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Monetary Policy, Bank Bailouts and the Sovereign-bank Risk Nexus in the Euro Area

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Abstract

The paper analyses the empirical relationship between bank risk and sovereign credit risk in the euro area. Using structural VAR with daily financial markets data for 2003-13, the analysis confirms two-way causality between shocks to sovereign risk and bank risk, with the former being overall more important in explaining bank risk, than vice versa. The paper focuses specifically on the impact of non-standard monetary policy measures by the European Central Bank and on the effects of bank bailout policies by national governments. Testing specific hypotheses formulated in the literature, we find that bank bailout policies have reduced credit risk in the banking sector, but partly at the expense of raising the credit risk of sovereigns. By contrast, monetary policy was in most, but not all cases effective in lowering credit risk among both sovereigns and banks. Finally, we find spillover effects in particular from sovereigns in the euro area periphery to the core countries.

JEL Classification: E52, G10, E60.

Keywords: credit risk, banks, sovereigns, monetary policy, bank bailout, heteroskedasticity, spillovers.

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1 Introduction

A key feature of the European crisis has been the ever closer link between sovereign and bank credit risk in the euro area. A major concern of policymakers was the feedback loop, in which adverse shocks to banks led to an increase in sovereign risk, and deterioration in sovereign risk, in turn, raised the credit risk for banks. Indeed, the correlation between credit default swap (CDS) spreads of banks and sovereigns in the euro area rose from 0.1 to 0.8 between 2007 and 2013 (see Figure 1). The feedback loop has also been blamed for deepening the recession, making an escape from the crisis ever more difficult.

Policymakers have adopted two principle approaches of dealing with sovereign risk and bank risk during the 2008-09 global financial crisis and the subsequent European crisis. On the one hand, national governments implemented bank rescue policies, by providing capital injections into ailing banks, by offering debt guarantees or by issuing deposit guarantees. On the other hand, monetary policy played a central role, by providing liquidity to banks on a massive scale and by intervening in sovereign debt markets through outright purchases or by giving an implicit guarantee against a speculative run.

Have these policies been effective in reducing sovereign risk and bank risk and in breaking the feedback loop? The academic literature has analysed different channels through which these two policy approaches function. Concerning government policies for banks, there are two competing hypotheses about how such policies affect bank risk and sovereign risk (see Allen et al., 2013, Leonello, 2013, and Acharya et al., 2015). Guarantees and capital injections essentially imply a transfer of risk from banks to governments. If such policies are effective not only in preventing bank runs and ensuring the viability of banks, reducing uncertainty and improving the outlook for the economy and the financial system, then these policies are expected to both lower risks to the banking sector and to improve sovereign risk. However, if the bailout policies are large in magnitude and imply a major challenge to the sustainability of public debt, then such a transfer of risk may actually worsen sovereign risk, while improving the risk to banks.

There is also an extensive literature focusing on the impact of non-standard monetary policies on financial markets during the global and European crisis. In particular, there is a growing literature on the effects of the Federal Reserve's quantitative easing policies (see, for example, Gagnon et al., 2011, or Fratzscher et al., 2012) and of the European Central Bank's (ECB) policies (see, among others, Manganelli, 2012, Eser and Schwaab, 2013). The controversy in this literature is to what extent these non-standard policies have been successful in reducing risks to banks and to sovereigns, but these risks have mostly been analysed in isolation, without studying the mutual feedback effects. Finally, there is also the possibility of a cross-country transmission of credit risk shocks. Caporin et al. (2013), for instance, find that transmission within sovereign debt markets of the euro area has decreased with the onset of the European crisis.

The paper provides an empirical test of the effect of bank rescue policies and non-standard policies of the ECB on the nexus between sovereign risk and bank risk in the euro area. The primary interest is whether such policies have helped to break the nexus, or whether they have intensified it. The paper starts with a more general analysis of the causality between bank risk shocks and sovereign risk shocks. It then goes into detail of this link, by investigating whether these two types of policies have functioned differently for healthy countries versus crisis countries, and whether the impact has changed over time. Importantly, we also analyse whether there is evidence for cross-country spillovers and a flight-to-safety phenomenon within the euro area.

