Loan supply shocks and the business cycle

Luca Gambetti[*]
Universitat Autonoma de Barcelona and Barcelona GSE

Alberto Musso[†]
ECB

November 20, 2014

Abstract

This paper provides empirical evidence on the role played by loan supply shocks over the business cycle in the Euro Area, the United Kingdom and the United States from 1980 to 2011 by estimating a time-varying parameters VAR model with stochastic volatility and identifying these shocks with sign restrictions consistent with the recent macroeconomic literature. The evidence suggests that loan supply shocks appear to have a significant effect on economic activity, inflation and credit market variables in all three economic areas. Moreover, we report evidence that over the past few years the short-term impact of these shocks on real GDP and inflation appears to have increased in all three economic areas, while this impact on loan volumes increased mainly for the Euro Area. The results of the analysis also suggest that the impact of loan supply shocks seems to be particularly important during recessions. As regards to the most recent recession, we find that adverse loan supply shocks contributed to between about 10% and about 20% of the total decline in real GDP growth between 2007 and 2009 in the three economic areas.

JEL classification: C32; E32; E51.

[*]The financial support from the Spanish Ministry of Economy and Competitiveness through grant ECO2012-32392 and the Barcelona Graduate School Research Network is gratefully acknowledged. Contact: Office B3.1130 Departament d'Economia i Historia Economica, Edifici B, Universitat Autonoma de Barcelona, Bellaterra 08193, Barcelona, Spain. Tel (+34) 935814569; e-mail: luca.gambetti@uab.cat

[†]Contact: ECB, Kaiserstrasse 29, 60311 Frankfurt am Main, Germany. Tel (+49) 6913447076; e-mail:alberto.musso@ecb.europa.eu. The views expressed in this paper are those of the authors and do not necessarily reflect those of the European Central Bank. The authors would like to thank for useful comments Pooyan Amir Ahmadi, Björn Fischer, James Talbot and participants to the presentation of previous versions of this paper at the Royal Economic Society 2012 Annual Conference (University of Cambridge, Cambridge, UK, March 2012), the ECB Workshop on "The role of credit in the macroeconomy" (ECB, Frankfurt, Germany, May 2012) and the 27th Annual Congress of the European Economic Association (University of Málaga, Málaga, Spain, August 2012). We are grateful also to Ryland Thomas for very useful input on the data for the UK.

Keywords: Loan supply; Business cycle; Euro Area; UK; US; time-varying VAR; sign restrictions.

1 Introduction

Financial intermediaries and credit markets more in general appear to have played a significant role in the context of the events which led to the severe recession experienced during 2008 and 2009 by advanced economies such as the Euro Area, the United Kingdom and the United States. Indeed, the economic crisis was preceded and accompanied by financial turbulence in various segments of financial markets, such as the US subprime mortgage market and the international interbank short-term liquidity market. Moreover, Lehman Brothers' default in September 2008 clearly exacerbated the financial and economic crisis, also bringing at the centre of the attention questions regarding the actual state of banks' balance sheets and their ability to provide loans to households and non-financial corporations to finance consumption and investment expenditure, among other effects. In addition, it is widely agreed that specific developments in the banking industry, such as the process of securitisation and the increasing recourse to short-term debt, contributed markedly to the lending boom and housing bubble of the mid-2000s and subsequent credit slowdown and house price fall (Brunnermeier, 2009; Diamond and Rajan, 2009; Gorton, 2009).

From a policy perspective it is important to assess the relative role of supply and demand forces in driving credit, output and inflation developments, especially during periods around crises such as the recent one. Indeed, these factors may call for a very different response of monetary and fiscal policy. Clearly, an insufficient provision of loans to the private sector by banks caused by balance sheet constraints affecting financial intermediaries may require a different policy response compared to the case of declining loan growth due to declining demand from households and enterprises. Thus, for a central bank it is essential to know whether loan flows to the private sector decline mainly because of problems affecting balance sheets of banks or largely because the demand for credit is diminishing. In the former case measures to support the banking system may be needed, while in the latter case measures to support the real economy may have priority. Another key challenge which policy-makers face is to disentangle the role of credit markets as propagators of shocks originating in other sectors of the economy (such as technological innovations, unexpected changes in oil prices or investors' changes in confidence, to make few examples relating to both aggregate supply and aggregate demand shocks) and as impulse mechanisms, that is sources of disturbances or shocks. Indeed, the provision of loans to the private sector by banks depends on the state of banks' capital and financing capability, which in turn change both (endogenously) due to the economy's changing conditions as well as (exogenously) due to factors directly affecting banks balance sheets. Clearly, the source of the potential problem is different in these two cases.

Against this background, a key challenge for policy-makers is to quantify the contribution of supply shocks to loan growth. The purpose of this paper is to propose a methodology which allows for such contributions to be estimated in the context of an empirical model which takes into account potentially important changes in the macroeconomy and to provide some empirical evidence for the Euro Area, the United Kingdom and the United States. To account for possibly significant changes in the macroeconomic environment is a potentially very important step in deriving reliable estimates of the impact of loan supply shocks, as major changes have been taking place in recent years. For example, there is evidence that the volatility of shocks may have changed over time (Cogley and Sargent, 2005, Fernández-Villaverde and Rubio-Ramírez, 2010). Moreover, in addition to the evidence for a Great Moderation starting between the mid-1980s and the early 1990s, depending on the countries considered, the recent economic and financial crisis may have induced a further gradual structural change in the economy, for example affecting persistently economic agents' risk aversion, and although it may be too early to conclude to which extent fundamental underlying changes may have taken place it is important to allow for them. Thus, it is critical to estimate the impact of loan supply shocks in a framework which allows for possible changes in stochastic volatility and time-varying parameters. The model we use, a time-varying parameter VAR with stochastic volatility, seems particularly suited for the purpose of this paper. This is one of the main advantages of the approach adopted in this study compared to the macroeconomic literature which has attempted to estimate the effects of loan supply shocks, which typically is based on fixed parameters and constant volatility models, as discussed in detail in the next section. The identification of loan supply shocks we adopt is based on sign restrictions. The latter have been applied before to identify these shocks (see for example Busch et al., 2010; De Nicoló and Lucchetta, 2011; Eickmeier and Ng, 2011; Hristov et al., 2012), but the way they have been specified has in most cases limitations which we try to overcome, as we will argue below. Moreover, our paper is the first to provide a systematic comparison of the relevance of loan supply shocks across the Euro Area, the United Kingdom and the United States.

The main results of the empirical analysis are the following. First, loan supply shocks appear to have on average a significant effect on economic activity and credit markets, but to some extent also inflation, in all three economic areas. However, some differences across geographic areas can also be uncovered. For example, the short-term impact on loan volumes appears to be stronger in the United Kingdom, than in the Euro Area or the United States. Second, the impact of these shocks may have changed over time, as for example the short-term impact of these shocks on real GDP and inflation seems to have increased in all three economic areas over the past few years, while this impact on loans has increased in recent years mainly in the Euro Area. Third, it appears that the contribution of loan supply shocks was particulary important during the most recent recession. For example, the contribution of these shocks can explain almost 20% of the decline in annual real GDP growth between 2007 and 2009 in the Euro Area and the United States and almost 10% of that observed in the United Kingdom. Finally, the contribution of loan supply shocks to the decline in the annual growth rate of loans observed from the peaks of 2006/2007 to the troughs of 2009/2010 was between almost 10% (UK and US) and about 25% (Euro Area) of the total decline.

The remainder of the paper is structured as follows. Section 2 provides a discussion of the relevant literature. Section 3 illustrates the empirical approach and describes the data. Section 4 reports and discusses the results. Section 5 provides conclusions.

2 Literature

Credit markets have received much attention in macroeconomics since at least the debt-deflation theory of Fischer (1933), which assigned a potentially important role to credit market developments in propagating business cycle fluctuations.[1] While most of the macroeconomic literature of last century focused mainly on credit markets in their role in transmitting disturbances originating in other markets (Bernanke, 1993, Brunnermeier et al., 2012, Gilchrist and Zakrajšek, 2012a), a number of more recent papers have focused on assessing the potential role of credit markets as sources of disturbances originating business cycles, including the implications of various types of credit supply shocks, largely inspired by the events which led to the recent economic and financial crisis. Some of these papers have introduced a banking sector and some type of credit supply shock into an otherwise standard New Keynesian DSGE model. For example, Goodfriend and McCallum (2007) model several types of interest rates, calibrating the model to replicate several steady-state interest differentials for the US economy, and assess the impact of various shocks originating from the banking sector – a shock to bank monitoring productivity and a shock to effective collateral reflecting financial distress – via impulse responses, showing that monetary policy needs to be adjusted in their presence. Gerali et al. (2010) estimate a standard New Keynesian DSGE model with an added imperfectly competitive banking sector for the euro area using Bayesian methods for the period 1998-2009 and find that financial shocks that can be associated to credit supply (such as shocks to loan-to-value ratios or shocks to bank capital) and find that the contribution of these shocks to the 2006-2007 expansionary phase and subsequent recession was large. Christiano, Motto and Rostagno (2010) formulate a medium-scale DSGE model with a competitive banking sector, several real and nominal frictions, and several shocks in the framework of an otherwise standard New Keynesian model and estimate it with

[1] See the Supplementary Material Annex for a more extensive review of the literature.

Bayesian methods for both the Euro Area and the US with data from 1981Q1 to 2009Q2. Among the shocks, they include two types of bank funding shocks, a bank funding technology shock and a shock to the bank's demand for reserves (against deposits, beyond a minimum required reserve ratio). Although variance decompositions suggest that on average these shocks do not play a major role in the macroeconomy, they show with historical decompositions that such shocks had a significant effect on real GDP growth in specific periods for both the Euro Area and the US, including adverse effects in 2008 and 2009.

Various empirical studies have attempted to estimate the impact of credit supply shocks on the macroeconomy. A number of papers attempted to assess the role of credit supply changes to the 1990-1991 US recession, although, as noted for example by Bernanke (1993) and Cochrane (1994), most papers focused on the role of credit markets in propagating shocks other than credit (supply) shocks. Other papers focus on the most recent economic crisis, attempting to proxy loan supply shocks by changes in, or the exogenous component of, some survey indicator, such as bank lending standards (for the US, using the Federal Reserve's Senior Loan Officer Opinion Survey, see Lown and Morgan, 2006; Berrospide and Edge, 2010; and Bassett et al., 2012; for the Euro Area, using the ECB's Bank Lending Survey, see Ciccarelli et al., 2010; Hempell and Kok Sørensen, 2010; and Del Giovane et al. 2011) or supervisors ratings on bank health (Peek at el., 2003). Unfortunately, such approach has important limitations, including endogeneity problems[2] which are difficult to overcome and the issue of the reliability of replies to the surveys.

A number of recent studies have attempted to identify credit supply shocks in macroeconometric frameworks, mainly in the context of structural VARs, largely to assess the relevance of these shocks in the recent financial and economic crisis.[3] Busch et al. (2010) aim at assessing the role of bank supply shocks in Germany from 1991Q1 to 2009Q2, with specific reference to loans to non-financial corporations. Bank loan supply shocks are identified with sign restrictions in a strucutral VAR model. Overall, they find that adverse loan supply shocks had a large impact on loan growth especially following the default of Lehman Brothers. De Nicoló and Lucchetta (2011) try to assess the role of demand and supply shocks to bank loans for the set of G-7 countries over the period 1980Q1 to 2009Q3 on the basis of a factor-augmented VAR (FAVAR) model and sign

[2]Identifying loan supply shocks using such indicators would require to fully extract the component associated with loan demand forces and the systematic loan supply responses to changes in the macroeconomy. The papers mentioned provide attempts to overcome this problem, but limited proxies for all relevant demand forces inevitably cast doubt on the extent of the success of this methodology.

