EUROPEAN CENTRAL BANK

EUROSYSTEM

Working Paper Series

Derrick Kanngiesser, Reiner Martin,
Laurent Maurin, Diego Moccero

Estimating the impact of shocks to bank capital in the euro area

No 2077 / June 2017

Abstract

We contribute to the empirical literature on the impact of shocks to bank capital in the euro area by estimating a Bayesian VAR model identified with sign restrictions. The variables included in the VAR are those typically used in monetary policy analysis, extended to include aggregate banking sector variables. We estimate two shocks affecting the euro area economy, namely a demand shock and a shock to bank capital. The main findings of the paper are as follows: i) Impulse-response analysis shows that in response to a shock to bank capital, banks boost capital ratios by reducing their relative exposure to riskier assets and by adjusting lending to a larger extent than they increase the level of capital and reserves per se; ii) Historical shock decomposition analysis shows that bank capital shocks have contributed to increasing capital ratios since the crisis, impairing bank lending growth and contributing to widen bank lending spreads; and iii) counterfactual analysis shows that higher capital ratios pre-crisis would have helped dampening the euro area credit and business cycle. This suggests that going forward the use of capital-based macroprudential policy instruments may be helpful to avoid a repetition of the events seen since the start of the global financial crisis.

JEL Codes: G21, C32, C11

Keywords: Euro area, Bank Balance Sheet Adjustment, Capital Ratio, Bayesian VAR, Macroprudential Policy, Sign Restrictions

Non-technical summary

The global financial crisis revealed a need for macroprudential policy tools to mitigate the buildup of risk in the financial system and therefore enhance the resilience of financial institutions. As a consequence, macroprudential policy has been ramped up in many jurisdictions, including the members of the euro area. Many of these macroprudential measures are capital-based instruments aimed at increasing banks' resilience to macro-financial shocks, such as the countercyclical capital buffer (CCyB), the systemic risk buffer (SRB) and capital buffers for systemically important institutions.

Estimating the impact of shocks to bank capital has thus received renewed attention recently. The idea behind the macroprudential use of countercyclical capital buffers is to impose a capital surcharge on banks in order to limit the excessive amplification of credit cycles and to incentivise banks to build up capital so that they are better prepared to withstand losses in a bust. In this context, the question is whether and to what extent changes in the buffers will affect bank lending, lending spreads and the broader macro-economy. Answering this question is not straightforward, as capital ratios are endogenous, influenced by monetary policy and demand conditions, as well as discretionary changes in policy. Furthermore, the empirical evidence with the macroprudential use of such buffers is very thin, in particular in the euro area. As a consequence, the literature on the impact of shocks to bank capital can offer useful insights in order to assess the impact of macroprudential buffers on the banking sector and the economy at large.

We contribute to the empirical literature on the impact of shocks to bank capital in the euro area by estimating a Bayesian VAR model identified with sign restrictions. Our goal is threefold. First, we estimate the impact of a shock to bank capital on macroeconomic and banking variables. We isolate three channels through which banks can adjust to such shock: deleverage (slashing bank loans to the non-financial private sector), de-risking the banking book (adjusting loans to households and non-financial corporations to a different extent) and boosting capital levels. Second, we estimate the contribution of demand shocks and shocks to bank capital on the observables over time. This historical contribution of shocks allows assessing the relevance of structural shocks on the evolution of the variables in the VAR. And third, we perform a counter-factual exercise to assess whether an increase in capital ratios before the start of the international financial crisis could have helped to prevent, or at least soften, the boom-bust cycle and economic crisis in the euro area.

The starting point of our analysis is the standard workhorse VAR used extensively in monetary policy analysis (comprising a proxy of the policy interest rate, economic activity and inflation), extended to include aggregate banking sector variables (bank lending to households and non-financial corporations, bank lending spreads, the capital ratio and capital and reserves).

Owing to the relatively short estimation sample, the model is estimated with Bayesian tech-

niques assuming a normal distribution for the coefficients in the VAR and an inverse-Wishart distribution for the covariance matrix. After the reduced-form VAR is estimated with Bayesian techniques, the structural model is identified with sign restrictions. We do not aim at identifying all the shocks in the economy, but only two shocks that appear to be relevant in shaping bank loan movements in the euro area economy since the early 2000s, namely a demand shock and a shock to bank capital.

The main findings of the paper are as follows. First, impulse-response analysis shows that as a response to a shock in bank capital, banks boost capital ratios by de-risking their balance sheets (e.g., by shifting the portfolio away from loans which are more capital intensive) and by adjusting lending (and hence RWAs) to a larger extent that they increase the level of capital and reserves per se. Second, a historical shock decomposition analysis shows that the shock to bank capital has contributed to boost capital ratios since the crisis, hence impairing bank lending growth and contributing to widened bank lending spreads. This observation is consistent with the responses to the ECB Bank Lending Survey (BLS), which suggest that the strengthening of the banking regulatory framework after the crisis resulted in pressures on banks to strengthen their capital positions, including by curtailing bank lending. The resulting estimated impact on real GDP growth is significant, accounting for about one-third of the estimated decline in 2009. Third, a counterfactual exercise shows that higher capital ratios already in the period leading to the start of the international financial crisis would have resulted in less buoyant and more expensive credit to the private sector, hence dampening the business cycle and inflation.

1 Introduction

The global financial crisis revealed a need for macroprudential policy tools to mitigate the build-up of risk in the financial system and therefore enhance the resilience of financial institutions. As a consequence, macroprudential policy has been ramped up in many jurisdictions, including the members of the euro area. More concretely, the ECB has been given some macroprudential powers to implement macroprudential measures as set out in the CRD IV package.[1]

Many of these macroprudential measures are capital-based instruments aimed at increasing banks' resilience to macro-financial shocks, such as the counter-cyclical capital buffer (CCyB), the systemic risk buffer (SRB) and capital buffers for systemically important institutions (Kok et al., 2014). Thus, estimating the impact of shocks to bank capital has received renewed attention recently. The idea behind the macroprudential use of countercyclical capital buffers is to impose a capital surcharge on banks in order to limit the excessive amplification of credit cycles and to incentivise banks to build up capital so that they are better prepared to withstand losses in a bust (Drehmann et al., 2011; Hanson et al., 2011). In this context, the question is whether and to what extent changes in the buffers will affect bank lending, lending spreads and the broader macro-economy. Answering this question is not straightforward, as capital ratios are endogenous, influenced by monetary policy and demand conditions, as well as discretionary changes in policy. Furthermore, the empirical evidence with the macroprudential use of such buffers is very thin, in particular in the euro area (Kok et al., 2014). As a consequence, the literature on the impact of shocks to bank capital can offer useful insights in order to assess the impact of macroprudential buffers on the banking sector and the economy at large.

There is a relatively long-standing tradition in the monetary and banking literature estimating the impact of shocks to bank capital on bank lending and the economy. In particular, the econometric literature has dealt with the endogeneity of bank capital in three manners. A first strand of literature has tried to isolate shocks to bank capital per se by estimating the response of banks to losses associated with real estate exposures (Bernanke and Lown, 1991; Watanabe, 2007; Puri et al., 2011) or a stock market collapse (Peek and Rosengren, 1997). Second, the literature has tried to isolate regulatory shocks to bank capital. For example, those associated with stricter supervision (Peek and Rosengren, 1995; Woo, 2003), changes in bank-specific minimum capital requirements (Francis and Osborne, 2009; Aiyar et al., 2012; Bridges et al., 2014), those associated with the dynamic provisioning framework introduced in Spain in the 2000s (Jiménez et al., 2016) or those associated with stricter system-wide capital requirements (Basten and Koch, 2015). The last manner to deal with the endogeneity issue is to identify the impact of a shock to bank capital in the context of a structural time series model. For example, several VAR or Global VAR (GVAR) models have been estimated and shocks to bank capital have been

[1] In the European Union (EU), several macro-prudential policy instruments were embedded in the legislation transposing the Basel III global standards on bank capital into the EU legal framework (via a Regulation and a Directive, the "CRD IV" package).

identified via Cholesky factorization or sign restrictions (Lown and Morgan, 2006; Berrospide and Edge, 2010; Noss and Toffano, 2014; Meeks, 2014; Groß et al., 2015). There seems to be widespread agreement in this literature suggesting that banks react to shocks to bank capital mainly by curtailing lending, increasing lending spreads and changing the composition of assets.

We contribute to the empirical literature on the impact of shocks to bank capital in the euro area by estimating a Bayesian VAR model identified with sign restrictions. Our goal is three-fold. First, we estimate the impact of a shock to bank capital on macroeconomic and banking variables. We isolate three channels through which banks can adjust to such shock: deleverage (slashing bank loans to the non-financial private sector), de-risking the banking book (adjusting loans to households and non-financial corporations to a different extent) and boosting capital levels.[2] Second, we estimate the contribution of demand shocks and shocks to bank capital on the observables over time. Such historical contribution of shocks allows assessing the relevance of structural shocks on the evolution of the variables in the VAR. And third, we perform a counter-factual exercise to assess whether an increase in capital ratios before the start of the global financial crisis could have helped to prevent, or at least soften, the boom-bust cycle and economic crisis in the euro area.

The starting point of our analysis is the standard workhorse VAR used extensively in monetary policy analysis (comprising a proxy of the policy interest rate, economic activity and inflation), extended to include aggregate banking sector variables (bank lending to households and non-financial corporations, bank lending spreads, the capital ratio and capital and reserves). The model is estimated with Bayesian techniques owing to the relatively short estimation sample and the relatively large number of variables included in the VAR. The structural model is identified with sign restrictions implemented using the methodology of Rubio-Ramirez et al. (2010). We do not aim at identifying all the shocks in the economy, but only two shocks that appear to be relevant in shaping bank lending dynamics in the euro area since the early 2000s, namely a demand shock and a shock to bank capital.

The main findings of the paper are as follows. First, impulse-response analysis shows that as a response to a shock to bank capital, banks boost capital ratios by de-risking their balance sheets (e.g., by shifting the portfolio away from loans which are more capital intensive) and by adjusting lending (and hence RWAs) to a larger extent than they increase the level of capital and reserves per se. Second, a historical shock decomposition analysis shows that the shock to bank capital has contributed to boosting capital ratios since the crisis, hence impairing bank lending growth and contributing to widened bank lending spreads. This observation is consistent with the responses to the ECB Bank Lending Survey (BLS), which suggests that the more stringent regulatory framework after the crisis resulted in pressures on banks to strengthen their capital positions, including by curtailing bank lending. The resulting estimated impact on real GDP growth is significant, at about one third of the observed fall in 2009. Third, a

[2] When de-risking, the choice of banks may be influenced by regulation (e.g., banks might prefer to deleverage first on assets with higher risk weights).

counterfactual exercise shows that higher capital ratios already in the period leading to the start of the international financial crisis would have resulted in less buoyant and more expensive credit to the private sector, hence dampening the business cycle and inflation.

The rest of the paper is organised as follows. The next Section provides a brief summary of the scant empirical literature estimating the impact of shocks to bank capital on macro and banking variables. The methodology is presented in Section 3, including a description of the variables in the VAR, the Bayesian econometric technique used in the estimations and the sign restrictions implemented to identify the demand and the capital shocks. The results are presented in Section 4. Section 5 concludes.

2 The impact of bank capital shocks on bank lending and the economy: review of the literature

Identifying the impact of changes in bank capital on lending and the economy is challenging because bank capital itself tends to respond to changes in bank lending and in the macroeconomic environment. Hence, a large part of the variation in bank capital is likely to result from disturbances to macroeconomic variables (such as economic activity or interest rates) as well as from economic policy per se. For example, changes in macroeconomic variables affect capital via changes in operating income, the valuation of assets and the creation of non-performing exposures, among others. The literature has dealt with this endogeneity issue in several manners. First, it has tried to isolate shocks to bank capital per se (e.g., stemming from losses associated with the burst of a real estate bubble). Second, it has tried to isolate regulatory shocks to bank capital, both at the bank and system-wide level (e.g., setting of bank-specific regulatory capital ratios). And third, the impact of a shock to bank capital has been identified in the context of structural time series models, such as SVARs or SGVARs.

The first strand of literature has estimated the impact of losses in bank capital associated with a burst in real estate prices and a stock market collapse. Bernanke and Lown (1991) find that a shortage of equity capital due to the burst of a real estate bubble played a role during the credit crunch observed in the early 1990s in the U.S. Hancock et al. (1995) also study the case of the credit crunch in the U.S. and found that bank capital and securities adjust faster to a capital shock than other asset categories. Peek and Rosengren (1997) found that lending of Japanese branches to U.S. non-financial corporations declined as a response to a hit in the parent's capital positions associated with the sharp decline in Japanese stock markets in the early 1990s. Watanabe (2007) also studied the case of Japan in the late 1990s and found that banks cut back on their lending supply in response to the large loss of bank capital associated with write-offs of non-performing loans (NPLs) in the real estate sector. Using data for the U.K., Mora and Logan (2012) found a lasting drop in loans and in interbank deposits associated with a shock to bank capital due to the write offs of loans of non-residents.