Using daily data for the period 2003-13, we employ a set of structural vector auto regression (VAR) models. To identify structural shocks to bank risk, sovereign risk, and the other variables of the system we exploit the heteroskedasticity in the data, following Sentana and Fiorentini (2001) and Rigobon (2003). We take as exogenous the non-standard monetary policy measures as well as the announcements of major bailouts. We find evidence for a two-way causality between sovereign risk and bank risk. The benchmark specification suggests that an increase in sovereign CDS spreads by 100 basis points raises bank spreads by 38 basis points on average. Equally, a deterioration in bank risk by 100 basis points worsens sovereign risk by 28 basis points. Shock transmission functions also via credit risk of non-financial institutions, the term spread, and equity markets. A decline in equity markets and a worsening in credit risk of non-financial firms both significantly raise the credit risk of banks and sovereigns. Moreover, shocks to sovereign or bank risk lead to a deterioration in equity markets and credit risk of non-financial institutions. If one interprets these variables as reflecting the prospects of the real economy, then the implication is that the feedback loop between banks and sovereigns extends to the real economy. In terms of economic significance, a forecast error variance decomposition suggests that indeed shocks to bank and sovereign risk explain a sizable magnitude of the variance of the other variables.

The analysis also reveals a high degree of heterogeneity across countries as well as over time. Before and during the global financial crisis, the impact of sovereign risk shocks on bank risk was generally insignificant. A main finding is that during the height of the global financial crisis in 2008/09, a reduction of bank credit risk by 100 basis points induces an increase in sovereign risk by 12 basis points. The finding suggests that bailouts and guarantees for banks have actually raised sovereign risk. Since the start of the European crisis in 2010, we find an increase in the impact of sovereign risk on bank risk. Moreover, a shock that raises the credit risk of banks during this period also increased sovereign risk. This finding confirms that the sovereign-bank feedback loop indeed intensified during the European crisis. As to the heterogeneity across countries, such a feedback loop hardly exists for core euro area countries, such as Austria, Germany and the Netherlands. By contrast, the loop intensified and reached high magnitudes for several crisis countries in the periphery. Later on, however, it largely ceased to exist in those crisis countries that were bailed out by IMF-EU programmes.

The empirical findings also suggest that there are strong cross-country spillovers of sovereign and bank risk. The largest spillovers stem from shocks to sovereign risk in the euro area periphery to sovereigns in the core, as well as from shocks to banks in the periphery to banks in the core. A positive shock to sovereign or bank CDS spreads by 100 basis points in the periphery raises credit risk in the corresponding market of core euro area countries by 15 and 29 basis points, respectively. What is striking is that the impact of sovereign risk in the periphery on the core countries has been larger than the causality running in the opposite direction. This is important since the core countries constitute the much larger share of the euro area and its underlying sovereign debt market.

Finally, the empirical analysis tends to question whether government policies on banks and ECB non-standard monetary policy measures were effective in reducing the feedback loop between banks and sovereigns. For bank bailout policies, the estimates indicate that debt and deposit guarantees and capital injections into banks were effective in reducing bank credit risk. Important bailout announcements by individual euro area countries lowered bank CDS spreads by 65 basis points on average. By contrast, these policies had a much smaller impact on sovereign risk, and in some instances induced an increase in the credit risk of national governments. All in all, these findings confirm the hypothesis that bailout policies indeed lowered default risk to the domestic banking sector but at the expense of a higher default risk of its sovereign.

As to monetary policy, ECB policies generally exerted a large and significant impact on sovereign risk and bank risk, but also on the real economy, as measured by stock returns and credit risk of non-financial firms. The empirical analysis reveals an interesting yet intuitive difference in the effects of monetary policy announcements as compared to their actual implementation. Announcements about the Securities Market Programme (SMP), consisting of government purchases, were initially quite effective in lowering both sovereign and bank CDS spreads. However, the actual implementation, that is, the purchases over the different weeks, tended to increase bank risk and be ineffective in reducing sovereign risk. While it is hard to deal with the underlying endogeneity, the empirical estimates seem fairly robust to different specifications.

Also the effects of the other non-standard ECB policies show an intriguing picture. While the announcement of the 3-year Longer-Term Refinancing Operations (LTROs) for banks was taken as a disappointment by financial markets, with sovereign and bank spreads increasing, the implementation was effective in reducing bank risk. Announcements regarding Outright Monetary Transactions (OMTs), consisting of conditional commitments to purchase public debt, also exerted a significant impact on financial markets, lowering sovereign CDS spreads on average by 56 basis points.