[3]A number of studies provide attempts at identifying credit shocks, without explicitly differentiating credit supply from credit demand shocks, including Gilchrist et al. (2009), Helbing et al. (2011), Gilchrist and Zakrajsek (2012b), Meeks (2012).

restrictions. As regards data for credit markets, they use data on bank loans and bank prime rates (i.e. lending rates for loans to prime customers). The identification scheme adopted allows them to identify only bank loan demand shocks, which are found to play an important role in explaining bank credit growth. Eickmeier and Ng (2011) attempt to identify credit supply shocks via sign restrictions using a global VAR model and assess how they propagate internationally, more specifically how such shocks in the US, Euro Area and Japan propagate to a sample of 33 countries over the period 1983Q4 to 2009Q4, and find that such shocks can have large effects internationally. As regards the credit data used, they identify credit supply shocks using data for domestic private non-financial sector loans as regards credit volumes and corporate bond yields with maturity between 5 and 10 years as regards the price of credit. Hristov et al. (2012) estimate a panel VAR with data for eleven euro area countries and try to identify the effect of loan supply shocks over the period 2003Q1 to 2010Q2. Using data for loan volumes and lending rates for non-financial corporations, they identify loan supply shocks via sign restrictions. They find that loan supply shocks played a significant role in driving both loan growth and real GDP growth especially during the financial crisis, although considerable cross-country heterogeneity is found.

Overall, the above-mentioned empirical macroeconometric papers have a similar approach and intent to the one of the present paper, but key differences between our approach and these other approaches can be highlighted, apart from the identification scheme discussed later: different modelling choices (ours is the only paper adopting a time-varying VAR with stochastic volatility, while all other papers employ models with fixed parameters and constant volatility); different country sets (ours is the only one presenting a systematic comparison across euro area, UK and US), different data sample period (ours has the most comprehensive period coverage), and different loan figures (ours is the only paper using data for volumes and lending rates for the total non-financial private sector, while other papers limit the scope to the non-financial corporations sector, providing about half of total private sector loans, or using data for loan volumes and lending rates not fully consistent with each other).

In parallel, a number of recent empirical contributions tackled the question of the role of credit supply using microeconomic data. Most of these studies attempt to disentangle the role of credit supply from credit demand, in response to various exogenous shocks (such as shocks to the money market as that of the summer of 2007, shocks to financial markets such as the default of Lehman Brothers in September 2008, monetary policy shocks, sovereign debt shocks etc.), via specific channels such as the bank lending channel or the bank capital channel (Ivashina and Scharfstein, 2010, Albertazzi and Marchetti, 2010, Gambacorta and Marques-Ibanez, 2011, Jimenez, Ongena, Peydró and Saurina, 2012, de Santis and Surico, 2013). Overall, these microeconomic studies find some interesting results pointing to the importance of credit supply factors, but they do not address the effect of bank loan supply shocks, focusing rather on the role of credit supply in propagating other shocks.

3 The empirical approach

In this section we describe the econometric model used as well as the data for the three economic areas considered.

3.1 The model

We use a time-varying VAR model with stochastic volatility as in Primiceri (2005) and Canova and Gambetti (2009). Let y_t be a vector containing the following variables: real GDP, consumer prices, loan volumes, a composite lending rate and a reference short-term interest rate. Let us assume that y_t follows

$$y_t = A_{0,t} + A_{1,t}y_{t-1} + ... + A_{p,t}y_{t-p} + \varepsilon_t \tag{1}$$

ε_t is a Gaussian white noise vector of innovations with time-varying covariance matrix Σ_t, $A_{0,t}$ is a vector of time-varying intercepts and $A_{i,t}$ are matrices of time-varying coefficients, $i = 1, ..., p$. Let $A_t = [A_{0,t}, A_{1,t} ..., A_{p,t}]$, and $\theta_t = vec(A_t')$, $vec(\cdot)$ being the stacking column operator. The VAR coefficients are assumed to evolve as random walk

$$\theta_t = \theta_{t-1} + \omega_t \tag{2}$$

where ω_t is a Gaussian white noise vector with covariance Ω.

We decompose the innovation variance as follows $\Sigma_t = F_t D_t F_t'$, where F_t is a lower triangular matrix with ones on the main diagonal and D_t a diagonal matrix. Let σ_t be a column vector containing the diagonal elements of $D_t^{1/2}$ and let $\phi_{i,t}$, $i = 1, ..., n-1$, be a column vector containing the first i elements of the $(i+1)$-th row of F_t^{-1}. We assume the following laws of motion

$$\log \sigma_t = \log \sigma_{t-1} + \xi_t \tag{3}$$

$$\phi_{i,t} = \phi_{i,t-1} + \psi_{i,t} \tag{4}$$

where ξ_t and $\psi_{i,t}$ are Gaussian white noise vectors with zero mean and variance Ξ and Ψ_i respectively. Let us define $\phi_t = [\phi_{1,t}', \dots, \phi_{n-1,t}']$, $\psi_t = [\psi_{1,t}', \dots, \psi_{n-1,t}']$ and let Ψ be the covariance matrix of ψ_t. We make two additional assumptions. First, $\psi_{i,t}$ and $\psi_{j,t}$ are uncorrelated for $j \neq i$. Second ξ_t, ψ_t, ω_t, ε_t are mutually uncorrelated.[4]

[4]For details about the estimation we refer the reader to the online appendix of Gali and Gambetti AEJ-Macro forthcoming.

The time-varying impulse response functions are $C_t(L) = \sum_{k=1}^{\infty} C_{k,t}L^k$, with $C_{0,t} = I$ and $C_{k,t} = \mathcal{S}_{n,n}(\mathbf{A}_t^k)$, where $\mathbf{A}_t = \left(\begin{smallmatrix} & A_t & \\ I_{n(p-1)} & & 0_{n(p-1),n} \end{smallmatrix}\right)$ and $\mathcal{S}_{n,n}(X)$ is a function which selects the first n rows and n columns of the matrix X. The structural impulse response functions are obtained as follows. Let S_t be the Cholesky factor of Σ_t ($S_t S_t' = \Sigma_t$) and let H_t be an orthogonal matrix ($H_t H_t' = I$) satisfying the identifying restrictions (see section 3.3). The structural impulse response functions are $C_t(L)S_t H_t$ and the structural shocks are $e_t = H_t' S_t^{-1} \varepsilon_t$.

3.2 Data

For each economy we estimate one model including five quarterly variables spanning the period 1980Q1 to 2011Q4: real GDP, a consumer price index, non-financial private sector loan volumes, a composite lending rate and a reference short-term interest rate. Chart 1 shows all time series used in the analysis, while details on the definition, treatment and sources of the data are reported in the Supplementary Material Annex.

The evolution of real GDP growth shows how all three economic areas experienced recessions in similar periods (the early 1980s, the early 1990s and between 2008 and 2009), although with some variation in terms of turning points. Moreover, the data are consistent with the evidence for a Great Moderation from the mid-1980s until the most recent crisis. It is striking how synchronised and of similar magnitude the slowdown in real GDP growth was between 2008 and 2009 across these economic areas.

The consumer price index selected for each economic area is that representing the main reference for the corresponding central bank: the harmonised index of consumer prices (HICP) for the Euro Area, the retail prices index (RPI) for the United Kingdom and the consumer price index (CPI) for the United States. In all three economic areas it is apparent how inflation gradually declined during the 1980s and has been at relatively low and stable levels since the early 1990s, with signs of increased volatility only reappearing over the last few years.

The reference short-term interest rates are represented by the 3-month Treasury bill rates for the United Kingdom and the United States, while for the Euro Area we use the 3-month Euribor up to the beginning of the recent crisis. The crisis which started in August 2007 affected interbank money markets significantly with a loss of confidence and associated disruption of unsecured interbank lending market, implying that the corresponding interest rates (Euribor or Eonia) may be of questionable representativeness as reference interest rates. Thus, we use the 3-month Euro Repo rate, for secured interbank lending, from 2007 onwards as a reference short-term interest rate for the Euro Area.

As regards to loan volumes, we consider series which correspond to indices for the outstanding amounts of loans granted by financial intermediaries to households and non-financial corporations, corrected for the impact of loan sales and securitisation. The latter correction is important to gauge the amount of loans originated by banks, as in recent years the fraction of loans granted and subsequently securitised and taken off banks' balance sheets has been significant. For the US we use data from the flow of funds statistics, which include not only loans obtained by US households and non-financial corporations by commercial banks, which in contrast to the Euro Area and to some extent also the United Kingdom represent only a small fraction to total loans obtained by these sectors, but also loans from other sources (see for example ECB, 2009). The data show how the credit cycles in the three economic areas appear to be relatively synchronised.

For the composite lending rates a weighted average of lending rates for loans to households and for loans to non-financial corporations are used, with weights corresponding to the respective loan outstanding amounts. Since no official series exists for any of these economic areas, we have constructed such series using available interest rates and (for the weights) loan data for the various loan categories. These series have some limitations, especially for the 1980s, as they do not cover all types of loans and are based on data not fully harmonised (for example across Euro Area countries, especially for the 1980s and to some extent also 1990s). The constructed series do not display unexplainable movements or excessive volatility and they seem to behave similarly across the three economic areas, but the limited quality of these data represents a source of uncertainty for the results of any analysis like the present one.

3.3 Identification

We identify four shocks: a loan supply shock, an aggregate supply shock, an aggregate demand shock and a monetary policy shock. Intuitively, a loan supply shock can be associated with various events, such as unexpected changes in bank capital available for loans (for example due to a change in regulatory capital ratio requirements), unanticipated changes in bank funding (for instance following bank runs or the introduction of credible deposit insurance schemes or changes in the ceiling of the latter), unexpected changes in the risk perception of potential borrowers by bank management (for example following changes in key bank managerial positions or innovations in bank monitoring technology) or unexpected changes in the degree of competition in the banking sector (which might induce a change in the structure of the industry and therefore affect primarily the role of credit markets in propagating shocks and be characaterised as a structural change but may also give rise to unexpected changes in the availability of loan supply that could be characaterised as structural shocks). Examples of aggregate supply shocks include technology or productivity shocks, oil price shocks and labour supply shocks. Aggregate demand shocks include consumption or preference shocks, investment demand shocks and fiscal policy shocks. Monetary policy shocks are associated with unexpected changes in policy interest rates, thus including so-called standard or conventional monetary policy shocks and not necessarily shocks associated with non-standard or unconventional monetary policy measures. While our empirical model includes five variables, therefore allowing us to identify up to five shocks, we prefer to identify only four structural shocks and leave one of the reduced form shocks unidentified in order for such residual shock to act as a buffer and capture the effects of omitted variables and other shocks conceptually not belonging to any of the four categories identified.