Regulatory shocks to bank capital, where banks are requested to hold higher capital ratios by a regulatory authority, can produce banks' responses analogous to those shocks to capital per se, also affecting lending and macro-economic outcomes. Such regulatory shocks may be bank-specific or system-wide.[3] Peek and Rosengren (1995) focus on the recession in the early 1990s in the region of New England in the U.S. and found that declines in bank capital associated with stricter capital requirements forced banks to shrink. Woo (2003) uses data for Japan and found that a regulatory-induced shortage of bank capital constrained the ability of Japanese banks to lend in the late 1990s. Several studies have been written for the U.K., where the regulators have imposed time-varying, bank-specific minimum capital requirements since Basel I. These studies show that more stringent capital requirements lead banks to curtail lending and lower risk-weighted assets (Francis and Osborne, 2009; Aiyar et al., 2012; Bridges et al., 2014). In the euro area context, Jiménez et al. (2016) exploit modifications in the dynamic provisioning framework in Spain and found that countercyclical dynamic provisioning helps to slow down bank lending growth in good times and boosts it in bad times, thus helping to smooth lending cycles and economic activity. Mésonnier and Monks (2014) find empirical evidence suggesting that banks that had to increase capital in the context of the EBA 2012 Capital Exercise tended to exhibit subsequently a lower annual growth rate of loans than banks that did not have to increase their capital ratio. Maurin and Toivanen (2012) focused also on the euro area and found that a wider gap between target and actual capital ratios dampens loan growth in the medium-term.

A drawback of the studies mentioned so far is that they tend to focus on specific one-off events and tend to neglect the dynamic interaction and feedbacks among banking variables and between these and macroeconomic variables (bank capital, different types of bank lending, monetary policy, economic activity, inflation, etc.). In particular, these studies have been based mainly on a single equation modelling framework, where sub-categories of loans are regressed against banking and macroeconomic variables. By modelling the dynamics of each of the asset categories separately, these studies neglect the dynamic interaction among all the asset categories, possibly wrongly assuming exogeneity across the variables. The same issue arises between the macro variables and the banking sector variables when neglecting the interaction between these two sides of the economy. This is expected to play an important role when many banks face simultaneous and correlated changes in capital, owing to regulatory changes, cyclical conditions, or need to strengthen their capital base to regain market confidence. To account for the dynamic interaction among variables, another strand of literature has included capital

[3] One complication with this approach is that it is debatable to what extent such regulatory changes can be considered to be fully exogenous. Normally, the regulators are expected to react to economic and financial developments, making the response endogenous to some extent. Another complication is the scant availability of such regulatory changes, both across countries and time, as in the case of most developed countries, capital requirements tend to be homogenous across institutions. Also, there are relatively few changes to aggregate regulatory capital requirements observable in past data across countries. For example, the counter-cyclical capital buffer had not been activated in any of the euro area countries at the time of writing.

ratios among a broader set of banking and macroeconomic variables in a time series vector autoregressive model (VAR).

Lown and Morgan (2006) estimate a VAR model for the U.S. over the period 1990 to 2000 to disentangle loan demand from loan supply shocks. They include the capital-to-asset ratio among the endogenous variables in the system and identify structural shocks based on a Cholesky factorization. The authors find that a shock to the capital ratio leads to a lasting decline in bank lending. Berrospide and Edge (2010) also estimate a VAR model for the U.S. but using balance sheet data for large bank holding companies. As before, the shock to the capital ratio is identified via a Cholesky factorization. By contrast to Lown and Morgan (2006), they find a modest effect of shocks to the bank capital ratio on bank lending and a more important role for factors such as economic activity and perceived macroeconomic uncertainty.

Noss and Toffano (2014) quantify the effect of changes in aggregate regulatory capital requirements on U.K. banks using a VAR framework identified with sign restrictions. They conclude that an increase in aggregate capital ratios of banks operating in the U.K. is associated with a lasting decline in the level of lending. The effect is found to be larger on lending to non-financial corporations than on lending to households, perhaps reflecting differences in capital requirements between lending types. Meeks (2014) also studies the case of the U.K. and exploits time varying capital buffer requirement available from the Prudential Regulation Authority (PRA) to estimate the impact of regulation-induced shocks to banking system capital. The author assesses the dynamic interactions between the banking system and the macroeconomy in a standard monetary policy VAR. The VAR is identified based on the methodology suggested by Rubio-Ramirez et al. (2010). He finds that changes in the level of capital requirements depress lending to households and non-financial firms, raises lending spreads and depress economic activity.

Groß et al. (2015) estimate a mixed-cross-section global vector autoregressive (MCS-GVAR) model combining bank and country specific data for 28 EU economies to study the propagation of bank capital shocks to the macroeconomy. In particular, they simulate the impact of three types of negative bank leverage shocks (a negative credit supply shock, a positive credit supply shock and an unconstrained capital ratio shock). The authors find that shocks to bank capital induce significant downward pressure on real activity if banks shrink the size of their balance sheet, i.e. reduce credit supply. By contrast, if they delever by raising capital while not compressing the size of their balance sheets, economic activity tends to expand. Finally, under the unconstrained deleveraging shock, results are mixed.

All in all, there is a widespread agreement in the literature suggesting that after controlling for the endogeneity of bank capital, banks tend to react to shocks to capital by curtailing lending, increasing lending spreads and changing the composition of assets (including de-risking of their balance sheets).

3 Empirical methodology

We estimate a VAR model comprising nine variables in order to estimate the impact of shocks to bank capital on the euro area economy. The following subsections describe in detail the methodology used to estimate the VAR, the variables included in the model and the sign restrictions to identify the structural shocks.

3.1 Econometric model

The impact of bank capital shocks on the euro area economy is estimated based on the following VAR(p) model:

$$Y_t = C + B_1 Y_{t-1} + \ldots + B_p Y_{t-p} + \ldots + B_P Y_{t-P} + \vartheta_t \tag{1}$$

Where Y_t is an N-dimensional vector ($N = 9$) of endogenous variables at time $t = 1, \ldots, T$. C denotes an N-dimensional vector of constants, B_p denotes the matrix of dimension $N \times N$ of coefficients associated with the pth lag ($p = 1, \ldots, P$) of Y_t and ϑ_t is an N-dimensional vector of residuals (reduced-form shocks) with the following properties:

$$\begin{aligned} \mathbb{E}[\vartheta_t \vartheta_s'] &= \Sigma \quad \text{if } t = s \\ \mathbb{E}[\vartheta_t \vartheta_s'] &= 0 \quad \text{if } t \neq s \\ \mathbb{E}[\vartheta_t] &= 0. \end{aligned}$$

Equation (1) can be rewritten as a system of multivariate regressions, as follows:

$$Y = X \cdot B + V \tag{2}$$

where Y is defined as $Y = \begin{pmatrix} Y_1 & \ldots & Y_T \end{pmatrix}'$ and is of dimension $T \times N$. The regressor matrix is of dimension $T \times (N \cdot P + 1)$ and is defined as $X = \begin{pmatrix} X_1 & \ldots & X_T \end{pmatrix}'$. The components X_t in the regressor matrix are defined as $X_t = \begin{pmatrix} Y_{t-1}' & \ldots & Y_{t-P}' & 1 \end{pmatrix}'$. The coefficient matrix B is defined as $B = \begin{pmatrix} B_1 & \ldots & B_P & C \end{pmatrix}'$ and is of dimension $(N \cdot P + 1) \times N$. The $T \times N$ matrix of reduced-form shocks is given by $V = \begin{pmatrix} \vartheta_1 & \ldots & \vartheta_T \end{pmatrix}'$. Given the relatively large number of variables included in our VAR and the relatively short sample, we shrink the parameter space of the reduced-form VAR using Bayesian techniques. An advantage of using Bayesian methods to estimate the VAR model is that it allows us to overcome the potential problem of underestimating persistence, which arises when using the conditional likelihood instead of the exact likelihood. In other words, there is no small sample bias in the context of our Bayesian analysis. Moreover, it has been shown that the presence of unit roots does not affect inference.

We use a standard natural conjugate prior that assumes a normal distribution for the coefficients in the VAR and an inverse-Wishart distribution for the covariance matrix. The prior can be specified and implemented using artificial/dummy variables. In particular, consider that there are dummy observations for Y and X, denoted Y_D and X_D. These dummy data can be used to generate a prior. First, obtain the OLS estimates as follows:

$$b_0 = (X_D^{'} X_D)^{-1}(X_D^{'} Y_D) \tag{3}$$

$$S = (Y_D - X_D b_0)^{'}(Y_D - X_D b_0) \tag{4}$$

Where b_0 is the vector of estimated coefficients and S is the variance-covariance matrix of the residuals. Then, vectorise the estimated coefficients $\tilde{b}_0 = vec(b_0)$. The Normal-Inverse-Wishart prior is then estimated as follows:

$$p(B|\Sigma) \sim \mathcal{N}(\tilde{b}_0, H) \tag{5}$$

$$p(\Sigma) \sim \mathcal{IW}(S, T_D - K) \tag{6}$$

Where Σ is the variance-covariance matrix of the VAR, $H = \Sigma \otimes (X_D^{'} X_D)^{-1}$, T_D denotes the length of the artificial dummy data and K denotes the number of regressors in each equation.

There are four hyperparameters $\{\tau, c, \delta_j, \sigma_j\}$ that together generate sequences of dummy data, which in turn imply a Normal-Inverse-Wishart prior. The first two hyperparameters control the degrees of prior tightness: τ governs the overall tightness of the prior while c determines the tightness of the prior on the constant. In line with values often used in the literature, we set these two hyperparameters to $\tau = 0.1$ and $c = 1$. In addition, we use an auxiliary AR(1) regression:

$$Y_t^j = const + \delta_j Y_{t-1}^j + e_t^j, \tag{7}$$

Where Y_t^j represents each individual variable $j \in (1, \dots, 9)$ in Y_t. We use the AR(1) coefficient δ_j and the standard error σ_j in the construction of the dummy variables. Following Banbura et al. (2010), we then construct the Normal-Inverse-Wishart prior with dummy observations as follows:

$$Y_D = \begin{pmatrix} diag(\delta_1\sigma_1, \dots, \delta_n\sigma_n)/\tau \\ 0_{N(P-1)\times N} \\ \dots \\ diag(\sigma_1 \dots \sigma_N) \\ \dots \\ 0_{1\times N} \end{pmatrix}, \qquad X_D = \begin{pmatrix} \frac{J_P \otimes diag(\sigma_1, \dots, \sigma_N)}{\tau} & 0_{N\cdot P\times 1} \\ 0_{N\times N\cdot P} & 0_{N\times 1} \\ \dots & \dots \\ 0_{1\times N\cdot P} & c \end{pmatrix} \tag{8}$$

Where J_p is defined as $J_p = diag(1, 2, ..., p)$ and P is the total lag-order. We use a lag-order of $P = 4$. Our Normal-Inverse-Wishart Prior resembles the standard Minnesota prior. We do not augment our prior with the other two components often used in the literature: the 'One-unitroot prior' (or Co-persistence prior, dummy initial observation prior) and the 'No-cointegration prior' (or sum-of-coeffcients prior, own-persistence prior). The reason for not specifying the two latter components is that we already consider stationary (differenced) data. Using stationary data facilitates the estimation of the VAR and it allows us to strengthen and substantiate our identification scheme by relating the signs of the restrictions to theoretical IRFs from a canonical Macro-Financial DSGE model (see the discussion below).

3.2 Variables included in the VAR

The starting point in our analysis is the standard VAR model used in monetary policy analysis, including the policy interest rate, economic activity and inflation. This standard VAR model is extended to include banking variables, such as bank lending volumes and spreads, on top of banks' capital ratios and the level of bank capital. Economic activity is measured by the annual rate of growth of real GDP of the euro area (adjusted for calendar and seasonal effects). Inflation is the annual rate of growth in the Harmonised Index of Consumer Prices (HICP). The source of the data for economic activity and inflation is Eurostat. The average of overnight rates for unsecured interbank lending in the euro area (Eonia) is used as a proxy for the policy interest rate.[4] The source of the data is ECB.