Overall, these findings suggest that both rescue policies of the banking system and monetary policy exerted a significant impact on sovereign and bank risk as well as on risks and prospects of the real economy. The empirical estimates also indicate that neither of the two policies was unanimously successful. Thus, this entails a note of caution to policymakers that policies that are intended to reduce risk can in fact lead to an intensification of the feedback loop between sovereigns and banks.

The paper contributes to a growing line of research on the sovereign-bank risk nexus. Several authors use time-series analysis (see Alter and Schüler, 2012, Alter and Beyer, 2013, Gross and Kok, 2013, or Bicu and Candelon, 2013). Different to our approach, these papers rely on generalised impulse response functions, following Pesaran and Shin (1998), and do not aim at identifying causal effects. Alternatively, Stanga (2011) uses sign restrictions which allow for causal inference. We prefer an agnostic identification approach, however, since competing theories predict differing signs for the effects of bank bailouts on sovereign risk and it is precisely a main aim of the paper to determine the sign empirically whithout imposing it a priori. Other studies are based on panel data analysis (see Ejsing and Lemke, 2011, Mody and Sandri, 2012, De Bruyckere et al., 2012, Dieckmann and Plank, 2012, Kallestrup et al., 2013, or Acharya et al., 2015). Distinct from our approach, they either focus only on one direction of the two-way relationship between banks and sovereigns, or they use different models for the two directions, whereas we quantify bi-directional causal effects in an encompassing model. This approach has two main advantages. First, it allows for a multidimensional comparison of the importance and magnitude of different types of credit risk shocks, that is, whether sovereign or bank risk shocks, in the core or in the periphery, have been more important for the evolution of the global financial and European debt crisis. Second, our approach enables us to actually quantify the feedback loop between banks and sovereigns in terms of how much it amplifies initial credit risk shocks.

The paper also relates to a rapidly evolving literature on unconventional monetary policy. Kozicki et al. (2011) or Stone et al. (2011) provide reviews for the US and UK. Regarding the euro area, most studies focus on the impact on monetary policy variables such as interest rates, credit supply, inflation, or output (see, among others, Giannone et al, 2011, De Pooter et al., 2012), while only few papers concentrate on CDS markets (see Lucas et al., 2013, and Pelizzon et al., 2013). Besides using different methodologies, the latter are limited to sovereign CDS markets, however, whereas we provide a comprehensive assessment of the implications for euro area CDS markets. Finally, a main contribution of the paper is to study the effects of bank bailouts and non-standard monetary policies jointly in a unified empirical framework which allows for a immediate quantitative comparison of the effectiveness of these two principle policy approaches.

The paper is organised as follows. Section 2 provides a conceptual discussion of the feedback loop between sovereign risk and bank risk, and its relation to other asset classes. The subsequent section discusses the empirical methodology and the data. Section 4 presents the empirical estimates for the transmission of bank shocks and sovereign risk shocks both domestically and internationally. Section 5 then focuses on the effects of non-standard monetary policies and of bank bailouts. The final section concludes.

2 Conceptual framework

In this section, we specify the main hypothesis tested in the empirical analysis. We first discuss transmission channels between bank risk, sovereign risk, and other asset prices. Then, we outline potential effects of non-standard monetary policies on asset prices.

2.1 The role of credit risk, the term spread, and stock returns

The literature discusses several transmission channels between bank risk and sovereign risk. Since we are particularly interested in the role of bank bailouts and in quantifying the sovereign-bank feedback loop, we formulate hypotheses which allow us to (i) estimate the amplification and overall effects between bank risk and sovereign risk and (ii) discriminate between different theories of the effect of bailouts on sovereign risk. That is, we do not aim at discriminating further between alternative non-bailout channels. We start with the transmission of bank risk to sovereign risk. According to a 'standard' credit supply channel, if banks incur unexpected losses they reduce credit supply which depresses investment, economic growth, and the tax base and increases sovereign risk. These arguments lead to the following hypothesis. In general,

Hypothesis 1: *Shocks to bank credit risk impact positively on sovereign credit risk.*

During bailout periods, however, there are two competing hypotheses in the literature. On the one hand, bailouts that reduce bank risk can lead to an increase in sovereign risk if the associated risk transfer is so large that it undermines public finances and increases sovereign default risk, as in Acharya et al. (2015). Hence, we test whether

