"[...] extremely important outstanding questions for research. One is the [...] role of the credit channel in our understanding of economic fluctuations and monetary policy. The literature in this area remains thin, and this thinness reflects difficulty in specifying the relevant mechanisms and finding the supporting empirical evidence."

Boivin, Kiley and Mishkin, 2011, Handbook of Monetary Economics

1 Introduction

The events of the last few years suggest that the financial sector – the banking sector in particular – is a crucial determinant of business cycle fluctuations. The worst financial crisis in Europe and in the U.S. since the Great Depression was followed by a severe recession. Credit provided by banks is key to fund investment and consumption. During periods of crisis, a credit reduction may be the result of weaker demand, lower net worth of firms and households and, possibly, tighter credit supply due to banks' solvency and liquidity problems. In these circumstances, central banks support aggregate demand and credit provision through monetary policy. Identifying and quantifying the linkages between monetary policy, credit channels and business cycles is therefore of utmost importance.

The main objective of this paper is to test the credit channel of monetary policy (see Bernanke and Gertler, 1987 and 1995; and Bernanke, 2007 for the definitions of credit channel and subchannels). We address the following three questions: (i) Does monetary policy affect GDP and inflation through the credit channel? (ii) How important are the different transmission channels – the non-financial borrower balance-sheet, the bank lending and the credit demand channels? (iii) Does the relative importance of these channels depend on whether the borrowers are households or firms?

The credit channel theory implies that monetary policy has real effects through credit supply and demand. A tightening of monetary policy reduces loan supply by increasing the external financing cost for banks (bank lending channel). At the same time, loan demand declines due to the higher external finance premia faced by non-financial borrowers (firm and household balance-sheet channel) and to the higher direct cost of loans (classical interest rate channel). Since changes of credit supply and demand are mostly unobserved, the *complete* identification of the credit channel and its subchannels is challenging. The academic literature using both macro and micro data has not yet addressed this fundamental identification challenge in a satisfactory manner.

From a macro perspective, credit aggregates do not convey enough information to identify supply (Bernanke and Gertler, 1995): If the average borrower's quality did not change, average credit quantities and prices would suffice to isolate demand and supply; however,

after a monetary tightening, a *flight to quality* of banks to borrowers of better quality occurs (Bernanke, Gertler and Gilchrist, 1996).[1]

Given these limitations, the literature has tried to improve identification using micro data, by testing the cross-sectional predictions from theory (see Bernanke and Gertler, 1995). However, the micro approach cannot fully identify the credit channel. As pointed out by Kashyap and Stein (2000), the micro identification cannot analyze the *total* effect of a monetary policy shock on real activity, but only a *difference-in-difference* effect by comparing banks (see e.g. Kashyap and Stein, 2000) or non-financial borrowers (see e.g. Gertler and Gilchrist, 1994) with different sensitivity to monetary policy. Moreover, financially constrained borrowers may obtain credit from constrained banks, thus making the firm balance-sheet channel difficult to disentangle from the bank lending channel (Gertler and Gilchrist, 1994). Furthermore, analyses based on micro data use actual credit granted and thus are forced to make restrictive assumptions on credit demand.[2] Kashyap and Stein (2000), for instance, assume that banks with different liquidity levels face similar changes in loan demand as a response to a monetary policy shock.

In this paper, we tackle the problem of unobserved credit channels by using the detailed answers of the confidential and unique Bank Lending Survey (BLS) for the Euro area and of the Senior Loan Officer Survey (SLOS) for the U.S. Euro area national central banks and regional Feds request from banks quarterly information on the lending standards that banks apply and on the loan demand that banks receive from firms and households. The information refers to the actual lending standards that banks apply to the whole pool of borrowers (not only to accepted loans). The detailed information reported in the surveys is very reliable, not least because the surveys are carried out by central banks, which are in most cases the bank supervisors and can cross-check the information received with exhaustive hard bank information.[3]

The data – especially the BLS – contain information on the *factors* affecting banks' lending standard decisions. These factors include (i) the bank lending channel effect –

[1] For the effects of business cycles on credit composition, see Matsuyama (2007). Note also that after a monetary tightening bank loan demand may increase to finance working capital and inventories, due to a limited access to market finance (Bernanke and Gertler, 1995; Friedman and Kuttner, 1993).

[2] An exception is Jiménez, Ongena, Peydró and Saurina (2012) who use loan applications; however, their objective is only to identify the bank lending (supply) channel.

[3] See Del Giovane, Eramo, and Nobili (2010) for an example of publicly available crosschecking of the bank lending survey data using detailed supervisory data on bank lending from Italy. They find robust evidence at the bank level that changes in lending standards from the survey are reflected in actual changes in lending conditions to firms (with a quarter lag). It should be noted also that the lending standards from the surveys are not only correlated with actual credit spreads and volume [see Maddaloni and Peydró (2011)] but are also good predictors of credit and output growth [see Lown and Morgan (2006) for the U.S. evidence, and De Bondt, Maddaloni, Peydró and Scopel (2010) for the Euro area].

related to bank balance-sheet capacity – and (ii) the quality of loan applicants – related to the net worth and risk of firms and households.[4] This detailed information is therefore crucial to assess the transmission of a monetary policy shock on real activity through the different channels – the (supply) bank lending, the non-financial borrower balance-sheet, and the credit demand channel.

Since lending standards and loan demand may react to – but also influence – business cycle fluctuations, we embed the rich information from the lending surveys into an otherwise standard vector autoregressive (VAR) model to account for the linkages between the credit and the business cycle. The VAR is estimated over the sample 1992:Q3–2013:Q1 for the U.S., and over the sample 2002:Q4–2013:Q1 for a balanced panel of 12 Euro area countries. For the identification strategy of monetary policy shocks, we follow Christiano, Eichenbaum and Evans (1999) and Angeloni, Kashyap and Mojon (2003), and use the overnight rate as the monetary policy instrument. The overnight rate in the Euro area is a sensible measure of monetary policy, also during the crisis period when credit enhancement actions were introduced (see ECB, 2009, and Lenza et al. 2010). For the sake of symmetry, we consider the federal funds rate as the measure of monetary policy for the U.S. during the whole period, although the Federal Reserve implemented a wider set of actions during the crisis. The main results of the paper are nevertheless robust to a shorter sample, ending before the introduction of unconventional monetary policy measures.

Monetary policy is effective. A monetary policy shock affects significantly GDP growth and inflation through credit channels and demand for loans. Results are significant for all types of loans, with differences in the size and timing of the impact across borrowers and economic regions.

We quantify the importance of the channels by analyzing the different impacts through appropriately designed counterfactuals. Overall, the credit channel is important both in the Euro area and in the U.S. In the former, for business loans, the amplification of monetary policy shocks is higher via the bank lending and balance-sheet channels than via the demand. Credit demand is the most important channel for mortgage loans. In the U.S., results suggest that the bank lending channel is not significant and a monetary policy shock is transmitted to real activity mainly through the firm balance-sheet channel, especially through the small firms.

[4]The information contained in the Euro area BLS is *unique* in different dimensions. Compared to the SLOS, it contains more comprehensive information on the factors affecting banks' decisions to change their lending standards, which is crucial to identify bank lending, firm and household balance sheet channels. Lending standards and loan demand are also significantly less correlated in the Euro area than in U.S. Finally, in the Euro area banks are the main providers of funds to the private sector, in contrast to the U.S., where markets and other financial intermediaries have a more important role (Allen et al., 2004).

Our paper makes a key contribution to the literature on monetary policy transmission. We disentangle the effects of monetary policy through the credit channels in a novel and direct way, by using unique data on the lending conditions applied by banks, and the loan demand from firms and households. Most importantly, we use the reasons behind banks' decisions to change lending conditions (changes in the net worth of borrowers or of banks).[5] This strategy allows to identify the impact of a monetary policy shock on aggregate output and prices through the different channels of transmission – bank lending, the non-financial borrower balance-sheet and credit demand channels (Bernanke and Blinder, 1992; Bernanke and Gertler, 1995; Diamond and Rajan, 2006; Gertler and Kiyotaki, 2010, Boivin, Kiley and Mishkin, 2010; Adrian and Shin, 2010). Following up on Den Haan et al. (2007), we also show the differential effects of monetary policy shocks on the credit channels for business, mortgage and consumer loans. Finally, our results shed light on theories linking monetary policy, business cycles and the financial sector, and have important policy implications for central banks and governments. In fact, BLS variables can be used to identify credit demand and supply shocks in a framework similar to the one used here and, therefore, help contributing to the literature that explains the recent crisis and the effects of credit shocks on real activity (Diamond and Rajan, 2012; Gertler and Karadi, 2011).

The rest of the paper is structured as follows. Section 2 describes the data and reviews the empirical identification. Section 3 presents and discusses the results. Section 4 summarizes the quantitative findings and discusses the research and policy implications.

2 Data and model

The main testable prediction of the credit channel is that a contractive monetary policy shock reduces aggregate output and prices through a reduction of loan supply (bank lending channel) and a tightening of lending standards due to lower net worth of non-financial borrowers (firm and household balance-sheet channel).[6] The main challenges are to disentangle

[5] Other studies have used the data from bank lending surveys to investigate the role of bank credit for output. In particular, Lown and Morgan (2006) use the answers from the SLOS to analyze the predictive power of lending standards for U.S. GDP. While they show that the survey contains valuable information on credit developments, they don't find a role for credit standards in transmitting monetary policy impulses. Our work differs from their analysis in aim and scope. They use the whole available sample for lending standards, which spans several decades, while we start the analysis only in the 90s, since questions on loan demand and on the reasons affecting changes in lending standards were included in the survey only at that time.

[6] See Bernanke and Gertler (1995). Holmstrom and Tirole (1997), Stein (1998 and 2010), and Diamond and Rajan (2006) show that bank loan supply is shaped by the frictions stemming from the agency costs of borrowing: between banks and their borrowers (firms and households), and between banks and their providers of funds (retail and wholesale depositors, and equity-holders). Monetary policy influences the severity of these frictions by changing the net worth (and external finance premia) of non-financial and financial borrowers,

credit demand from supply, and to identify the different balance-sheet channels.

In this section we explain our empirical strategy, focusing mainly on the data that are crucial to address the identification challenges. In particular, Section 2.1 summarizes the Euro area and the U.S. surveys; Section 2.2 describes the credit and macroeconomic variables; Section 2.3 illustrates the empirical model.

2.1 The surveys

2.1.1 The Euro area Bank Lending Survey

The national central banks of the Eurosystem request a representative sample of banks in each country to provide quarterly information on the lending standards that banks apply to customers and on the loan demand that banks receive. The survey contains 18 specific questions on past and expected (bank) credit market developments. Banks are asked about lending standards applied and loan demand received over the previous three months, and on the expectations of the same figures over the following quarter. The survey focuses on two borrowing sectors, firms and households. Loans to households are further disentangled in loans for house purchase and for consumer credit (Berg et al., 2005, describe in detail the setup of the survey)

The questions imply only qualitative answers and no figures are required. The questionnaire is sent to senior loan officers, such as the chairperson of the bank's credit committee. The analysis reported in this paper is based on the aggregate answers at the country level received from a sample of around 90 banks, which comprises banks of different size.[7] The response rate has been virtually 100%. The regular questions have been kept fixed throughout the sample while a number of ad-hoc questions were added at times to shed light on specific issues. We do not use the answers to the ad-hoc questions, since they are available only for few quarters.

Survey results for the Euro area (a weighted average of the results obtained for each Euro area country) are published every quarter on the website of the ECB.[8] In very few

thus affecting credit demand and supply and, in turn, aggregate output and prices (Bernanke and Blinder, 1988; Bernanke and Gertler, 1989; Kiyotaki and Moore, 1997, 2008; Bernanke, Gertler, Gilchrist, 1999; Adrian and Shin, 2009; Stiglitz and Greenwald, 2003; and Stiglitz and Weiss, 1981). In this paper bank lending channel, bank balance-sheet channel and (bank) credit supply channel are synonimous (see Bernanke, 2007).

[7] At the start, there were 87 banks answering the survey. In 2008, the sample was enlarged for Italy and Germany, and with the inclusion of Cyprus, Malta and Solvenia joining the Euro area, the number of banks became 112.

[8] See http://www.ecb.europa.eu/stats/money/surveys/lend/html/index.en.html. The survey results are published at the beginning of a quarter and they report the responses of the survey taken at the end of the previous quarter.

countries, the aggregate answers of the domestic samples are published by the respective national central banks. However, the overall sample including all the answers at the country and bank level is confidential.

The questionnaire covers both demand and supply of bank loans. Two questions relate to loan demand: the first concerns changes in loan demand received from each type of borrowers (firm or household); the second, the factors affecting loan demand (investment needs, limited access to other sources of finance etc.).

