogeneity, which is reflected by the timing as well as the magnitude of the shocks. In a counterfactual exercise we find that in some countries, e.g. Austria, Finland or Italy, the dampening effects of loan supply shocks were particularly relevant in the course of 2008, while in other countries, e.g. Germany, Spain or France, they predominantly emerged during 2009 and 2010. At least partly, this dichotomy across countries can be explained by the time pattern of equity increases by the national banking sector.
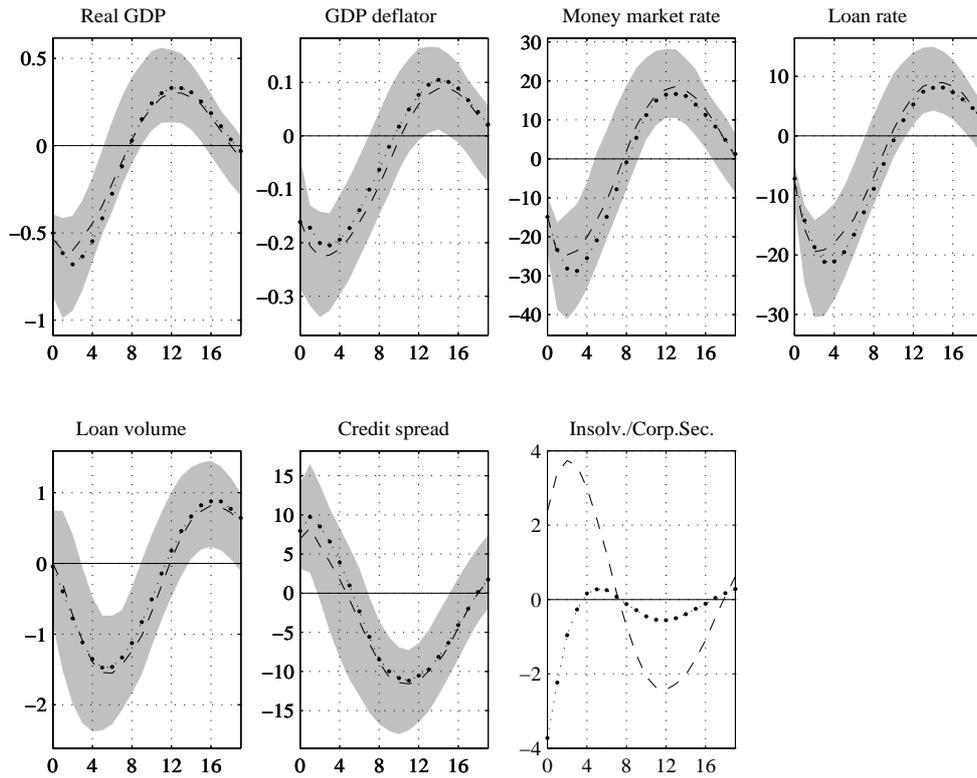
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[21]We also experimented with restrictions on the credit spread within the baseline specification as well as with an alternative measure of borrowers' quality based on data from the Bank Lending Survey of the ECB. The results are largely in line with that presented in Section 3 and are available upon request.

Figure 10: Loan supply shock (alternative identification approaches)

Notes: The shaded areas are the 68% confidence intervals of the impulse responses result-
ing from the baseline model of Section 3. The dashed lines show the median of the impulse
responses from the model that additionally includes firm insolvencies. The dotted lines are
those from the model that additionally includes the outstanding amount of corporate secu-
rities. All impulse responses are estimated from a Bayesian vector-autoregression with 500
draws. Real GDP, the GDP deflator, the loan volume, insolvencies and corporate securities
are expressed in percent terms, while the money market rate, the loan rate and the credit
spread are expressed in basis points. The impulse responses are normalized to an adverse
one–standard deviation shock. The horizontal axis is in quarters.

Figure 11: Aggregate demand shock (alternative identification approaches)

Notes: The shaded areas are the 68% confidence intervals of the impulse responses resulting from the baseline model of Section 3. The dashed lines show the median of the impulse responses from the model that additionally includes firm insolvencies. The dotted lines are those from the model that additionally includes the outstanding amount of corporate securities. All impulse responses are estimated from a Bayesian vector-autoregression with 500 draws. Real GDP, the GDP deflator, the loan volume, insolvencies and corporate securities are expressed in percent terms, while the money market rate, the loan rate and the credit spread are expressed in basis points. The impulse responses are normalized to an adverse one–standard deviation shock. The horizontal axis is in quarters.

