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Loan supply in Germany during the financial crisis

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Abstract

Distinguishing pure supply effects from other determinants of price and quantity in the market for loans is a notoriously difficult problem. Using German data, we employ Bayesian vector autoregressive models with sign restrictions on the impulse response functions in order to enquire the role of loan supply and monetary policy shocks for the dynamics of loans to non-financial corporations. For the three quarters following the Lehman collapse, we find very strong negative loan supply shocks, while monetary policy was essentially neutral. Nevertheless, the historical decomposition shows a cumulated negative impact of loan supply shocks and monetary policy shocks on loans to non-financial corporations, due to the lagged effects of past loan supply and monetary policy shocks. However, these negative effects on loans to non-financial corporations are overcompensated by positive other shocks, which implies that loans developed more favorably than implied by the model, over the past few quarters.

Keywords: Loan supply; Bayesian VAR; sign restrictions

JEL classification: C11, C32, E51

Non-technical summary

The drastic decline observed in loan growth during the intensification of the financial crisis in the fourth quarter 2008 raised widespread concerns regarding an imminent or existing supply-side constraint of bank lending. This paper seeks to shed some light on the economic determinants of the weak loan growth during the financial crisis. Particularly, we analyze how far the loan development remains consistent with historical regularities and to which extent bank sided restrictions might serve as an explanation.

The identification of loan supply and demand shocks is in the end an unsolved methodological problem, because for every point in time only the realized combination of price and quantity is observable but not the supply and demand curves. Consequently, empirical methods require identifying assumptions. For identifying loan supply shocks and monetary policy shocks and using them to explain loan dynamics to non-financial corporations in Germany, we employ a Bayesian VAR model with sign restrictions. This identification method proposed by Uhlig (2005) enables us to identify both shocks by imposing sign restrictions based on the theoretical and empirical literature (Christiano, Eichenbaum and Evans (2005) and Gerali, Neri, Sessa and Signoretti (2008)) on the impulse response functions.

The main results of our empirical analysis can be summarized as follows. First, the intensification of the financial crisis results in significantly negative loan supply shocks in the fourth quarter of 2008 and the first quarter of 2009. Second, monetary policy has been neutral since the fourth quarter 2008, relative to the model framework. Third, the historical decomposition shows that the cumulated lagged negative effect of past monetary policy and loan supply shocks are more than compensated by other, non-identified shocks. Accordingly, the actual loan volume exceeds that implied by the model. Fourth, the negative loan supply shocks on the peak of the crisis have not yet been fully comprised in our sample in the loan aggregate due to the lagged effect of loan supply and monetary policy shocks on the loan volume.

In interpreting these results some caution is needed, though, as estimation results come with an extraordinarily high degree of uncertainty. This reflects besides the sources of uncertainty usually involved with empirical work the fact that this identification method is still relatively unexperienced for the euro area. For a future project we plan, therefore, comprehensive robustness checks.

Nichttechnische Zusammenfassung

Der mit der Verschärfung der Finanzkrise im vierten Quartal 2008 einhergehende Einbruch des Kreditwachstums schürte weitverbreitete Sorgen um eine drohende oder existierende angebotsseitige Beschränkung der Kreditvergabe durch Banken. Das vorliegende Papier versucht etwas Licht ins Dunkel zu bringen und Einblick in die ökonomischen Bestimmungsgründe des schwachen Kreditwachstums in der Finanzkrise zu gewähren. Insbesondere untersuchen wir, inwieweit die Kreditentwicklung historischen Gesetzmäßigkeiten folgt und bis zu welchem Grad möglicherweise bankseitige Restriktionen als Erklärung dafür dienen könnten.

Die Identifikation von Kreditangebots- und -nachfrageschocks ist dabei letzt-lich ein ungelöstes methodisches Problem, weil für jeden Zeitpunkt nur die realisierte Kombination aus Preis und Menge, nicht aber Angebots- und Nachfragekurven beobachtet werden können. Daher erfordern empirische Ansätze identifizierende Annahmen. Um Kreditangebots- und geldpolitische Schocks zu identifizieren und auf deren Grundlage die Dynamik der Kredite an nichtfinanzielle Kapitalgesellschaften in Deutschland zu erklären, verwenden wir ein Bayesianisches VAR-Modell mit Vorzeichenrestriktionen. Bei dieser auf Uhlig (2005) zurückgehenden Identifikationsmethode werden die beiden Schocks anhand von aus der theoretischen und empirischen Literatur (Christiano et al. (2005) and Gerali et al. (2008)) abgeleiteten Vorzeichenrestriktionen auf die Impuls-Antwortfolgen identifiziert.

Die Kernaussagen unserer empirischen Analyse lassen sich wie folgt zusammenfassen. (1) Mit der Verschärfung der Finanzkrise ergeben sich für das vierte Quartal 2008 und das erste Quartal 2009 signifikant negative Kreditangebotsschocks. (2) Die Geldpolitik war, gemessen am Modell, seit dem vierten Quartal 2008 neutral. (3) Im Rahmen der historischen Dekomposition zeigt sich, dass die kumulierte, verzögerte negative Wirkung der vergangenen geldpolitischen und Kreditangebotsschocks auf das Kreditaggregat durch andere, nicht identifizierte Schocks überkompensiert wird, so dass derzeit das ausstehende Kreditvolumen größer ist als durch das Modell impliziert. (4) Aufgrund der verzögerten Wirkung von Kreditangebots- und geldpolitischen Schocks auf das Kreditvolumen haben sich die negativen Kreditangebotsschocks auf dem Höhepunkt der Krise im Untersuchungszeitraum noch nicht vollständig im Kreditaggregat niedergeschlagen.

Bei der Interpretation der Ergebnisse ist jedoch Vorsicht geboten, da die Schätzergebnisse einem außergewöhnlich hohen Maß an Unsicherheit unterliegen. Dies resultiert neben den üblichen im Zusammenhang mit empirischer Arbeit genannten Gründen aus der im Eurosystem bislang noch relativ unerprobten Identifikationsmethode. Umfangreiche Robustheitstests sind daher für eine zukünftiges Projekt geplant.

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Loan supply in Germany during the financial crisis*

1 Introduction

Against the background of tightened credit conditions, increasing loan loss provisions and the remaining lack of confidence between banks following the aggravation of the financial crisis in autumn 2008, politicians and entrepreneurs' associations in Germany soon began to express their concerns that loan supply would die down, and that in consequence, the real side of the economy would be adversely affected by the malfunctioning of the financial system. In fact, outstanding loans to non-financial corporations have declined since early 2009.