Regarding bank lending, most of the VAR analysis performed so far has included one or at most two categories of bank's assets.[5] In this paper, we include in the VAR the annual rate of growth in bank lending to non-financial corporations and to households for house purchase. Originally, these two variables are defined in terms of an index of notional stocks. Using notional stock indices to compute the annual growth rates, rather than outstanding amounts, is important because the latter reflect not only the cumulative effect of financial transactions but also the impact of other non-transaction-related changes (e.g., instrument reclassifications, changes in exchange rates, price fluctuations and loan write-offs/write-downs, etc.). Excluding such non-transaction-related changes is more meaningful for economic analysis. The series of bank lending to households and non-financial corporations have not been adjusted for securitisations, meaning that only the exposures that remain in banks' balance sheets are used to compute the annual rates of growth.[6] The source of these series is MFI Balance Sheet Statistics of the ECB.

[4] Several studies have included Eonia as a proxy for the policy interest rate in the euro area. See Hristov et al. (2012), Ciccarelli et al. (2013) and Ciccarelli et al. (2015), among others.

[5] Lown and Morgan (2006) and Berrospide and Edge (2010) estimated VAR models including commercial loans and total loans, respectively. Noss and Toffano (2014) estimated a VAR including total lending to private sector firms, while Meeks (2014) estimated a VAR including lending to private non-financial corporations and mortgage lending. Mora and Logan (2012) included also investments in securities. Bridges et al. (2014) estimated bivariate equations between bank capital and secure and unsecure household lending, commercial real estate and lending to non-real estate corporations. More categories of assets have been considered based mainly on a single equation modelling framework.

[6] This is the relevant concept to include in the VAR because it captures the risk that remains in banks' balance sheets and for which banks need to hold capital to cover for potential losses. Besides, the series is available over a longer-time period.

Most of the literature identifying shocks to bank capital has neglected the presence of bank lending spreads among the regressors in the VAR (Hancock et al., 1995; Lown and Morgan, 2006; Berrospide and Edge, 2010; Mora and Logan, 2012; Bridges et al., 2014; Noss and Toffano, 2014). Inclusion of these variables is relevant because a shock to bank capital is likely to lead to a re-pricing of bank loans, affecting the quantity of loans provided on top of the impact stemming from the bank capital shock itself. The bank lending spread is defined as the difference between bank lending rates (to households for house purchase and to non-financial corporations) and Eonia. These lending rates refer to interest rates on new business loans granted in euros, all maturities combined. The source of the lending rate series is the MFI Interest Rate Statistics of the ECB. We include spreads instead of lending rates because spreads are a proxy for net interest margins and are therefore a better indicator of bank capacity to generate income than lending rates.[7]

In order to account for the shock to bank capital, the capital ratio is included in the VAR together with the annual rate of growth in capital and reserves. The capital ratio is computed as the median of the core tier 1 capital ratio of 51 listed banks located in the euro area reported in Datastream.[8] While the concept refers to Basel II and is therefore not directly comparable to the Basel III common equity tier 1 ratio, this measure is available over a longer time period. However, given the poor data coverage prior 2005, the capital ratio computed using regulatory data is extrapolated backwards using the MFI Balance Sheet Statistics of the ECB.[9] The rate of growth of capital and reserves is computed from an index of notional stock, obtained from MFI Balance Sheet Statistics of the ECB.[10]

All in all, the VAR comprises nine variables. Data are quarterly and the sample spans the period from the fourth quarter of 2003 to the third quarter of 2016. The series included in the analysis are reported in Figure 1.

The bank capital ratio, one of the most relevant variables in the analysis, has hovered in a relative narrow range from the beginning of the sample until mid-2008, when it increased substantially, by around one-half, until the middle of 2013. Since then, it has been broadly stable. The sharp increase in the capital ratio in the early stages of the crisis has been attributed to strong market pressure to rebuild capital, as there seems to be agreement that banks entered the most recent crisis with thin capital levels relative to the riskiness of their portfolios. While pressure from the market to rebuild capital abated after the peak of the crisis, regulatory pressure started to build up. The EU-wide stress test in early 2011 and measures taken by the EU Heads

[7] Moreover, an exogenous change in lending rates implies, ceteris paribus, an equal increase in bank lending spreads.

[8] See Maurin and Toivanen (2012) for more details regarding the sample used to calculate this variable.

[9] A potential drawback of using risk-weighted capital is that the capital ratio is affected by portfolio shifts towards assets with different risk weights. To alleviate this concern, an alternative would be to include in the VAR the bank capital to asset ratio available from MFI Balance Sheet Statistics of the ECB. Estimations including this variable (available upon request) show that the results are broadly in line with those reported in this paper.

[10] The capital ratio and capital and reserves have different sources because the level of capital is not available from Datastream for most of the 51 banks used in the calculation of the median capital ratio for the euro area.

of State or Government late in 2011 to strengthen the resilience of the euro area banking sector against sovereign debt exposures have also played an important role. Moreover, since the end of 2010 banks also started to strengthen their capital positions in anticipation of stricter capital regulations prescribing significantly higher capital ratios under the so-called Basel III framework. Banks also boosted capital ratios early in 2014 due to the implementation of the EU Wide Stress Test, coupled with a review of the asset quality of the banks (AQR).[11]

The observed increase in the capital ratio since the start of the crisis was explained in part by raising capital and reserves, though to different extents over the sample. For example, the build-up of capital and reserves seems to have contributed particularly in the period between 2005 and 2008, and also between 2011 and 2012. The contribution of the capital ratio diminished elsewhere in the sample, as the annual rate of growth of capital and reserves decelerated. Deleveraging appears to have played a prominent role in shaping the capital ratio, as seen in the substantial deceleration in lending to households and non-financial corporations and the increase in the capital ratio observed between 2008 and early 2010. The rebound in bank lending observed in 2010 and in 2011 is consequently associated with a less dynamic increase in the capital ratio. The collapse of bank lending to households and corporations and soaring bank lending spreads coincided with a sharp deterioration in economic activity.

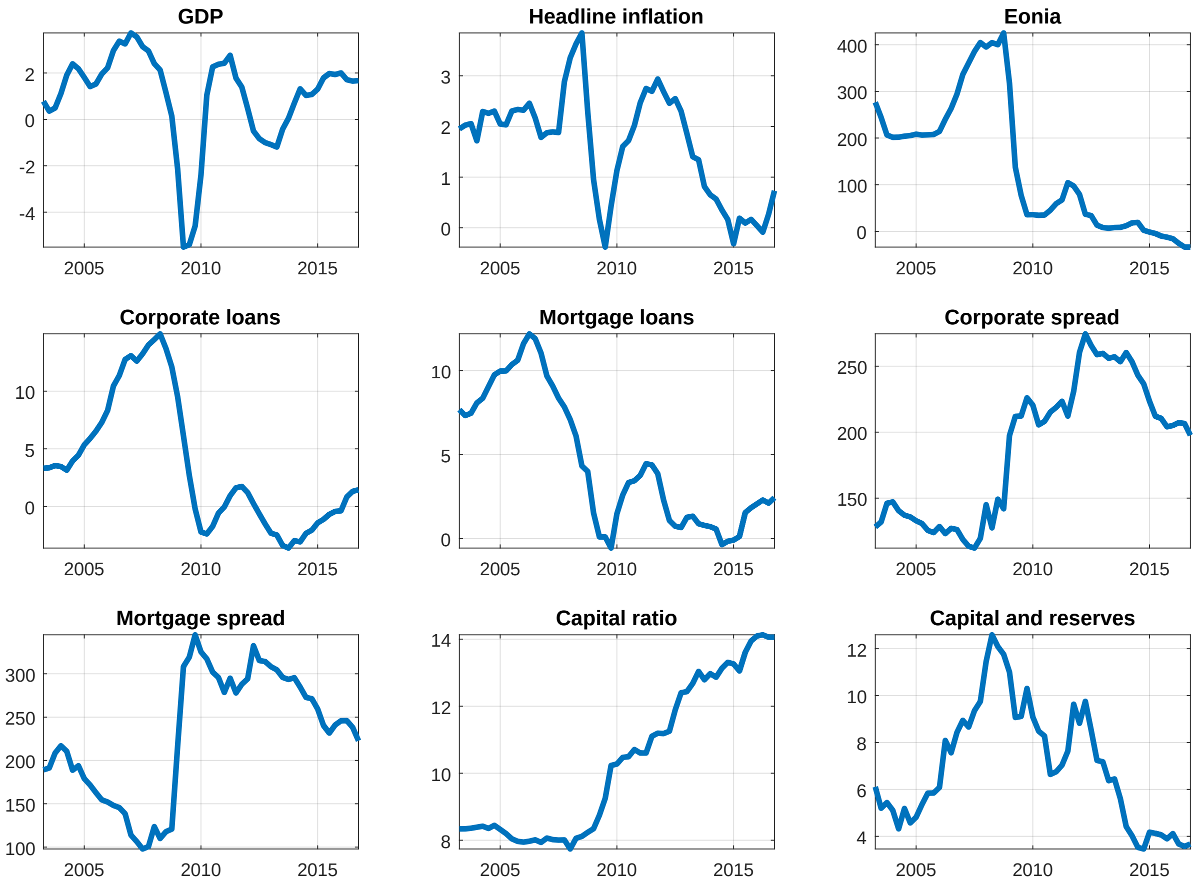
This narrative of the evolution of the variables offers prima facie evidence of the potential presence of demand and bank supply shocks affecting banking and macroeconomic variables in the euro area. However, the concomitant falls in bank lending and economic activity and the widening of bank lending spreads, together with the observed raise in bank capital ratios makes it difficult to disentangle the particular drivers of bank lending. On the one hand, the drop in bank lending growth coincided with the economic downturn, pointing to demand factors affecting lending. On the other hand, it is likely that the increase in regulatory capital may have led banks to curtail lending to households and corporations and to increase lending spreads. In turn, more expensive and less buoyant lending has contributed to the slowdown observed in economic activity and in headline inflation. In what follows, we propose a shock identification scheme that formally disentangles the impact of these two shocks.

3.3 Shock identification

Traditionally, the time series econometric literature has attempted to estimate the impact of bank capital shocks based on a recursive identification scheme. However, such identification scheme suffers from three major drawbacks. First, the choice regarding the ordering of the variables is difficult to establish (among macro and banking variables and within banking variables in particular) and it is often ad-hoc, leading to disagreement in the literature regarding the proper ordering of the variables. As it is well known, altering the ordering of the variables in the system may lead to different impulse response functions, which is an unwelcome property of

[11]Interestingly, to a large extent banks frontloaded the capital adjustment foreseen by the regulator.

Figure 1: Variables Included in the VAR



Source: Data available from Datastream, ECB and Eurostat.
Note: The sample spans the period 2003Q4-2016Q3. Real GDP, headline inflation, corporate and mortgage loans and capital and reserves are expressed in percentage points of annual growth. Eonia and the bank lending spreads are reported in basis points and the capital ratio is expressed in percentage points.

this identification scheme.[12] Second, and related to the previous one, such identification scheme is not based on economic theory. Instead, it is based on the speed at which different variables are assumed to adjust to different shocks. However, economic theory does not usually deliver restrictions that take this form but rather suggests relationships among variables (e.g., negative bank lending supply shocks are characterised by a decline in lending volumes and an increase in lending rates). And third, the recursive identification scheme sometimes delivers doubtful results. In particular, Mumtaz et al. (2015) perform a Monte-Carlo experiment where different

[12] For example, Hancock et al. (1995) and Mora and Logan (2012) estimate a small scale panel VAR model with banking variables for the U.S. and the U.K., respectively. They assume that bank capital is exogenous, entering relatively on top of the ordering of the Cholesky factorization and before bank lending volumes. Lown and Morgan (2006) and Berrospide and Edge (2010) estimate a monetary VAR for the U.S., extended to include bank lending volumes, bank lending standards and bank capital. By contrast, they assume that bank capital is relatively endogenous, entering penultimate in the system and after bank lending volumes.

models are estimated based on data generated from a DSGE featuring credit supply shocks. They find that recursive VARs are sensitive to the variable ordering and can produce estimates that are mis-leading (both in terms of magnitude and dynamics of the resulting responses). By contrast, estimating VARs with sign restrictions delivers impulse responses that match those from the DSGE.