Concerning loan supply, addressed in ten different questions, consideration is given to *whether*, *why* and *how* banks change lending standards for each type of borrower, being firms or households.[9] First, banks are asked *whether* they have changed lending standards over the previous quarter and what they expect for the following quarter.[10] Next, the survey asks *why* banks have modified the standards. In particular, the questions ask about the impact that changes in bank balance-sheet capacity, competitive pressures, and borrowers' creditworthiness and net worth have had on the decision to change lending standards. Finally, the third set of questions relates to *how* banks have changed terms and conditions for the loans, e.g. via changes in loan spread, size, collateral requirements, maturity and covenants.

For the purpose of this study, we concentrate only on few questions from the BLS that we describe in detail in the Appendix. In particular, we use the answers related to *whether* and *why* lending standards have changed to identify **credit channel variables** (as in Bernanke and Gertler 1995), while the answers related to the change in loan demand are **credit demand variables**. We also use information on lending conditions applied by banks to small and large firms. Moreover, since the U.S. survey does not include expected changes in lending standards, for the sake of comparability, we concentrate only on variations in lending standards occurred over the previous quarter.

To use a balanced panel, we restrict the analysis to the 12 countries which comprised the Euro area at the inception of the survey (2002:Q4). The answers cover the period from 2002:Q4 to 2013:Q1. Over this period we consistently have quarterly data for 12 Euro area countries (Austria, Belgium, France, Finland, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, and Spain).

2.1.2 The U.S. Senior Loan Officer Survey

The Federal Reserve publishes every quarter the results of a survey on bank lending standards, the Senior Loan Officer Opinion Survey on Bank Lending Practices (SLOS). The

[9] Lending standards are the internal guidelines or criteria for a bank's loan policy (see Loan and Morgan, 2006, and Freixas and Rochet, 2008).

[10] In cases where foreign banks are part of the sample, the credit standards refer to the loans' policy in the domestic market which may differ from guidelines established for the headquarter bank.

Survey covers both business and household loans, and focuses on availability and demand for bank loans. The focus is on past developments, without regular questions on expectations.

The current sample is composed of around 60 banks, usually the largest in each of the 12 Federal Reserve Districts. The Survey is conducted by the regional Fed involved. The response rate is virtually 100%. More information on the setup of the survey can be found in Lown and Morgan (2006).[11] Similarly to the Euro area BLS, for business (C&I) loans the SLOS asks about the changes in lending standards and the factors that have determined these decisions. These factors are broadly related to bank balance-sheet positions, bank competition factors, and borrower risk/outlook. Unfortunately, and differently from the BLS, the SLOS information on factors is not available for mortgage and consumer loans. In addition, some of the factors affecting lending standards were added only in recent years, which further constrains the available time series.

The survey was introduced for the first time in 1967. Since then the questions and frequency of the survey have changed several times. Therefore, the time series that can be used for a consistent econometric analysis exploiting the full information of the survey is considerably shorter. Since the first years of the 1990s the survey is carried out four times per year; it includes questions on credit standards and demand for bank credit, as well as different answers for small and large firms. Based on these observations and on the data available, we start the U.S. analysis in 1991:Q3. We use for our benchmark analysis the answers related to large enterprises, and we report results based on lending conditions for small firms in the section on heterogeneity. For the purpose of this paper we concentrate only on few questions from the SLOS that are described in detail in the Appendix.

2.2 The variables

2.2.1 Credit channel variables

We use the answers from the bank lending surveys as a proxy for the credit channel variables. We *trust the bankers* and interpret their assessment as truthfully reflecting conditions in the bank credit markets.

That lending surveys are carried out by the central banks – often supervisory authorities with very detailed data to cross-check information – contributes to the reliability of the information received and to the overall credibility of the survey. For example, Del Giovane, Eramo and Nobili (2010) show the consistency at the bank level between the BLS answers and detailed credit data using supervisory information from Italy. They find that the answers from the survey are reliable indicators of actual developments in bank loans, and that changes

[11] The results of the survey are available at http://www.federalreserve.gov/boarddocs/SnLoanSurvey.

in BLS variables are translated into changes in actual lending standards in around one quarter.

Credit demand is the answer related to changes in the loan demand that banks receive from firms and households (questions Q4 and Q13 of the BLS; Q4, Q14 and Q26 of the SLOS). The answers related to the changes in lending standards that banks apply to customers define the *broad credit channel* variable (questions Q1 and Q8 of the BLS; Q1, Q13 and Q20 of the SLOS). We use the factors affecting banks' decisions to change lending standards to disentangle the broad credit channel variable into (i) *bank lending channel variable* (factors related to bank balance sheet strength and competition pressures – factors A and B in questions Q2, Q9 and Q11 of the BLS; factor A in Q3 of the SLOS) and (ii) *borrower's balance sheet channel variable* (factors related to the quality of loan applicants such as outlook, net worth and risk of borrowers – factor C in questions Q2,Q9 and Q11 of the BLS; factors B and C in Q3 of the SLOS, for firms). Bank lending channel variables and borrower's balance sheet variables are available for all type of loans in the Euro area survey but only for business loans in the U.S. survey.[12]

The questions asked in the BLS and in the SLOS allow for five possible replies. The answers range from "eased considerably" to "tightened considerably" for the questions related to changes in lending standards, and from "decreased considerably" to "increased considerably" for the questions related to the demand for loans. We follow Lown and Morgan (2006) and quantify the different answers by using *net percentages*.[13]

The proxy for the broad credit channel variable is the difference between the percentage of banks reporting a tightening of lending standards and the percentage of banks reporting a softening of standards in each country and for each quarter. The net percentage of banks that have changed standards due to factors linked to bank balance sheet capacity and competition defines the bank lending channel variable. The net percentage of banks that have changed standards due to factors linked to firm (household) balance-sheet strength defines borrower's balance sheet channel variables. In all cases a *positive value* implies that there is a *net tightening* of lending standards and therefore a restriction of the terms and conditions for loans. For changes in credit demand, the net percentage is the difference between the percentage of banks reporting an increase in the demand for loans and the percentage of banks reporting a decrease. In this case, a *positive figure* indicates a *net increase* in demand for loans.

[12] See Appendix for the detailed questions in both surveys.

[13] The use of these statistics implies that no distinction is made for the degree of tightening (easing) of lending standards and, similarly, for the degree of decrease (increase) of demand. This issue can be addressed for example by using diffusion indexes. Results of the analysis carried out using diffusion indexes do not differ qualitatively from those obtained with net percentages.

Figure 1 plots the Euro area aggregate and the U.S. figures for the credit demand, the broad credit channel variable, the bank lending and the borrower's balance sheet channel variables. Credit channel variables and demand for loans are not highly correlated. The correlations between credit demand and the bank lending and borrowers' balance sheet channel variables is around 40-45% in the Euro area for all loan categories, and around 50-70% for business loans and 20-25% for households in the U.S.

2.2.2 Macroeconomic variables

We include in the analysis three macroeconomic variables: aggregate output, prices and the monetary policy rate. Output is proxied by the log of real GDP an d prices are proxied by the log level of the GDP deflator for each Euro area country and for the U.S. The monetary policy interest rate is the overnight money market rate, EONIA for the Euro area and the effective federal funds rate for the U.S. In the U.S. the fed funds rate has been extensively used as an indicator of the stance of monetary policy (see e.g. Bernanke and Blinder, 1992; and Christiano, Eichenbaum and Evans, 1999; Bernanke and Mihov, 1997). In the Euro area, the Governing Council of the ECB decides the interest rate on the main refinancing operations (MRO) which is directly linked to the EONIA (see also Angeloni, Kashyap and Mojon, 2003).

In response to the financial crisis, in October 2008 the ECB eased the monetary policy stance by reducing the policy rate and introducing several measures of credit enhancement. These measures allow the Eurosystem to lend to banks through fixed-rate full-allotment liquidity auctions . The implementation of these policies brought the EONIA significantly below the MRO (Trichet, 2009; ECB, 2009; Lenza et al. 2010). In 2010-2012 the ECB engaged in additional non-standard monetary policy measures aimed at supporting a smooth monetary policy transmission by enhancing the balance sheet capacity of banks – mainly long-term liquidity provisions. We do not explicitly include these measures in our model, partly because of difficulties in the evaluation of these different programs. It should be noted, however, that the impact of these measures is reflected in the level of EONIA. Therefore, we believe that the EONIA rate is still the sensible measure of monetary policy even during the crisis time.[14] For the sake of consistency, we consider the federal funds rate as the measure of monetary policy for the U.S. However, the actions taken by the Fed during the crisis were directed towards several markets (Bernanke, 2009, and ECB, 2009), and therefore the

[14] As a robustness check, in non-reported analyses we have also used the 3-month Euribor rate and the overnight interest swap rate on EONIA (OIS). These measures carry additional information compared with the overnight rates and, therefore, the results obtained may be more difficult to interpret. The 3-month Euribor also reflects a component of bank credit risk. The OIS rate is a proxy of expectations of monetary policy, but it may also be affected by liquidity in the swap market.

overnight rates may not be a comprehensive measure of monetary policy stance during the crisis. Nonetheless, the main results of the paper are robust to a shorter sample, ending in 2008:Q3 – the time of Lehman Brothers' failure and the introduction of unconventional measures of monetary policy.

2.3 Empirical methodology

We process the credit and macro variables with a VAR model:

$$Y_t = C + A(L) Y_{t-1} + \varepsilon_t \tag{1}$$

where $t = 1, .., T$ denotes time, Y_t is an m–dimensional vector of endogenous variables, $A(L)$ is a matrix polynomial of order p in the lag operator L, and ε_t is a vector of white noise residuals.

2.3.1 US model

For the U.S. the available time series cover twenty years of quarterly observations (1992:3-2013:1) and the model is estimated with standard Bayesian techniques. Let us write (1) as a multivariate linear regression model:

$$\mathbf{Y} = \mathbf{XB} + \mathbf{E} \tag{2}$$

$$\mathbf{y} = (\mathbf{I}_m \otimes \mathbf{X}) \beta + \varepsilon \tag{3}$$

$$\varepsilon \sim N(0, \Sigma \otimes \mathbf{I}_T) \tag{4}$$

where $\mathbf{Y}$ is the matrix of endogenous variables with dimensions $T \times m$; $\mathbf{X}$ is the matrix of lagged endogenous variables with dimensions $T \times k$; k is the number of parameters in each equation, i.e. $k = m \cdot p + 1$, where p is the number of lags; $\mathbf{B}$ is the matrix of parameters of dimensions $k \times m$ (the columns are the parameters associated with each equation); $\mathbf{E}$ is the matrix of error terms of dimensions $T \times m$; $\mathbf{y} \equiv vec(\mathbf{Y})$ is the column vectorization of $\mathbf{Y}$, with dimensions $mT \times 1$; $\beta \equiv vec(\mathbf{B})$ is the column vectorization of $\mathbf{B}$, with dimensions $mk \times 1$; $\boldsymbol{\varepsilon} \equiv vec(\mathbf{E})$ is the column vectorization of $\mathbf{E}$, with dimensions $mT \times 1$; Σ is the variance-covariance matrix of dimension $m \times m$; $\mathbf{I}_T$ is an identity matrix with dimensions $T \times T$; $\mathbf{I}_m$ is an identity matrix of dimensions $m \times m$.

The model for US is estimated with an informative prior given by the ML estimation of the same model based on the (aggregate) euro area data. Specifically, given the likelihood

function

$$\ell\left(B,\Sigma \mid \mathbf{Y}\right) \propto |\Sigma|^{-\frac{k}{2}} \exp\left\{-\frac{1}{2}\left(\beta-\hat{\beta}\right)'\left(\Sigma^{-1}\otimes \mathbf{X}'\mathbf{X}\right)\left(\beta-\hat{\beta}\right)\right\} \times |\Sigma|^{-\frac{m-k}{2}} \exp\left\{-\frac{1}{2} tr\left[\left(\mathbf{Y}-\mathbf{X}\hat{\mathbf{B}}\right)'\left(\mathbf{Y}-\mathbf{X}\hat{\mathbf{B}}\right)\Sigma^{-1}\right]\right\}$$

where

$$\hat{\mathbf{B}} = \left(\mathbf{X}'\mathbf{X}\right)^{-1}\mathbf{X}'\mathbf{Y} \qquad \hat{\beta} \equiv vec\left(\hat{\mathbf{B}}\right),$$

and a conjugate prior for the parameters:

$$\begin{aligned} p\left(\beta \mid \Sigma\right) &= N\left(vec\left(\bar{\mathbf{B}}\right), \Sigma\otimes\bar{\Omega}\right) \\ p\left(\Sigma\right) &= iW\left(\bar{\Sigma},\alpha\right), \end{aligned}$$

where $iW\left(\bar{\Sigma},\alpha\right)$ denotes an inverse-Wishart with α degrees of freedom and scale matrix $\bar{\Sigma}$.