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Appendix

A Data

We use data for 11 European countries that is taken from the Eurostat, the ECB, Creditreform Germany and the Bank of International Settlements (BIS) databases covering the period from 2003Q1 to 2010Q2. The panel of countries includes Austria (AUT), Belgium (BEL), Finland (FIN), France (FRA), Germany (DEU), Greece (GRC), Ireland (IRL), Italy (ITA), the Netherlands (NLD), Portugal (PRT) and Spain (ESP). The data comprises:

1. Real GDP (y_t): Gross domestic product at market prices, calendar and seasonally adjusted, in constant 2000 EUR (Eurostat).

2. GDP deflator (p_t): Price index, 2000=100, gross domestic product at market prices, calendar and seasonally adjusted (Eurostat).

3. Money market rate (s_t): Euro Area interbank rates (Euro Overnight Index Average, EONIA), in percent (ECB).

4. Loan rate (r_t): Interest rate charged by monetary financial institutions (excluding Eurosystem) for loans to non–financial corporations (outstanding amounts, all maturities), in percent (ECB).

5. Loan volume (l_t): Outstanding amount of loans (all maturities) from monetary financial institutions (excluding Eurosystem) to non–financial corporations, in EUR (ECB).

6. Corporate insolvencies: Absolute number of corporate insolvencies (Creditreform Germany).

7. Corporate debt securities: International debt securities by corporate issuers, amounts outstanding in US dollars. Converted into Euro (BIS).
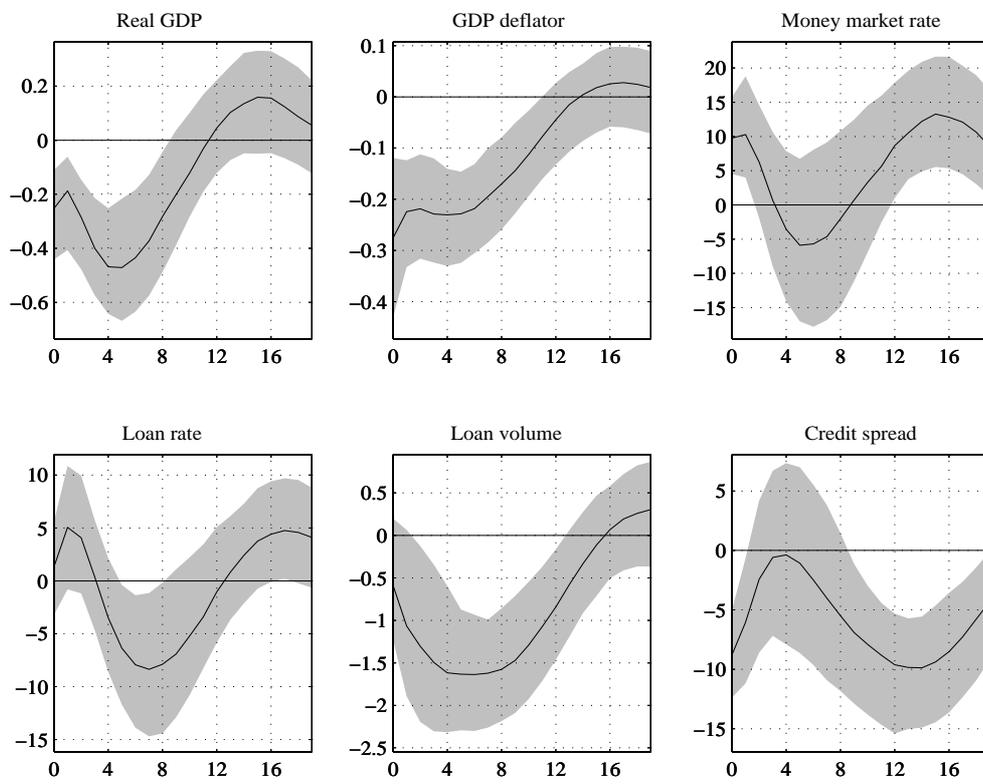
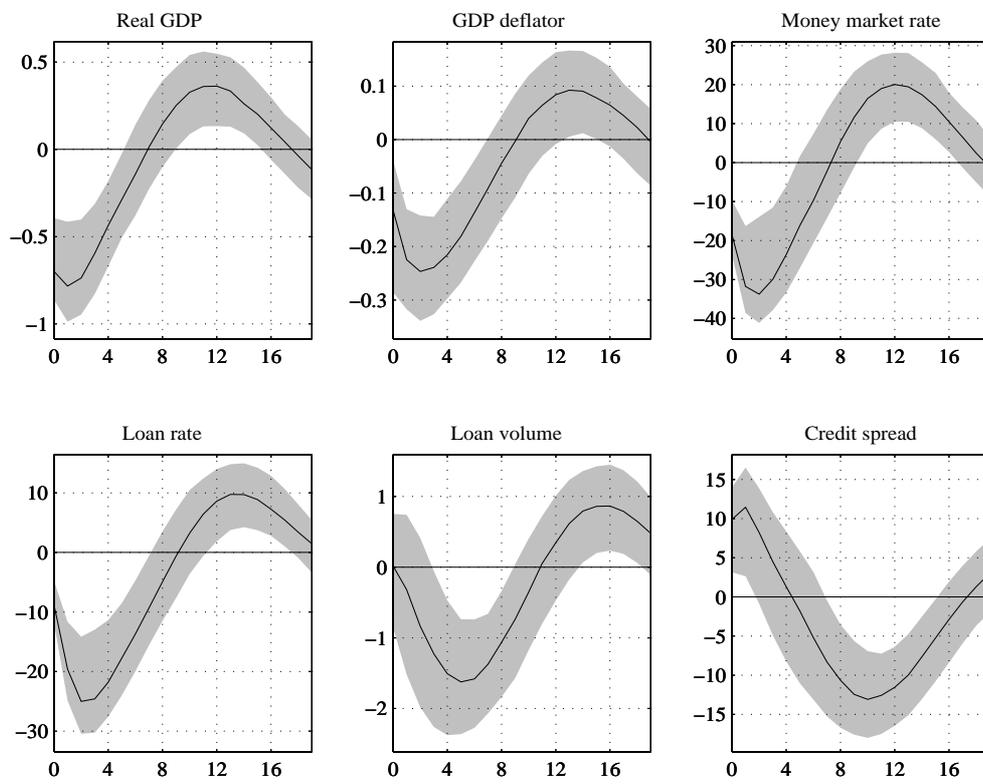## B Impulse responses of other shocks