According to recent surveys, entrepreneurs have blamed banks for an increasing reluctance to extend credit, implying that bank-sided factors (such as capital restrictions) rather than increasing credit risk were responsible for the subdued credit growth. At the same time, banks broadly denied to have reduced their loan supply due to shortages of capital, see Deutsche Bundesbank (2009). These conflicting views are well explained by the conflicting economic interests of the relevant parties.

As it is hard to determine whether banks on aggregate are overanxious, feel restricted by current or future capital requirements, or just correctly anticipate the future development of credit risk, we find it worthwhile to evaluate the development of the loan volume against the past and current macroeconomic conditions, as represented by aggregate time series data. Thus, we hope to obtain insight in the economic causes of the recent moderate development of loans to non-financial corporations.

Any attempt to seriously address this question will be plagued by the difficulty to separate loan supply from loan demand effects, see Bernanke and Lown (1991). Recent research has made progress in developing theoretical and empirical tools for distinguishing supply and demand effects on loan markets. The theoretical approach relies on DSGE models augmented by a role for financial intermediation, money and credit, see e.g. Goodfriend and McCallum (2007), Gerali

*We are grateful to Alberto Musso, Sandra Eickmeier, Christina Gerberding, Martin Kliem, Andreas Worms and participants of the DIW Macroeconometric Workshop for valuable comments.

et al. (2008), Atta-Mensah and Dib (2008) and Gilchrist, Ortiz and Zakrajšek (2009).

One strand of the empirical literature on this issue employs cointegration methodology. Examples include Gambacorta and Rossi (2007) and Sørensen, Marqués Ibáñez and Rossi (2009). Restrictions on the cointegration vectors allow to interpret cointegrating relations as credit supply and credit demand equations. While the cointegration approach offers the identification of excess supply and demand for credit, it does not allow decomposing the aggregate outstanding volume of loans into structural shocks.

This paper, in contrast, employs a Bayesian VAR framework with sign restrictions on the impulse response functions, which has been applied by Chadha, Corrado and Sun (2008) in the context of the identification of money demand and supply. Our work is most closely related to research by Musso (2009) who identifies a large number of shocks, including loan supply and demand shocks.

The identification strategy for the shocks is based on a method developed by Uhlig (2005), which employs randomly drawn orthogonalization matrices for structural identification in a Bayesian VAR framework. In particular, Uhlig's *pure sign restriction approach* combines *random* identification schemes (i.e., rotation matrices) with *random* sets of model parameters (drawn from the posterior distribution of the VAR). Only those combinations are retained, where the respective structural shock generates impulse responses that conform to a predetermined pattern, in line with theoretical considerations.

The relevant outcome of such an exercise could be a median impulse response function for the respective shock of interest, possibly with quantiles to indicate the degree of uncertainty in the responses. However, Fry and Pagan (2007) emphasize that the so-generated median impulse response function does not correspond to a set of model parameters that was estimated from the data. Following their suggestion, we select the specific combination of rotation matrix and set of model parameters drawn from the posterior distribution that provides the best match of the median impulse responses. We call this best match the *median model*. It implies sequences of structural shocks, which are used for the historical decomposition of loans to non-financial corporations (NFCs).[1]

[1] Musso (2009) computes the historical decomposition as an average decomposition of the

Our VAR comprises six variables. Besides standard variables such as real GDP, the price level and the short term interest rate, we include our key variables of interest, the volume of loans to non-financial corporations and the corresponding loan rate. Furthermore, we add the corporate bond spread in order to control for expectations about credit risk over the relevant time horizon. We identify only two shocks, a loan supply shock and a monetary policy shock. Thus, we increase – relative to Musso (2009) – the fraction of admitted identification schemes, at the expense of a greater share of the structural shocks remaining unexplained.[2]

The identification procedure yields the following results. Since autumn 2008, there was a sequence of negative loan supply shocks of extraordinary magnitude. Furthermore, there were no significant monetary policy shocks, indicating that monetary policy – as implied by our identification procedure – was essentially neutral.

The historical decomposition of loans to non-financial corporations shows a somewhat less clear picture, as it comprises also the lagged effects of past shocks, which tend to increase over the medium term due to the hump-shaped pattern of some of the impulse response functions. During the past few quarters, the cumulated effect of present and past loan supply shocks – and, to a lesser extent, monetary policy shocks – on loans to NFCs turned out to be negative, in spite of the recent sequence of rate cuts by the ECB.

However, these adverse effects of loan supply shocks and monetary policy shocks on loans to NFCs were more than compensated by all other shocks, which could possibly incorporate not only aggregate demand and loan demand effects, but also policy measures that remain largely uncovered in our set of explanatory variables, such as government's rescue packages for banks or the unconventional monetary policy measures of the eurosystem.[3]

The remainder of our paper is organized as follows. In section 2, we describe the methodology of Bayesian VARs with sign restrictions on the impulse response functions. The following section explains our model, data, and sign restrictions. Section 4 presents the results, in particular impulse response functions, the series of the

accepted models and identification schemes.

[2]For a discussion of the merits of identifying only few shocks, see Uhlig (2005) and Christiano, Eichenbaum and Evans (1999).

[3]However, the various policy actions likewise may have been recorded to some extent as loan supply shocks or monetary policy shocks.

identified loan supply and monetary policy shocks, and the historical decomposition. Section 5 concludes the paper.

2 Methodology: BVAR models and sign restrictions

As Uhlig (2005), we use conventional notation to define a VAR model as

$$\begin{aligned} Y_t &= B_1 Y_{t-1} + B_2 Y_{t-2} + \cdots + B_p Y_{t-p} + u_t \\ u_t &\sim N(0, \Sigma) \end{aligned} \tag{1}$$

where Y_t is an $n \times 1$ vector of data (n variables), B_i are coefficient matrices of size $n \times n$ and u_t is the one-step ahead prediction error with variance-covariance matrix Σ. It can be stacked as for example in Kadiyala and Karlsson (1997)

$$\underset{(T\times n)}{\mathbf{Y}} = \underset{(T\times k)}{\mathbf{X}}\underset{(k\times n)}{\mathbf{B}} + \underset{(T\times n)}{\mathbf{u}} \tag{2}$$

where $\mathbf{Y} = [Y_1, ..., Y_T']'$, $\mathbf{X} = [X_1, ..., X_T]'$, $X_t = \left[Y_{t-1}', Y_{t-2}', ..., Y_{t-p}'\right]'$, $\mathbf{B} = [B_1, ..., B_p]'$ and $\mathbf{u} = [u_1, ..., u_T]'$. $\mathbf{X}$ may be augmented by a constant and a deterministic trend. Abstracting from deterministic terms, $k = np$ is the number of dynamic parameters to be estimated.