Although the main focus of the paper is on loan supply shocks, identification of other key categories of disturbances helps the identification of the loan supply shock (Paustian, 2007). Identification is achieved by means of sign restrictions, as summarised in Table 1. The latter are chosen with reference to a set of benchmark macroeconomic models. Instead of adopting sign restrictions implied by a specific model, it can be argued that it is more robust to derive identification restrictions which are common to a set of recent benchmark models in the literature. Unfortunately, it is virtually impossible to derive restrictions to identify loan supply shocks which are fully consistent with even a small set of benchmark models. Indeed, as shown in Table 2, benchmark models including shocks which can be associated with loans supply disturbances, such as those by Christiano et al. (2010), Cúrdia and Woodford (2010), Gerali et al. (2010) and Gertler and Karadi (2011), tend to have somewhat different implications for the sign of the impact impulse responses to even the small set of macroeconomic and credit market variables under consideration.[5] Differences can, of course, be explained by different modelling choices as well as different estimation approaches, although in most respects these models reflect standard modelling and estimation choices. At the same time, a number of restrictions seem very frequent. Indeed, an expansionary loan supply shock (defined as loan supply shock which leads to an increase on real GDP on impact as well as cumulatively during the first four quarters) appears to have most often a positive immediate impact on all variables except the lending rate, for which a negative impact is most commonly found. Thus, we choose to adopt these five identification restrictions for loan supply shocks: on impact a loan supply shock implies changes with the same sign for real GDP, inflation, the short-term interest rate and loan volumes, and changes of the opposite sign for the lending rate. These restrictions are consistent with all specific loans supply shocks of the Cúrdia and Woodford (2010) and Gertler and Karadi (2011) models and with some specific credit supply shocks of the models of Christiano et al. (2010) and Gerali et al. (2010). The idea underlying these restrictions is that, in the case of an expansionary loan supply shock, if a bank decides exogenously to expand the supply of loans to the private sector it

[5]We are very grateful to Vasco Cúrdia, Peter Karadi, Roberto Motto and Stefano Neri for discussions, clarifications and additional material on their respective models.

would do so by increasing the quantity made available and/or by decreasing the lending rate (or, more likely, both), such that at aggregate level both effects are observed. This would have an expansionary effect on output as households would borrow more and use some of these funds to expand their consumption and enterprises would borrow more and use some of these funds to expand their investments. The increased expenditure would exert inflationary pressures which would lead the central bank to increase the interest rate to contain them. These restrictions differ from those adopted by other authors in some respect, as for example Eickmeier and Ng (2011) and Hristov et al. (2012) do not impose any restriction on inflation on the ground that some models have conflicting implications in this regard, but then in order to identify these shocks and ensure they are not confused with other shocks such as aggregate supply shocks or monetary policy shocks they have to include restrictions on additional variables (such as various spreads, as Eickmeier and Ng (2011), who also impose restrictions on the sign of the response of the spread between the corporate bond yield and long-term interest rates and of the spread between the corporate bond yield and short-term interest rates, although it is difficult to find a model with all these implications) or unnecessary restrictions for other shocks (such as on the sign of the response of the short-term interest rate to aggregate supply shocks, as Hristov et al., 2012). [6]

Restrictions for the other three shocks are selected on the basis of the same benchmark models used as reference for loans supply shock identification (to the extent possible, as not all of these four models include all four types of shocks considered), complemented by the implications of another benchmark macroeconomic model, the Smets and Wouters (2007) model (which does not include a credit sector), to increase the robustness of the selected restrictions. As regards aggregate supply shocks, most of these models imply opposite signs of the impact responses of real GDP and inflation, which are sufficient to identify them and are therefore adopted in our scheme (Table A in the Supplementary Material Annex). Aggregate demand shocks tend to imply impact responses of the same sign for all variables except for loan volumes and accordingly we impose these restrictions to real GDP, inflation, the short-term interest rate and the lending rate, which is enough to identify these shocks (Table B in the Supplementary Material Annex). Finally, monetary policy shocks can be identified by assuming that real GDP and inflation react on impact with the same sign while the impact response of short-term interest rates is of opposite sign to that of real GDP, which is in line with most models considered

[6] The restrictions imposed to identify loan supply shocks also differ from other authors such as Busch et al. (2010), who impose the same set of sign restrictions but for different periods, such as a positive sign of the response of inflation to an expansionary loan supply shock but only after one period, which forces them to impose also sign restrictions for monetary policy shocks with different lags, such as the impact of inflation to a monetary policy shock which is imposed only after two periods, which appears somewhat arbitrary.

(Table C in the Supplementary Material Annex).

The restrictions are imposed on the lending rate and not on the spread between the lending rate and the short-term interest rate as changes in the latter as well as loan volumes may also be induced by shocks other than loan supply disturbances, including for example wealth shocks (i.e. an expansionary wealth shock may induce an increase in the demand for loans, leading to a possible increase in the lending rate but also inflationary pressures with a possible increase in the policy rate, with an uncertain sign of the spread in the short run). Moreover, the impulse responses of the various shocks for the spread within the benchmark models considered are more uncertain than the correponding ones for the lending rate.

The sign restrictions adopted are imposed on the variables only on impact, as the variation of the sign of impulse responses to the various shocks considered across the benchmark models discussed is higher for the case of the impulse responses in the short term (i.e. with lags from one to four, both for each single quarter and cumulatively) as well as the medium term (i.e. twelve quarters). Thus, in the specific case under consideration (i.e. for the four shocks considered) imposing the sign restrictions only on impact implies a relatively more robust identification scheme with reference to theoretical models compared to the approach of imposing sign restrictions for multiple periods, as several other authors chose to do, including Busch et al. (2010), Eickmeier and Ng (2011) and Hristov et al. (2012).

Technically speaking, at each point in time and for each draw of the reduced form coefficients we draw H_t in such a way that the elements of each row represent the coordinates of a point uniformly distributed over the unit hypersphere and that is orthogonal to the other points defined by the remaining columns, see Rubio-Ramirez, Waggoner and Zha (2010).

4 Results

4.1 Evidence of time-variation

The evolution of the residual time-varying variances is shown in Chart 2. In most cases there is evidence of significant time-variation in the residual variances, with spikes appearing most often in the most recent years in correspondence to the latest economic and financial crisis. Moreover, for the short-term interest rate there are clear signs of a decrease in their volatility during the first half of the sample for all three models. Overall, the evidence supports the use of stochastic volatility specifications for all three models.

Table 3 shows the posterior mean of the trace of Ω as well as 68% confidence bands and the trace of Ω_0 (i.e. the prior variance-covariance matrix). This is a way to establish whether time-variation in the parameters is a feature of the data, see Cogley and Sargent (2005). In all three cases, the trace of Ω_0 is lower than the 16% percentile, pointing to the presence to time-variation in the data, as the sample points towards greater time-variation in the parameters than that of the prior selected.

4.2 The average effect of loan supply shocks

The average impulse response functions to loan supply shocks over the whole sample period show remarkable similarities across the three economic areas. The posterior mean of the impulse responses and the 68% confidence bands appear in most cases very similar (Chart 3). For example, an expansionary loan supply shock seems to have a large but short-lasting (less than a year) positive impact on real GDP in all three cases. However, it appears to be stronger in the short run for the United Kingdom and United States, than for the Euro Area, although only to a very minor extent. Moreover, for all three economic areas the positive impact on inflation tends to last two years (for the United Kingdom and United States) or longer (more than four years for the Euro Area), with the short-run impact being stronger in the United Kingdom. On average, expansionary loan supply shocks seem to correspond to a larger increase in loan volumes in the United Kingdom compared to the Euro Area and the United States, with also clear differences in the persistence of such positive effects (ranging from about two and a half years in the United States to three and a half in the Euro Area and to more than five years in the United Kingdom). The decline in the lending rate tends to be very short-lived in all three economic regions, starting to increase after one quarter after the shock and remaining positive for a longer period, especially in the United Kingdom and in the Euro Area. The responses of short-term interest rates seem to be in line with those of inflation, as for example the former is larger in the short term in the United Kingdom, where the inflationary impact of loan supply shocks appears to be stronger, while the positive response of short-term interest rates lasts for a shorter period in the United States compared to the Euro Area and the United Kingdom, as in the Nort-American economy the impact of loan supply shocks on inflation tends to last relatively fewer quarters.

The average importance of loan supply shocks can be assessed on the basis of variance decompositions, shown in Chart 4 for various horizons. Overall, these shocks seem to explain a sizeable fraction of the variance of all variables in all three economic areas, especially beyond the very short horizon of one quarter. In all three areas, these shocks appear to explain about 15% to 20% of the variance of both real GDP growth (for which loan supply shocks seems to be relatively slightly more important in the Euro Area) and inflation at business cycle frequency (i.e. between one year and three years horizons). Loan supply shocks seem to explain a larger fraction of the variance of loan volumes in all three cases, ranging between 25% and 30% beyond very short horizons. By contrast, loan supply shocks appear to be less important to explain the variance of the lending rate, explaining on average between 5% and 15% of their variance, while the average contribution of these shocks to the variance of the short-term interest rate is slightly higher, ranging from10% to 20%.

4.3 The evolution of the effect of loan supply shocks over time

The evolution of the impulse responses over time for different horizons suggests that some time-variation can be detected in several cases (Chart 5 and Charts A to C and G to K in the Supplementary Material Annex). In general, it appears that the short-term impact of these shocks on real GDP and inflation may have increased in all three economic areas over the past few years. For loan growth, the impact of loan supply shocks seems to have increased in the most recent years in both the short and medium-run (i.e. one- to three-year) in the Euro Area, while in the United Kingdom they appear to have decreased in the second half of the sample compared to the first half. By contrast, for the United States some time variation for the impact of loan supply shocks on loan growth can be detected, but rather than displaying different regimes it appears to be cyclical in the short-run. Finally, the responses of the lending rate and the short-term interest rate appear to have remained close to zero beyond the short term in all three areas over the whole period, with at most signs of a slightly stronger response of these rates in the initial part of the sample in all three economic areas and possibly signs of an increasing impact of the short-term interest rate in the short run in the Euro Area and the United Kingdom.

Observing variance decompositions over time also provides some impression of time-variation in some cases (Charts D to F and L in the Supplementary Material Annex). More specifically, the fraction of real GDP growth variance explained by loan supply shocks appears to have increased since the early 2000s in both the Euro Area (from about 20% in the 1990s to between 25% and 30% in th emost recent years) and in the United States (from close to 10% in the second half of the 1990s to above 20% in the most recent years). By contrast, over the sample period considered the fraction of loan growth variance explained by these shocks appears to have gradually decreased in the United Kingdom and the United States (in both cases from close to 30% in the initial years of the sample to close to 20% in the most recent years for most horizons) and, from the early 2000s onwards, also in the Euro Area (from above 30% to close to 20% in the most recent years). Moreover, the fraction of lending rates variance explained by these shocks seems to have decreased significantly in the first decade of the sample in all three economic areas (from between 15% and 30% in the intial years of the sample to close to 10% in the most recent years). By contrast, for inflation and short-term interest rates no major signs of time-variation can be detected in the Euro Area and the United Kingdom, while signs of a lower fraction of variance of these two variables explained by loan supply shocks can be seen for the United States for the second half of the sample.