Hypothesis 2a: *During bailout periods, shocks to bank credit risk impact negatively on sovereign credit risk.*

On the other hand, bailouts that reduce bank risk can reduce sovereign risk, if good fundamentals of the economy render the scheme credible, stimulate credit supply and the economy, as in Leonello (2013). We thus test alternatively whether

Hypothesis 2b: *During bailout periods, shocks to bank credit risk impact positively on sovereign credit risk.*

Moreover, after bailouts, there can be a post-bailout channel that works through sovereigns explicitly guaranteeing for banks' liabilities. As it predicts a positive effect, we subsume it in Hypothesis 1. Further, whereas Hypothesis 2a and 2b are mutually exclusive, Hypotheses 1 and 2a are not. The latter two just refer to different sample periods: full sample or non-bailout periods versus bailout periods.

Regarding a transmission of sovereign risk shocks, reflecting for example an unexpected widening of the deficit, to bank risk, there are three main channels discussed in the literature which all predict a positive impact. The first functions through prices of government bonds. If sovereign risk increases, bond prices fall and banks incur portfolio losses. In addition, their funding conditions deteriorate as the value of (bond) collateral used in refinancing operations declines. Kallestrup et al. (2013), Angeloni and Wolff (2012), and De Bruyckere et al. (2012) provide evidence for these mechanisms in the euro area. A second channel is based on rating ceilings according to which private entities cannot be rated higher than their sovereign. A downgrade of the sovereign then triggers a down rating of domestic banks which increases bank risk since many investors are legally constrained regarding the rating structure of their portfolios. Arezki et al. (2011) find evidence for this channel. Finally, there can be a post-bailout channel if sovereigns explicitly guarantee banks' liabilities, as discussed above. Hence, we test whether

Hypothesis 3: *Shocks to sovereign credit risk impact positively on bank credit risk.*

If we find evidence for Hypotheses 1 and 3, we can test for the existence of a feedback loop between both sectors that amplifies both shocks to bank risk and to sovereign risk.

Regarding shocks to credit risk of the non-financial corporate sector, reflecting negative surprises regarding its economic performance, they increase both bank risk and sovereign risk as the number of non-performing loans rises and the tax base declines. Indeed, Ejsing and Lemke (2011) show that a common credit risk factor accounts for large part of the variation of sovereign and bank CDS spreads. As concerns sovereign risk, Gerlach and Schulz (2010) find that its first principal component explains more than three fourths of its variance. Regarding bank risk, Acharya et al. (2015) identify the iTraxx Europe CDS index as one important determinant. Guided by these findings, we include non-financial credit risk into the model and expect it to increase both sovereign and bank risk.

The term spread consists of two components: expectations of future real rates and of inflation and sovereign credit risk. The first component reflects business cycle expectations. In recessions, public deficits widen and the number of non-performing loans grows. Hence, this component implies a negative co-movement between the term spread and credit risk of sovereigns and banks. Conversely, the credit component reflects sovereign risk perception in the cash bond market and therefore implies a positive co-movement. Palladini and Portes (2011) suggest that the European sovereign CDS market moves ahead of its cash market while Fontana and Scheicher (2010) find that price discovery can run in both directions. Overall, we expect the business cycle component to dominate in normal times and the credit component in times of financial stress.

Equity markets reflect real growth expectations and risk appetite of investors. Both elements lower credit risk in the sovereign, banking, and non-financial sector, respectively. Longstaff et al. (2011) and Dieckmann and Plank (2012) show that stock returns are one important determinant of sovereign CDS spreads. Altogether, we expect a negative relation between equity markets and credit risks.

2.2 Non-standard monetary policy and credit risk

In this subsection, we discuss potential transmission channels of selected ECB policies to sovereign risk and bank risk. We consider LTROs with maturity 6-12 and 12-36 months, respectively, SMP, and OMTs. For LTROs and SMP, we distinguish between implementation and announcement effects. The latter work through anticipation of future monetary policy and economic conditions thereby affecting asset prices today. We group the measures into two but expect each measure to affect both risks in the same direction.