The quasi maximum likelihood estimator for $(\mathbf{B}, \mathbf{\Sigma})$ is equivalent to the least squares estimator:

$$\begin{aligned} \hat{\mathbf{B}} &= (\mathbf{X}'\mathbf{X})^{-1}\mathbf{X}'\mathbf{Y} \\ \hat{\mathbf{\Sigma}} &= \frac{1}{T}\left(\mathbf{Y} - \mathbf{X}\hat{\mathbf{B}}\right)'\left(\mathbf{Y} - \mathbf{X}\hat{\mathbf{B}}\right) \end{aligned} \tag{3}$$

In line with Uhlig (2005), we assume that prior and posterior for $(\mathbf{B}, \mathbf{\Sigma})$ follow an $n-$dimensional Normal-Wishart distribution which is the natural conjugate prior for normal data, see Kadiyala and Karlsson (1997). The parameters of the Normal-Wishart distribution and the choice of the non-informative prior are as in Appendix B of Uhlig (2005).

Sign restrictions

The reduced form residuals u_t of a VAR have no structural interpretation. In order to identify the fundamental innovations, additional restrictions are needed.[4] Following Uhlig (2005), we assume that there are n unobserved fundamental innovations (or structural shocks) v_t, which are mutually independent and can be normalized with variance 1.

$$E\left(v_t v_t'\right) = I_n$$

Consider the $n \times n$ matrix A, which relates reduced-form residuals u_t to structural shocks v_t,

$$u_t = Av_t \tag{4}$$

There are $n\left(n-1\right)/2$ degrees of freedom in specifying A, as only $n(n+1)/2$ restrictions on A emerge from the covariance structure:

$$\Sigma = E\left(u_t u_t'\right) = AE\left(v_t v_t'\right)A' = AA'$$

It is readily seen that for any orthogonal matrix Q with $QQ' = I_n$, also $\Sigma = AQQ'A'$ is an admissible decomposition for Σ, in which case $u_t = AQ\widetilde{v}_t$, $E(\widetilde{v}_t\widetilde{v}_t') = I_n$.[5]

Although different Q-matrices produce different signs and magnitudes of the impulse responses, it is not possible to discriminate among them on the basis of data, as they imply identical VAR representations.[6] Thus, for any decomposition $\Sigma = AA'$, there exist infinitely many identification schemes $AQ^{(f)}$, $f = 1, \ldots, \infty$, $Q^{(f)}Q^{(f)\prime} = I_n$, such that $\Sigma = AQ^{(f)}Q^{(f)\prime}A'$.

We use a variant of Uhlig's *pure sign restriction approach* that deviates from Uhlig (2005) as we attempt to identify *two* structural innovations rather than only one (the procedure can be easily extended to $n-1$ shocks; however, computation time explodes with the number of shocks identified). The method works as follows:

1. Draw $d = 1, \ldots, m$ models from the posterior distribution of the VAR (a model d consists of a covariance matrix $\Sigma^{(d)}$ and corresponding VAR-parameters $\mathbf{B}^{(d)}$).

2. For $j = 1, 2, \ldots$, draw randomly from the m models.

[4]Traditional solutions to the identification problem are the triangular Cholesky-decomposition, the Blanchard-Quah decomposition and restrictions that are derived from theory (structural relations); see e.g. Enders (2004), Chapter 5.

[5]Due to the orthogonal matrix Q, the structural shocks $\widetilde{v}_t$ implied by the identification differ from the v_t in (4), and therefore receive a different notation.

[6]The ambiguity of the impulse responses of a VAR is familiar from the Cholesky decomposition, where different orderings of the variables imply different impulse responses.

3. Choose $A := \widetilde{A}^{(j)}$, where $\widetilde{A}^{(j)}$ is the Cholesky decomposition of $\Sigma^{(j)}$, such that $\Sigma^{(j)} = \widetilde{A}^{(j)}\widetilde{A}^{(j)\prime}$.[7]

4. For each j, draw random Q-matrices $Q^{(f(j))}$, $f(j) = 1, \ldots, F$ until the impulse response functions implied by $\mathbf{B}^{(j)}$ and the identification schemes $\widetilde{A}^{(j)}Q^{(f(j))}$ fulfill the sign restrictions that we consider appropriate to define loan supply and monetary policy shocks (see Section 3). We call the combination of model j and identification scheme $\widetilde{A}^{(j)}Q^{(f(j))}$ an *accepted model* (indexed by θ) if the sign restrictions are fulfilled.[8]

5. Iterate over (2) to (4), until $\Theta = 5,000$ models are accepted.

As proposed by Rubio-Ramirez, Waggoner and Zha (2005), we generate the random draws of $Q^{(\cdot)}$ in step 4 as follows: In a first step, we draw a random matrix $W^{(\cdot)}$ from a $N(0, I_n)$ density. The QR-decomposition

$$W^{(\cdot)} = Q^{(\cdot)}R^{(\cdot)}$$

yields an orthogonal matrix $Q^{(\cdot)}$, which has columns of unit length. $Q = I_n$ would correspond to the matrix used in recursive orderings.

Median model

The adaptation of Uhlig's *pure sign restriction approach* described in the previous subsection yields a collection of impulse responses, which may be summarized by their median and some lower and upper quantiles at each horizon (see Figures 2 and 3 in Section 4). Fry and Pagan (2007) point out that the distribution of impulse responses is across (accepted) models, and neglects the uncertainty of the estimated parameters. Furthermore, the impulse responses of some particular quantile do in general belong to different accepted models, which implies that there exists no model that would generate the median impulse responses or those of any other quantile.

Hence, Fry and Pagan (2007) suggest to determine from the accepted models the model $\theta^* \in \{1, \ldots, \Theta\}$, which produces impulse

[7] Note that it is *not* important that a Cholesky decomposition with a particular ordering is drawn. Any decomposition works.