The evolution of the effect of loan supply shocks can also be assessed on the basis of historical decompositions, or counterfactuals (which indicate how each variable would have evolved in the absence of these shocks). Overall, it appears that the contribution of loan supply shocks has been particulary important during the mosr recent recession (Chart 6). For example, the contribution of these shocks can explain almost 20% of the decline in annual real GDP growth between 2007 and 2009 (i.e., from the peaks in 2007 to the troughs in 2009) in the Euro Area and the United States and almost 10% of that observed in the United Kingdom. For example, instead of falling from 3.8% growth in 2007Q1 to -5.0% in 2009Q1 (or 8.8 percentage points), Euro area real GDP annual growth would have fallen from 3.6% to -3.5% (or 7.1 percentage points) over the same period. By contrast, in all three economic areas loan supply shocks appear to have contributed to a mimimal extent to the recessions of the early 1990s. Loan supply shocks accounted also for significant fractions in the evolution of loan volumes in all three economies in specific periods. In particular, in the absence of loan supply shocks the decline in the annual growth rate of loans observed from the peaks of 2006/2007 to the troughs of 2009/2010 would have been about 25% smaller in the Euro Area and almost 10% smaller in the United Kingdom and the United States.

4.4 The role of loan supply shocks during specific recessions and recoveries

As discussed in the previous section, counterfactuals indicate that loan supply shocks appear to have played significant roles in driving both the early 1990s and the 2008/2009 recessions in all three economic areas. This is confirmed by the impulse responses of real GDP especially during the most recent recession in all three economies, as the impact responses are clearly stronger than the average ones (Chart 7 and Charts M to O in the Supplementary Material Annex).[7] By contrast, the difference between the responses during the early 1990s recession do not seem very much different from the average ones. Similar evidence emerges for the responses of loans to loan supply shocks, with stronger impacts observed for the most recent recession, for the Euro Area (but not for the United Kingdom and the United States), while not much difference can be observed for the early 1990s recession.

[7]Turning points are those identified by the CEPR Euro Area Business Cycle Dating Committee for the Euro Area and the NBER Business Cycle Dating Committee for the United States, while for the United Kingdom they are based on real GDP growth with recessions defined as periods of two or more consecutive negative quarter-on-quarter growth rates.

A comparison of the responses across recent recessions and the subsequent recoveries - defined here as developments in the four quarters following the trough - suggests that no major asymmetries emerge. In particular, in most cases the response of real GDP to loan supply shocks during the recessions discussed and subsequent recoveries appears very similar. Similarly, the responses of loan growth to the loan supply shock are very similar across these recessions and recoveries. Thus, there does not seem to emerge evidence of systematic asymmetries across business cycle phases in the response of loan supply shocks.

Beyond counterfactuals and impulse responses during specific business cycle phases, the series of structural shocks can also provide useful information on the role of loan supply shocks around recession periods. Moreover, a visual inspection of these series can provide an indirect way to assess the plausibility of the method adopted to identify loan supply shocks. Indeed, although there is no perfect way to assess whether the shocks identified correspond in fact to exogenous or unexpected changes in loan supply, an informal assessment of their plausibility can be undertaken by observing the series of structural shocks and discussing particular spikes with reference to anecdotal information on real world events. Chart 8 shows the series for the loan supply shocks for all three economic areas. It can be observed that large negative spikes can be found in all three cases in 2008Q4, i.e. immediately after the default of Lehman Brothers (September 2008), which presumably had an immediate unexpected adverse effect on the balance sheet of most banks, among other effects. For the United States this negative spike corresponds to the largest adverse shock over the whole sample. For the Euro Area a large negative spike can be found in 2008Q4, which is not the largest in the sample, but was followed by another large negative spike in 2009Q1, marking the strongest adverse cumulative spikes over two adjacent periods in the whole sample. Similarly, the negative spike in 2008Q4 in the United Kingdom was not the largest in the sample but together with that in 2008Q3 gives the strongest adverse cumulative spikes over two adjacent periods in the whole sample (together with two contiguous spikes in 2000). Moreover, for the United States large negative spikes can also be observed in the early 1990s, in coincidence with the so-called "capital crunch " associated to the early 1990s recession (Bernanke and Lown, 1991; Peek and Rosengren, 1995) and in 1999Q2, in the aftermath of the Long-Term Capital Management crisis.[8] Overall, it can be observed that in all three economies considered a number of consecutive negative spikes can be found during

[8] A comparison of the loans supply shocks with available banking survey data would be tempting but would have severe limitations. Indeed, indicators from surveys such as the ECB Bank Lending Survey, the Federal Reserve's Senior Loan Officer Opinion Survey or the Bank of England's Credit Conditions Survey are all endogenous, that is they reflect changes in response to both the economic situation and exogenous changes independent of the latter. Trying to estimate both components is difficult and inevitably affected by high uncertainty, not least due to the short span of the survey indicators.

most of the main recessions. Moreover, these series are in line with a significant role played by adverse loan supply shocks during the early 1990s and 2008/2009 recessions in all three economies.

5 Conclusions

This paper provides some evidence that loan supply shocks have played an important role in business cycle fluctuations in the Euro Area, the United Kingdom and the United States over the past three decades. The model adopted, a time-varying parameters VAR with stochastic volatility, seems to be particularly useful to capture the role of these shocks over the business cycle, as evidence can be found of both significant time variation in parameters and stochastic volatility. The main results of the empirical analysis suggest clearly that loan supply shocks have a significant effect on economic activity, inflation and credit markets in all three economic areas, although some differences across geographic areas and changes over time can be uncovered. Moreover, while there is no evidence of a systematic asymmetry in the impact of loans supply shocks between recent recessions and the subsequent recovery, it appears that the contribution of loan supply shocks was particulary important during the most recent recession in all three economic areas considered. This evidence suggests that policy-makers in the Euro Area, the United Kingdom and the United States should monitor closely developments in credit markets, and close attention to developments in the banking sector is warranted.

As a follow-up to this work, it would be of much interest to try to identify more specific types of loan supply shocks, including those arising from unexpected developments in bank capital, bank funding and credit risk. This would however require adopting larger models, including for example more detailed credit market variables. Although currently estimating and simulating large models with time-varying parameters and stochastic volatility still poses difficult technical challenges, it is likely that soon advances in econometric research will allow for such an undertaking.

References

Albertazzi, U. and D. Marchetti (2010): "Credit Supply, Flight to Quality and Evergreening: An Analysis of Bank-Firm Relationships after Lehman", Working Paper N. 756, Bank of Italy.

Bassett, W. F., M. B. Chosak, J. C. Driscoll, and E. Zakrajšek (2012): "Changes in Bank Lending Standards and the Macroeconomy," Finance and Economics Discussion Series 2012-24. Board of Governors of the Federal Reserve System (U.S.).

Benati, L. (2008): "The "Great Moderation" in the United Kingdom", Journal of Money, Credit and Banking, vol. 40(1), pp. 121-147.

Bernanke, B. (1993): "Credit in the macroeconomy", Quarterly Review, Federal Reserve Bank of New York, issue Spr, pages 50-70.

Bernanke, B. and C. Lown (1991): "The credit crunch", Brookings Papers on Economic Activity, vol. 2, pp. 205-247.

Berrospide, J. M. and R.M. Edge (2010): "The Effects of Bank Capital on Lending: What Do We Know, and What Does It Mean? ", International Journal of Central Banking, vol. 6 (4), Dec. 2010, pp.5-54.

Brunnermeier, M. K. (2009): "Deciphering the Liquidity and Credit Crunch 2007-2008," Journal of Economic Perspectives, vol. 23(1), pp. 77-100.

Brunnermeier, M. K., T. M. Eisenbach and Y. Sannikov (2012): "Macroeconomics with Financial Frictions: A Survey," NBER Working Papers, N. 18102.

Busch, U., M. Scharnagl and J. Scheithauer (2010): "Loan Supply in Germany During the Financial Crisis", Discussion Paper Series 1 05/2010, Deutsche Bank.

Canova, F. and L. Gambetti (2009): "Structural changes in the US economy: Is there a role for monetary policy?", Journal of Economic Dynamics and Control, vol. 33(2), pp. 477-490.

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

Ciccarelli, M., A. Maddaloni and J.-L. Peydró (2010): "Trusting the bankers: a new look at the credit channel of monetary policy", ECB Working Paper n. 1228, July 2010.

Cogley, T. and T. J. Sargent (2005): "Drift and Volatilities: Monetary Policies and Outcomes in the Post WWII U.S.", Review of Economic Dynamics, vol. 8(2), pp. 262-302.

Cochrane, John H. (1994): "Shocks," Carnegie-Rochester Conference Series on Public Policy, Elsevier, vol. 41(1), pages 295-364, December.

Cúrdia, V. and M. Woodford (2010): "Credit Spreads and Monetary Policy," Journal of Money, Credit and Banking, vol. 42(s1), pages 3-35, 09.

D'Agostino, A., L. Gambetti and D. Giannone (2013): "Macroeconomic Forecasting and Structural Change", Journal of Applied Econometrics, vol. 28 (1), pp. 82-101.

De Nicolò, G. and M. Lucchetta (2011): "Systemic Risks and the Macroeconomy," NBER Working Paper 16998, April 2011.

De Santis, R. and P. Surico (2013): "Bank lending and monetary transmission in the euro area ", Economic Policy, vol. 28, pp. 423-57.

Del Giovane, P., G. Eramo and A. Nobili (2011): "Disentangling demand and supply in credit developments: A survey-based analysis for Italy," Journal of Banking & Finance, Elsevier, vol. 35(10), pages 2719-2732, October.

Diamond, D. W. and R. G. Rajan (2009): "The Credit Crisis: Conjectures about Causes and Remedies," American Economic Review, vol. 99(2), pp.606-10.

ECB (2009): "The external financing of households and non-financial corporations: a comparison of the euro area and the United States", Monthly Bulletin, April 2009.

Eickmeier, S. and T. Ng (2011): "How Do Credit Supply Shocks Propagate Internationally? A GVAR approach," CEPR Discussion Paper N. 8720.

Fisher, I. (1933): "The Debt-Deflation Theory of Great Depressions", Econometrica, vol. 1 (4), pp. 337-57.

Fernández-Villaverde, F. and J. F. Rubio-Ramírez (2010): "Macroeconomics and Volatility: Data, Models, and Estimation," NBER Working Papers 16618.

Galí, J. and L. Gambetti. "The Effects of Monetary Policy on Stock Market Bubbles: Some Evidence." American Economic Journal: Macroeconomics forthcoming.

Galí, J. and L. Gambetti (2009): "On the Sources of the Great Moderation," American Economic Journal: Macroeconomics, vol. 1(1), pp. 26-57.

Gambacorta, L. and D. Marques-Ibanez (2011): "The bank lending channel: lessons from the crisis," Economic Policy, vol. 26(66), pp. 135-182.

Gerali, A. S. Neri, L. Sessa and F. M. Signoretti (2010): "Credit and Banking in a DSGE Model of the Euro Area," Journal of Money, Credit and Banking, vol. 42(s1), pp. 107-41

Gertler, M. and P. Karadi (2011): "A model of unconventional monetary policy," Journal of Monetary Economics, vol. 58(1), pages 17-34, January.

Gilchrist, S., V. Yankov and E. Zakrajšek (2009): "Credit market shocks and economic fluctuations: Evidence from corporate bond and stock markets," Journal of Monetary Economics, vol. 56(4), pp. 471-93.

Gilchrist, S. and E. Zakrajšek (2012a): "Credit Supply Shocks and Economic Activity in a Financial Accelerator Model", in Rethinking the Financial Crisis, ed by A. Blinder, A. Lo and R. Solow, Russell Sage Foundation, forthcoming.

Gilchrist, S. and E. Zakrajšek (2012b): "Credit Spreads and Business Cycle Fluctuations," American Economic Review, vol. 102, no. 4, pp. 1692-1720.