First, LTROs provide liquidity to banks. Their objective is to restore the functioning of impaired interbank markets. Lower funding risk reduces the probability that liquidity turns into default risk. Hence, we expect LTROs to reduce bank credit risk. If this translates into higher credit supply, output and tax revenues, it can also lower sovereign risk. But given that LTROs are targeted at banks, we test whether

Hypothesis 4: *Longer-Term Refinancing Operations reduce bank credit risk.*

Second, SMP and OMTs support the depth and liquidity of secondary government bond markets through purchases of government securities. There are three main channels. The first two mainly affect sovereign risk while the third channel seems more relevant for banks. First, through a portfolio channel, ECB purchases lower the outstanding amount of debt securities. If assets are imperfect substitutes, bond prices increase (see Tobin, 1958, or Vayanos and Vila, 2009). Second, large potential demand for bonds by the ECB lowers their liquidity premia (see De Pooter et al. 2012). Both channels, by lowering sovereign yields, reduce public financing costs and hence credit risk. A third channel works in the opposite direction via holdings of government bonds by private banks (see Buiter and Rahbari, 2012). These bonds, which are claims on sovereigns, can be crowded out and devalue if the ECB has a senior creditor status. This mechanism suggests a positive effect of SMP purchases primarily on bank risk. But given that both SMP and OMTs are targeted at sovereign debt markets, we test whether

Hypothesis 5: *The Securities Market Programme and Outright Monetary Transactions reduce sovereign credit risk.*

3 Empirical methodology and data

In this section, we present our baseline econometric model, the data as well as our identification strategy and the estimation procedure.

3.1 Model specification and data

Our baseline specification is a five-variable VAR which includes credit default risk of sovereigns, banks, and non-financial corporations, respectively, the term spread, and a stock market index. The endogenous variables depend on current and past values of themselves and of the other endogenous variables, and on exogenous variables

$$Ay_t = \tilde{c} + \tilde{A}_1 y_{t-1} + \cdots + \tilde{A}_p y_{t-p} + \tilde{\Gamma}_0 x_t + \cdots + \tilde{\Gamma}_q x_{t-q} + \varepsilon_t, \qquad (1)$$

where y_t and x_t is the vector of endogenous and exogenous variables, respectively, $\tilde{c}$ is a vector of constants, $\tilde{A}_i$ with $i = 1,\ldots,p$ and $\tilde{\Gamma}_j$ with $j = 0,\ldots,q$ are coefficient matrices, and ε_t a vector of structural shocks with diagonal variance matrix $\Sigma_\varepsilon = E(\varepsilon_t \varepsilon_t')$. The focus of the paper is on A and $\tilde{\Gamma}_j$. The off-diagonal elements of A contain the contemporaneous effects of structural shocks on the endogenous variables and $\tilde{\Gamma}_j$ includes the effects of non-standard monetary policies and bank bailout announcements.

We collect daily data until 31 July 2013. We provide a detailed list of variable definitions and sources in Appendix 3. To measure credit risks, we use CDS spreads on senior unsecured debt, modified-modified restructuring, mid spread, with maturity of five years. It is the most liquid maturity segment. We collect sovereign CDS spreads for Austria, Belgium, France, Germany, Greece, Ireland, Italy, Netherlands, Portugal, and Spain and of altogether 41 banks and 56 non-financial corporations in these countries.[3] The country sample is restricted by the joint availability of country-specific CDS data for all three credit sectors. We compute unweighted CDS averages for each sector at the euro area level and at the country level. We exclude Greece from euro area and periphery averages since the sovereign CDS series ends shortly after the sovereign default in 2011. For the term spread, we use the difference between the yield on government bonds with maturity of ten years and the three month interest rate on treasury bills. Concerning equity markets, we employ the Euro Stoxx 50 return index for the euro area level and benchmark local stock market return indices when looking at individual countries.

As regards the exogenous variables, we distinguish between ECB announcements regarding a specific programme, indicated by dummy variables, and their actual implementation, measured in billion euros. We outline the construction of the bailout announcements dummies in Section 5.2. Concerning control variables, we employ the VDax New, which measures option-implied volatility in the German stock market index Dax, to capture uncertainty in euro area financial markets.[4] Moreover, we use the difference between the three month Euribor and the corresponding OIS spread to control for risk premia in the money market. Finally, to account for macroeconomic news shocks, we include the unexpected component of 12 economic indicators of the euro area (for details see Appendix 3). They are computed as the difference between expectations and actual realisations.

[3] We combine CDS data from two sources, Thomson Reuters and Credit Market Analysis (CMA). Since CMA data end in 2010, we use growth rates of respective Reuters series for updating. The correlation between prices from both sources is mostly higher than 0.98 for an overlapping period 2007-2010.