[8] If none of the F draws implies that the sign restrictions are fulfilled, discard model j. The implications of this procedure are partly discussed in the second paragraph of Uhlig (2005), p. 391. For this paper, we choose F based on some informal experiments. Note that choosing F too small may affect the results in an important way. Discussing this at length is, however, beyond the scope of this paper.

responses that are as close as possible to the median impulse response. We call this model *median model.* The impulse response function matching is based on the minimization of a distance measure between the median IRF and the IRFs of the accepted models indexed by θ over a fixed horizon of h periods.[9] The matching exercise involves the standardization of the impulse responses with respect to mean and standard deviation, as described in Fry and Pagan (2007) in detail. With the index of the median model θ^* we obtain indices j^*, $f^*(j^*)$ and d^*, which give the respective VAR-parameters $\mathbf{B}^{(d*)}$, Cholesky decomposition $\widetilde{A}^{(j*)}$ and orthogonal matrix $Q^{f*(j*)}$. For simplicity of exhibition, we summarize the most relevant information of the median model as $A^* := \widetilde{A}^{(j*)}Q^{(f*(j*))}$.

Historical decomposition

The impulse response functions are based on the vector moving average (VMA) representation corresponding to the median model, as indicated by an asterisk.

$$Y_t = D^*(L)\, u_t^* \tag{5}$$

where

$$D^*(L) = I_n + D_1^* L + D_2^* L^2 + \cdots$$

To allow for an economic interpretation, the calculation of impulse responses requires orthogonal disturbances.

$$u_t^* = A^* v_t^*$$

The orthogonalized VMA representation is given by

$$Y_t = D^*(L)\, u_t^* = D^*(L)\, A^* v_t^* = C^*(L)\, v_t^* \tag{6}$$

where

$$\begin{aligned} C^*(L) &= C_0^* + C_1^* L + C_2^* L^2 + \cdots \\ C_i^* &= D_i^* A^* \end{aligned}$$

The VMA representation (6) may be rewritten as

$$Y_t = \sum_{s=0}^{j-1} C_s^* v_{t+j-s} + \sum_{s=j}^{\infty} C_s^* v_{t+j-s}$$

[9] We choose $h = 20$.

which gives the historical decomposition. The second term represents the expectation of Y_{t+j} given information available at time t. This can be interpreted as the base projection. The first term is given as the difference between the series and the base projection which is due to structural innovations in the variables subsequent to period t. This gap is the weighted sum of contributions of structural innovations to the individual series.

3 A simple model for loans to non-financial corporations in Germany

While there is a general consensus concerning the effect of economic activity on loan growth, the relative importance of supply and demand factors for loan development is discussed quite controversially in the literature. Owing to a long theoretical debate between the advocates of the *money view* (who emphasize the importance of demand effects for loan growth) and the proponents of the *credit view* (who highlight the role of supply effects), the majority of the literature focuses on either the demand side or the supply side of the credit market.[10] The more recent empirical literature advances on this shortcoming by either modeling both loan demand and loan supply in separate equations (see e.g. the cointegration literature cited above) or by employing a VAR approach that identifies structural shocks such as loan supply or demand shocks.

We employ the VAR approach with sign restrictions as described in the previous section. Our choice of variables is inspired by the aforementioned literature and by casual considerations. In order to keep the analysis tractable, we confine the number of variables to six. In particular, the level of nominal loans will be driven by real GDP and the price level. Demand for loans will in principle decrease in the rate charged for loans. Supply of loans may decrease in the risk associated with the extension of credit. The corporate bond spread may serve as a proxy of such credit risk. Loan supply may in addition depend on the banks' funding cost, which can be approximated by the short term interest rate. In contrast to the majority of the empirical literature, we choose the overnight rate instead of the 3-month Euribor as the short term interest rate representing

[10] For a critical discussion of both views see for example Trautwein (2000).

monetary policy, since the latter has been abnormally high during financial turmoil. The risk premium included in the 3-month rate could impede a proper identification of monetary policy shocks.

Other relevant factors such as bank capital[11] are omitted at the present stage, but may be considered in future extensions of the basic model.

Hence, we choose the following six variables for our analysis: (1) Loans to non-financial corporations (L), (2) real GDP (G), (3) a consumer price index (P), (4) the German interbank overnight rate (i), (5) the interest rate on loans to non-financial corporations (r), and (6) the spread between German corporate bonds and government bonds (s). L, P and G enter in the form of natural logs, such that $l = \ln(L)$, $p = \ln(P)$ and $g = \ln(G)$. Thus, our vector of variables is $Y = (l, p, g, i, r, s)$.[12]

3.1 Data

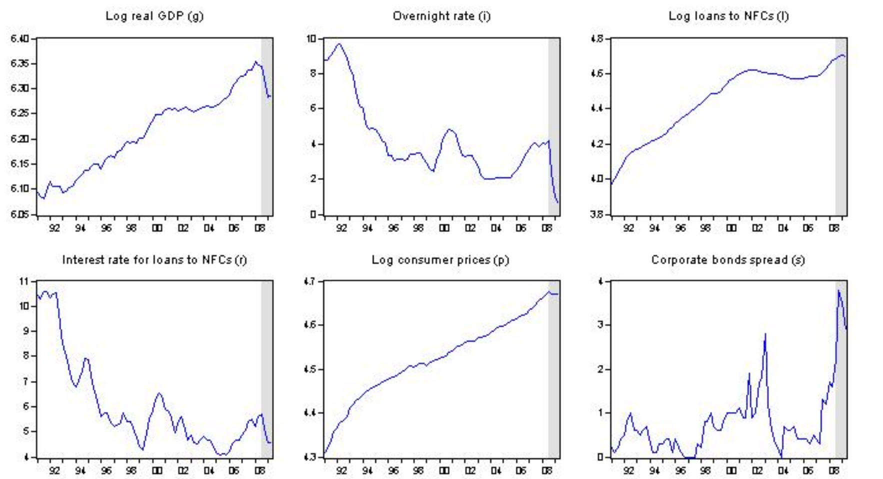
Our set of quarterly data ranges from 1991Q1 to 2009Q2. The starting point of our data set is determined by the availability of coherent series for loans to NFCs and corresponding interest rates, and by the German reunification. For loans to non-financial corporations (l), we choose a newly constructed seasonally adjusted index for loans to non-financial corporations in Germany.[13] For real GDP (G), we choose the seasonally adjusted series. As the corresponding interest rate (r) on loans to NFCs, we choose effective rates for new business for loans of more than one million euro, with an initially fixed rate of five years or more (series from the MIR-interest rate statistic and its historical backcast). As consumer price index (P) we choose the seasonally adjusted CPI-index for Germany. As the interbank overnight interest rate (i), we employ the German interbank overnight rate. The corporate bond spread (s) is calculated as the difference between the yield on outstanding corporate bonds and government bonds. All series are presented in Figure 1.