Goodfriend, M. and B. McCallum (2007): "Banking and interest rates in monetary policy analysis: A quantitative exploration," Journal of Monetary Economics, vol. 54(5), pages 1480-1507, July

Gorton, G. B. (2009): "The panic of 2007", in Maintaining stability in a changing financial system, Proceedings of the 2008 Jackson Hole Conference.

Helbling, T., R. Huidrom, M. A. Kose and C. Otrok (2011): "Do credit shocks matter? A global perspective," European Economic Review, vol. 55(3), pp. 340-53.

Hempell. H. S. and C. Kok Sørensen (2010): "The impact of supply constraints on bank lending in the euro area - crisis induced crunching?," Working Paper Series 1262, European Central Bank

Hristov, N., O. Hülsewig and T. Wollmershäuser (2012): "Loan Supply Shocks during the Financial Crisis: Evidence for the Euro Area", Journal of International Money and Finance, vol. 31 (3), pp. 569–92.

Ivashina, V. and D. Scharfstein (2010): "Bank lending during the financial crisis of 2008," Journal of Financial Economics, vol. 97(3), pp. 319-38.

Jiménez, G., S. Ongena, J. L. Peydró and J. Saurina (2012): "Credit Supply and Monetary Policy: Identifying the Bank Balance-Sheet Channel with Loan Applications," American Economic Review, vol. 102(5), pp. 2301-26.

Lown, C. and D. P. Morgan (2006): "The Credit Cycle and the Business Cycle: New Findings Using the Loan Officer Opinion Survey," Journal of Money, Credit and Banking, vol. 38(6), pp. 1575-97.

Meeks, R. (2012): "Do credit market shocks drive output fluctuations? Evidence from corporate spreads and defaults," Journal of Economic Dynamics and Control, vol. 36(4), pp. 568-84.

Paustian, M. (2007): "Assessing Sign Restrictions", The B.E. Journal of Macroeconomics, Berkeley Electronic Press, vol. 7(1), pages 23.

Peek, J. and E. Rosengren (1995): "The Capital Crunch: Neither a Borrower nor a Lender Be," Journal of Money, Credit and Banking, vol. 27(3), pp. 625-38.

Peek, J., E. Rosengren and G. Tootell (2003): "Identifying the Macroeconomic Effect of Loan Supply Shocks," Journal of Money, Credit and Banking, vol. 35(6), pages 931-46.

Primiceri, G. (2005): "Time Varying Structural Vector Autoregressions and Monetary Policy ", The Review of Economic Studies, vol. 72, pp. 821-852.

Rubio-Ramirez, J. F., D. F. Waggoner and T. Zha (2010): "Structural Vector Autoregressions: Theory of Identification and Algorithms for Inference," Review of Economic Studies, vol. 77(2), pp. 665-96.

Smets, F. and R. Wouters (2007): "Shocks and Frictions in US Business Cycles: A Bayesian DSGE Approach," American Economic Review, vol. 97(3), pp. 586-606.

Table 1 – Identification restrictions

SHOCK	real GDP	inflation	short term interest rate	lending rate	loan volumes
Aggregate supply	+	-	no restriction	no restriction	no restriction
Aggregate demand	+	+	+	+	no restriction
Monetary policy	+	+	-	no restriction	no restriction
Loan supply	+	+	+	-	+

Note: Sign imposed on the impulse response on impact of all variables for the case of an expansionary shock (i.e. a shock causing an increase in real GDP).

Table 2 – Impulse responses to an expansionary loan supply shock in selected models

model	shock to	real GDP	inflation	policy interest rate	lending rate	loan volumes
Christiano et al. (2010)	bank funding technology	+	-	-	-	≈0
	bank reserve demand	+	+	uncertain	-	+
Cúrdia-Woodford (2010)	bank resource cost function	+	+	+	-	+
	bank loss rate	+	+	+	-	+
Gerali et al. (2010)	bank capital	+	-	-	-	+
	loan to value ratio E	+	+	+	+	+
	loan to value ratio HH	≈0	+	+	+	+
	loan rate E	+	+	+	-	+
	loan rate HH	+	+	+	+	+
Gertler-Karadi (2011)	bank capital quality	+	+	+	-	+
	bank's net worth	+	+	+	-	+

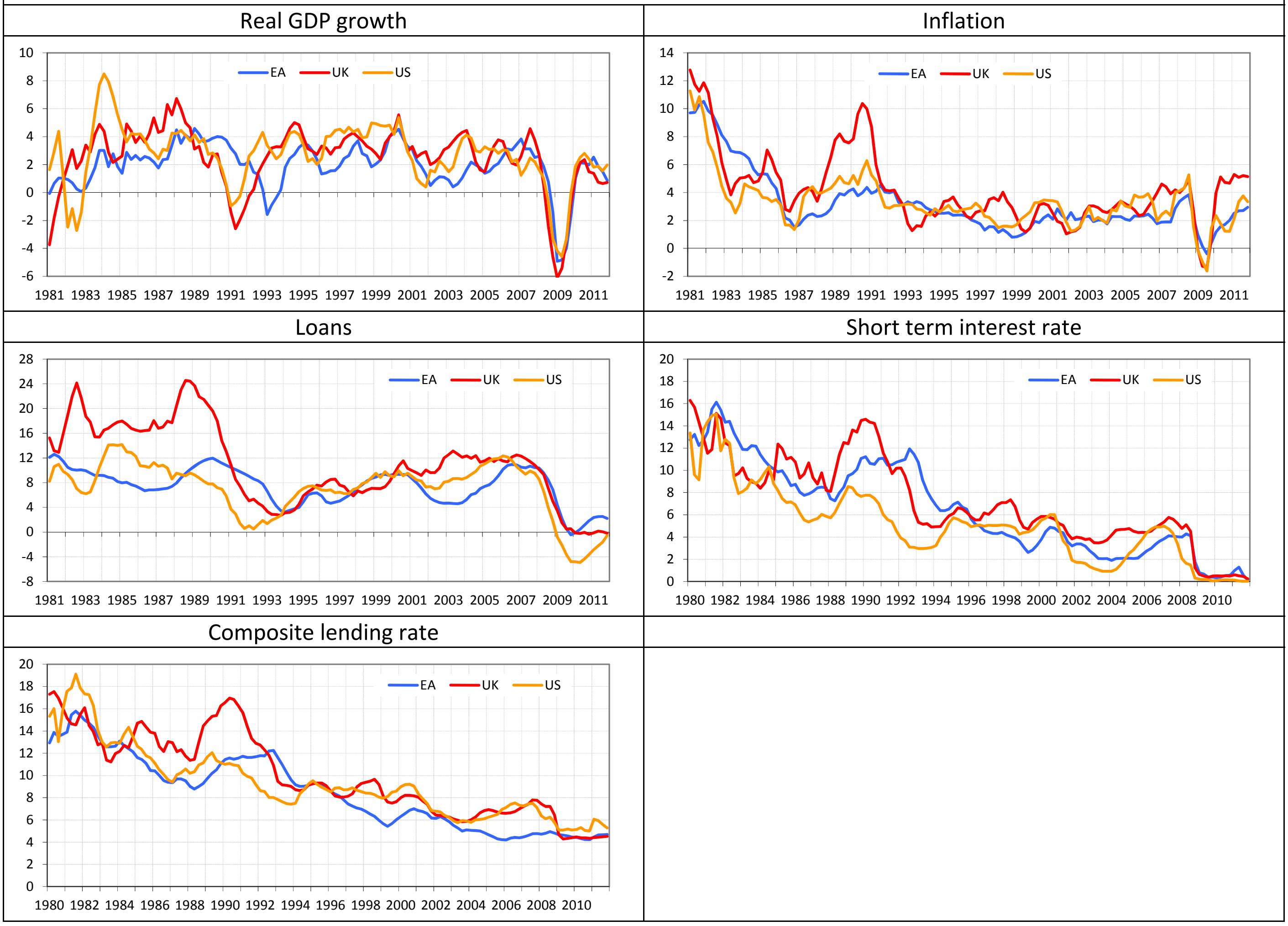
Note: Sign of the impact impulse response of an expansionary loan supply shock (i.e. a loan supply shock causing an increase in real GDP) of key macroeconomic and credit variables. The response of the policy interest rate to the shock to bank reserve demand in the Christiano et al. (2010) model is uncertain as results are of opposite sign for the euro area and the US. For the signs of impact impulse responses to both shocks discussed in Christiano et al. (2010) see Fig. 15, p. 120. For the signs of impact impulse responses in Cúrdia and Woodford (2010) see Fig. 2, p. 17 (for the baseline case with standard Taylor monetary policy rule, reported for the symmetric case of a contractionary shock) for the bank loss rate shock (while for the bank resource cost function shock they are based on additional material kindly provided to us by Vasco Cúrdia). For the signs of impact impulse responses in Gerali et al. (2010) see Fig. 8, p. 136 for the bank capital shock, reported for the symmetric case of a contractionary shock (while for the other loan supply shocks they are based on additional material kindly provided to us by Stefano Neri). For the signs of impact impulse responses in Gertler and Karadi (2011) see Fig. 2, p. 28 (for the baseline case with a financial accelerator, reported for the symmetric case of a contractionary shock) for the bank capital quality shock (while for the bank's net worth shock they are based on additional material kindly provided to us by Peter Karadi).

Table 3 – Trace tests

	16% perc.	50% perc.	84% perc.	trace(Q0)
Euro area	1.086	1.667	2.899	0.068
United Kingdom	0.847	1.146	1.639	0.095
United States	3.431	5.046	8.164	0.292

Note: The first three columns with figures show the 16%, 50% and 84% percentiles of the posterior of the trace of the variance-covariance matrix of the error term of the law of motion of the parameters of the VAR, while the fourth column shows the trace of the prior variance-covariance matrix. Following Cogley and Sargent (2005), since the value of the trace of the prior variance-covariance matrix is smaller than even the 16% percentile, this can be interpreted as evidence pointing to the presence of time variation in the parameters of the VAR (i.e. the sample points towards greater time variation in the parameters than that of the prior selected).