[4] We use the VDax New instead of its analogue for the Euro Stoxx 50, namely, the VStoxx. The latter is only available since 2009. The correlation between both indices is 0.92. Yet an alternative would be the Chicago Board Options Exchange Market Volatility Index (VIX) which is frequently used as a measure of global or US financial market uncertainty. While it correlates strongly with the VDax New, at 0.88, we chose the latter index as it more precisely reflects European financial market uncertainty.

For expectations, we use the mean of Bloomberg surveys, taken a few days prior to data releases. Our choice of indicators follows the construction of the Citi Economic Surprise Index which is widely observed by financial market participants.

To account for non-stationarity of the data, we estimate the model in first differences of CDS spreads, the term spread, the VDax New and the interbank risk premium as they are already expressed in basis points.[5] For stock indices, we employ log differences. We include two lags of the endogenous variables, mainly based on the Hannan and Quinn information criterion. All exogenous variables enter the model contemporaneously, except of monetary policy announcements. Here, we incorporate ten lags to account for information processing in financial markets.

3.2 Identification

For estimation of the structural parameters, we pre-multiply equation (1) by A^{-1}

$$y_t = A^{-1}\tilde{c} + A^{-1}\tilde{A}_1 y_{t-1} + \cdots + A^{-1}\tilde{A}_p y_{t-p} + A^{-1}\tilde{\Gamma}_0 x_t + \cdots + A^{-1}\tilde{\Gamma}_q x_{t-q} + A^{-1}\varepsilon_t. \quad (2)$$

Next, we define $c \equiv A^{-1}\tilde{c}$, $A_i \equiv A^{-1}\tilde{A}_i$, $\Gamma_j \equiv A^{-1}\tilde{\Gamma}_j$ and re-write (2) as

$$y_t = c + A_1 y_{t-1} + \cdots + A_p y_{t-p} + \Gamma_0 x_t + \cdots + \Gamma_q x_{t-q} + u_t, \quad (3)$$

where u_t is a vector of reduced-form residuals. It is related to the structural shocks ε_t through the impact matrix A according to $u_t = A^{-1}\varepsilon_t$. The matrices c, A_i, Γ_j and Σ_u of model (3) can be estimated consistently by ordinary least squares.

To recover the structural parameters from these estimates, we need to identify the impact matrix A. From equations (1)-(3), we know that the covariance matrices of reduced-form and structural shocks are related according to $\Sigma_u = A^{-1}\Sigma_\varepsilon (A^{-1})'$. However, in this system, the number of unknown parameters is larger than the number of independent equations. Hence, we need additional information and, to address this, exploit heteroskedasticity in the data. To see how, consider a bivariate system without constants, lags, and exogenous variables for expositional purposes. Suppose that there are two regimes in the variances of the structural shocks: low and high volatility (indexed by superscripts L and H, respectively).Then, the system is identified, here and in the general case, as we have six independent equations and six unknowns

$$\begin{pmatrix} \omega_{11}^L & \omega_{12}^L \\ . & \omega_{22}^L \end{pmatrix} = \begin{pmatrix} 1 & -a_{12} \\ -a_{21} & 1 \end{pmatrix}^{-1} \begin{pmatrix} \sigma_{11}^L & 0 \\ 0 & \sigma_{22}^L \end{pmatrix} \begin{pmatrix} 1 & -a_{12} \\ -a_{21} & 1 \end{pmatrix}^{-1'}$$

$$\begin{pmatrix} \omega_{11}^H & \omega_{12}^H \\ . & \omega_{22}^H \end{pmatrix} = \begin{pmatrix} 1 & -a_{12} \\ -a_{21} & 1 \end{pmatrix}^{-1} \begin{pmatrix} \sigma_{11}^H & 0 \\ 0 & \sigma_{22}^H \end{pmatrix} \begin{pmatrix} 1 & -a_{12} \\ -a_{21} & 1 \end{pmatrix}^{-1'}.$$

Two assumptions are necessary for identification. First, the structural shocks are uncorrelated, which is a standard assumption in structural VAR modelling. Second, the parameters a_{kl} are constant across regimes which is also common in (G)ARCH models. Finally, two regimes are in principle enough for identification.