Figure 12: Aggregate supply shock
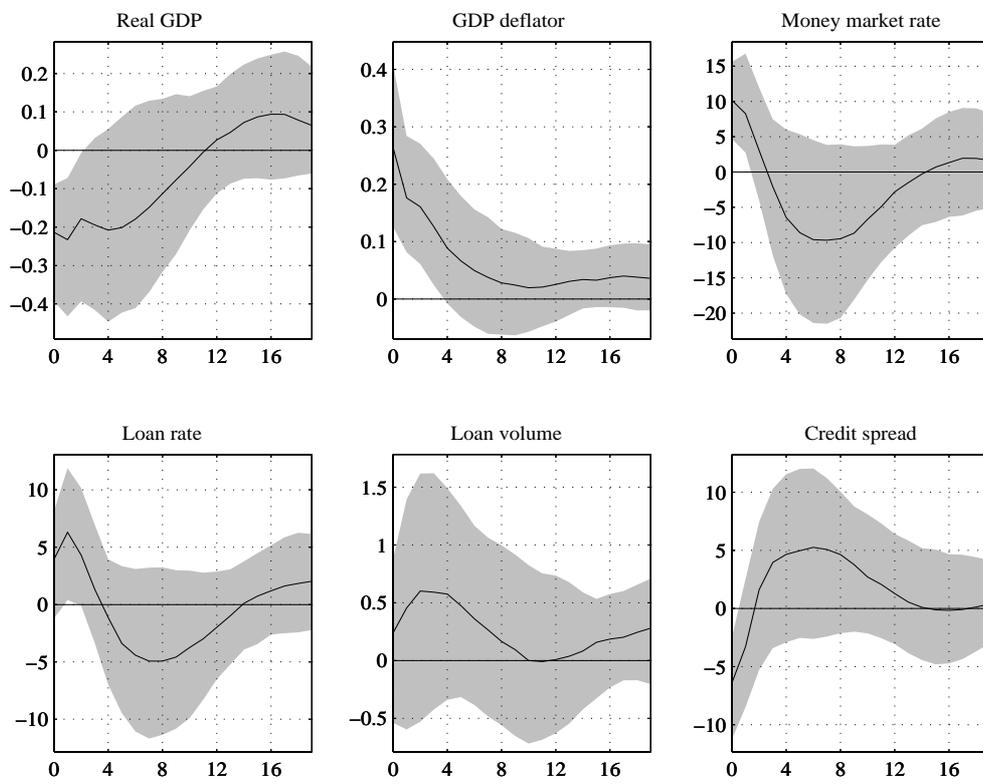
Notes: See Figure 1.

Figure 13: Monetary policy shock

Notes: See Figure 1.

Figure 14: Aggregate demand shock

Real GDP   GDP deflator   Money market rate

Loan rate   Loan volume   Credit spread

Notes: See Figure 1.