It can be shown (Kadiyala and Karlsson, 1995) that the posterior distribution is given by

$$p\left(\beta,\Sigma \mid Y\right) = p\left(\beta \mid \Sigma, Y\right) p\left(\Sigma \mid Y\right)$$

where

$$p\left(\beta \mid \Sigma, Y\right) = N\left(\tilde{\beta}, \Sigma\otimes\tilde{\Omega}\right) \tag{5}$$

$$p\left(\Sigma \mid Y\right) = iW\left(\tilde{\Sigma}, T+\alpha\right) \tag{6}$$

and

$$\begin{aligned} \tilde{\Omega} &= \left(\bar{\Omega}^{-1}+\mathbf{X}'\mathbf{X}\right)^{-1}, \qquad \tilde{\mathbf{B}} = \tilde{\Omega}\left(\bar{\Omega}^{-1}\bar{\mathbf{B}}+\mathbf{X}'\mathbf{X}\hat{\mathbf{B}}\right) \\ \tilde{\Sigma} &= \hat{\mathbf{B}}'\mathbf{X}'\mathbf{X}\hat{\mathbf{B}}+\bar{\mathbf{B}}'\bar{\Omega}^{-1}\bar{\mathbf{B}}+\bar{\Sigma}+\left(\mathbf{Y}-\mathbf{X}\hat{\mathbf{B}}\right)'\left(\mathbf{Y}-\mathbf{X}\hat{\mathbf{B}}\right)-\tilde{\mathbf{B}}'\left(\bar{\Omega}^{-1}+\mathbf{X}'\mathbf{X}\right)\tilde{\mathbf{B}} \end{aligned}$$

For the hyperparameters we take $\bar{\beta}=\hat{\beta}^{ML}_{EA}$, $\bar{\Sigma}=\hat{\Sigma}^{ML}_{EA}$, $\bar{\Omega}=\left(\mathbf{X}'\mathbf{X}\right)^{-1}_{EA}$, and assume $\alpha=50$.[15] For inference, samples for β and Σ are obtained by first drawing Σ from (6) and then, conditional on this value, by drawing β from (5).

[15] The reason for a relatively tight informative prior for the US model is to ensure a more direct comparison with the results based on the Euro area model. While US data contain about 90 observations, the euro area model is estimated on a panel which contains about 470 observations which ensure a relateively more precise characterization of the posterior distributions of the parameters of interest.

2.3.2 Euro area model

For the Euro area, as the sample is shorter (2002:4-2013:1), we estimate a panel VAR on a data set of the 12 countries comprising the Euro area in 2002, with heterogeneity in the constant and the slope and a Bayesian hierarchical prior of the type described in Canova and Ciccarelli (2013) and Jarocinski (2010). More specifically, for each country i the model is a country-specific version of (2), i.e.

$$\mathbf{Y}_i = \mathbf{X}_i\mathbf{B}_i + \mathbf{E}_i \tag{7}$$

We assume that all parameters (including the variance-covariance matrix) are country-specific. The prior is specified as follows:

$$\begin{aligned} \beta_i &\equiv vec\left(\mathbf{B}_i\right) = \bar{\beta} + \eta_i \\ \eta_i &\sim N\left(0, \tau^2\omega_i\Delta\right) \\ p\left(\Sigma_i\right) &\propto \left|\Sigma_i\right|^{-\frac{(m+1)}{2}} \\ \tau^2 &\sim \mathcal{IG}\left(\nu_0/2, \delta_0/2\right) \end{aligned}$$

where $\mathcal{IG}\left(\alpha, \beta\right)$ denotes an inverse-gamma with shape α and scale β; ω_i is the inverse of the euro area country weights for each country i, and Δ, ν_0 and δ_0 are known hyperparameters. We assume a non-informative prior for $\bar{\beta}$ (i.e. $p\left(\bar{\beta}\right) \propto 1$) and independence throughout, i.e. $p\left(\beta_i, \bar{\beta}, \Sigma_i, \tau^2\right) = p\left(\beta_i\right) p\left(\bar{\beta}\right) p\left(\Sigma_i\right) p\left(\tau^2\right)$.

This framework is very convenient to pool diverse information from all countries, while appropriately accounting for the common monetary policy and some degree of cross-country heterogeneity in the business and credit cycles. The prior for β_i introduce heterogeneity in a parsimonious way: it is assumed that country VARs have heterogeneous parameters which shrink towards a common mean. This is a convenient assumption commonly used in the literature of hierarchical Bayesian models (Canova and Ciccarelli, 2013 and reference therein). The variance of β_i depends on three elements: (i) The parameter τ determines the general degree of heterogeneity: if $\tau = 0$ country VARs have a common slope; (ii) The weight ω_i ensures that the parameters of the members states with the largest share in the euro area have a smaller variance and hence determine the common mean $\bar{\beta}$; and (iii) the fix matrix Δ accounts for the cross-variable interactions.

Given the likelihood, which is proportional to

$$p\left(Y \mid \beta_i, \bar{\beta}, \Sigma_i, \tau^2\right) \propto$$
$$\prod_i |\Sigma_i|^{-T/2} \exp\left\{-\frac{1}{2} tr \sum_i \left(\mathbf{Y}_i - \mathbf{X}_i\mathbf{B}_i\right)\left(\mathbf{Y}_i - \mathbf{X}_i\mathbf{B}_i\right)' \Sigma_i^{-1}\right\},$$

the joint posterior distribution of the parameters is given by

$$p\left(\beta_i, \bar{\beta}, \Sigma_i, \tau^2 \mid Y\right) \propto p\left(\beta_i, \bar{\beta}, \Sigma_i, \tau^2\right) \cdot p\left(Y \mid \beta_i, \bar{\beta}, \Sigma_i, \tau^2\right)$$

and is proportional to

$$\prod_i |\Sigma_i|^{-T/2} \exp\left\{-\frac{1}{2} \sum_i \left[\mathbf{y}_i - \left(\mathbf{I}_m \otimes \mathbf{X}_i\right)\beta_i\right]' \left(\Sigma_i^{-1} \otimes I_T\right)\left[\mathbf{y}_i - \left(\mathbf{I}_m \otimes \mathbf{X}_i\right)\beta_i\right]\right\}$$
$$\times \prod_i \left|\tau^2 \omega_i \Delta\right|^{-k/2} \exp\left\{-\frac{1}{2} \sum_i \left(\beta_i - \bar{\beta}\right)' \left(\tau^2 \omega_i \Delta\right)^{-1} \left(\beta_i - \bar{\beta}\right)\right\}$$
$$\times \left(\tau^2\right)^{-(\nu_0/2+1)} \exp\left\{-\frac{1}{2}\frac{\delta_0}{\tau^2}\right\}$$
$$\times \prod_i |\Sigma_i|^{-(m+1)/2}$$

Full conditional distributions for a Gibbs sampling algorithm can be easily derived from the joint posterior (se e.g. Jarocinsky, 2010):

$$\begin{aligned} p\left(\beta_i \mid Y, \bar{\beta}, \Sigma_i, \tau^2\right) &= N\left(\tilde{\beta}_i, \tilde{\Delta}_i\right) \\ \tilde{\Delta}_i &= \left(\Sigma_i^{-1} \otimes \mathbf{X}_i'\mathbf{X}_i + \left(\tau^2 \omega_i \Delta\right)^{-1}\right)^{-1} \\ \tilde{\beta}_i &= \tilde{\Delta}_i \left(\left(\Sigma_i^{-1} \otimes \mathbf{X}_i'\right)\mathbf{y}_i + \left(\tau^2 \omega_i \Delta\right)^{-1} \bar{\beta}\right) \end{aligned} \tag{8}$$

$$\begin{aligned} p\left(\bar{\beta} \mid Y, \beta_i, \Sigma_i, \tau^2\right) &= N\left(b, G\right) \\ G &= \left[\sum_i \left(\tau^2 \omega_i \Delta\right)^{-1}\right]^{-1} \\ b &= G\left(\sum_i \left(\tau^2 \omega_i \Delta\right)^{-1} \beta_i\right) \end{aligned} \tag{9}$$

$$p\left(\Sigma_i \mid Y, \beta_i, \bar{\beta}, \tau^2\right) = iW\left[\left(\mathbf{Y}_i - \mathbf{X}_i\mathbf{B}_i\right)'\left(\mathbf{Y}_i - \mathbf{X}_i\mathbf{B}_i\right), T\right] \tag{10}$$

$$p\left(\tau^2 \mid Y, \beta_i, \bar{\beta}, \Sigma_i\right) = \mathcal{IG}\left(\frac{Nmk + \nu_0}{2}, \frac{\sum_i \left(\beta_i - \bar{\beta}\right)' \left(\omega_i \Delta\right)^{-1} \left(\beta_i - \bar{\beta}\right) + \delta_0}{2}\right) \tag{11}$$

For the inference, samples of the parameters are obtained by cycling from (8) through (11). The results we present are based on 15000 draws of the Gibbs sampling discarding the first 5000 to reduce dependence from the initial conditions. For the hyperparameters we assume a Minnesota structure for Δ with standard parameters determining the tightness (between 0.2 and 0.5) and the lag decay (equal to 1), and take $\nu_0 = 0.0$, and $\delta_0 = 0.0$, i.e. an uninformative degree of prior heterogeneity.[16]

2.3.3 Specification and identification

The vector Y_t in (1) is composed of three sets of variables, as in Christiano, Eichenbaum and Evans (1999): the macroeconomic variables (log levels of GDP and prices), the credit variables (given by the BLS and the SLOS) and the monetary policy rate. Standard AIC and BIC criteria would suggest only one lag for both models. We use instead 2 lags to better capture the macroeconomic dynamics.

We use two specifications related to the transmission channels that we want to analyze. In particular, we consider the following models:

- Model 1 (Broad credit channel) includes demand and broad credit channel variables for *business, mortgages and consumer loans.*
- Model 2 (Bank, firm and household balance-sheet channels) includes demand, bank-lending channel and borrower's balance-sheet channel variables for *business, mortgages and consumer loans.*

We also analyze an alternative specification of Model 1 and 2 where we consider only loans to firms, for the sake of comparability with the previous literature (see Bernanke and Gertler, 1995), and also since the SLOS contains information on the factors affecting lending standards only for business loans. It should be noted, however, that business loans are only a fraction of bank loans (51% in Euro area and around 30% in the U.S.) and, as already pointed out by Bernanke et al. (1996), the credit channel may be more relevant for loans to households than to firms. In addition, Den Haan et al. (2007) point out the importance of the whole portfolio of bank loans when analyzing a monetary tightening. The volume of

[16] Robustness checks have been carried out to consider alternative set ups. In particular, in a not-for-publication appendix (available upon request) we report results based on (i) a shorter sample that excludes the financial crisis; (ii) a diffuse prior for the US data, and (iii) an aggregate model of the Eurozone. Our findings are overall robust – with different degree of precision – to sample, different prior assumptions and data aggregation.

loans granted to different borrowers (business, mortgages and consumer loans) may react differently to an interest rate shock due to the strategic decision of banks to reallocate their loan portfolio.

For the identification of the monetary policy shock, we assume that policy makers observe current output, prices and the results of the bank lending surveys when deciding the policy rate. Therefore, all these variables do not change at time t in response to a time t policy shock, and the policy rate is ordered after the macro and the credit variables. This ordering partly differs from what typically assumed in the previous literature, as for instance in Christiano, Eichenbaum and Evans (1999), where the credit variables follow the monetary policy rate. Our choice is motivated by the fact that policy makers, in particular in the Euro area, take interest rate decisions based on a strategy that explicitly takes into account developments in credit markets. For instance, as part of the monetary analysis assessment (the so-called *second pillar* of the monetary policy strategy), the ECB policy makers monitors closely the developments in the BLS. Loan demand and lending standards referring to different borrowers are included in the VAR following an order that broadly reflects the importance of the different loan markets in the Euro area, i.e. business loans come first, then mortgage loans and finally consumer loans. Nevertheless, we conduct several robustness checks using different ordering of variables in Y_t, and the results obtained are robust to the different specifications because the correlation matrices of the reduced-form residuals indicate that correlations across innovations (in particular between the policy rate and the credit variables as well as among credit variables) are relatively small, implying that the impulse response functions are broadly invariant to a reordering of the variables (see for this Ciccarelli et al, 2013).

For the transmission of a monetary policy shock to the macroeconomy through the credit channel, we use the changes in the answers related to the demand for loans to analyze the credit demand channel, and the changes in lending standards to analyze the broad credit channel. Similarly, we use changes of lending standards due to changes in bank balance-sheet strength and competition to analyze the bank-lending channel, and changes of lending standards due to changes in firm/household balance-sheet strength to analyze the firm/household balance-sheet channel.

3 Results

We present the results in four main subsections. First, we analyze the full dynamics of the credit channel. Second, we focus on its sub-channels, both the bank lending and the firm and household balance-sheet channels. Third, we interpret the results discussing also the

differences between the Euro area and U.S. Finally, we discuss some additional analysis of the impact of heterogeneity of borrowers and lenders on the credit channel of monetary policy.

The results are presented by means of impulse response functions – to analyse the responses of macroeconomic and credit variables to a monetary policy shock – and of counterfactual analyses – to test how much of the shock is transmitted to output and prices through the credit variables. All responses have been normalized by the size of the monetary policy shock (25 bp), thus they can be compared on a single scale. We show the median responses along with 68 and 90 percent Bayesian credible intervals.