[11]For example, Hülsewig, Winker and Worms (2004) include bank capital into their cointegration analysis in order to obtain a cointegration vector that represents credit supply.

[12]We agree with Blank and Dovern (2009) that the ordering of the variables should not matter in the sign restriction approach, however we cannot provide a proof for this assumption. Therefore, our results are conditional on the validity of this statement.

[13]We thank Matthias Klimpel for the computation and provision of the series.

Figure 1: Data



Note: The shaded area comprises the period after the Lehman collapse and has been excluded from the estimation sample.

3.2 Sign restrictions on the impulse response functions

A large part of the VAR-literature concerning the identification of shocks is dedicated to modeling the effects of monetary policy on aggregate variables. Accordingly, signs of the impulse responses to monetary policy shocks are broadly discussed, see for example Bernanke and Gertler (1995), Leeper, Sims and Zha (1996), Christiano et al. (2005) and Eickmeier, Hofmann and Worms (2009). However, in some of the models, loans show a puzzling reaction to a monetary policy shock, see Giannone, Lenza and Reichlin (2008) for possible explanations. More recently, the incorporation of the financial sector into DSGE models allows for a separate analysis of monetary policy shocks and loan supply shocks, see e.g. Gerali et al. (2008), Atta-Mensah and Dib (2008) and Gilchrist et al. (2009). Nevertheless, the behavior of loans is still an open issue in a part of the literature (e.g. Gilchrist et al. (2009) do not provide the impulse response of loans to a monetary policy shock).

Our choice regarding specification and timing of sign restrictions on the impulse response functions as displayed in Table 1 is based on a critical review of the literature. According to Faust (1998) and

Table 1: Sign restrictions on impulse response functions

shock	loan supply shock			monetary policy shock			
lag	$d = 0$	$d = 1$	$d = 2$	$d = 0$	$d = 1$	$d = 2$	$d = 3$
loans (l)	+	+	+		+	+	
gdp (g)	+	+	+	+	+	+	+
prices (p)		+	+			+	+
loan rate (r)	-	-	-		-	-	
overnight rate (i)			+	-	-	-	

Note: The corporate bond spread (s) has been omitted, because we do not want to restrict its response to the two shocks.

Paustian (2007), a rather large number of sign restrictions is needed to ensure identification of the respective shocks. Hence, in order to distinguish between two shocks which originate from different sources but have similar effect, we need to impose a comparatively elaborated identification scheme. Note that restraining only a subset of periods is less restrictive than the common practice of imposing identical sign restrictions for all horizons. The implied economic structure in our system is consistent with results from impulse response analysis using DSGE models, see for instance Gerali et al. (2008).

While the maximum number of fundamental innovations is directly linked to the number of variables, the decision on the number of shocks to be identified involves several considerations. First of all, it is not generally advisable to identify as many shocks as there are variables in the system.[14] By identifying fewer shocks than there are variables in the VAR, the effect of variables not included in the system could be captured by the unidentified components of the shock vector v_t, see Canova, Gambetti and Pappa (2007). However, a smaller number of identified shocks tends to imply a larger cumulated amount of unexplained shocks. The more detailed economic interpretation offered by a larger number of identified shocks, on the other hand, comes at a higher computational cost (because more matrices $Q^{(f(j))}$ will be discarded).

The choice of the number of shocks to be identified depends on these considerations, and on the goal of the research. Musso (2009), for example, assesses the impact of different fundamental economic

[14] Identification is meant here in the sense of associating a clear-cut economic interpretation to each component of v_t. The bivariate case is an exception, see Chadha et al. (2008).

shocks on key economic variables by identifying four shocks in a VAR system with six variables. In contrast, Uhlig (2005) emphasizes the advantage of identifying only one type of shock, since his focus is mainly on the effects of monetary policy shocks on GDP.

The main goal of this paper is to identify loan supply effects. As an expansionary monetary policy shock is hard to separate from a loan supply shock, we focus our analysis on this issue by identifying those two shocks. It would in principle be desirable to identify also a loan demand shock at the same time, but this shock is hard to separate from an aggregate demand shock. Hence, a dependable identification also of loan demand shocks would imply that four shocks must be identified, which proved to be too demanding in terms of computation time for the data set at hand. The logic of the sign restrictions is as follows.

Loan supply shock

The loan supply shock is defined as a shock that has an expansionary impact on loans to NFCs (expansionary loan supply shock). As loans are highly persistent, we assume that the impact on loans prevails for at least three quarters. The response of GDP to this shock should be positive, as NFCs will typically use the funds obtained to invest.[15] The price level may respond with a lag, but in any case, the response should be positive and persist for more than one quarter.

The impact of the loan supply shock on the loan rate should be unambiguously negative: In order to separate conceptually the loan supply shock from potential loan demand shocks or aggregate demand shocks, there must be a negative response of the loan rate to the shock. Finally, we require monetary policy to respond, albeit with a lag of up to two quarters, to the expansionary loan supply shock.[16] The lag can be motivated by considering the time needed to identify the loan supply shock and to implement the policy response. The lag in no way excludes an immediate reaction by the monetary authorities, it only *requires* them to react latest in the second quarter after the shock occurred.

[15] A lagged impact of the loan supply shock on GDP could be appropriate, if the funds obtained are kept in bank deposits for some period of time. In the aggregate however, we expect an immediate response of GDP.

[16] At a first glance, this restriction may appear to be overly restrictive. However, for distinguishing loan supply shocks from monetary policy shocks, it is inevitable to decide in what sense the two differ from each other.

Note that only for the purpose of exhibition, we defined and explained the loan supply shock as an expansionary shock. Due to the symmetry of the VAR, the inverted signs and arguments must hold for a contractionary loan supply shock.

Monetary policy shock

An expansionary monetary policy shock is one that implies a contemporaneous increase in output, accompanied by a decrease in the overnight rate. The loan rate should follow the overnight rate, albeit a lag of one quarter is allowed. Correspondingly, the loan aggregate is expected to increase with the decrease of the loan rate. Finally, prices should increase, possibly with a further lag of another quarter, after the increase in the loan volume.[17] Thus, we explicitly account for the results of the literature on inflation inertia and output persistence after a monetary policy shock, see e.g. Christiano et al. (2005).