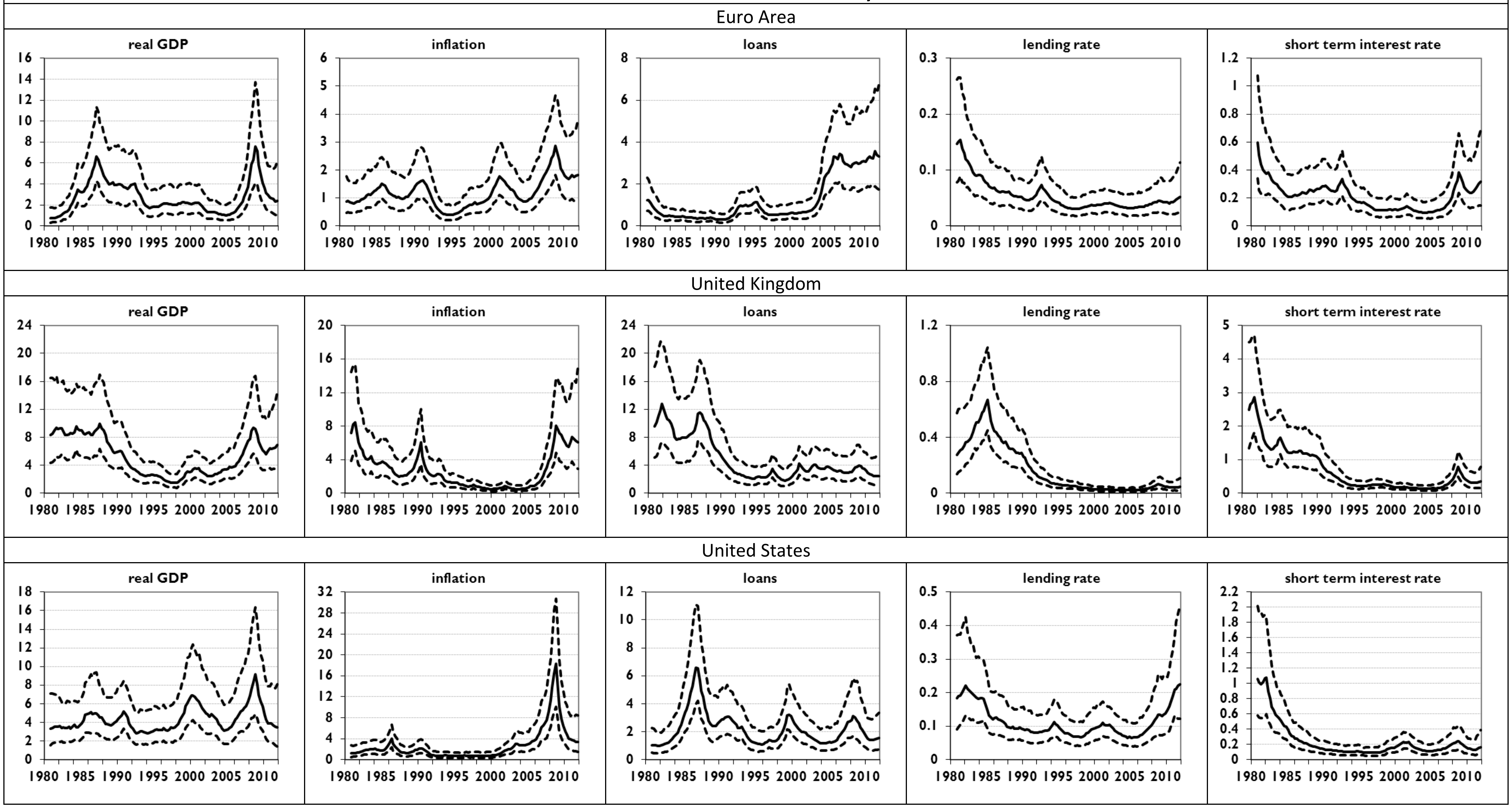
Chart 1 - Data



Sources: Bank of England, EABCN, ECB, Eurostat, UK ONS, US BEA, US Board of Governors.

Note: See Appendix A for details on data sources, definitions and treatment.

Chart 2 - Stochastic volatility

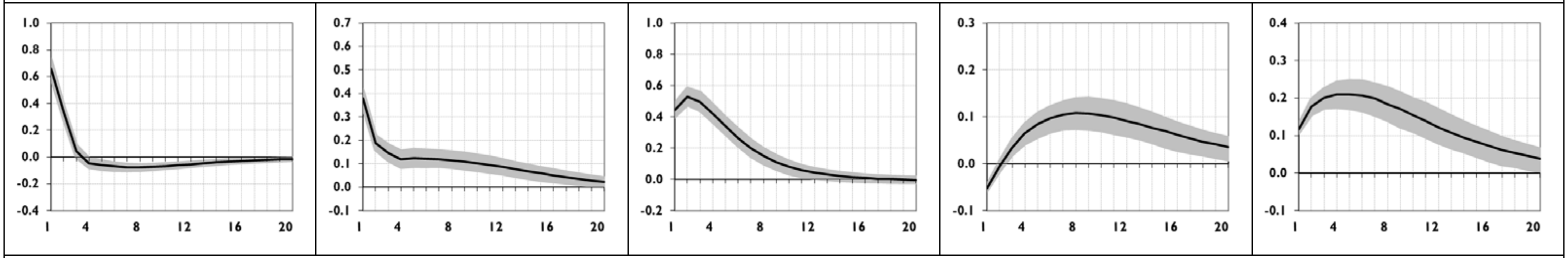


Note: Residual time-varying variances, median, 16% and 84% percentiles.

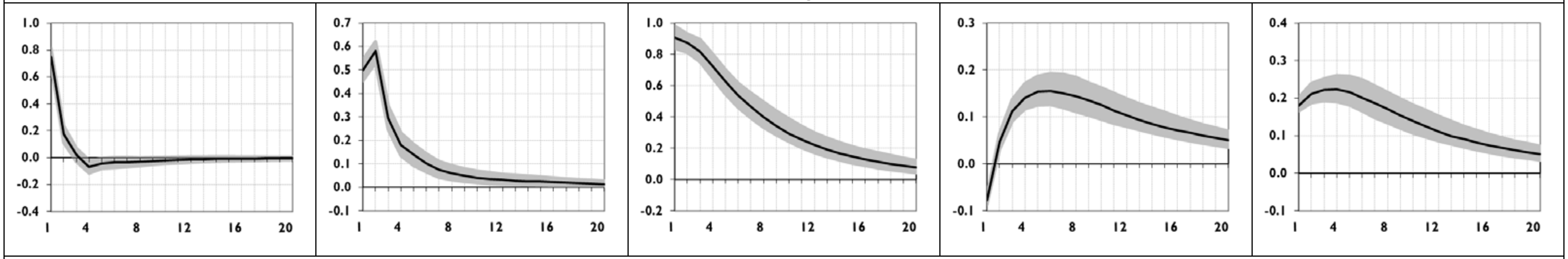
Chart 3 - Impulse response functions to loan supply shock (median whole sample period)