We construct the counterfactuals as hypothetical impulse responses which feature only the "direct" impact of an interest rate movement on the macroeconomic variables and neutralize the indirect effect through the BLS credit variables (channels). This is done by constructing a sequence of shocks to the BLS credit variables such that the impulse response of these variables to an interest rate shock is equal to zero at all horizons.[17] As also stated elsewhere (see Ciccarelli et al, 2013) counterfactuals are a useful tool to assess the impairment of the transmission mechanism due to frictions in the credit markets.

The comparison of these hypothetical responses with the actual responses estimated in the full model provides a statistical measure of the importance of the credit channel and sub-channels in the transmission of the monetary policy shock. Nevertheless, some words of caution are necessary. In principle, to zero out the responses of the credit channels and neutralize the effect of the monetary policy shock in our triangular identification scheme, several sequences of variable residuals could be used. Without a structural model this amount to comparing the response of the macroeconomy to a monetary policy shock with the response to a combination of monetary policy and other generic shocks. However, if we believe that the BLS variables correctly identify the credit channel in our cholesky orthogonalization, in order to neutralize the effect of the all sub-channels we can simply use the residuals of the variables associated with them for all loan categories. To the extent that we can interpret these shocks as shocks to the credit variables, the counterfactuals should be meaningful.[18]

[17] This is equivalent to obtain out-of-sample forecasts of the main macro variables conditional on a given path for the credit variables over the forecast horizon and compare them with unconditional forecasts. For the same counterfactual analysis applied to a different context, see also Bachmann and Sims (2012). Note that, in principle, this approach is not immune to the Lucas' critique, especially if the counterfactual does not imply a "modest" policy intervention (see Leeper and Zha, 2003).

[18] The impulse response functions of the macro variables to a shock to BLS variables using our choleski identification produces results which are very much consistent with what one would expect from a shock to demand and supply of credit. We find that a tightneing of the credit standard implies a negative reaction of GDP and inflation, whereas an increase in the demand have the opposite signs. Interestingly, an increase in credit demand has a positive effect on the policy rate, while an increase in credit standards has a negative effect on the policy rate (a positive effect would have made it indistinguishable form a monetary policy shock). The full transmisison mechanism is reported in a not-for-publication appendix.and is available upon request.

3.1 The broad credit channel (Model 1)

In this subsection we analyze the existence and the importance of the broad credit channel of monetary policy. We look at the impact of a monetary policy shock on all variables, and then, by means of appropriately designed counterfactual experiments, we quantify the credit channel by reporting the amplification effect of a monetary policy shock due to credit. We measure the amplification effect on the responses of GDP growth and inflation.

As explained in Section 2.3, the VAR of Model 1 includes demand and broad credit channel variable for business, mortgage and consumer loans. Figure 2 and Figure 3 show the responses of macro and credit variables to a 25 bp monetary policy shock for the Euro area and the U.S. Consistently with theory, when monetary policy is tightened, GDP and price levels decrease, lending standards are tightened (broad credit channel variable), whereas credit demand declines in both economic areas.[19] Responses of GDP and prices are in line with the existing literature on the monetary transmission mechanism (see, inter alia, Christiano et al., 1999, for the U.S., and Angeloni et al., 2003, for the Euro area).

In the Euro area, as shown in Figure 2, the level and persistence of the responses of the broad credit channel variable are generally similar across different types of loans: the median responses peak between four and five quarters with the supply for business loans showing a higher response. For credit demand, instead, the median responses peak between three and six quarters, with the response of mortgage loans being larger and less persistent than the responses of other loans. When comparing credit demand and credit channel variables, the responses are different across types of loans. In particular, the response of credit channel variables is slightly more sizeable and less persistent for business loans, whereas demand responds much more strongly and less persistently for mortgage loans.

In the U.S. (Figure 3), the median responses of credit channel variables for all types of loans are of similar size as the responses of credit demand. Results are, however, less precise than in the Euro area: The median responses are lower but slightly more persistent than in the Euro area. The response of demand for consumer loans is also marginally significant.

To quantify the economic relevance of the credit channel and analyze to what extent the reduction of GDP growth and inflation is due to credit, we use counterfactual experiments. In particular, we focus on the following questions: Does broad credit channel variables amplify the impact of a monetary policy shock on GDP and prices? How does the impact differ for loans to firms and households? What is the relative importance of the broad credit channel and the (credit) demand channel?

[19] For the sake of interpretation, it is important to recall here that a *positive reaction* of the broad credit channel (and of the borrower's balance sheet channel) variables is a *tightening* of lending standards, while a *positive reaction of* credit demand indicates an *increase* in demand for loans.

The results of the counterfactual analysis are reported in Figure 4 and 5, where we compare the dynamics of the responses of GDP and price levels to a 25 basis points monetary policy shock (68% interval and median) with the median counterfactual responses of the same variables obtained when closing down the credit channel or the credit demand for each type of loan (red line with diamonds). The 68% Bayesian credible intervals (dashed lines) and the black line in the middle represent the responses in a system where all the channels are active. The red lines instead are the median responses computed from a system where the broad credit or the demand channel have been closed down, i.e. where these channels are not allowed to react to a monetary policy impulse. As discussed above, we restrict to zero the reaction of the credit channels by choosing a sequence of lending standards or demand innovations that exactly neutralizes the impact of the monetary policy shock on these variables.

For the Euro area (Fig. 4), the charts show that the impact of a monetary policy shock on GDP growth and – less evidently – on inflation would be significantly different if we closed the broad credit channel for business loans and the demand for mortgage loans. For business loans, the credit channel is quantitatively more important than the demand channel. For mortgage loans, closing down the demand channel would have a stronger effect on GDP and prices than closing down the credit channel. Results indicate that when the credit channel and the demand for mortgage loans are shut down, the median responses of GDP to a monetary policy shock would be reduced by about 50 percent at the peak.

For the U.S. (Fig 5) results show that the broad credit channel is the most importan transmission channel for GDP (business and mortgage loans) and for prices (business loans more than mortgage loans): closing down these channels would imply an effect on GDP and prices lower by more than 50%.

3.2 Firm, household and bank balance-sheet channels (Model 2)

with the aim of qualifying the results just illustrated, in this subsection we analyze the main sub-channels of the broad credit channel of monetary policy. We assess the relative importance of the transmission mechanisms of monetary policy shocks through the strength of the balance-sheets of banks, firms and households – the bank lending channel and the firm and household balance-sheet channels.

For this purpose, we use a VAR with the bank lending channel and the borrower's balance sheet channel variables (see Section 2.2 for the definition of the variables and Section 2.3 for the description of Model 2). As discussed in Section 2.1, in the SLOS these two variables are available only for business loans. As a consequence, we present results for all the balance-

sheet channels in the Euro area, while for the U.S. we discuss the results only for business loans.

Figure 6 shows that the responses of the bank lending channel, the borrower's balance sheet channel and the credit demand variables to a monetary tightening are significant for all types of loans and have the expected signs. In particular, a monetary tightening worsens lending conditions related to both bank lending and borrower's balance sheet variables while reducing credit demand. The responses are broadly similar for all types of loans. The impact of the bank lending channel for business loans peaks earlier and higher than for mortgage and consumer loans. The effect through the borrower's balance sheet channel are instead more comparable in size and timing. Demand of mortgage loans reacts faster and stronger than the reaction of business or consumer loans as alss seen for model 1.

Results for U.S. business loans are reported in Figure 7. Overall, they are comparable in size to those in the Euro area (with a stronger effect of monetary policy on the borrower's balance sheet variable) and point to the same conclusions: A monetary tightening clearly implies a tightening of standards related to the bank lending and the borrower's balance sheet channel, as well as a reduction of credit demand.

To what extent the significant responses of credit variables is reflected onto the macroeconomy is what we check next. The available empirical evidence in the literature on the U.S bank lending channel is not conclusive and comprises analyses supporting the existence of the bank lending channel (e.g., Kashyap and Stein, 2000) and of a more conventional transmission mechanism (Romer and Romer 1990; Ramey 1993).[20] To assess the economic relevance of the different channels of transmission we run a counterfactual experiment, as done for Model 1 above. Results are reported in Figure 8 and 9.

The findings for the Euro area (Fig. 8) indicate that, for business loans, a monetary policy shock has a stronger impact on GDP through the bank lending channel and the firm balance sheet channel. The counterfactual experiments say that if we shut down these channels, the median effect on GDP of a monetary policy shock would be reduced at the peak by about 30-35 percent (from -0.35% to -0.25%) with a negligible effect on prices. Note that monetary policy shocks are transmitted to the macroeconomy through all channels: while bank lending and firm balance sheet are the most important channels for business loans, the demand channel is significantly relevant for mortgages. It is also interesting to note that the credit demand channel for mortgages has a sizeable impact on prices. Given this detailed analysis, it does not surprise that if we aggregate results for loan categories (not reported)

[20] Monetary policy may also affect bank risk-taking (compositional changes of credit supply). For evidence, see Jiménez et al. (2010), Ioannidou et al. (2010), and Maddaloni and Peydró (2011). For evidence on the household balance-sheet channel, see Mishkin (1977) and (1978). For evidence on the firm balance-sheet channel, see Gertler and Gilchrist (1994) and Lang and Nakamura (1995).

results show that closing down one of the three channels at a time would imply a similar overall effect on GDP, whereas the demand channel is considerably more effective on inflation than the bank lending or the (firms/households) balance-sheet channels.

For the U.S., our results qualify what discussed above for model 1 and suggest that while the bank lending channel is not significant, a monetary policy shock is transmitted to real activity and prices mainly through the borrower's balance sheet channel (Figure 9). Results show that the median response of GDP growth in the counterfactuals would be reduced at the peak by about 50 percent for GDP (from -0.3% to -0.15%) and prices (from -0.16% to -0.08%).

3.3 Discussion of the results

The previous findings show that the credit channel is operational and amplifies the impact of a monetary policy shock on GDP and price levels through the strength of the balance sheets of households, firms and banks. Based on the results of our analysis, the credit channel is overall as important in the Euro area as in the U.S. Moreover, in the Euro area, for business loans, the amplification of monetary policy shocks is higher via the bank lending and balance sheet than via the demand channel. For household loans, credit demand is the most important channel. In the U.S. the bank lending channel of monetary policy is irrelevant and a monetary policy shock is transmitted to real activity mainly through the firm balance-sheet channel.

The differences in the results obtained for the Euro area and for the U.S. can be largely interpreted in light of the financial structures of the two areas. A relevant feature of the Euro area is that corporations fund themselves externally mainly through bank loans: around 70% of external financing in the balance sheets of Euro area firms is constituted by bank loans, while in the U.S. this percentage is around 20% (Trichet 2009). Moreover, a large fraction of corporate equity in the Euro area is non-listed, i.e. not issued and traded in financial markets, as opposed to the U.S. (see ECB, 2007 and Allen et al., 2004). A monetary policy shock transmitted through the bank lending channel may therefore have a higher impact on real activity in the Euro area than in the U.S. where firms can, at least partly, diversify their financing needs between banks, other financial intermediaries (not included in the sample of the bank lending surveys) and markets.

Transmission through the bank lending channel may be less important for household loans, especially in the Euro area. Households are financially constrained because of human capital inalienability (Hart and Moore, 1994). In most Euro area countries, differently from the U.S., mortgage loans are with recourse – the borrower is responsible for any remaining

debt after foreclosure (Campbell, 2013). This implies that mortgage loans are highly collateralized (not only with the value of the house but also other assets of the borrower) and agency problems may be less severe. In this case, bank financial constraints are less binding and monetary policy affects the economy significantly more through the demand and the (collateral) household balance sheet channel than through the bank lending channel.

Finally, for household loans, the results for the U.S. may be more subdued than for the Euro area because a significant part of U.S. mortgage loans are granted by non-bank financial intermediaries not included in the bank lending surveys. Therefore, our analysis for the U.S. mortgage market may be less comprehensive than for the Euro area and our results may underestimate the importance of credit channels for U.S. mortgage loans.

In the next subsection, we further qualify these results by providing a limited analysis of the impact of heterogeneity of borrowers and lenders on the importance of the credit channel.

3.4 Heterogeneity and the credit channel

The impact of the credit channel of monetary policy may differ according to the heterogeneity of borrowers and lenders, notably differences in firm size (Gertler and Gilchrist, 1994) and in bank size (Kashyap and Stein, 2000). In particular, monetary policy effects should be higher on credit granted to smaller firms or by smaller banks, typically more financially constrained.

Using the responses of the lending surveys can help shed light on this aspect. In the Euro area, the BLS contains answers for lending standards applied by small and large banks, and for loans to small and large enterprises. Correlations among the answers of banks of different size is on average not greater than 50%, while the answers for large and small firms are relatively more correlated (around 80%). In the SLOS, the series on lending standards for large and small enterprises have a correlation of 96%.

As the survey information for small and large banks is available only for the Euro area, we focus on the comparison between small and large firms only.