4 Results

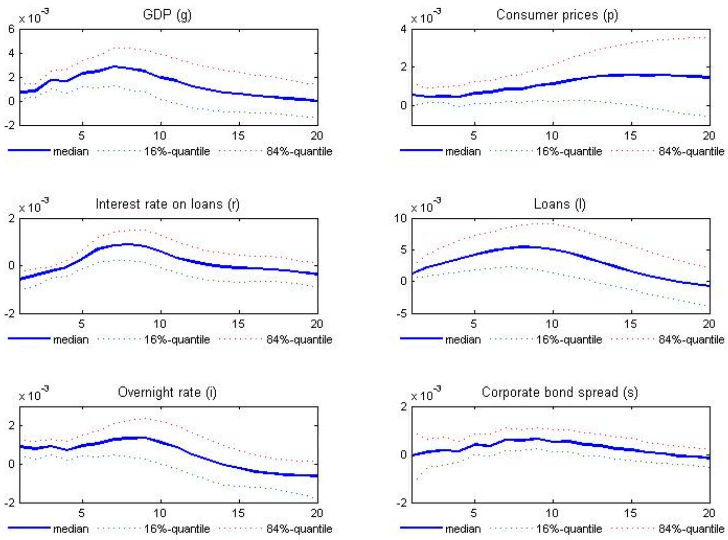
We estimate the VAR model with a constant and four lags, as indicated by information criteria. The sample used for estimation is restricted to the period from 1991Q1 to 2008Q3, as the inclusion of data from the financial turmoil may imply that parameter estimates become unstable. The prior used is Normal-Wishart. From the posterior distribution, we draw $m = 200$ sets of VAR-parameters. From these m models, we take repeated draws and combine them with random identification matrices (rotation matrices), in order to check whether the sign restrictions are fulfilled. For each model drawn, we try up to $F = 200,000$ rotation matrices until the sign restrictions on the impulse response function are fulfilled. If no rotation matrix is found within the F draws, the algorithm continues with another model from the set of m models.

[17] As a matter of fact, our sample comprises two different monetary policy regimes before and after the start of the EMU in 1999. Following the literature, we abstract from this institutional change to keep the full data set, see e.g. Eickmeier et al. (2009).

4.1 Impulse response functions

Figure 2 shows the median impulse response function of the six variables to the loan supply shock, along with the 16% and 84% quantiles. The responses conform to the specification of the sign restrictions made in Table 1. Note that the first quarter refers to the contemporaneous response.

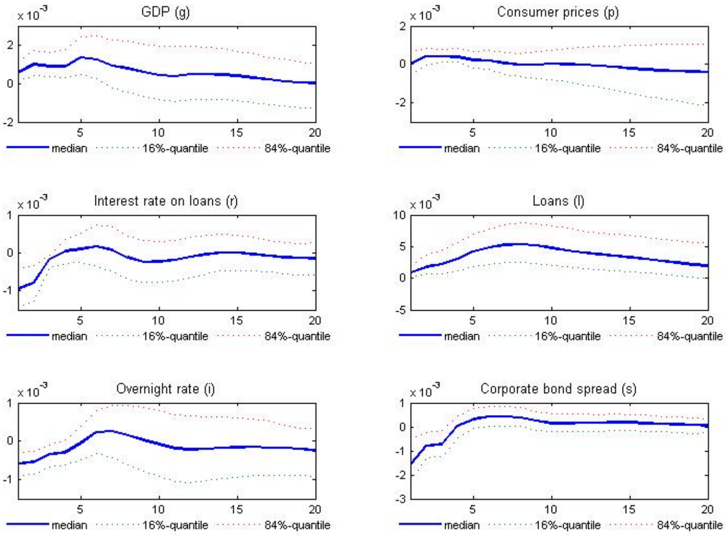
Figure 2: Impulse responses to the expansionary loan supply shock



According to Figure 2, an expansionary loan supply shock has a positive impact on real GDP that remains significant for more than two years and reaches its maximum after about seven quarters. Consumer prices increase immediately, but rather insignificantly. The loan rate exhibits an immediate negative response for three to four quarters and turns positive soon thereafter. The response of loans remains persistently positive and reaches its maximum after about eight quarters.

The immediate increase in the overnight rate may be seen as a plausible reaction of monetary policy to the expansionary loan supply shock. This counteraction of policy prevails for up to ten quarters. The response of the corporate bond spread to the loan supply shock is not very pronounced. The slight increase in the

Figure 3: Impulse responses to the expansionary monetary policy shock



corporate bond spread after about eight to ten quarters may reflect an increase in credit default risk after the peak of the expansion of both loans and economic activity.

Figure 3 shows the median impulse response function of the model variables to the monetary policy shock, again with the quantiles. An expansionary monetary policy shock implies a positive response of real output that lasts even for the lower quantile for about six quarters. The pattern of the reaction of the price level is – somewhat surprisingly – not very pronounced. Note that the positive response of the price level to an expansionary monetary policy shock in periods three and four is merely enforced by the sign restrictions imposed, which seems to suggest that monetary policy surprises did not usually imply marked responses of the price level over the sample period. Alternatively, monetary policy could be seen as very successful in stabilizing consumer prices over the sample period. The loan rate displays a marked, but short response, following the decrease in the overnight rate implied by the expansionary monetary policy shock. The pattern of the response of the loan rate is again closely determined by the sign restrictions imposed. The loan volume experiences a relatively persistent increase and peaks approximately seven periods after the initial monetary policy shock. The response of the overnight rate itself remains negative only over the horizon determined by the sign restrictions. The corporate bond spread shows a plausible immediate decrease before turning slightly positive one year after the shock.