Real GDP	Inflation	Loans	Lending rate	Short term interest rate

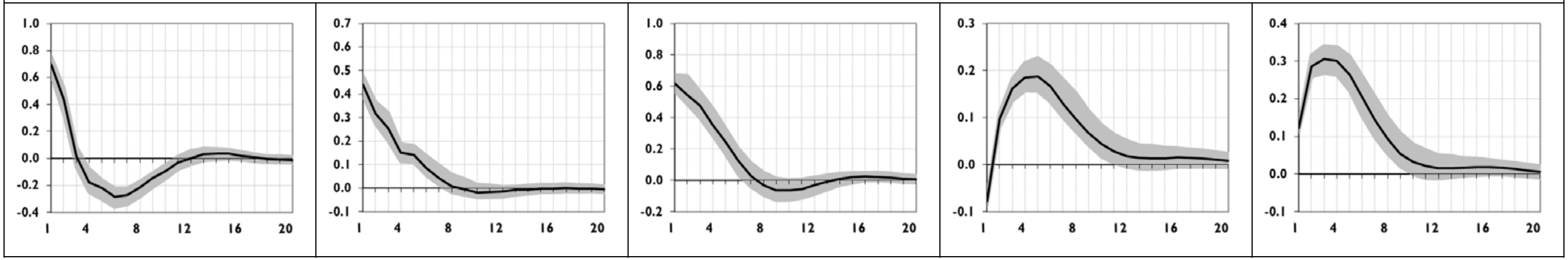
Euro Area



United Kingdom

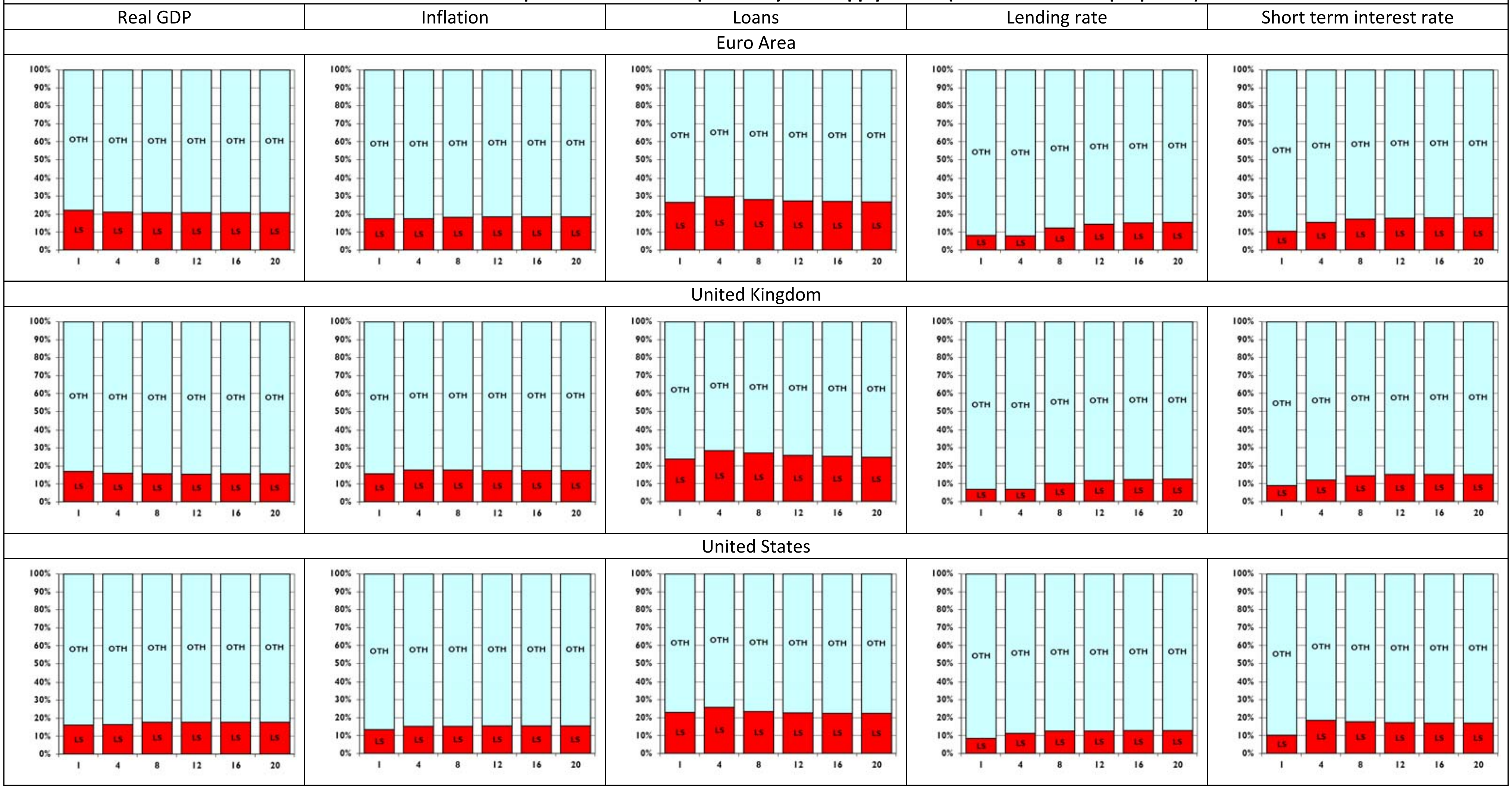


United States



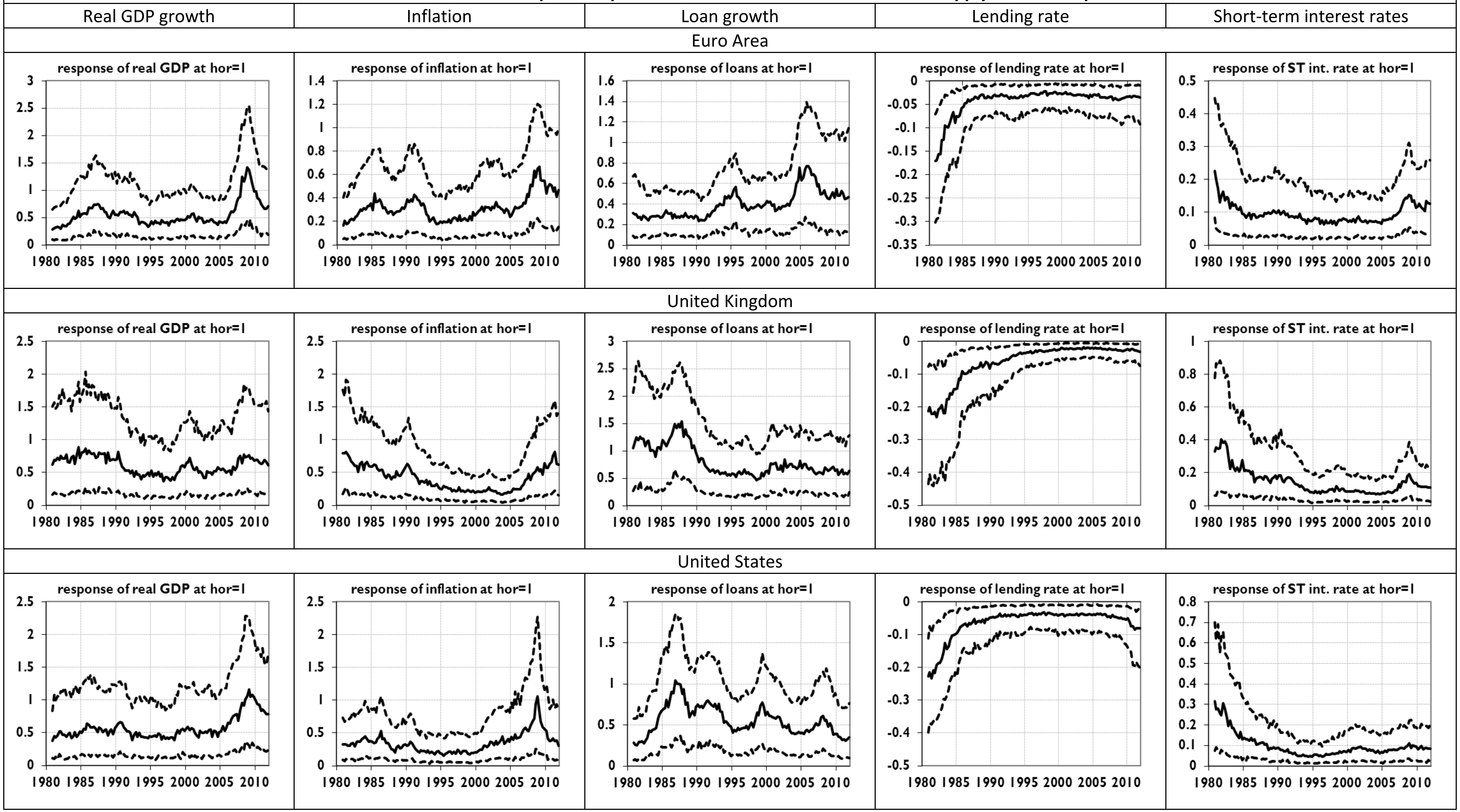
Note: Averages of impulse response functions over time. Line is the median, grey are delimits the space between the 16% and 84% percentiles.

Chart 4 – Variance decomposition: fractions explained by loan supply shocks (median whole sample period)



Note: Fractions of variances of each variables explained by loan supply shocks at various horizons. “LS” stands for fraction of variance explained by loans supply shocks, while “OTH” stands for fraction of variance explained by other shocks.

Chart 5 – Evolution of impulse response functions of all variables to a loan supply shock at impact

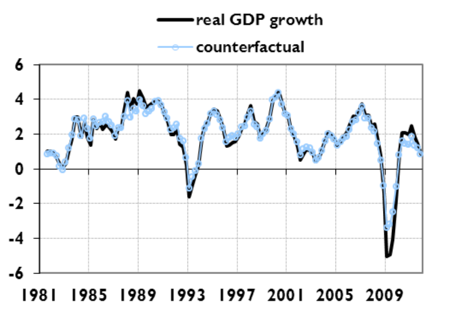


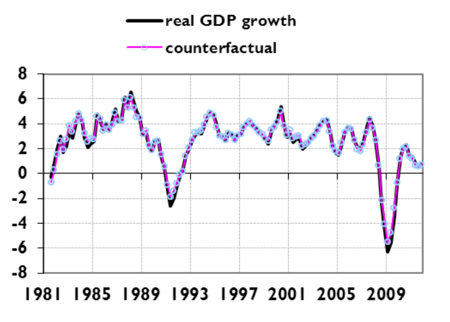
Note: Evolution of impulse responses of real GDP growth to a loan supply shock at specific horizons over time, median, 16% and 84% percentiles.

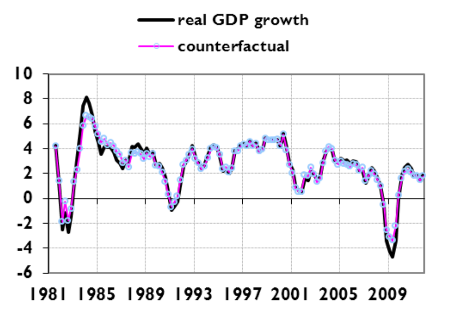
Chart 6 – Counterfactual: evolution of the variables in the absence of loan supply shocks