Figure 10 plots the counterfactuals with the impact of firm size. We report the results by shutting down demand and credit channel contemporaneusly. The impulse responses show that the impact of monetary policy on GDP through a broad credit channel is significant via both large and small firms in the Euro area, and more via small firms in the U.S. The latter, in particular, is consistent with the evidence provided by e.g. Gertler and Gilchrist (1994). The results are also consistent with differences in the firms' financing structure. In the Euro area, the effect on GDP through large firms is higher, because these firms borrow mainly from banks (Trichet, 2009) and their overall impact on the economy is larger, notwithstanding the fact that changes in monetary policy affect more significantly credit to

small firms. Differently, in the U.S., the credit channel is stronger through small firms, since bank loans to large firms do not represent their main source of financing.

Regarding heterogeneity of lenders, in another paper we have shown that in the Euro area both small and large banks have been equally important in transmitting a monetary policy shock to the real economy via the bank lending channel. However, in financially more stressed countries, the amplification of a monetary policy shock through the non-financial borrower balance-sheet channel has operated mainly through small banks (Ciccarelli et al, 2013). These results somewhat qualify the findings of Kashyap and Stein (2000) who, over a different sample period (1976 to 1993) and a different country (U.S.), find that the bank lending channel is stronger mainly through small banks.

All in all, results suggest that heterogeneity of firms and banks matters for the credit channel of monetary policy and that transatlantic differences may depend on the financial structure (in particular the importance of the banking system as provider of funds to non financial sectors) more than on the borrower's category.

4 Concluding remarks

The recent crisis in Europe and U.S. suggests that identifying and quantifying the channels linking monetary policy, credit provision and business cycles is of utmost importance. In this paper, we test the credit channel of monetary transmission and explore the dynamics of credit during the recent financial crisis.

Credit channels are typically unobserved, therefore the complete identification of the credit channel of monetary policy and of its subchannels is generally unfeasible. However, bank lending surveys by central banks contain reliable information on broad credit channel variables and demand for loans. Therefore, to analyze the credit channel we use the answers from the unique, confidential Euro area Bank Lending Survey and from the U.S. Senior Loan Officer Survey. National central banks of the Eurosystem and regional Feds request banks quarterly information on the loan demand that banks receive and on the lending conditions that banks apply to firms and households, most importantly including the factors affecting banks' decisions to change standards – namely whether loan conditions change due to bank or to non-financial borrower balance-sheet constraints.

Overall, our results suggest that the credit channel is operational and amplifies a monetary policy shock on GDP and inflation, through the strength of balance sheets of households, firms and banks. In the Euro area, all channels are somewhat important in transmitting monetary policy shocks to the macroeconomy, with the bank lending and the demand channel being the most important channels for corporate and mortgage loans respectively. Counter-

factual experiments suggest that if we shut down the bank lending channel and the borrower's balance sheet channel for business loans, the median effect on GDP growth of a monetary policy shock would be reduced at the peak by about 35-40%.

In the U.S., the bank lending channel is not significant, whereas a monetary policy shock is transmitted to real activity mainly through the firm balance sheet channel. Counterfactual experiments suggest that shutting down this channel would reduce the median GDP response at the peak by about 50 percent for both GDP and prices.

Further analysis based on disaggregated data suggests that heterogeneity of firms and banks may matter for the credit channel of monetary policy, with differences depending on the financial structure and on the borrower's category. Monetary policy has more impact on GDP through the credit granted to both large and small firms in the Euro area, and mainly to small firms in the U.S.

Our analysis has important implications for theory and policy. For economic theory, our findings imply that the bank lending channel should be included explicitly when modelling the linkages between monetary policy, credit provision and the real economy. In turn, this is likely to amplify the mechanisms of the financial accelerator of Bernanke, Gertler, and Gilchrist (1999) – see, in this respect, the recent macro models by Gertler and Kiyotaki (2011), Gertler and Karadi (2011), Del Negro et al. (2010), Angeloni and Faia (2013), Christiano et al. (2010); also the micro finance models by Adrian and Shin (2010), Diamond and Rajan (2006 and 2009) and Stein (2011). Moreover, our results also stress the importance of an accurate calibration of the models, taking into account heterogeneity and differences among financial systems (the bank lending channel is more important in the Euro area than in the U.S.), as well as different lending markets (supply restrictions affect business lending more than household mortgage lending).

From a policy perspective, our results are consistent with the measures implemented during the crisis by the ECB, with interventions (almost) uniquely targeting banks, given the importance of the bank lending channel in the Euro area, whereas in the U.S. support was directed by the Federal Reserve also to the non financial sector.

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Appendix: BLS and SLOS data description

The Bank Lending Survey

Question		Definition of variables	Measures
Supply of loans		*Broad credit channel variable* for:	
Over the past three months, how have your bank's credit standards as applied to the approval of loans…	or credit lines to enterprises changed? (Q1)	business loans	**Net percentage** is equal to the difference between the sum of banks answering "tightened considerably" and "tightened somewhat" and the sum of banks answering "eased somewhat" and "eased considerably" in percentage of the total number of banks.
	to households for house purchase changed? (Q8)	mortgage loans	
	to households for consumer credit and other lending changed? (Q8)	consumer loans	
Factors affecting the supply of loans			
Q2**:** Over the past three months, how have the following factors affected your bank's credit standards as applied to the approval of loans or credit lines to enterprises?	A Costs of funds and [bank] balance sheet constraints	*bank lending channel variable* is the average of the net percentage of banks answering A and B	**Net percentage** is equal to the difference between the sum of the banks answering "contributed considerably to tightening" and "contributed somewhat to tightening" and the sum of the banks answering "contributed somewhat to easing" and "contributed considerably to easing" in percentage of the total number of banks
Q9**:** Over the past three months, how have the following factors affected your bank's credit standards as applied to the approval of loans to households for house purchase?	B Pressure from competition [from banks and other financial intermediaries]		
Q11**:** Over the past three months, how have the following factors affected your bank's credit standards as applied to the approval of consumer credit and other lending to households?	C Perception of risk	*borrower's balance sheet channel variable* is the average of the net percentage of banks answering C	
Demand for loans		*Credit demand* for:	
Over the past three months, how has the demand for loans or credit lines to […] changed at your bank, apart from normal seasonal fluctuations?	enterprises (Q4)	business loans	**Net percentage** is equal to the difference between the sum of the banks answering "increased considerably" and "increased somewhat" and the sum of the banks answering "decreased somewhat" and "decreased considerably" in percentage of the total number of banks
	households (Q13)	mortgage loans	
		consumer loans	

Source: http://www.ecb.europa.eu/stats/money/surveys/lend/html/index.en.html

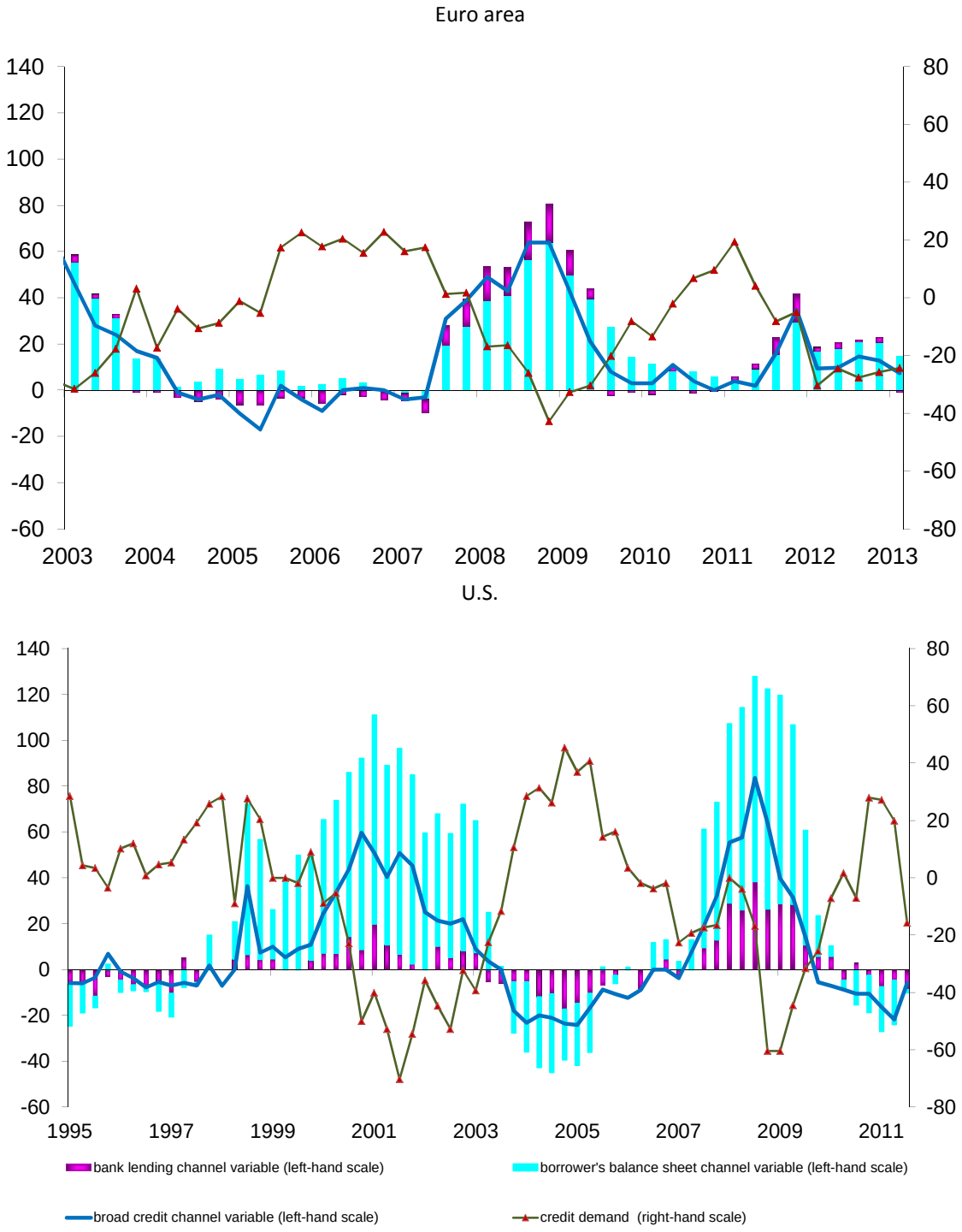
The Senior Loan Officer Opinion Survey

Question		Variable	Definition of variables
Supply of loans		*Broad credit channel variable for:*	
Over the past three months, how have your bank's credit standards for …	approving applications for C&I loans or credit lines - other than those to be used to finance mergers and acquisitions - to large and middle-market firms changed? (Q1	business loans	**Net percentage** is equal to the difference between the sum of banks answering "tightened considerably" and "tightened somewhat" and the sum of banks answering "eased somewhat" and "eased considerably" in percentage of the total number of banks.
	from individuals for mortgage loans to purchase homes changed? (Q13)	mortgage loans	
	for consumer loans other than credit card loans changed? (Q20)	consumer loans	
Factors affecting the supply of loans		*bank lending channel variable* is the average of the net percentage of banks answering A	
Q3**:** if your bank has tightened or eased its credit standards or its terms for C&I loans or credit lines over the past three months, how important have been the following possible reasons for the change?	A. Deterioration in your bank's current or expected capital position		**Net percentage** is equal to the difference between the sum of the banks answering "very important" and "somewhat important" for tightening and the sum of the banks answering "somewhat important" and "very important" for easing
	B. Less favourable or more uncertain economic outlook	*borrower's balance sheet channel variable* is the average of the net percentage of banks answering B and C	
	C. Worsening of industry specific problems		
Demand for loans		*Credit demand* for:	
Apart from normal seasonal variation, how has demand for…	C&I loans changed over the past three months? (Q4)	business (C&I) loans	**Net percentage** is equal to the difference between the sum of the banks answering "substantially stronger" and "moderately stronger" and the sum of the banks answering "moderately weaker" and "substantially weaker" in percentage of the total number of banks
	mortgage to purchase homes changed over the past three months? (Q14)	mortgage loans	
	consumer loans of all types changed over the past three months? (Q26)	consumer loans	

Source: http://www.federalreserve.gov/boarddocs/snloansurvey/

Note: Q# indicates the number of the question in the survey.