Several alternative identification strategies exist. Zero restrictions on A, resulting from delayed responses of some endogenous variables to others, are one prominent way. With daily financial markets data this seems too

[5] We perform augmented Dickey-Fuller and Phillips-Perron tests on the levels of the average sovereign and bank CDS spreads of the euro area. The tests do not reject the null hypothesis of a unit root, irrespective of whether we include a drift term.

restrictive, however, as financial markets are likely to respond to each other at much shorter frequencies.[6] Sign restrictions on the parameters of *A* are another route. They allow for simultaneous effects among all variables. However, as outlined in Section 2.1, neither theory nor empirical evidence gives unambiguous predictions for many of the contemporaneous signs, in particular regarding the transmission of bailout shocks to sovereign risk and it is at the core of this paper to determine them empirically.

Our parsimony in using restrictions comes at a cost, however. The system of simultaneous equations is identified only up to a rotation of the *A*-matrix, that is, up to a row permutation of the underlying economic model. To pin down the rotation that reflects the true model, we need to impose one sign restriction (for further details see Ehrmann et al., 2011). Hence, we assume that stock market shocks impact negatively on credit risk of non-financial corporates. We choose this assumption for several reasons. First, it seems economically fairly uncontroversial as, say, higher expected revenues and profits in the overall corporate sector are likely to lower credit risk of non-financial entities. Second, the constraint does not restrict the signs of the bi-directional effects between sovereign risk and bank risk. Third, it is mainly not binding in the estimation.

Before estimation, we need to determine the volatility regimes. We use a narrative approach, following Rigobon (2003). The global financial and the European debt crisis provide a natural framework for this methodology as they are characterised by strong and persistent increases in financial market volatility. We use media reports and previous studies to construct a time line of major economic and political events (see BIS, 2009, Alter and Schüler, 2012, Mody and Sandri, 2012, Alter and Beyer, 2013). Based on the events, we divide the sample period into seven regimes.[7] Figure 2 shows the time line and the regimes. It also contains the 200 days rolling standard deviations of the (differenced) euro area sovereign and bank CDS spreads, respectively. They increase in several steps which coincide well with our regimes. Appendix 1 provides a detailed account and analysis of the regimes. It also contains further stylised facts on the relation between sovereign risk and bank risk in individual member countries and groups thereof.

Following Ehrmann et al. (2011), we estimate the parameters of *A* by minimising

$$\left\| g' g \right\| = \sqrt{tr(g' g)} = \sqrt{vec(g)' vec(g)}, \quad whith \quad g = \sum_{i=1}^{7} \left[A\Sigma_{u,i} A' - \Sigma_{\varepsilon,i} \right],$$

where $\Sigma_{\varepsilon,i}$ is the variance of structural shocks and $\Sigma_{u,i}$ is the covariance matrix of estimated reduced-form shocks for regime $i=1,\ldots,7$. We perform 200 bootstrap replications. In each replication, we use the regime-specific covariance matrices to generate new data from which we obtain estimates using the minimisation procedure. We calculate significance of the estimates by computing the share of estimates beyond zero.

Finally, regarding monetary policy and bailout announcements, which we include as exogenous variables, it is more difficult to deal with potential issues of reverse causality. However, using daily data reduces this risk as we use only major announcements that are unlikely to have occurred in response to conditions in CDS markets on one particular day. They are rather the reaction to a generally worsening financial market and economic environment. This assumption seems also plausible given that these large announcements are typically preceded by lengthy internal discussions and preparations. Some announcements even may have been anticipated partly. However, what matters econometrically is the market impact of the daily impulse variables which reflects the unexpected component of these announcements. Lastly, we also present single country estimates, exploiting the cross-sectional dimension to reduce reverse causality risks.

[6] This is also the reason why we do not use long run restrictions. The data do not contain much persistence.

[7] The split dates are 07/01/2007, 09/15/2008, 05/02/2010, 04/06/2011, 10/27/2011, and 07/26/2012.

4 Credit risk propagation in the euro area and in member countries

In this section, we present the empirical results on the effects between sovereign risk, bank risk, and other asset prices. First, we analyse the euro area as one block before we look at single countries. Then, we split the sample into sub-periods. Finally, we explore the relationship between the euro area core and periphery. Throughout the section, we standardise the endogenous variables prior to estimation to facilitate a direct comparison of the economic significance of the effects across variables and countries and over time.