Because of the arguments mentioned above, the recent literature has focused more prominently on the identification of shocks to bank capital based on sign restrictions (Noss and Toffano, 2014; Groß et al., 2015; Meeks, 2014). In this paper we follow the same approach. The identification scheme is implemented via the methodology exposed in Rubio-Ramirez et al. (2010). We do not aim at identifying all the shocks in the economy, but only two shocks that appear relevant in shaping bank lending, output and inflation in the euro area economy since the early 2000s: a demand shock and a bank capital shock. In order to remain agnostic, all the restrictions are imposed on impact, with the exception of inflation. The latter is expected to react with a one quarter lag to both the demand and the capital shock, reflecting a sluggish price adjustment mechanism in the euro area (Angeloni et al., 2003). Table 1 summarises the set of restrictions to a demand and a bank capital shock.[13]

The response of output and inflation to an increase in demand is standard in the literature, both empirical (Peersman, 2005; Hristov et al., 2012; Gambetti and Musso, 2012; Barnett and Thomas, 2013) and theoretical (Straub and Peersman, 2006; Canova and Paustian, 2011). Though traditionally it has been assumed that monetary policy is tightened in response to a demand shock, this response is left unrestricted due to the fact that the monetary policy rate is close to the zero lower bound at the end of the sample. Corporate and mortgage lending increase following a positive demand shock (Gambetti and Musso, 2016). However, corporate and mortgage spreads are left unrestricted in the model. On the one hand, an increase in demand for loans would tend to increase bank lending spreads, reflecting the concomitant increase of price and quantity in the case of a demand shock. On the other hand, the credit risk channel would suggest a decline in the spread. Indeed, the perceived riskiness of borrowers tends to decrease in boom times, putting downward pressure on bank lending spreads.[14] Because of the increase in lending (and in RWAs), banks need to increase the level of capital and reserves.[15] However, we leave the capital ratio unrestricted after a demand shock, as there is uncertainty up to where the increase in RWAs would be stronger than that one in capital and reserves.

The restrictions regarding the impact of a shock to bank capital are derived from theoretical

[13]While we identify two shocks but the VAR contains nine variables, potentially seven shocks remain unspecified. This observation is important because the results could be affected by remaining, unidentified shocks that could be similar to the two identified in the paper. An Appendix (available upon request) provides a robustness check that shows that our findings remain by and large unaffected by the identification of three additional shocks. We remain agnostic as to the source of the additional shocks, while imposing the constraint that they are orthogonal to the demand and capital shock analysed here.

[14]In Figure 1 it is observed that the bank lending spreads declined somewhat in the boom period.

[15]In Section 3, it was observed that in the period of fast growing lending, between 2005 and 2008, banks accumulated a large amount of capital and reserves.

Table 1: Sign restrictions enabling the identification of shocks to bank capital and demand

	Real GDP	Headline Inflation	Eonia	Corp. Loans	Mortg. Loans	Corp. Spread	Mortg. Spread	Capital Ratio	Capital & Reserves
Demand Shock	+	+		+	+				+
Bank Capital Shock	−	−		−	−	+	+	+	+

Note: A demand shock is associated with an increase in activity. A shock to bank capital is associated with an increase in the capital ratio. A blank in the cell means that the response is left unrestricted. In order to be agnostic, all the restrictions are imposed on impact except for inflation for which the impact is delayed by one quarter.

impulse responses from a canonical macro-financial DSGE model (a modified version of Gerali et al., 2010), from the literature that estimates the impact of shocks to bank lending (de Nicolo and Lucchetta, 2011; Hristov et al., 2012; Bassett et al., 2014; Gambetti and Musso, 2016; Barnett and Thomas, 2013) and from bank survey data (the ECB BLS).

In particular, Gerali et al. (2010) develop a DSGE model with financial frictions enriched with an imperfectly competitive banking sector to study the impact of supply factors in business cycle fluctuations. The model captures several relevant features of the banking sector: banks issue loans to both households and firms, obtain funding via deposits and accumulate capital out of retained earnings. Moreover, it is costly for banks to deviate from a target capital ratio. In order to capture the impact of an exogenous shock to the capital ratio, we extend this model to introduce a role for macroprudential policy as in Angelini et al. (2014). In particular, we allow the authorities to set the target value of the capital ratio and add an exogenous shock to it. The combined model is appealing in our setting because it contains theoretical counterparts for all of our nine variables in the VAR. We use the parameter estimates of Gerali et al. (2010) to calibrate the model and study the effects of a bank capital shock on our nine variables of interest. Results for the IRFs (available upon request) support by and large the sign restrictions reported in Table 1.

At the same time, a large body of literature has attempted to estimate the impact of shocks to bank lending and lending spreads (de Nicolo and Lucchetta, 2011; Hristov et al., 2012; Bassett et al., 2014; Gambetti and Musso, 2016; Barnett and Thomas, 2013). To identify bank lending shocks, part of this literature has estimated relatively small scale VARs where the identifying assumption is based on the theoretical response of lending volumes and lending rates. In particular, a negative bank lending shock is reflected in lower lending volumes and higher rates (de Nicolo and Lucchetta, 2011; Gambetti and Musso, 2016; Barnett and Thomas, 2013; Mumtaz et al., 2015; Hristov et al., 2011). In this paper we follow the same approach and assume that a shock to bank capital has the same impact on bank lending volumes and bank lending spreads as a bank lending shock. Hence, the shock to bank capital results in an increase in bank lending rates relative to the monetary policy rate, both to households and corporations when lending is being curtailed.[16]

It should be noted that by contrast to the literature on bank lending shocks, we are more specific about the source of the shock hitting the banking sector. In particular, by focusing on the response of lending volumes and spreads, this literature has been silent regarding the precise source of shocks affecting banks and has omitted bank capital from the estimated models. Hence, inclusion of bank capital among a wider set of regressors in the model allows to identify a bank capital shock. As shown in Table 1, we assume that a shock to bank capital is characterised by an increase in the capital ratio. We also assume that the shock results in an increase in the level of capital and reserves.[17] Hence, part of the increase in the bank capital ratio is assumed to be achieved by slashing loans (potentially changing their composition) and also by increasing the amount of capital held by banks.

These assumptions are also supported by the observation that capital ratios increased substantially since the start of the crisis, backed by a strong decrease in bank lending and an increase in capital and reserves. They are also supported by the responses of banks to the ECB Bank Lending Survey (BLS).[18] In the BLS, Banks have been requested to report the impact of regulatory and supervisory requirements on average and riskier loans and on retained earnings and capital issuance. Since 2011 an overwhelming majority of banks responded to mounting pressure on bank capital positions by decreasing both average and riskier loans (deleveraging) and by decreasing riskier loans in particular (de-risking). Banks also responded by strengthening their capital positions. Hence, survey evidence seems to support the assumption that banks adjust their balance sheets by cutting back on lending and by increasing capital when facing a shock to bank capital.[19]

The response of the macroeconomic variables to a shock in bank capital in Table 1 is not only supported by theoretical IRFs derived from a DSGE model, but also by the empirical literature on bank lending supply shocks. This literature assumes that output and inflation fall following the shock, consistent with the contraction in bank lending (Busch et al., 2010; Hristov

[16]The increase in bank capital should put upward pressure on bank lending spreads because it makes the overall cost of funding more expensive, as equity and retained earnings are the most expensive source of bank's finance (Baker and Wurgler, 2013). Banks may also increase spreads to reduce lending, above and beyond the curtailment of lending volumes per se.

[17]This assumption is sufficient to uniquely identify both shocks in the system.

[18]Since 2011, the BLS has included two ad-hoc biannual questions (in the January and July surveys) regarding the adjustment of banks to regulatory and supervisory requirements affecting banks' capital ratios. Concretely, the BLS specifies that: "These requirements include those set out in the "CRR/CRD IV" legislation, additional measures of the European Banking Authority, and any other specific national regulations concerning banks' capital ratios that have recently been approved or are expected to be approved in the near future." The wording of the question was amended starting with the January 2014 round so that banks, in their reply, would also take into account any new supervisory action, such as the comprehensive assessment of 2014.

[19]See the publication of the various issues of the BLS:
https://www.ecb.europa.eu/stats/money/surveys/lend/html/index.en.html

et al., 2012; Mumtaz et al., 2015).[20] As with the demand shock, the response of the monetary authority is left unrestricted.

4 Estimating the impact of shocks to bank capital

Having presented the methodology to estimate the model and the assumptions regarding the identification of shocks, we illustrate the impact of an adjustment in bank capital on the euro area economy based on three sets of results. First, we present the estimated impulse response functions. Second, we estimate the historical contribution of the two shocks to the evolution of the observables. Finally, we develop a scenario in which the capital ratio would have started to rise prior to the crisis and compute the associated response of the remaining variables in the VAR.

4.1 Impulse response analysis

Based on the estimated VAR model described in Equation (1), we generate impulse responses of the variables to the structural shocks. Figures 2 and 3 report the response of the endogenous variables to one standard deviation demand and capital shocks, respectively. The median of the accepted draws is plotted together with the 16% and 84% Bayesian error bands.

Figure 2 reports the response of the endogenous variables to a positive demand shock. The shock boosts the rate of growth of economic activity in the euro area by more than 0.2 percentage points innitially and has an impact on inflation of about 0.15 percentage points after two quarters. As a response, monetary policy is tightened and Eonia increases by 15 basis points after three to four quarters.

The impact of the demand shock on the rate of growth of bank lending volumes is delayed in the case of lending to corporations (by about four quarters compared with GDP), while it is faster in the case of mortgage loans. The rate of growth of the former increases from about 0.21 on impact to about 0.5 percentage points after a year and the latter by 0.2 percentage points on impact, when the peak is reached. This delayed pattern for corporate lending possibly reflects the existence of overdrafts or credit lines from which corporations can draw in the short-run.

The demand shock leads to a fall in the median response of both corporate and mortgage spreads, in line with the hypothesis that a positive demand shock decreases the perceived riskiness of the borrowers. The decline is smaller on impact and becomes stronger during the first three subsequent quarters, when the minimum is reached in the case of the mortgage spread.

Note as well that the levels of both bank lending rates increase in response to a demand shock, as the fall in the spreads is smaller than the increase in Eonia. The responses of Eonia

[20] Bassett et al. (2014) find the same macroeconomic responses based on a VAR estimated for the U.S. and identified with a Cholesky decomposition.

and bank lending spreads have been left unconstrained in the system.

Regarding the impact of the demand shock on bank capital, the capital ratio falls by slightly more than 0.05 percentage points after one year and a half, while the rate of growth of capital and reserves increases by 0.4 percentage points after eight quarters. The negative response of the capital ratio, which is left unconstrained in the identification scheme, is consistent with the hypothesis that bank capital tends to be run down during economic expansions. This result is largely attributed to the fact that institutions tend to underestimate actual risks during upswings (Ayuso et al., 2004 and Jokipii and Milne, 2008).[21]

Figure 3 reports the responses of the endogenous variables to a shock to in bank capital. This shock is characterised by an increase in the capital ratio of about 0.12 percentage points after about one year and a half. The rate of growth of capital and reserves also increases, by slightly more than 0.1 percentage points on impact. The adjustment in the capital ratio is more sluggish than that on capital and reserves, because the former is also affected by the response of loans, which takes time to adjust to economic shocks. After two to three quarters, the shock to bank capital leads to a fall of about 0.3 percentage points in the rate of growth of euro area real GDP. As it is typical in the literature, the impact on headline inflation is somewhat delayed, reaching a bottom at slightly less than -0.1 percentage points about three quarters after the shock. As before, monetary policy, which is left unconstrained, is relaxed following the deterioration in economic activity and inflation, by about 15 basis points after five quarters.

Because shocks to bank capital are akin to bank supply shocks, the rate of growth of corporate loans falls by 0.6 percentage points after five quarters, while that one of mortgage loans falls by slightly more than 0.2 percentage points after two to three quarters.[22] Both in the case of this shock and the demand shock, the response of corporate loans is stronger than that one of mortgage loans.[23] Such de-risking of the balance sheet seems to reflect a strategy to raise the capital ratio by shifting the portfolio away from loans which are more capital intensive.[24] The speed of adjustment of mortgage loans to a bank capital shock is also faster than that one of corporate loans. In particular, the response of mortgage loans fades after about eight quarters,

[21] These papers use panel data econometric techniques and find that capital buffers fluctuate countercyclically over the business cycle, even when controlling for other fundamental determinants of capital, such as bank level characteristics. The magnitude of the response of the bank capital ratio to a positive demand shock looks highly plausible when compared with the associated relative impact on GDP. For example, Jokipii and Milne (2008) find that a one percentage point rise in the growth rate of real domestic GDP is associated with a 0.13 percentage point fall in the capital ratio.

[22] Lown and Morgan (2006) find for the U.S. that a shock to the capital ratio leads to a decline in loan growth rates which reaches a minimum after about six quarters.

[23] The model has been estimated also without restricting the response of bank lending to the shock to bank capital. Results (available upon request) show that the response of bank lending is broadly in line with that one presented in Figure 3.