Figure 1. Lending standards and demand for loans

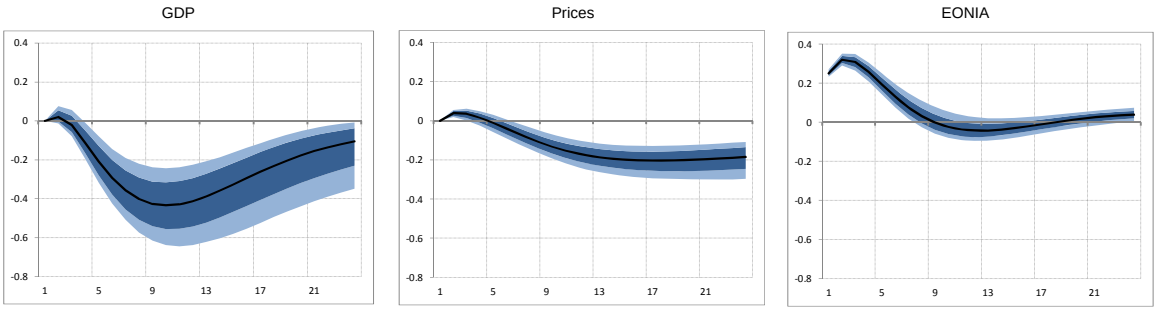


Note: This chart plots the lending standards and the demand for loans in the Euro area and in the U.S. as reported in the BLS and in the SLOS. The responses refer to business (C&I) loans. The broad credit channel variable is the net percentage of banks that have tightened overall lending standards. The bank lending channel variable is the average net percentage of banks that have tightened lending standards because of balance sheet constraints and competition pressures. The borrower's balance sheet channel variable is the average net percentage of banks that have tightened lending standards due to the economic outlook and to industry and borrower specific risks. Credit demand is the net percentage of banks answering that the demand for business loans has increased. See Section 2 and the Appendix for a detailed definition of the variables.

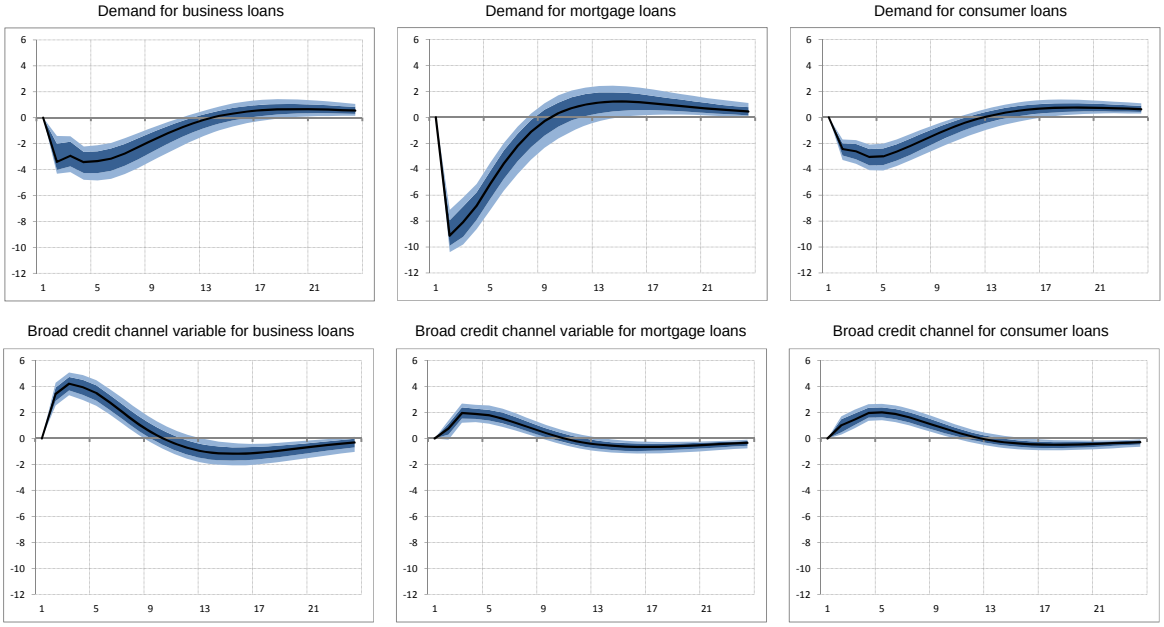
Source: European Central Bank and Federal Reserve Board

Figure 2. Responses to a monetary policy shock - Model 1 - Euro area

Panel A. Macroeconomic variables



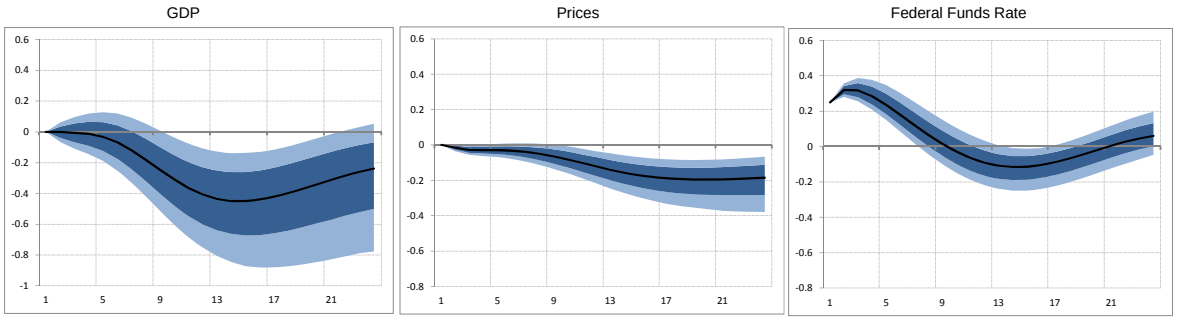
Panel B. Credit variables



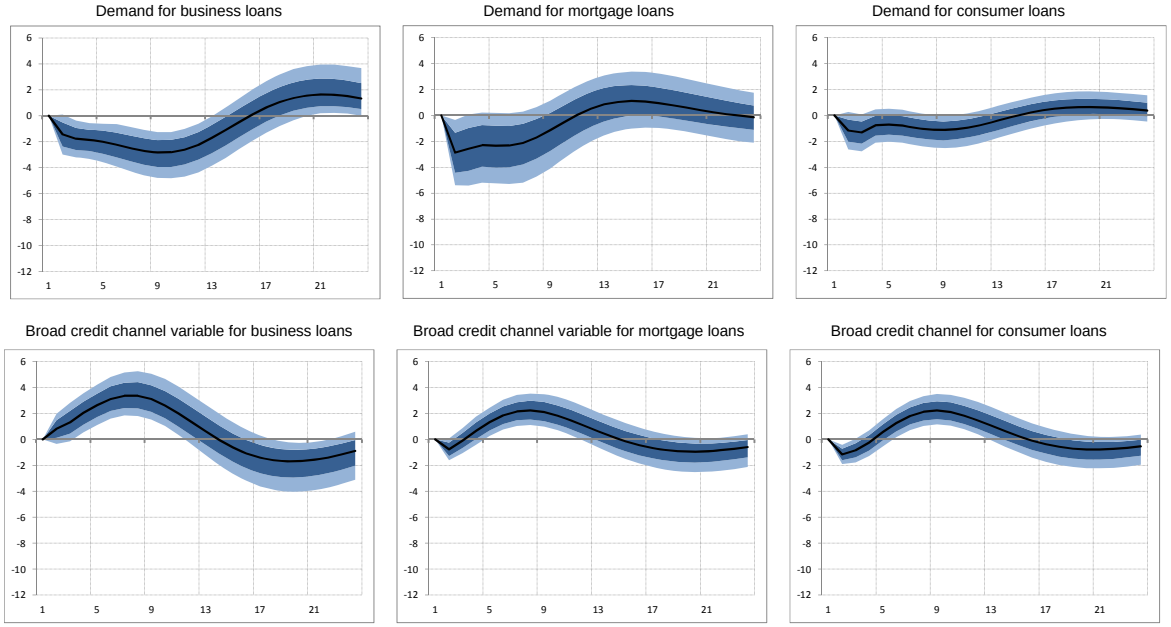
Note: The charts in Panel A plot the responses of output, prices and the monetary policy rate to a 25 basis point monetary policy shock in the Euro area. The charts in Panel B plot the responses of the credit demand variables and the broad credit channel variables to a 25 basis point monetary policy shock for different types of loans (business, mortgages and consumer loans) in the Euro area. Responses of the series are normalised and divided by the size of the shock so that all responses to a shock are expressed in percentage points and are comparable on a single scale. On the x-axis steps are in quarters. The median response (black line) is shown along with 68 and 90 percent Bayesian credible intervals (shaded areas), computed by estimating the panel VAR with a hierarchical prior on the parameters and assuming normality of the error terms as explained in Section 2. The specification of the panel VAR includes 9 variables for each country: log level of GDP, log level of price index, demand and total lending standards for business, mortgages and consumer credit, EONIA rate. See MODEL 1 in Section 2.3 and the Appendix for a detailed definition of the variables.

Figure 3. Responses to a monetary policy shock - Model 1 - U.S.