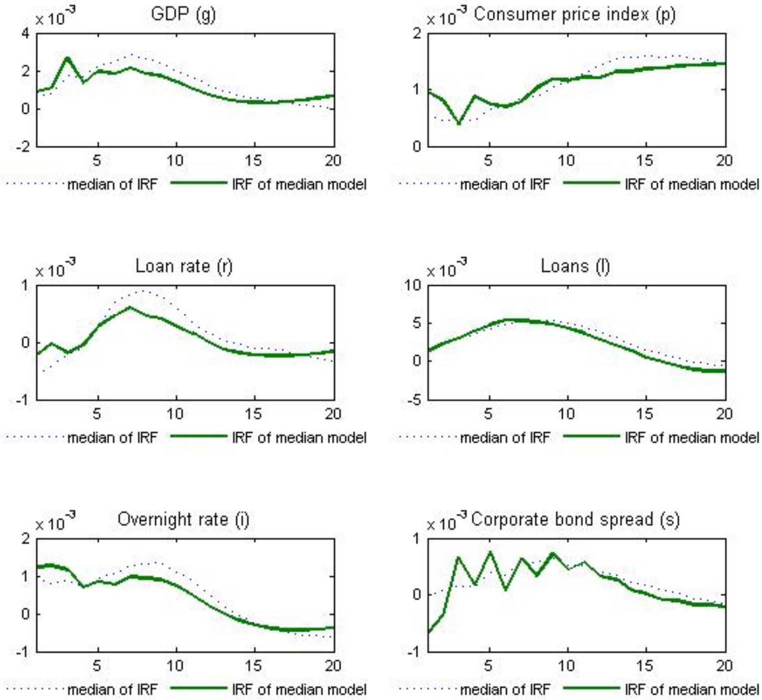
4.2 Median impulse responses and impulse responses of the median model

As described in Section 2, the outcome of the sign restriction algorithm is not a single model but a set of $\Theta = 5,000$ models (indexed by $(\theta \in \{1, \ldots, \Theta\})$ with corresponding identification schemes and impulse response functions. Impulse response analysis in a Bayesian VAR framework is often based on the median of the impulse responses together with the respective quantiles, see for instance Peersman (2005), Uhlig (2005) and Lippi and Nobili (2008). The median impulse response, however, cannot be produced by a single set of model parameters. Hence, we employ the method proposed by Fry and Pagan (2007) to find the median model θ^* that provides the closest match to the median impulse responses.

The matching of IRFs involved in Fry and Pagan's method has a free parameter that needs to be determined: the horizon over which the matching takes place. We choose 20 quarters, i.e., with the matching exercise, we cover approximately the period of one business cycle. Figures 4 and 5 show the median impulse responses and the impulse responses of the median model for the loan supply shock and the monetary policy shock, respectively.

Figures 4 and 5 reveal that the IRFs of the median model in general provide a reasonable match of the median IRFs. In most cases, the impulse response functions of the median model display a pattern that is similar to the median of the impulse responses of all accepted models. Moreover, the impulse response functions of the median model for the loan supply shock almost entirely remain between the 16% and 84% quantiles of the IRFs displayed in Figures 2 and 3. For the monetary policy shock, the IRF of the loan aggregate generated by the median model is visibly less strong than the median of the IRFs of the accepted models over the short to medium horizon. Nevertheless, we share the view of Fry and Pagan (2007) that the median model is a convincing representa-

Figure 4: Loan supply shock: Median impulse responses and impulse responses of the median model

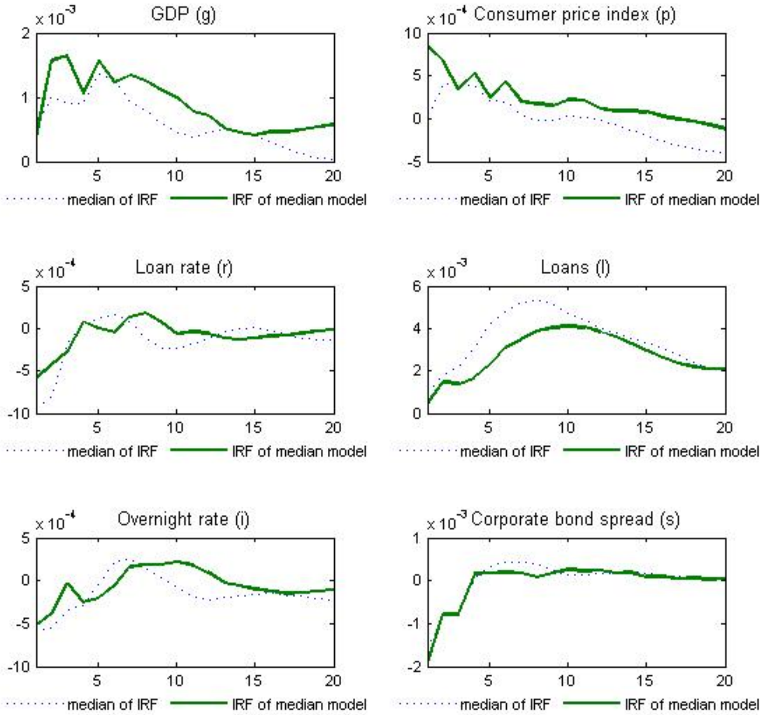


tion of the outcomes of the Bayesian sign restriction approach. The gaps between the impulse response functions of the median model and the median of all admitted IRFs show that it makes a difference whether impulse response analysis and historical decompositions are presented as median representations of a large quantity of models or on a suitably chosen single model, such as the median model. Hence, the structural innovations and the historical decomposition in the following subsection are derived from the median model.

4.3 Shock accounting: structural innovations and historical decomposition

In order to obtain a better understanding of the dynamics of the loan aggregate in terms of the historical decomposition, we first

Figure 5: Monetary policy shock: Median impulse response and impulse response of the median model

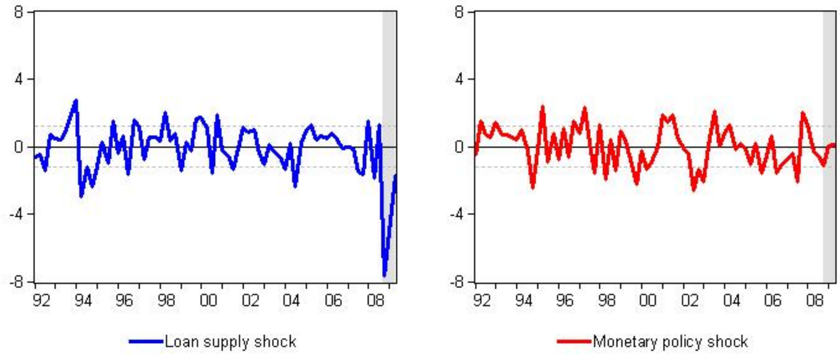


present the series of loan supply shocks and monetary policy shocks in Figure 6. Technically, the series of structural loan supply shocks and monetary policy shocks are given by the first two components of v_t^*, $t = 1, \ldots, T$, where $v_t^* = A^{*-1}u_t^*$.