[24] This result is consistent with survey evidence for the euro area and empirical evidence for other countries. In particular, responses to the BLS show that banks prefer to adjust mainly risky rather than average loans as a response to regulatory and supervisory pressure to boost bank capital positions. At the same time, empirical evidence for the U.K. also shows that corporate lending falls more strongly than mortgage loans following a shock to bank capital (Bridges et al., 2014; Meeks, 2014; Noss and Toffano, 2014).

Figure 2: Impulse-response function of endogenous variables to a demand shock

Notes: The impulse-response-functions (IRFs) are estimated based on the VAR presented in Equation (1). The shocks are identified with sign restrictions (Table 1). The responses of real GDP, headline inflation, corporate and mortgage loans and capital and reserves are expressed in percentage points of annual growth. Eonia and the bank lending spreads are reported in basis points and the capital ratio is expressed in percentage points.

whereas that one of corporate loans still remains in negative territory after eighteen quarters.[25]

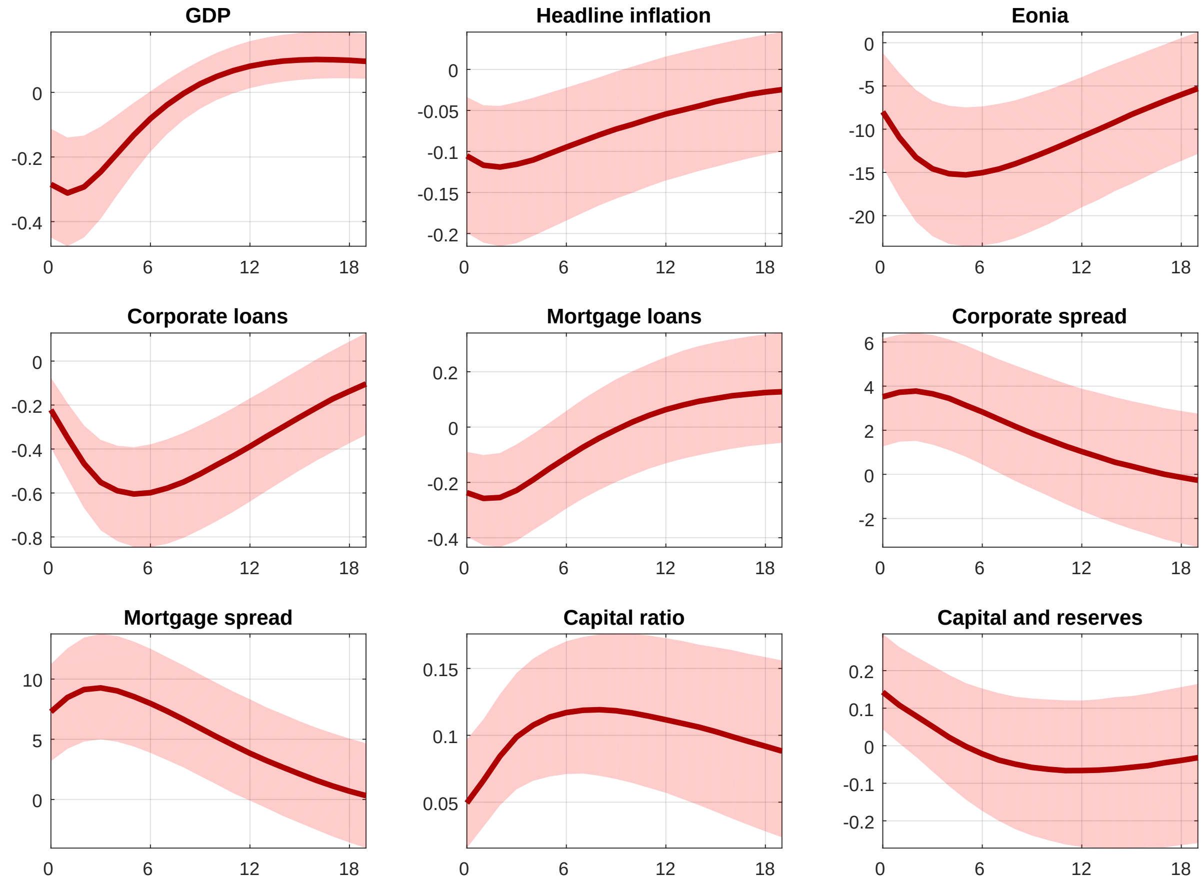
It can be seen from Figure 3 that the response to a shock to bank capital is relatively stronger for corporate and mortgage loans than for capital and reserves, pointing to the fact that the main driver of the capital ratio after such a shock is the former and not the latter.[26] This finding is consistent with the literature and suggests that banks find it less costly to adjust lending rather than capital due to frictions in the market for bank capital and to the impossibility to generate organic capital in some occasions.

The disruption in the supply of bank lending is also characterised by a substantial widening in bank lending spreads. Such spreads rise after the shock and reach a peak of around 9 basis

[25] Meeks (2014) also finds for the U.K. that the response of corporate loans is more sluggish.

[26] One year after the shock, corporate loans have declined by 0.6% and mortgage loans by about 0.2%, while capital and reserves have increased only very slightly.

Figure 3: Impulse response function of endogenous variables to a shock to bank capital



Notes: The impulse-response-functions (IRFs) are estimated based on the VAR presented in Equation (1). The shocks are identified with sign restrictions (Table 1). The responses of real GDP, headline inflation, corporate and mortgage loans and capital and reserves are expressed in percentage points of annual growth. Eonia and the bank lending spreads are reported in basis points and the capital ratio is expressed in percentage points.

points around three quarters after the shock in the case of mortgage lending, while they increase by about 4 basis points after two to three quarters for lending to corporations. The adjustment of bank lending spreads is stronger in the case of mortgage lending, which is likely due to the fact that corporations have access to wider sources of finance than households and can substitute among sources of finance.[27] Whether or not bank lending rates increase or decrease after the shock, depends on the response of monetary policy. Following the bank capital shock, monetary policy is relaxed, as mentioned before. To result in a lower bank lending rate, the decline in the monetary policy rate must be stronger than the rise in the spread and this is what we found.[28]

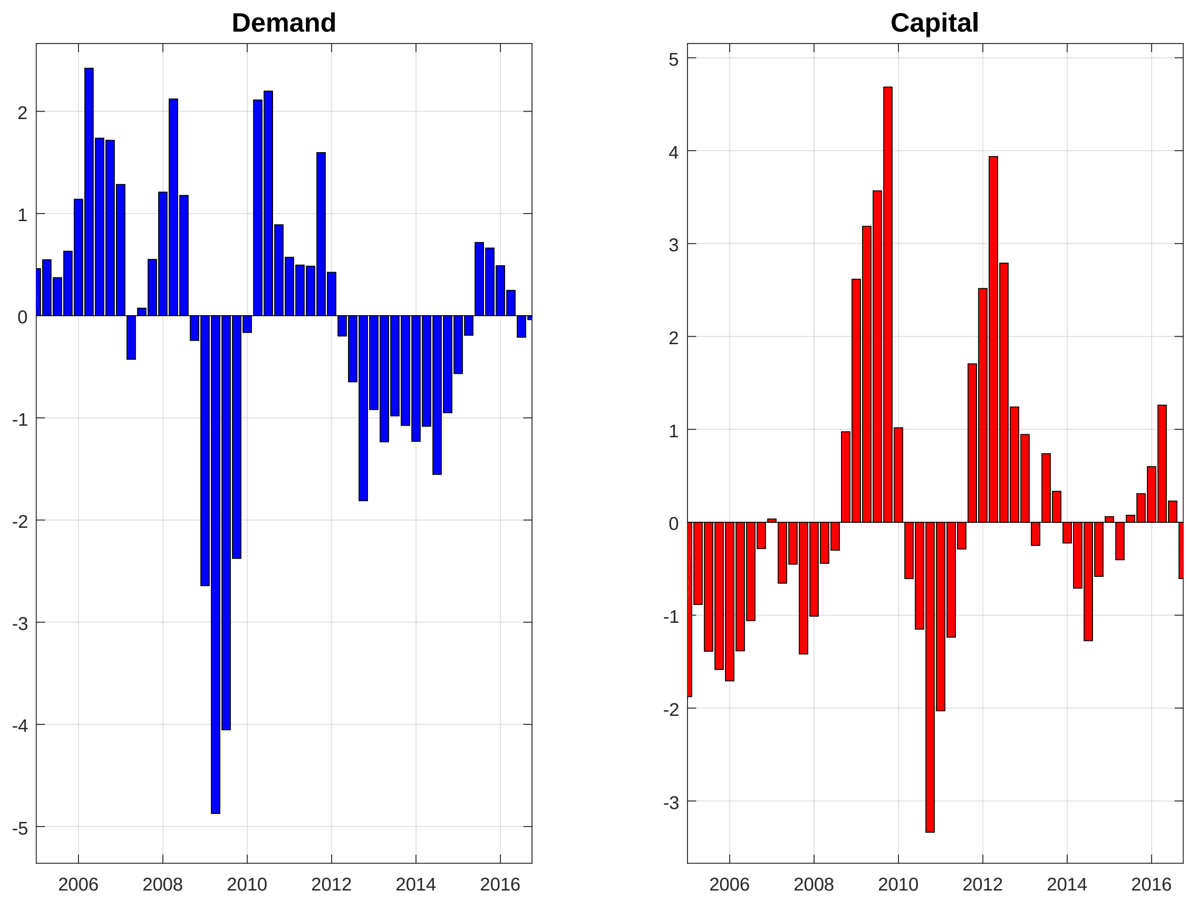
[27] The same results are found by Meeks (2014) for the case of the U.K.

[28] These results are similar to those in Gambetti and Musso (2016), Hristov et al. (2012) and Moccero et al. (2015). These authors estimate the impact of a bank supply shock in the euro area.

4.2 Historical shock decomposition

The evolution of the structural demand shock and the shock to bank capital is reported in Figure 4. Our results for the shock to bank capital are in line with those in Hristov et al. (2011), who report an adverse bank supply shock for euro area countries mainly since the last quarter of 2008 and until the second quarter of 2010 (the last observation in their estimation sample). They are also in line with those of Gambetti and Musso (2016) for the euro area as a whole, who report a strong adverse bank supply shock during the crisis, between 2008 and 2009.

Figure 4: Estimated Structural Demand Shocks and Shocks to Bank Capital



Notes: The charts report the 4-quarter moving average of the structural shocks to demand and to bank capital. A positive value for the demand shock is expansionary for economic activity. A positive shock to bank capital is associated with an increase in the capital ratio.

The historical contribution of shocks allows us to assess the relevance of structural shocks on the evolution of the variables in the VAR at a particular point in time (Figure 5). The historical contribution is based on the estimation of the structural shocks reported in Figure 4 and the orthogonalised impulse-response-functions, following the methodology described in Section 3. In Figure 5, the median contribution is reported. Other papers that have estimated the impact of shocks to bank capital in a time series context have not computed the contribution of the historical structural shocks to the observables (Lown and Morgan, 2006; Noss and Toffano, 2014; Groß et al., 2015).[29] Meeks (2014) computed the historical contribution of structural shocks on the observables for the U.K. but omitted from the estimation the period starting with the international financial crisis.

Empirical evidence presented in Figure 5 shows that demand shocks and shocks to bank capital have played an important role in shaping macroeconomic and banking variables in the euro area over the last twelve years. In particular, demand shocks exerted a positive effect on GDP growth in 2006 and 2007 while they depressed economic activity at the trough of the financial crisis and again in 2013 and 2014. The contribution of the demand shock to headline inflation and Eonia mimics broadly that one on GDP growth.[30] The positive demand shock also boosted bank loans in the pre-crisis period, until 2007 in the case of mortgage lending and until 2008 in the case of lending to corporations. At the peak of the impact, the shock contributed to boosting lending growth by about 0.3 percentage points in the case of mortgages and by about 1.3 percentage points in the case of lending to corporations. By contrast, the negative demand shock observed during the crisis and since 2013 has contributed to putting downward pressure on the rate of growth of bank loans. At the same time that bank lending subsided, the negative demand shock contributed to widening bank lending spreads. The impact of the demand shock on the bank capital ratio is more clearly visible in the period leading to the crisis, when it contributed to depressing it, and in the more recent recovery. Regarding capital and reserves, they were boosted by the positive demand shock in the pre-crisis period and until 2012, while they were depressed towards the end of the sample.