Panel A. Macroeconomic variables

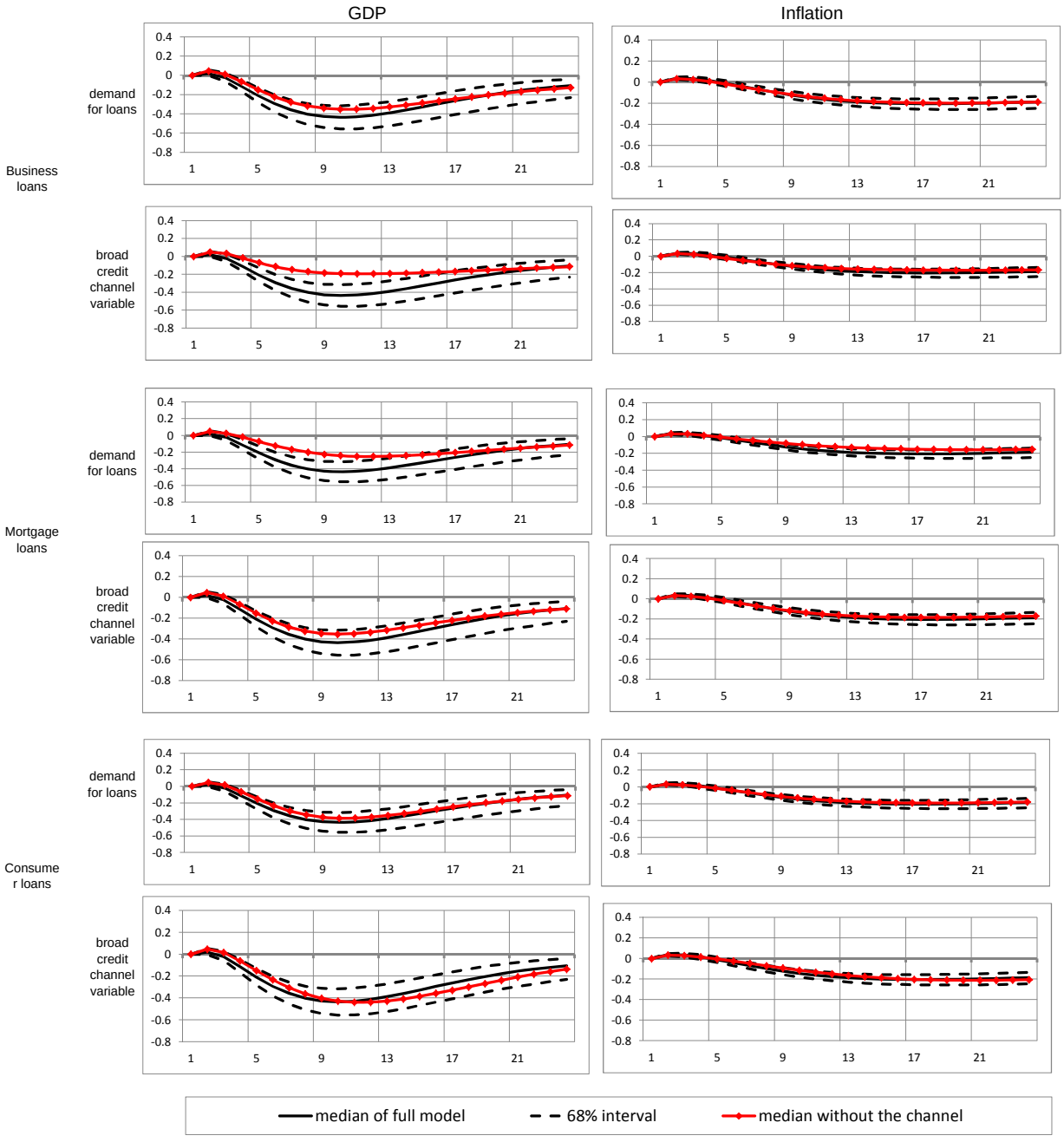


Panel B. Credit variables



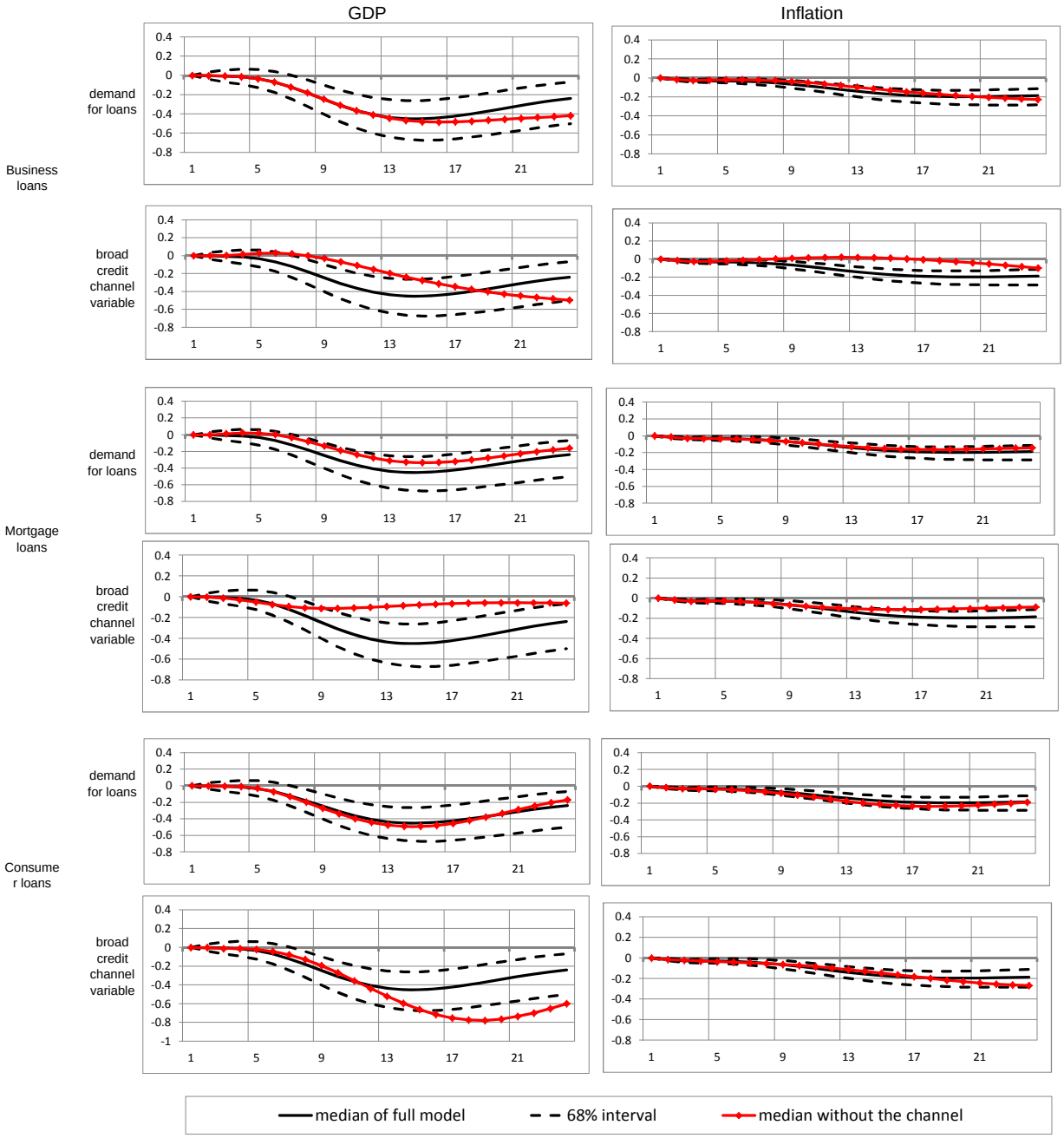
Note: The charts in Panel A plot the responses of output, prices and the monetary policy rate to a 25 basis point monetary policy shock in the U.S. The charts in Panel B plot the responses of the credit demand variables and the broad credit channel variables to a 25 basis point monetary policy shock for different types of loans (business, mortgages and consumer loans) in the U.S. Responses of the series are normalised and divided by the size of the shock so that all responses to a shock are expressed in percentage points and are comparable on a single scale. On the x-axis steps are in quarters. The median response (black line) is shown along with 68 and 90 percent Bayesian credible intervals (shaded areas), computed by estimating the VAR with an informative prior on the parameters and assuming normality of the error terms as explained in Section 2. The specification of the panel VAR includes 9 variables: log level of GDP, log level of price index, demand and total lending standards for business, mortgages and consumer credit, EONIA rate. See MODEL 1 in Section 2.3 and the Appendix for a detailed definition of the variables.

Figure 4. Counterfactual analysis - Model 1 - Euro area



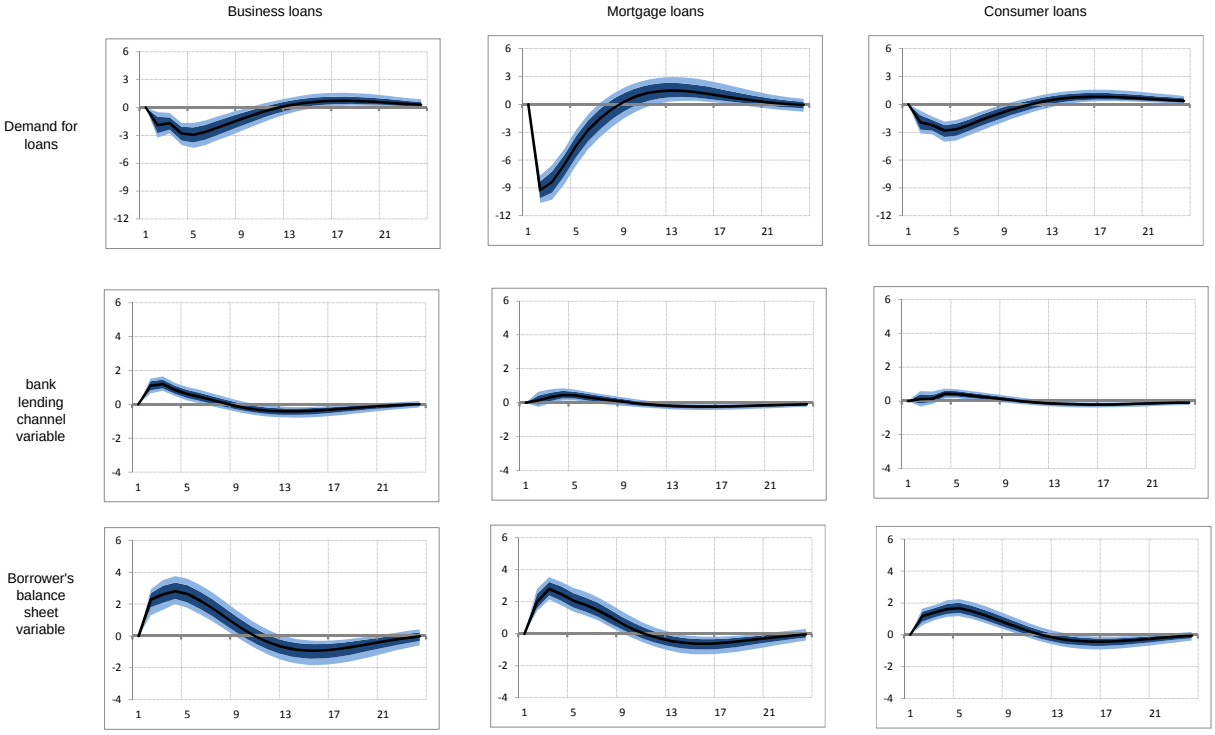
Note: These charts report counterfactual experiments. The responses of output growth and inflation to a 25 basis point monetary policy shock in a full model (solid black line) are compared with the responses obtained when closing down the credit channels (demand or broad credit channel, red marked lines) in the Euro area. The 68% Bayesian credible intervals (dashed lines) represent the responses in a system where all the channels are active. All types of loans are considered. Responses of the series are normalised and divided by the size of the shock so that all responses to a shock are comparable on a single scale. On the x-axis, steps are in quarters. The specification of the panel VAR includes 9 variables for each country: log level of GDP and prices, demand and total lending standards for business, mortgages and consumer credit, federal funds rate. See MODEL 1 in Section 2.3 and the Appendix for a detailed definition of the variables.

Figure 5. Counterfactual analysis - Model 1 - U.S.



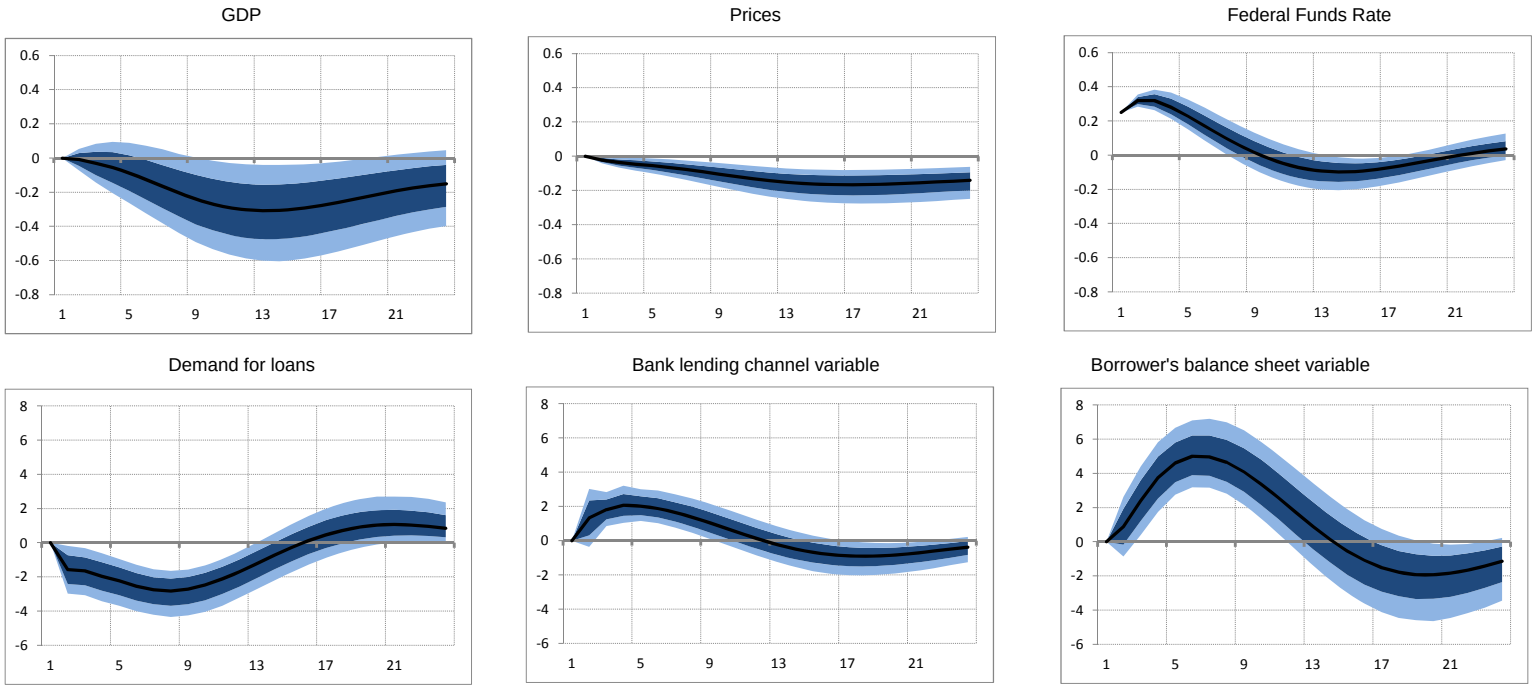
Note: These charts report counterfactual experiments. The responses of output growth and inflation to a 25 basis point monetary policy shock in a full model (solid black line) are compared with the responses obtained when closing down the credit channels (demand or broad credit channel, red marked lines) in the U.S. The 68% Bayesian credible intervals (dashed lines) represent the responses in a system where all the channels are active. All types of loans are considered. Responses of the series are normalised and divided by the size of the shock so that all responses to a shock are comparable on a single scale. On the x-axis, steps are in quarters. The specification of the VAR includes 9 variables: log level of GDP and prices, demand and total lending standards for business, mortgages and consumer credit, federal funds rate. See MODEL 1 in Section 2.3 and the Appendix for a detailed definition of the variables.