During the estimation period from 1991Q1 to 2008Q3, both loan supply shock and monetary policy shock display little persistence and a constant variance. With the aggravation of the financial crisis on 15 September 2008 (which became fully visible in the data only for 2008Q4), Figure 6 shows a negative loan supply shock of unprecedented magnitude.[18] For the first quarter of 2009, a similar and only slightly smaller shock is recorded. During the second quarter of 2009, our identification procedure still yields a large negative

[18]This result for the loan supply shock is particularly robust and holds across a variety of variants and parameterizations of the identification algorithm.

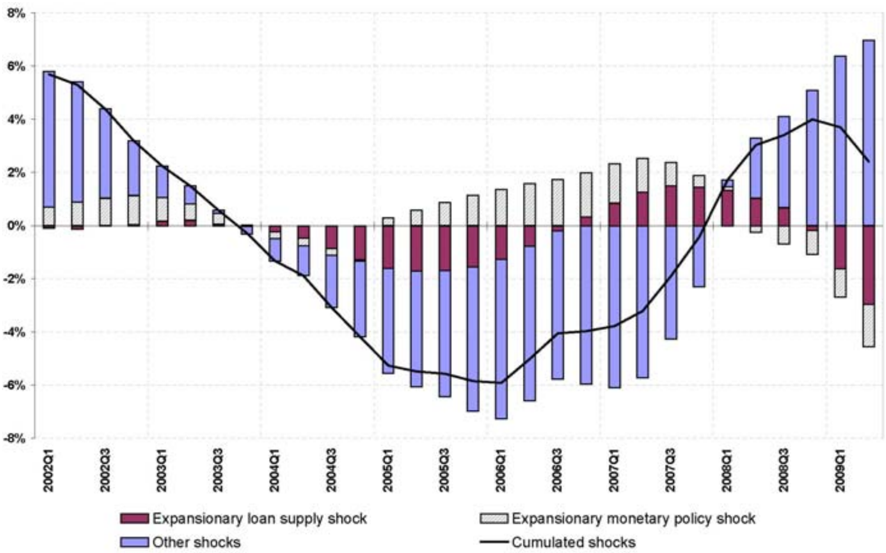
Figure 6: Loan supply shock and monetary policy shock: structural innovations



Note: The dashed lines give the standard deviations of the structural shocks over the estimation sample (1992Q1 – 2008Q3).

shock – but one that is not, in a historical perspective, of an entirely unusual magnitude.

Figure 7: Historical decomposition of loans to NFCs into loan supply shocks, monetary policy shocks and other shocks



While our focus is on loan supply shocks, it is interesting to note that according to our identification procedure, monetary policy shocks did not seem to contribute to the crisis, as monetary policy was only somewhat restrictive in the fourth quarter of 2008 and very much neutral during the first two quarters of 2009.[19]

Figure 6 shows the evolution of the two structural innovations identified over time, which seem to be stationary. The high persistence of the loan aggregate, however, causes lasting effects of these shocks, which may cumulate over time. This cumulated impact on loans to NFCs is depicted in the historical decomposition in Figure 7. It adds a dynamic, medium-term oriented perspective to the current, policy driven debate of a credit crunch. For the interpretation of the results, it is important to keep in mind what the historical decomposition offers: a partial economic interpretation of the deviation of the seasonally adjusted index of the volume of outstanding loans (not only new loans) from the model baseline.

Our view of Figure 7 is as follows. In the wake of the downturn following the 9/11-attack, the positive cumulated impact mainly of *other shocks* vanished over time, probably due to the cumulated effect of negative shocks. These built up over time and implied a strong cumulated negative deviation of loans to NFCs from the baseline during the period from 2004Q1 to 2007Q4.

From 2005Q1 onwards, the lagged cumulated impact of expansionary monetary policy shocks counteracted the relatively subdued development of loans. For the period from 2004Q1 to 2006Q3, we observe a cumulated negative impact of loan supply shocks, which contributed to the slow increase of the outstanding loan volume. From 2007Q3 onwards, i.e. starting with the rising tension on the interbank money market, the previous cumulated positive impact of loan supply shocks started to decline, ending up in a marked negative cumulated impact on loans until 2009Q2. From the patterns observed previously, it seems likely that the cumulated negative impact of loan supply shocks on loans to NFCs will further increase in the near future.

With the aggravation of the financial crisis in autumn 2008, monetary policy shocks have exerted a cumulated negative impact on

[19]The pattern of the monetary policy shock is somewhat less robust across alternative variants of the algorithm. Informal robustness checks occasionally produced positive and negative monetary policy shocks during the most recent quarters, which implies that the separation of the monetary policy shock from other shocks is difficult.

the loan volume. However, the cumulated impact of *other shocks* turned positive in 2008Q1, implying a positive cumulated effect of all shocks on loans since 2008Q2. The upshot of our results is, that loans are currently stronger than implied by the model baseline, because the negative cumulated impact of loan supply shocks and monetary policy shocks on loans is more than compensated by the cumulated positive impact of *other shocks*.

5 Conclusion

In the present paper, we used a Bayesian VAR with sign restrictions on the impulse responses to loan supply shocks and monetary policy shocks in order to explain the recent dynamics of loans to NFCs in Germany.

Our main results are as follows: First, the level of outstanding loans is currently higher than implied by our model, i.e. conditional on GDP, price level, credit risk as approximated by the corporate bond spread, and interbank overnight rate. Second, starting in 2008Q4, a sequence of unprecedentedly strong negative loan supply shocks was recorded in the aftermath of the collapse of Lehman Brothers. In 2009Q2, there was still a strong negative loan supply shock, but on a level that is not unusual, from the perspective of the past two decades. Third, the pattern of monetary policy shocks recorded for the period of the recent crisis indicates that monetary policy was essentially neutral. Finally, owing to the persistent nature of loans and the dimension of the negative loan supply shocks since the last quarter of 2008, the cumulated negative effect of these shocks may considerably dampen loan growth in the near future. A similar lasting effect could be observed for the period between 2004 and 2007, when the cumulated negative impact of loan supply shocks and monetary policy shocks resulted in a considerably slower pace of the expansion of the loan volume than implied by the model baseline.

The results obtained are affected by considerable uncertainty, which exceeds the level of uncertainty normally associated with empirical work. To some extent, the increased level of uncertainty is due to specific decisions in the empirical process of the identification of the shocks. A part of these decisions could not be made based on economic insight, but needed to be taken on the basis of experience and informal robustness checks.

For future work, it would be desirable not only to explore the robustness of the results in more detail, but also to identify a larger portion of the shocks that are currently presented in a cumulated fashion as *other shocks*. More identified shocks could deliver deeper insights into the economic mechanisms underlying the evolution of loans to NFCs.

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