Turning to the impact of shocks to bank capital, Figure 5 shows that the impact on real GDP growth is particularly strong at the peak of the crisis, accounting for about one third of the recorded decline in 2009. The shock is also estimated to have contributed to depressing GDP growth in 2012, though to a much lower degree. By contrast, the shock appears to be boosting economic activity towards the end of the sample. Headline inflation and Eonia have responded to the shock as well, which has boosted both variables until 2008 while it has put downward pressure thereafter.

The impact on the banking variables is in line with the impact on the macro-economy. The rate of growth of corporate loans has been boosted by the shock to bank capital in the pre-crisis period, at a time when banks eroded capital ratios to engage in new lending. The impact on mortgage lending is more muted. By contrast, mounting pressures to rebuild capital in the banking system after the crisis have led banks to cut on bank lending. The contribution is stronger in the case of lending to corporations, where the shock is estimated to have depressed

[29] In the case of Groß et al. (2015), their goal was rather to simulate the adjustment to a shock to bank capital following specific assumptions regarding the response of the banking sector.

[30] Evidence of a positive demand shock exerting upward pressure on inflation in 2011 is consistent with the tightening in the monetary policy rate observed in April and in July 2011.

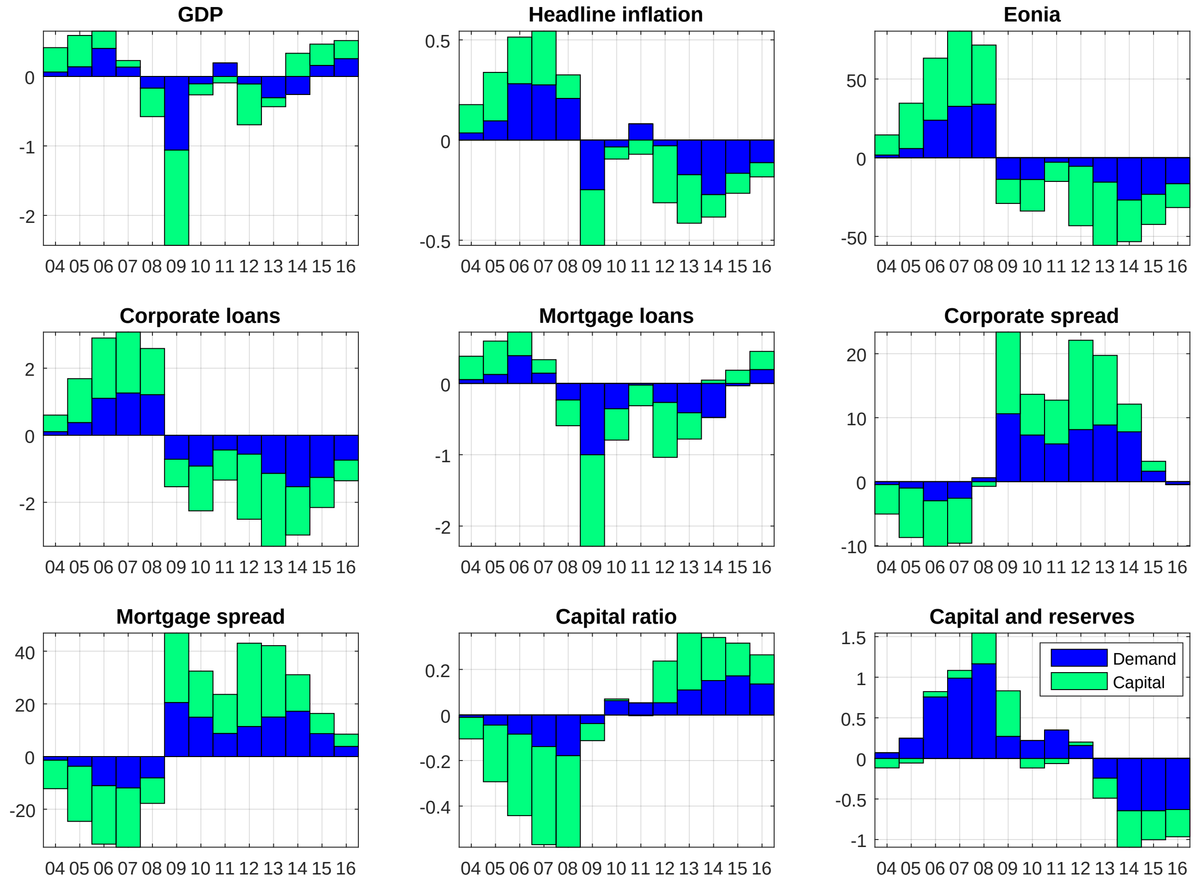
the annual rate of growth in lending by up to 2.6 percentage points. In the case of mortgage lending, the strongest impact is recorded in 2009, where the impact reaches about -1.3 percentage points. Towards the end of the sample period, the impact of the shock start to lessen in the case of bank lending to corporations while it contributes to boost lending in the case of mortgage loans.

The impact on bank lending spreads tends to mimic broadly that one on lending volumes. In particular, bank lending spreads have been compressed in the run up to the crisis, by up to 10 basis points in the case of corporations and by up to 30 basis points for mortgages. With the start of the crisis, the shock to bank capital has contributed to widening bank lending spreads. As with lending volumes, the impact seems to be fading towards the end of the sample. Finally, the impact of the shock to bank capital has contributed to lowering the capital ratio in the run up to the crisis while it has boosted the capital ratio since 2012. A similar, though more volatile pattern is observed in the case of capital and reserves.

Empirical evidence reported in this section regarding the quantitative impact of the shock to bank capital on economic activity is within the range of impacts found in the literature identifying credit and bank supply shocks. However, our findings are somewhat weaker in the case of bank lending. In particular, Moccero et al. (2015) estimate the impact of credit supply shocks in the euro area and find that at the peak of the financial crisis, in 2009, credit supply conditions exerted an adverse effect on manufacturing production amounting to about one fifth of the recorded decline. This finding is somewhat weaker than ours. However, they also find that at the peak of the crisis (and also later in the sample, in 2011), the contribution of the shock to the rate of growth of corporate loans and lending spreads amounts to about 2.5 percentage points and 30 basis points, respectively. Hristov et al. (2012) estimate the impact of bank supply shocks in euro area countries. For Belgium, Germany, Spain, France, Greece and the Netherlands, the authors show that absent an adverse bank loan supply shock in the crisis period (i.e., from early 2009 to early 2010, the growth rate of the loan volume would have been larger by up to 2.8 percentage points and that one of real GDP by up to 1.4 percentage points. Although qualitatively similar, Gambetti and Musso (2016) report somewhat stronger effects from adverse bank supply shocks in the euro area. Their results suggest that the contribution of these shocks can explain about one half of the decline in annual real GDP growth during 2008 and 2009 and that in the absence of loan supply shocks, the decline in the annual growth rate of loans observed from the peaks of 2007 to the troughs of 2009/2010 would have been about 40% smaller.

A counterfactual analysis complements the contribution analysis presented in Figure 5. In this exercise, we report what would have been the evolution of the variables in the VAR, had the shocks not been observed. In particular, rather than reporting the median of the accepted draws, Figures 6 and 7 report the variables in the VAR where the 16% and 84% contributions are subtracted. Hence, differently from before, the counterfactual analysis enables us to display

Figure 5: Contribution of demand shocks and shocks to bank capital

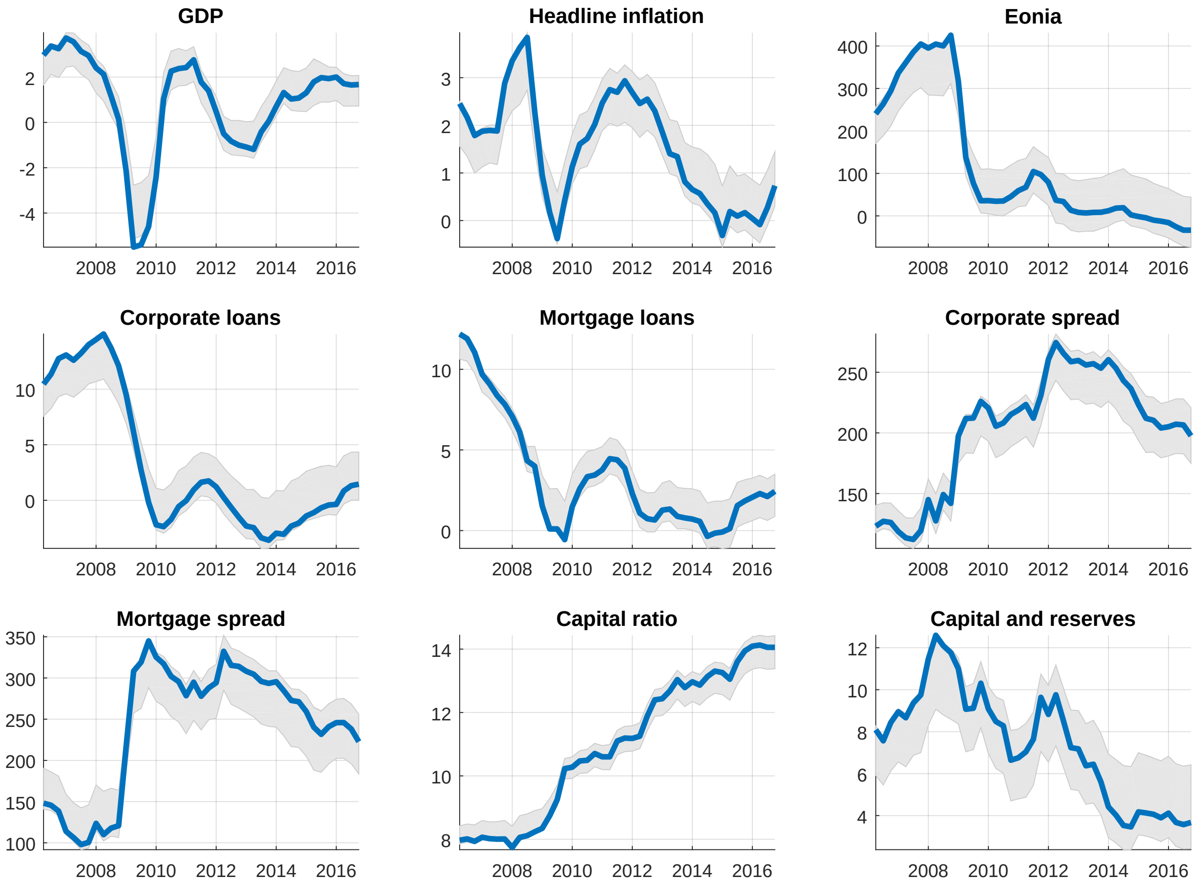


Notes: The charts report annual contributions of each shock to the evolution of the endogenous variables based on the median of the accepted draws. The contribution of shocks was computed based on the structural shocks and the corresponding impulse-response-functions (IRFs). The structural shocks and the IRFs are computed based on the VAR presented in Equation (1). The shocks are identified with sign restrictions (Table 1). Real GDP, headline inflation, corporate and mortgage loans and capital and reserves are expressed in percentage points of annual growth. Eonia and the bank lending spreads are reported in basis points and the capital ratio is expressed in percentage points.

confidence bands around the actual evolution of the variables and therefore to put the impact of the shock into perspective. As before, this exercise allows assessing the relevance of demand shocks and shocks to bank capital on the evolution of the variables in the VAR over the estimation period.

All in all, empirical evidence reported in those charts suggest the hypothesis of a positive demand shock boosting GDP growth, inflation and monetary policy between 2006 and 2008, while a negative demand shock took a tall on these variables at the peak of the crisis and afterwards since 2013. At the same time, the shock to bank capital is estimated to have contributed to boosting capital levels since the crisis, hence impairing bank lending growth and contributing to widen bank lending spreads. This shock resulted in lower real GDP growth and Headline inflation during the crisis.