Figure 6. Responses to a monetary policy shock - Model 2 - Euro area



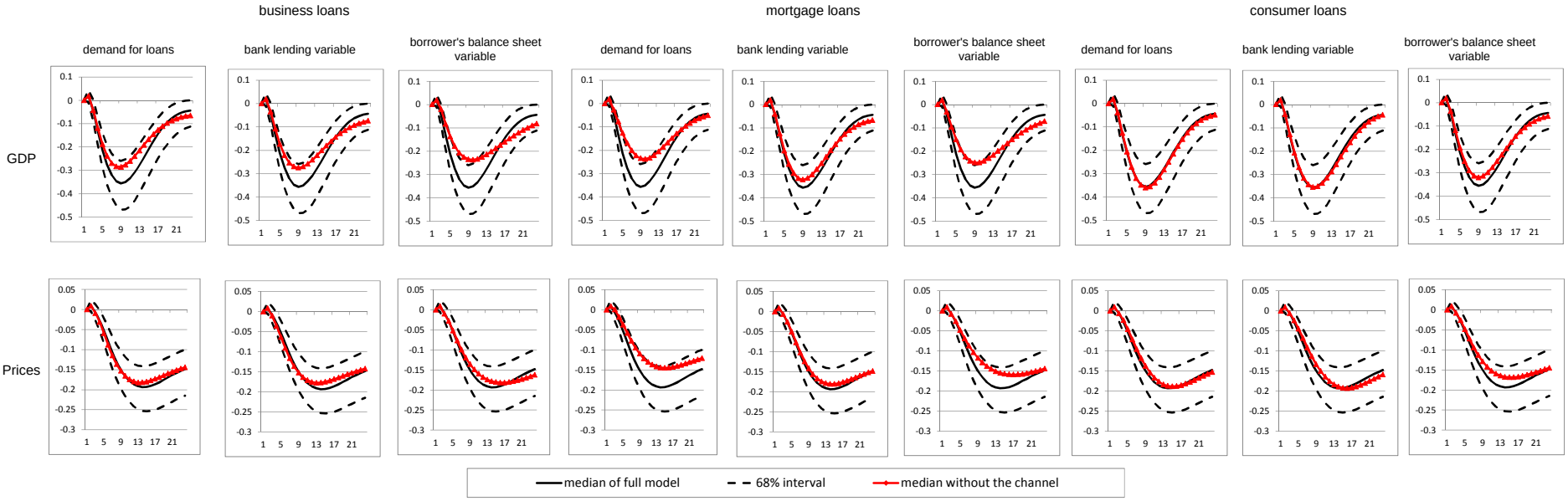
Note: These charts report the responses of credit demand and credit channel variables (via bank lending and borrower's balance sheet channels) to a 25 basis point monetary policy shock for all borrower categories, for the Euro area. Responses of the series are normalised and divided by the size of the shock so that all responses to a shock are comparable on a single scale. On the x-axis, steps are in quarters. The median response is shown along with 68 and 90 percent Bayesian credible intervals (shaded areas), computed by estimating the panel VAR with a hierarchical Bayes prior on the parameters and assuming normality of the error terms, as explained in Section 2. The specification of the VAR includes 12 variables for each country: log levels of GDP and prices, demand, bank lending channel and borrower's balance sheet channels variables for all type of loans, and the EONIA rate. See MODEL 2 in Section 2.3 and the Appendix for a detailed definition of the variables.

Figure 7. Responses to a monetary policy shock - Model 2 - U.S.



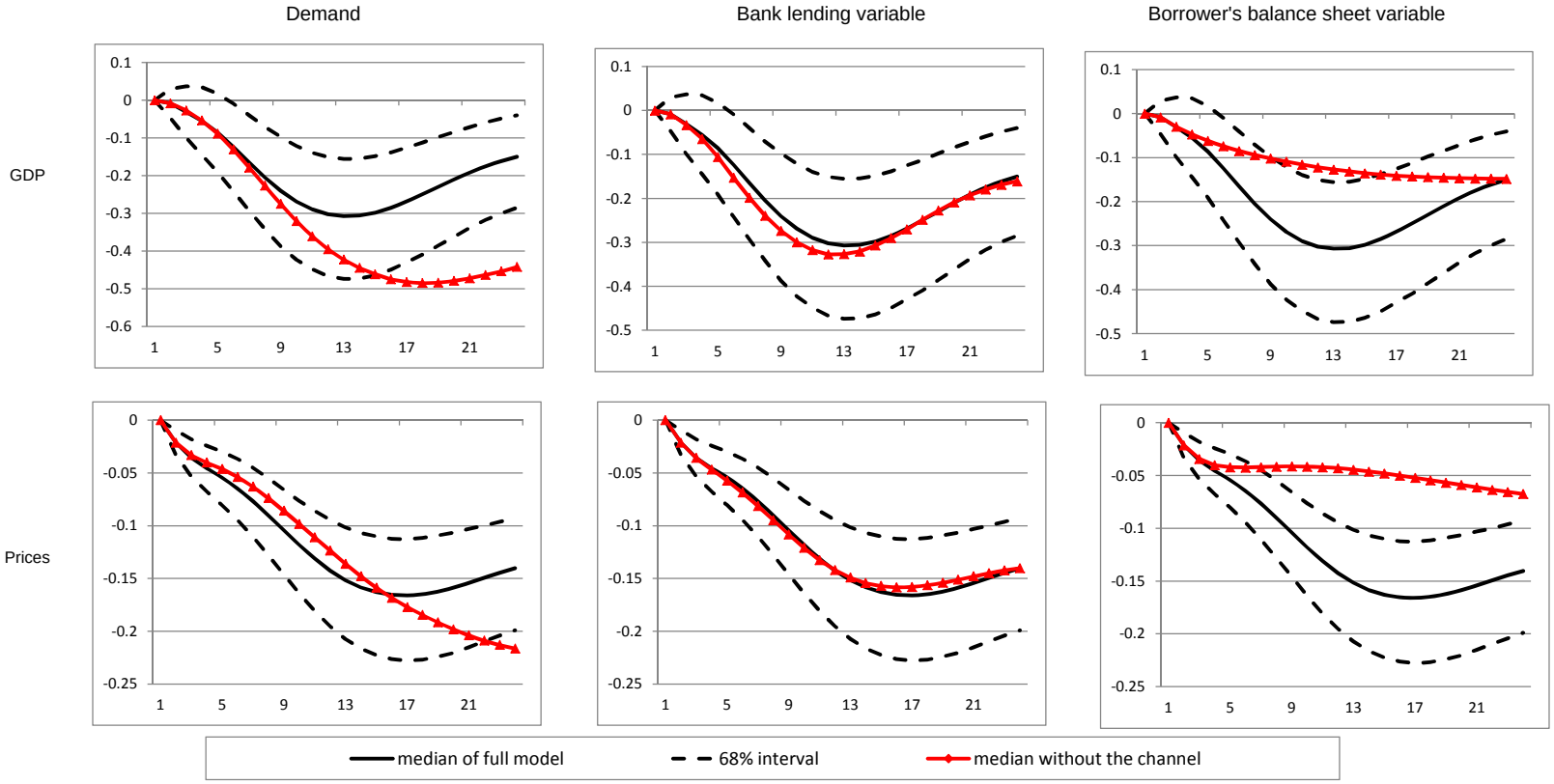
Note: These charts report the responses of credit demand and credit channel variables (via bank lending and borrower's balance sheet channels) to a 25 basis point monetary policy shock for all borrower categories in the U.S. Responses of the series are normalised and divided by the size of the shock so that all responses to a shock are comparable on a single scale. On the x-axis, steps are in quarters. The median response is shown along with 68 and 90 percent Bayesian credible intervals (shaded areas), computed by estimating the VAR with an informative prior on the parameters and assuming normality of the error terms. The specification of the VAR includes 9 variables: GDP growth, inflation, overnight rates, demand, bank lending channel and borrower's balance sheet channels variables for all type of loans. See MODEL 2 in Section 2.3 and the Appendix for a detailed definition of the variables and prior assumptions.

Figure 8. Counterfactual analysis - Model 2 - Euro area



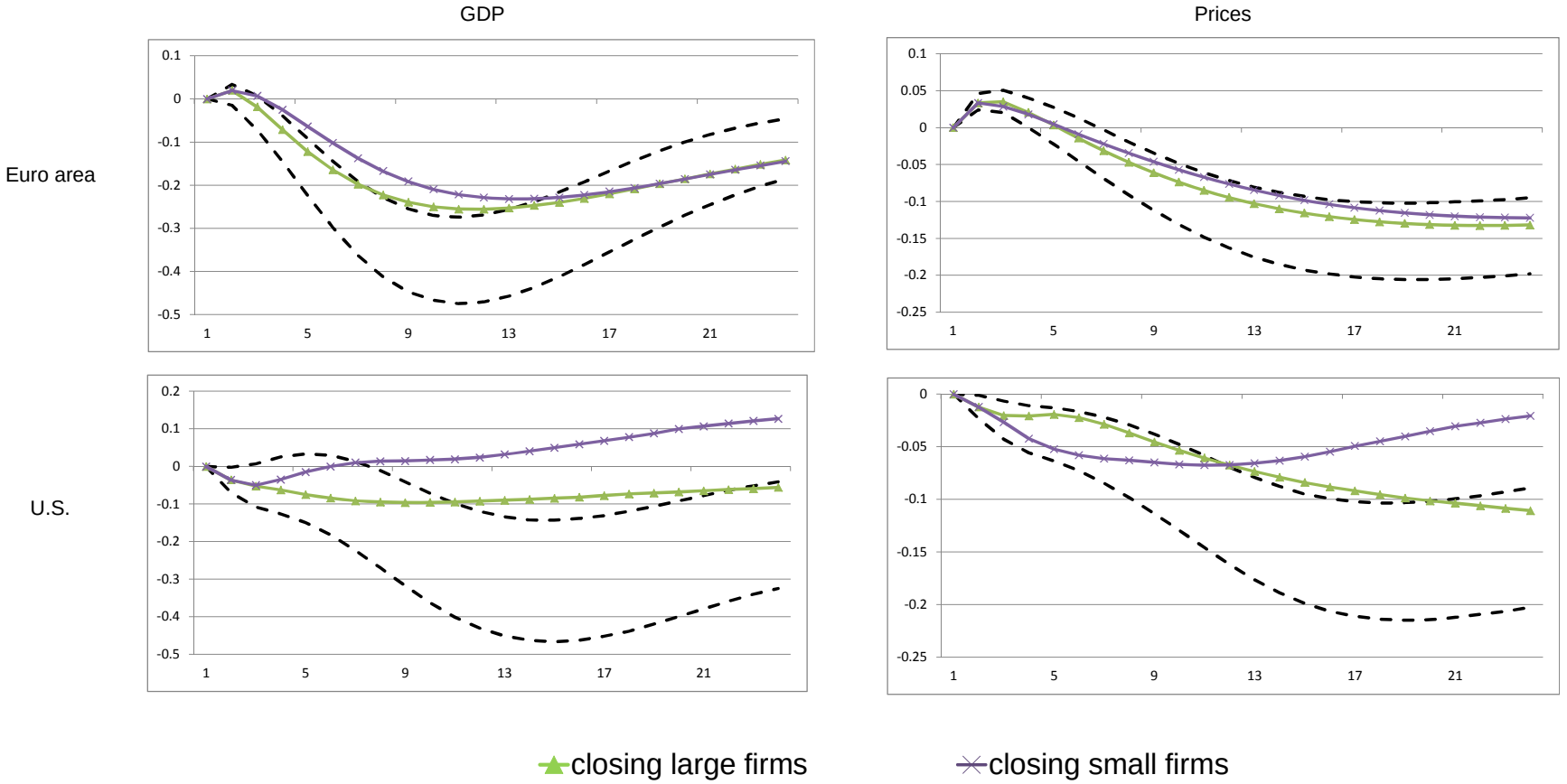
Note: These charts report counterfactual experiments. The responses of output growth and inflation to a 25 basis point monetary policy shock in a full model are compared with the responses obtained when closing down the credit channels (demand for loans, bank lending and borrower's balance sheet channels) for each type of loan at a time. The results of the full system (black solid line) are compared with the results of the system where the correspondent channel has been closed down (red marked line). The 68% Bayesian credible intervals represent the responses in a system where all the channels are active. Responses of the series are normalised and divided by the size of the shock so that all responses are comparable on a single scale. On the x-axis, steps are in quarters. All the responses refer to the Euro area. The panel VAR is estimated with a hierarchical Bayesian prior as explained in Section 2. The specification of the VAR includes 12 variables for each country: log levels of GDP and price, demand for loans, bank lending channel and borrower's balance sheet channel variables for all type of loans and the EPNIA rate. See MODEL 2 in Section 2.3 and the Appendix for a detailed definition of the variables.

Figure 9. Counterfactual analysis - Model 2 - U.S.



Note: These charts report counterfactual experiments. The responses of output growth and inflation to a 25 basis point monetary policy shock in a full model are compared with the responses obtained when closing down the credit channels (demand for loans, bank lending and borrower's balance sheet channels) for each type of loan at a time in the U.S. The results of the full system (black solid line) are compared with the results of the system where the correspondent channel has been closed down (red marked line). The 68% Bayesian credible intervals (dashed lines) represent the responses in a system where all the channels are active. Responses of the series are normalised and divided by the size of the shock that they are comparable on a single scale. The specification of the VAR includes 9 variables: log levels of GDP and prices, demand for loans, bank lending channel and borrower's balance sheet channel variables for all type of loans and the fed funds rate. See MODEL 2 in Section 2.3 and the Appendix for a detailed definition of the variables.

Figure 10. Counterfactual analysis - Large vs. small firms



Note: These charts report counterfactual experiments. The responses of output growth and inflation to a 25 basis point monetary policy shock in a full model (dashed lines interval) are compared with the responses obtained when closing down the demand and credit channels for small (violet) and large (green) firms. Only business loans are considered. The 68% Bayesian credible intervals (dashed lines) represent the responses in a system where all the channels are active. The graphs in the first row refer to the Euro area, while the graphs in the second row to the U.S.