Euro Area	United Kingdom	United States

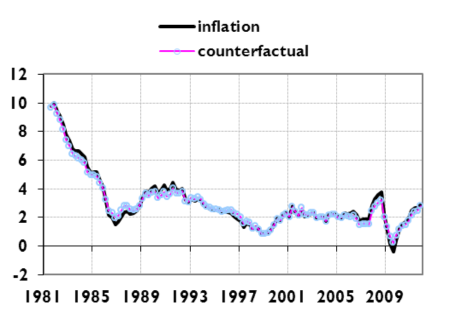
real GDP growth

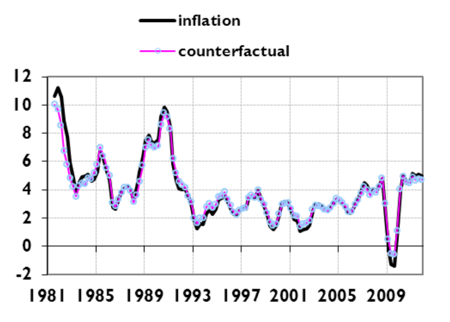


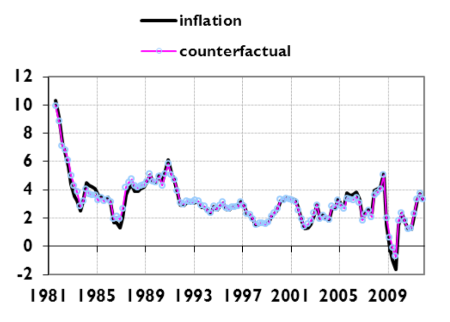




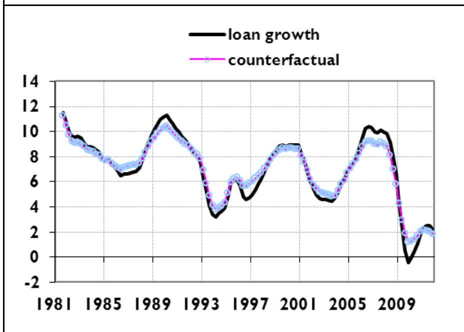
inflation

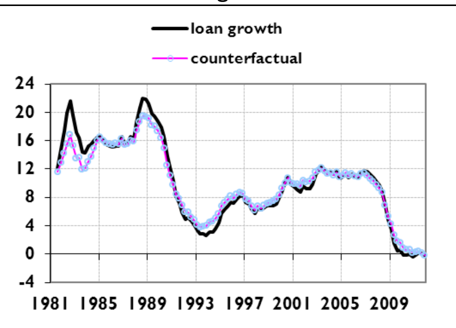


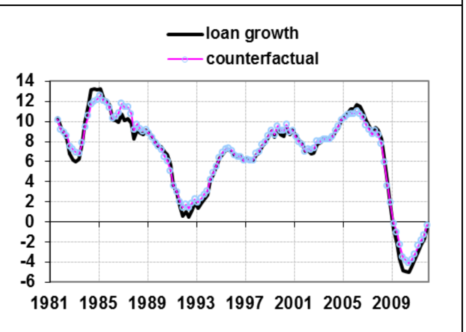




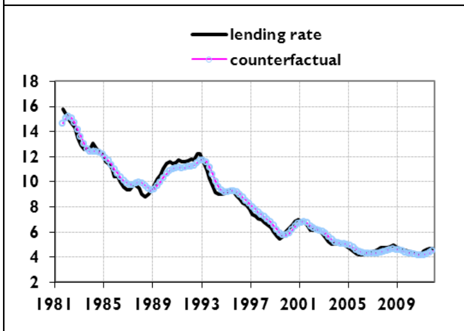
loan growth

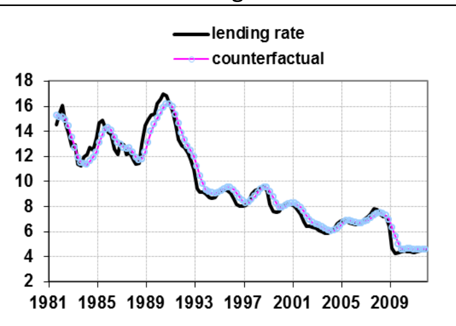


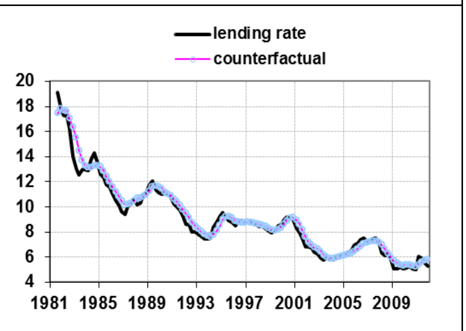




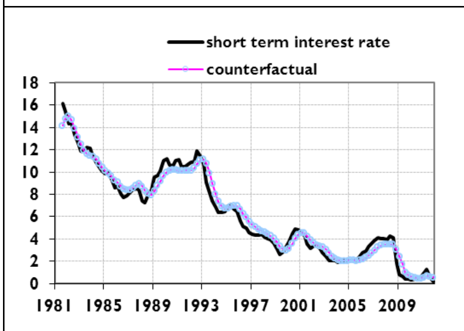
lending rate

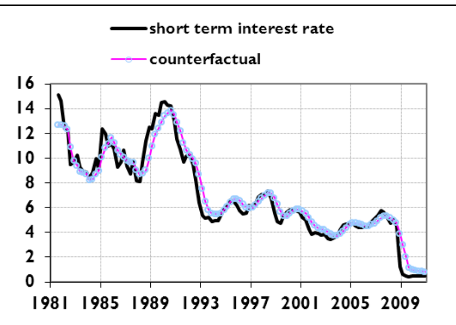


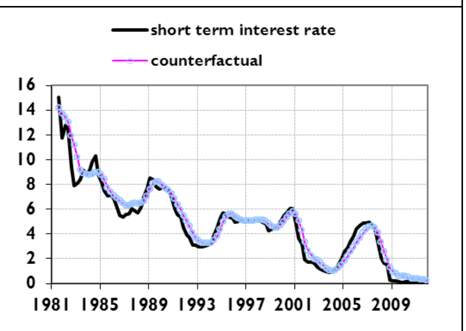




short term interest rate

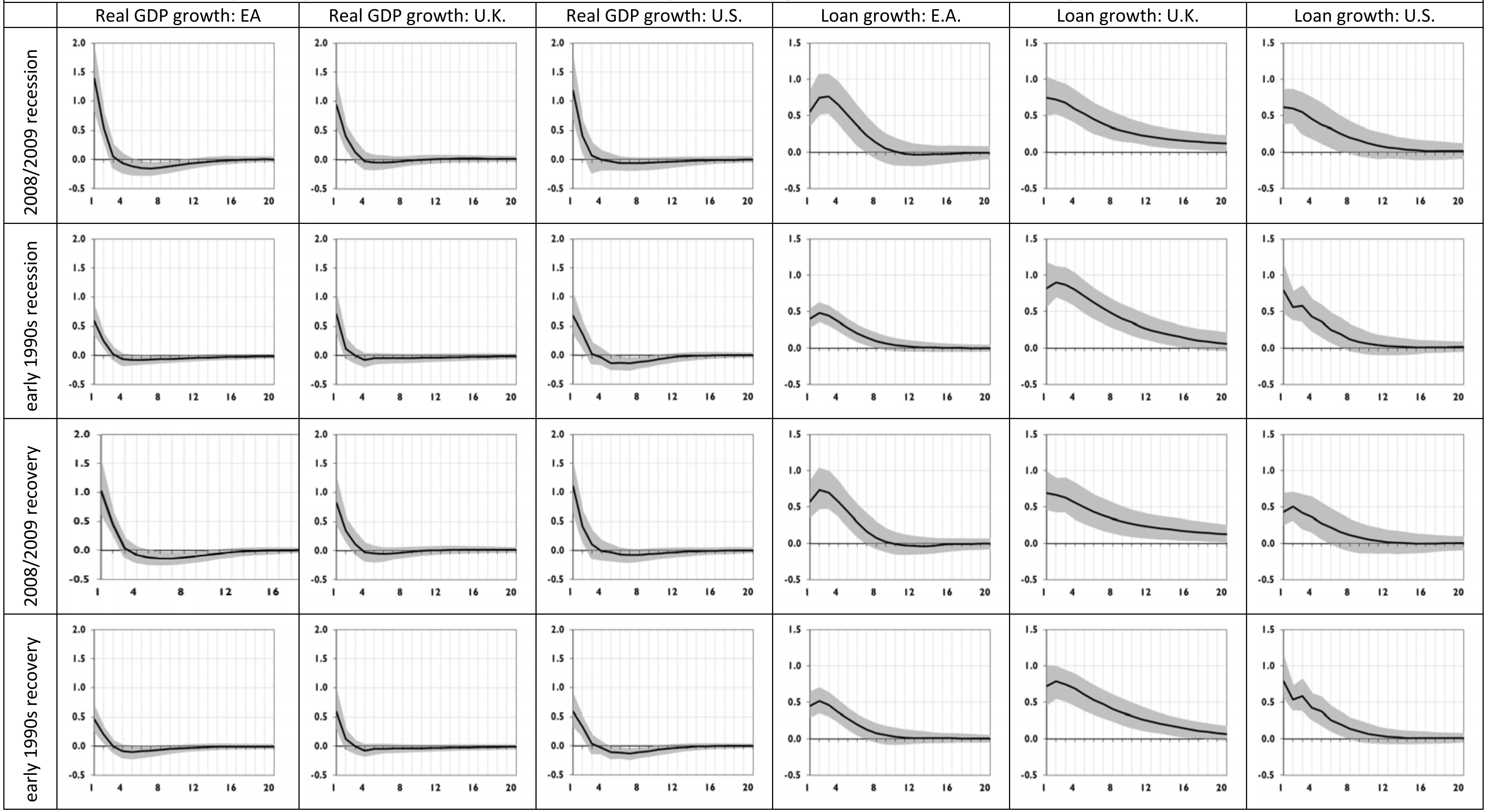






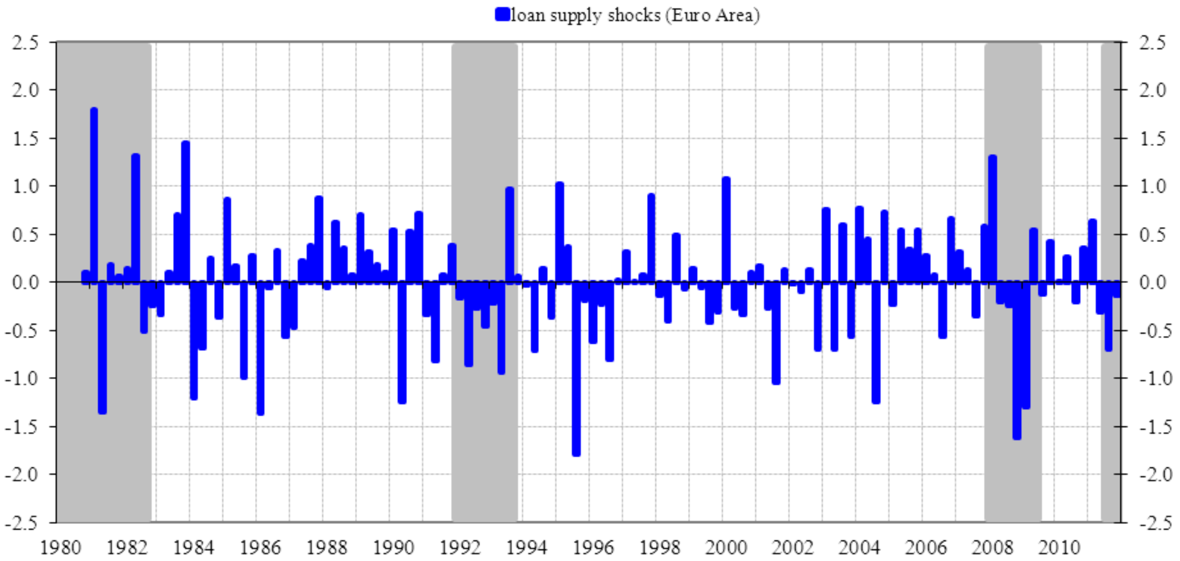
Note: Counterfactual exercises: evolution of variables in the absence of loan supply shocks.

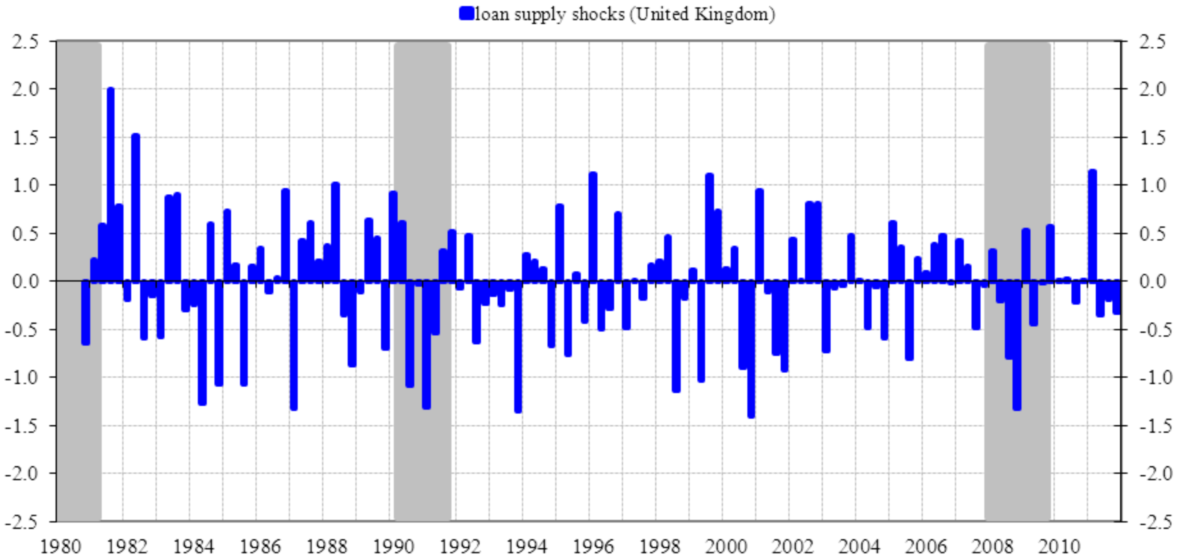
Chart 7 - Impulse response functions of all variables to loan supply shocks during and after the 2008/2009 and early 1990s recessions in the euro area

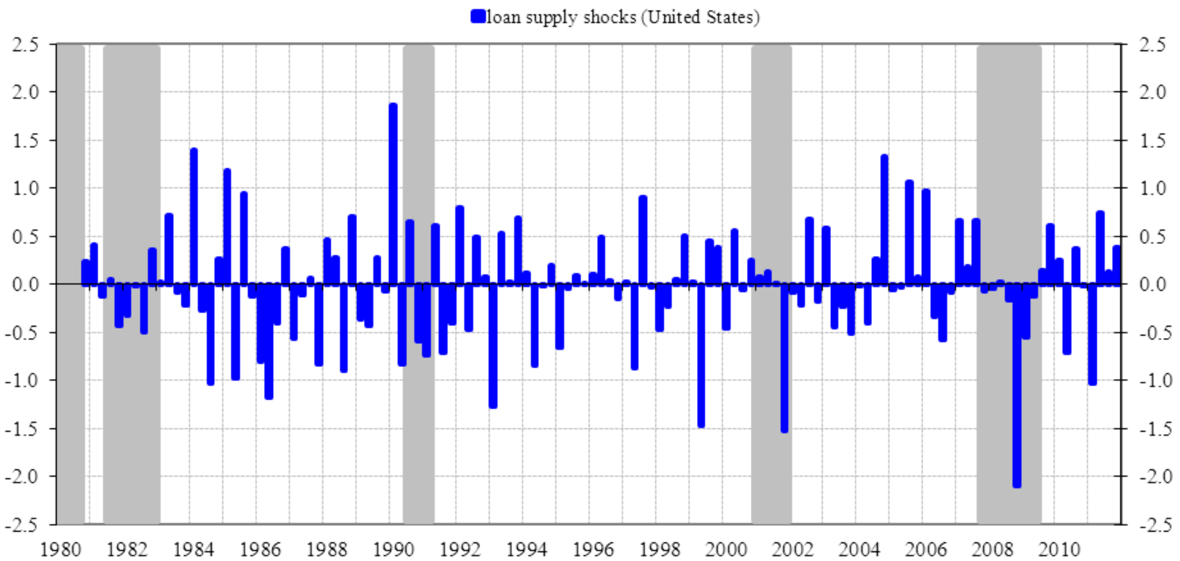


Note: Impulse response functions averages in specific recessions and subsequent recoveries as defined in first column in the Euro Area. Line is the median, grey area delimits the space between the 16% and 84% percentiles. Recessions as identified by the CEPR, recoveries as first four quarters after troughs.

Chart 8 – Series of structural loan supply shocks







Note: Shaded areas delimit recession periods, as identified by the CEPR for the Euro Area, by the Bank of England for the United Kingdom and by the NBER for the United States.