Figure 6: Counterfactual evolution of the variables with no demand shock

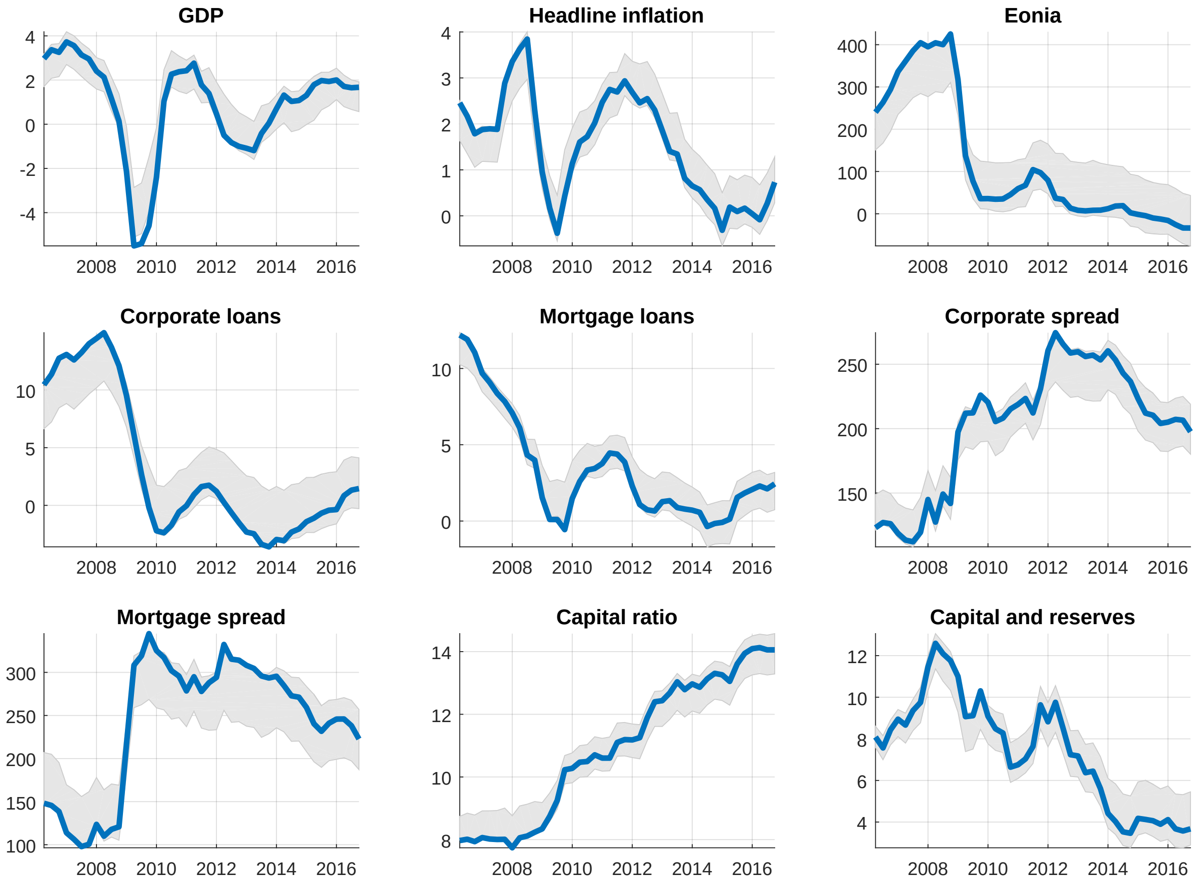


Notes: The sample spans the period between 2003Q1 and 2016Q3 (the first two years are discarded to reduce the sensitivity to the shocks which cannot be estimated but have occurred before the estimation starts). The blue lines report the actual evolution of the variables. The grey bands report the percentile contributions of the shock to the evolution of each variable based on the accepted draws, at the 16% and 84% level. Real GDP, headline inflation, corporate and mortgage loans and capital and reserves are expressed in percentage points of annual growth. Eonia and the bank lending spreads are reported in basis points and the capital ratio is expressed in percentage points.

4.3 Scenario illustrating the frontloading of the increase in the capital ratio prior to the crisis

In this subsection, an explicit path for the capital ratio is assumed and the path for the remaining variables in the VAR is estimated, conditional on the evolution of the capital ratio. In particular, starting in the first quarter of 2005, when the capital ratio stood at about 8%, the ratio is assumed to increase proportionally during every quarter until the value observed in the first quarter of 2011 (about 9.4%). This counterfactual path for the capital ratio assumes higher capital ratios

Figure 7: Counterfactual evolution of the variables without shock to bank capital



Notes: The sample spans the period between 2003Q1 and 2016Q3 (the first two years are discarded to reduce the sensitivity to the shocks which cannot be estimated but have occurred before the estimation starts). The blue lines report the actual evolution of the variables. The grey bands report the percentile contributions of the shock to the evolution of each variable based on the accepted draws, at the 16% and 84% level. Real GDP, headline inflation, corporate and mortgage loans and capital and reserves are expressed in percentage points of annual growth. Eonia and the bank lending spreads are reported in basis points and the capital ratio is expressed in percentage points.

than those actually observed during this period, particularly on account of strong corporate and mortgage lending growth. In the counterfactual, the increase in the capital ratio is assumed to take place at a time when the observed capital ratio was about to start falling. At the same time, the path for the increase in the ratio contains the peak of the rate of growth of bank lending to households (mid-2006) and to corporations (mid- 2008). This exercise could provide a quantitative illustration of the possible impact of the use of macro-prudential tools during the financial cycle.

Because the capital ratio is an endogenous variable in the VAR, one has to be careful when interpreting the counterfactual evolution of this variable. One option is to think about it as a voluntary increase in the ratio on the side of banks, whereby banks might have internalised the fact that too much riskiness was being accumulated in their portfolios and decided to act accordingly. Another, perhaps more realistic option, is to think about it as a response to economic policy. For example, one can think of it as resulting from capital requirements implemented across the board in the euro area. There is a high degree of uncertainty as to the response of bank lending, lending spreads and the broader macro-economy to the activation of macroprudential capital buffers in the euro area. In this regard, this exercise could provide a quantitative illustration of the possible impact of the use of capital-based macro-prudential tools during the financial cycle.[31] The conditional forecast presented in this section is computed based on the methodology developed by Waggoner and Zha (1999), where only the structural shock to the capital ratio is assumed to adjust to ensure the new path for this variable.[32] Bands for the counterfactual evolution of the observables are also reported at the 16% and 84% credibility interval.

Results presented in Figure 8 show that real GDP growth would have been lower during the boom period, by up to 2.5 percentage points. In particular, at the time when real GDP growth was booming in the euro area in early 2007, a higher capital ratio would have implied a lower rate of growth of GDP, by about 1 percentage point. By contrast, economic activity would have been more resilient to the following crisis, from late 2008 to late 2010 and the rebound would have been stronger. At the same time, headline inflation would have hovered at about 1% between late 2006 and early 2008, compared with the 2% observed. Inflation would have been somewhat lower also thereafter, until 2009. As a response, monetary policy would have been looser during the boom period but somewhat tighter thereafter.

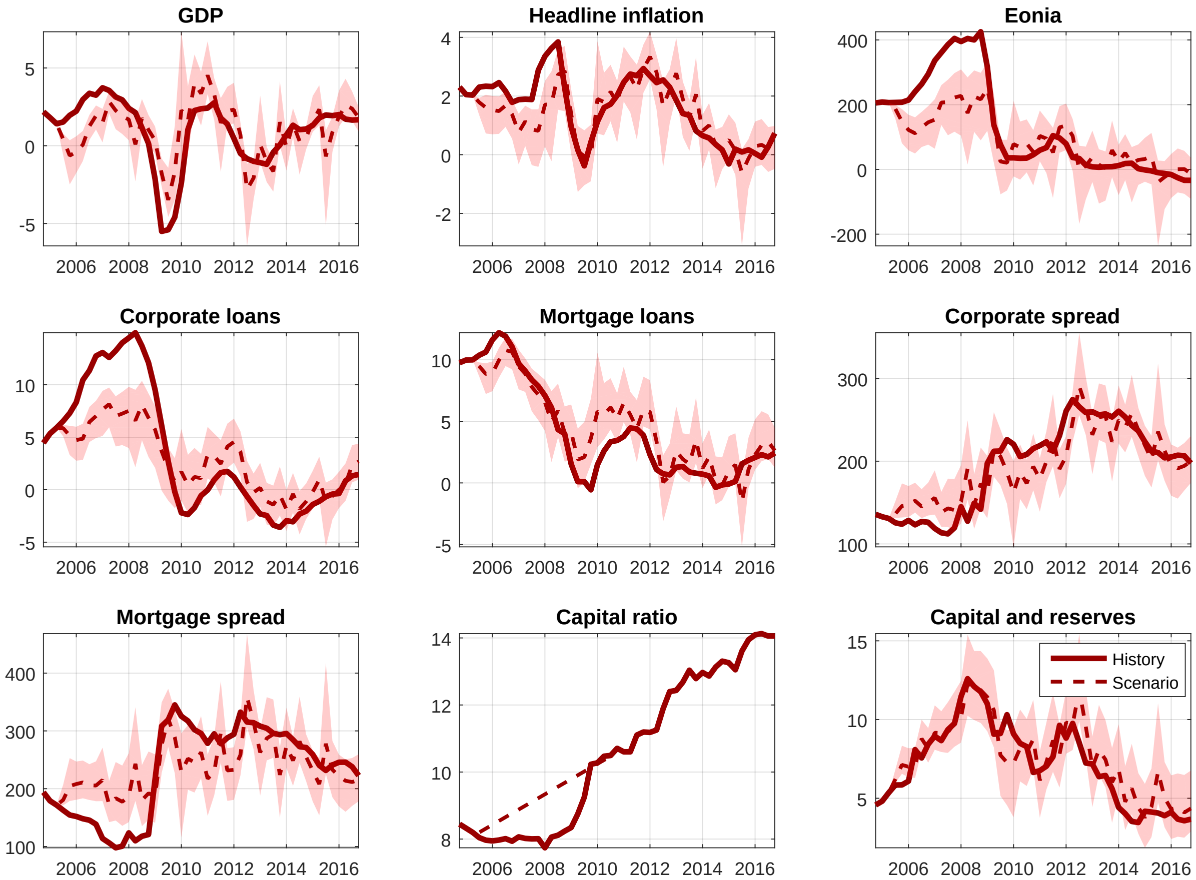
The impact of the capital shock generating the counterfactual evolution of the capital ratio is also clearly visible in the lending cycle, as banks would have needed to adjust to a higher capital ratio during the boom period. In particular, higher capital ratios would have dampened the rapid expansion in corporate lending during the pre-crisis period. The impact is strong, implying that lending growth would have been lower by up to 8 percentage points at the peak of lending in mid-2008. By contrast, corporate lending would have been stronger thereafter. The impact on mortgage lending would have been less strong, because mortgage lending peaked already in the first quarter of 2006, much earlier than lending to corporations. The deceleration in bank lending growth can be attributed to a great extent to the increase in bank lending spreads triggered by the higher capital ratio during that period. Thereafter, spreads would have been somewhat lower than those actually observed, particularly in the case of lending to corporations. Finally, because capital and reserves were estimated not to respond strongly to the shock to bank capital, most of the increase in the capital ratio is supported by the fall in

[31] Strictly speaking, the power to initiate and implement macro-prudential policy measures in the EU remains primarily at the level of the member states, although the ECB has been empowered, if deemed necessary, to strengthen (although not to weaken) macro-prudential measures. See Council Regulation (EU) No 1024/2013.

[32] The remaining shocks are those identified after the estimation of the VAR.

lending rather than by the accumulation of capital and reserves.

Figure 8: Counterfactual evolution of the variables conditional on a new path for the capital ratio



Notes: The charts report the counterfactual evolution of the observables, had the capital ratio increased between early 2005 and early 2011. The conditional forecast is computed based on the methodology developed by Waggoner and Zha (1999) where only the structural shock to the capital ratio is assumed to adjust to ensure the new path for this variable. The remaining shocks are those actually observed from the estimation of the SVAR. Bands are reported at the 16% and 84% level. Real GDP, headline inflation, corporate and mortgage loans and capital and reserves are expressed in percentage points of annual growth. Eonia and the bank lending spreads are reported in basis points and the capital ratio is expressed in percentage points.

A few other studies have also tried to assess the impact of changes in capital requirements on the economy, particularly in the case of the U.K. For example, Francis and Osborne (2009) simulate the potential impact of higher capital requirements by imposing three one-point increases in capital requirements during the early phases of the lending boom, between the late 1990s and the early 2000s. The authors find that higher capital requirements achieve their aim of reducing the rapid expansion of credit during this period. Noss and Toffano (2014) also compute the impact of a counterfactual evolution of the capital ratio, assuming higher regulatory capital ratios pre-crisis, but lower thereafter. In particular, the authors assume that bank capital ratios remain constant at their level observed in early 2006 and find that higher capital requirements during 2006-7 would have increased bank resilience of the banking sector and reduced the severity of the subsequent crisis. Rather than assuming a pre-determined path for the capital ratio, Meeks (2014) simulates the impact of a potential policy feed-back rule for system wide bank capital requirements.[33] Results indicate that a counter cyclical capital buffer could be an effective macroprudential tool, though the quantitative impact on GDP is found to be modest.[34] Finally, assuming an unconstrained response from the banks, Groß et al. (2015) simulate the impact of a one percentage point increase in the capital ratio of individual euro area countries and find that it depresses GDP growth in the concerned country.

All in all, empirical evidence presented in this section shows that higher capital ratios would have gone a long way in dampening the lending and business cycle in the euro area in the pre-crisis period and would have helped to reduce the severity of the subsequent crisis. Such results could provide a quantitative illustration of the possible impact of the use of macro-prudential tools to smooth the lending cycle and show that these tools are suitable to help preventing the future build-up of vulnerabilities in euro area countries. These results are broadly in line with those found in the literature.

5 Conclusion

We have contributed to the empirical literature on the impact of shocks to bank capital in the euro area by estimating a Bayesian VAR model identified with sign restrictions. The variables included in the VAR are those typically used in monetary policy analysis, extended to include aggregate banking sector variables. The model was estimated with Bayesian techniques. The structural model was then identified with sign restrictions á la Rubio-Ramirez et al. (2010). We estimated two shocks affecting the euro area economy, namely a demand shock and a shock to bank capital. While the restrictions for the demand shock are standard in the literature, those about the shock to bank capital are based on theoretical IRFs derived from a canonical macro-financial DSGE model, from the literature that estimates the impact of shocks to bank lending and from the ECB Bank Lending Survey (BLS).

Impulse-response analysis showed that as a response to a shock to bank capital, banks boost capital ratios by de-risking their balance sheets and by adjusting lending to a larger extent than they increase the level of capital and reserves per se. A historical shock decomposition analysis showed that the shock to bank capital has contributed to boosting capital ratios since the crisis, hence impairing bank lending growth and contributing to widen bank lending spreads. This observation is consistent with the responses to the ECB Bank Lending Survey (BLS), which suggests that the strengthening of the banking regulatory framework after the crisis resulted in pressures on banks to strengthen their capital positions, including by curtailing bank lending.

[33] A similar analysis would have not been possible to implement in this paper because of the lack of time varying capital requirements at the euro area level.

[34] This finding is perhaps due to the fact that Meeks (2014) excludes the crisis period from the estimations.

Finally, a scenario analysis showed that higher capital ratios pre-crisis would have helped to dampen the euro area business cycle.

Our empirical findings are broadly in line with those found in the literature, particularly regarding the impact of demand shocks and shocks to bank capital on banking variables. Regarding the former, we provide empirical evidence supporting the view that an expansionary demand shock is associated with a fall in banks' capital ratios (Jokipii and Milne, 2008). Concerning shocks to bank capital, our findings are in line with simulation results in Groß et al. (2015) for European countries, who find that such shocks tend to induce significant downward pressure on real activity when banks are assumed to shrink their balance sheets. They are also in line with results for the U.K., suggesting that an increase in capital requirements is associated with a reduction in bank lending, particularly to corporations (Bridges et al., 2014; Noss and Toffano, 2014) and with an increase credit spreads and a fall in aggregate expenditure (Meeks, 2014). More generally, our findings are consistent with empirical evidence suggesting that adverse credit and bank lending supply shocks are important drivers of bank lending growth, lending spreads and economic activity in the euro area (Hristov et al., 2011; Gambetti and Musso, 2016; and Moccero et al., 2015).

Bibliography

Aiyar, S., C.W. Calomiris and T. Wieladek (2012), "Does macro-pru leak? Evidence from a U.K. policy experiment", No. 17822, National Bureau of Economic Research, Cambridge, MA.

Angelini, P., S. Neri and F. Panetta (2014) "The Interaction between Capital Requirements and Monetary Policy", Journal of Money, Credit and Banking, Vol. 46, Nr. 6, pp. 1073-1112.

Angeloni, I., Kashyap, A., and B. Mojon (2003), Monetary policy transmission in the euro area, Cambridge University Press (2003).

Ayuso, J., D. Pérez and J. Saurina (2004), "Are capital buffers procyclical? Evidence from Spanish panel data", Journal of Financial Intermediation, Vol. 13, pp. 249-64.

Baker, M. and J. Wurgler (2013), "Do strict capital requirements raise the cost of capital? Banking regulation and the low risk anomaly", Working Paper, No. 19018, National Bureau of Economic Research, Cambridge, MA.

Banbura, M., D. Giannone and L. Reichlin (2010), âĂIJLarge Bayesian Vector Auto RegressionsâĂİ, Journal of Applied Econometrics, Vol. 25, pp. 71âĂŞ92.

Barnett, A. and R. Thomas (2013), "Has weak lending and activity in the United Kingdom been driven by credit supply shocks?", Working Paper, No. 482, Bank of England.

Bassett, W.F., M.B. Chosak, J.C. Driscoll and E. Zakrajsek (2014), "Changes in bank lending standards and the macroeconomy", Journal of Monetary Economics, Vol. 62, pp. 23-40.

Bernanke, B.S. and C.S. Lown (1991), "The Credit Crunch", Brookings Papers on Economic Activity, No. 2, Broookings Institution, pp. 205-39.

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, December.

Bridges, J., Gregory, D., Nielsen, M., Pezzini, S., Radia A. and M. Spaltro (2014), "The impact of capital requirements on bank lending", Working Paper, No. 486, Bank of England.

Busch, U., M. Scharnagl and J. Scheithauer (2010), "Loan supply in Germany during the financial crisis", Economic Studies, No .05, Deutsche Bundesbank.

Canova, F. and M. Paustian (2011), "Business cycle measurement with some theory", Journal of Monetary Economics, Vol. 58, pp. 345-361.

Curdia, V. and M. Woodford (2010), "Credit Spreads and Monetary Policy", Journal of Money, Credit and Banking, Supplement to Vol. 42, No. 6, pp. 3 - 35.

De Nicolo, G and M. Lucchetta (2011), "Systemic risks and the macroeconomy", Working Paper, No. 16998, National Bureau of Economic Research, Cambridge, MA.

Drehmann, M., C. Borio and K. Tsatsaronis (2011), "Anchoring Countercyclical Capital Buffers: The Role of Credit Aggregates", International Journal of Central Banking, Vol. 7, Nr. 4, pp. 189-240, December.

Francis, W. and M. Osborne (2009), "Bank regulation, capital and credit supply: Measuring the impact of Prudential Standards", Occasional Paper Series, No. 36, U.K. Financial Services Authority, London.

Gambetti, L. and A. Musso (2016), "Loan supply shocks and the business cycle", Journal of Applied Econometrics, pp. 1099-1255.

Gerali, A., S. Neri, L. Sessa, and F. Signoretti (2010) "Credit and Banking in a DSGE Model of the Euro Area", Journal of Money, Credit and Banking, Vol. 42, Nr. 6, pp. 107-141.

Groß, M., C. Kok and D. Zochowski (2015), ”The impact of bank capital on economic activity: Evidence from a Mixed-Cross-Section GVAR model”, mimeo.

Hancock, D., A.J. Laing, J.A. Wilcox (1995), ”Bank capital shocks: Dynamic effects on securities, loans, and capital”, Journal of Banking & Finance, No. 19, pp. 661-77.

Hanson, S.G., A.K. Kashyap and J.C. Stein (2011), ”A Macroprudential Approach to Financial Regulation”, Journal of Economic Perspectives, Vol. 25, No. 1, pp. 3-28.

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, pp. 569-92.

Jiménez, G., S. Ongena, J-L. Peydro and J. Saurina (2016), ”Macroprudential Policy, Countercyclical Bank Capital Buffers and Credit Supply: Evidence from the Spanish Dynamic Provisioning Experiments”, Journal of Political Economy, forthcoming.

Jokipii, T. and A. Milne (2008), ”The cyclical behaviour of European bank capital buffers”, Journal of Banking and Finance, Vol. 32, pp. 1440-51.

Kok, C, R. Martin, D. Moccero and M. Sandstroem (2014), ”Recent experience of European countries with macro-prudential policy”, Financial Stability Review, May, pp. 113-126.

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. 37, No. 6, pp. 1575-97.

Maurin, L. and M. Toivanen (2012), ”Risk, capital buffer and bank lending: A granular approach to the adjustment of euro area banks”, Working Paper, No. 1499, European Central Bank, Frankfurt am Main.

Meeks, R. (2014), ”Capital regulation and macroeconomic activity: Implications for macroprudential policy”, mimeo.

Mésonnier, J-S. and A. Monks (2015), ”Did the EBA Capital Exercise Cause a Credit Crunch in the Euro Area?”, International Journal of Central Banking, Vol. 11, No. 3, pp. 75-117.

Moccero, D., M. Darracq Paries and L. Maurin (2014), ”Financial Conditions Index and Identification of Credit Supply Shocks for the Euro Area”, International Finance, Vol. 17, Issue 3, pp. 297-321.

Mora, N. and A. Logan (2012), ”Shocks to bank capital: evidence from UK banks at home and away”, Applied Economics, Vol. 44, pp. 1103-19.

Mumtaz, H., G. Pinter and K. Theodoridis (2015), ”What do VARs Tell Us about the Impact of a Credit Supply Shock? An Empirical Analysis”, Working Paper, No. 716, Queen Mary University of London.

Noss, J. and P. Toffano (2014), ”Estimating the impact of changes in aggregate bank capital requirements during an upswing”, Working Paper, No. 494, Bank of England.

Peek, J. and E.S. Rosengren (1995), ”The Capital Crunch: Neither a Borrower nor a Lender Be”, Journal of Money, Credit and Banking, Vol. 27, No. 3, pp. 625-38.

Peek, J. and E.S. Rosengren (1997), ”The International Transmission of Financial Shocks: The Case of Japan”, The American Economic Review, Vol. 87, No. 4, pp. 495-505.

Peersman, G. (2005) ”What caused the early millennium slowdown? Evidence based on vector autoregressions”, Journal of Applied Econometrics, Vol. 20, pp. 185-207.

Puri, M., J. Rocholl and S. Steffen (2011), ”Global retail lending in the aftermath of the U.S. financial crisis: Distinguishing between supply and demand effects”, Journal of Financial Economics, Vol. 100, pp, 556-78.

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, pp. 665-96.

Straub, R. and G. Peersman (2006), ”Putting the New Keynesian Model to a Test”, Working Paper, No. 06/135, International Monetary Fund, Washington, D.C.

Waggoner, D.F. and T. Zha (1999), ”Conditional Forecasts in Dynamic Multivariate Models”, The Review of Economics and Statistics, Vol. 81, No. 4, pp. 639-51.

Watanabe, W. (2007), ”Prudential Regulation and the ”Credit Crunch”: Evidence from Japan”, Journal of Money, Credit and Banking, Vol. 39, No. 2-3, pp. 639 - 65.

Woo, D. (2003), ”In Search of ”Capital Crunch”: Supply Factors behind the Credit Slowdown in Japan”, Journal of Money, Credit and Banking, Vol. 35, No. 6, pp. 1019-38.

Acknowledgements

The paper does not necessarily reflect the views of the EIB or the ECB. The authors thank, without implicating, an anonymous referee, Marek Jarocinski, Matthieu Darracq Paries, Michele Lenza, Albert Marcet, Gert Peersman, Giorgio E. Primiceri, Joao de Sousa, Marcin Wolski as well as participants at the Econometrics Clinic Seminar (ECB), the 4th Journee d'Econometrie Appliquee a la Macroeconomie (University of Paris Nord), the World Finance & Banking Symposium (University of Dubai), the Econ Seminar (European Investment Bank), a seminar organised by the Macro-Prudential Policies Division and the Monetary Analysis Division (ECB), a seminar organised by the Financial Stability & Prudential Supervision Department (Central Bank of Luxembourg) and the RiskLab/BoF/ESRB Conference on Systemic Risk Analytics (Arcada University of Applied Sciences).

Derrick Kanngiesser
Universitat Pompeu Fabra, Department of Economics and Business, Barcelona, Spain; email: derrick.kanngiesser@upf.edu

Reiner Martin
European Central Bank, Frankfurt am Main, Germany; email: reiner.martin@ecb.int

Laurent Maurin
European Investment Bank, Luxembourg, Luxembourg; email: l.maurin@eib.org

Diego Moccero
European Central Bank, Frankfurt am Main, Germany; email: diego.moccero@ecb.int

Postal address	60640 Frankfurt am Main, Germany
Telephone	+49 69 1344 0
Website	www.ecb.europa.eu

This paper can be downloaded without charge from www.ecb.europa.eu, from the Social Science Research Network electronic library or from RePEc: Research Papers in Economics. Information on all of the papers published in the ECB Working Paper Series can be found on the ECB's website.

ISSN	1725-2806 (pdf)	DOI	10.2866/688406 (pdf)
ISBN	978-92-899-2799-4 (pdf)	EU catalogue No	QB-AR-17-089-EN-N (pdf)