4.1 Analysis of the euro area as a single entity

We start by analysing the contemporaneous causal relationships among the endogenous variables at the euro area level. The upper part of Table 1 shows the estimated *direct* causal effects of a structural shock of one standard deviation (in columns) on the endogenous variables (in rows), keeping all other variables constant. It corresponds to the *A* matrix of the structural model $Ay_t = ... + \varepsilon_t$ of equation (1). We reverse the signs of the off-diagonal entries for ease of interpretation. The lower part of the table shows the *overall* causal effects in the initial period, contained in the A^{-1} matrix. They take into account all contemporaneous propagation among the endogenous variables. We denote statistical significance at the 1%, 5%, and 10% levels by *a*, *b*, *c* below point estimates.

Regarding the relation between sovereign risk and bank risk, both the direct and the overall effects are positive in both directions. Moreover, they are statistically and economically significant. A one standard deviation increase in bank risk has a *direct* impact on sovereign risk of 0.14 standard deviations. The reverse effect is substantially stronger with a point estimate of 0.46. A feedback between sovereign risk and bank risk (and other asset prices) amplifies both types of shocks substantially. Comparing direct and overall effects, bank risk shocks are magnified by 43% and sovereign risk shocks by 17%. The overall effects imply that a shock of 100 basis points to bank risk pushes up sovereign spreads by 28 basis points. Vice versa, the effect is 38 basis points. All in all, these findings support Hypotheses 1 and 3. Moreover, they indicate that over the full sample actual bailout shocks play a secondary role in driving bank risk.

Concerning shocks to other asset prices, they significantly affect both sovereign and bank risk and the signs of the point estimates correspond well to our priors. Focusing on the overall effects, non-financial credit risk shocks increase sovereign and bank risk by 0.07 and 0.29 standard deviations, respectively. The effects of stock market shocks are of similar (absolute) size.[8] In the reverse direction, shocks to sovereign and bank risk increase non-financial credit risk and the term spread and they reduce stock returns.

To understand what drives the positive correlation between sovereign risk and bank risk shown in Figure 1 and reflected in their positive bi-directional effects, we perform the following counterfactual exercise. First, we compute a historical decomposition of sovereign and bank CDS spreads, respectively, which yield the contribution of each structural shock to the daily evolution of each series. Then, we calculate the evolution of both series under the assumption that only one particular shock materialised and compute the correlation between both (counterfactual) series over rolling windows of 200 days. Finally, we compare the shock implied correlations to the actual correlation to assess the importance of each shock for the evolution of the latter.[9]

Figure 3 contains the results. The shock implied correlations can be grouped in two. The first group accounts for the dynamics and overall level of the actual correlation (see upper panel). It contains the correlations implied by shocks to bank risk, to non-financial risk, and to stock returns, respectively. Bank risk shocks explain a large part of the higher frequency movements of the actual correlation. Non-financial risk shocks and stock market shocks account for its level. Altogether, however, shocks in the first group alone cannot explain the large shift in the level of the actual correlation.

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[8] In case of the term spread the results are less conclusive. The ambiguity seems to reflect the off-setting effects of its components.

[9] We neglect the correlation implied by term spread shocks since they are insignificant in explaining sovereign and bank risk (see lower part of Table 2).

Instead, it can be explained by sovereign shocks and by own shocks (see lower panel). Own shocks refer to sovereign risk being driven by sovereign shocks only and bank risk by bank shocks only. These shocks drive up the implied correlation by about 0.5-1.0. To understand the low level of the correlation implied by own shocks before approximately 2010, we consider two shock scenarios. First, the implied correlation is low if mainly bank shocks occur. This scenario corresponds well to the period where the US subprime crisis spilled over the Atlantic and severely stressed European interbank markets, while sovereigns stood sheltered at the side line. In the second scenario, the implied correlation is low if both shocks to sovereign risk and bank risk occur but if they tend to go in opposite directions. This scenario reflects the period after the collapse of Lehman Brothers when most euro area sovereigns implemented major bailout packages for their domestic banking sectors. These bailouts came as negative shocks to bank risk and tended to push up sovereign risk. To understand the high level of the correlation implied by own shocks after 2010, we consider a third scenario. Here, sovereign risk and bank risk are positively correlated if shocks to both variables occur and if they move in the same direction. This scenario seems particularly relevant for the period since 2010, when the European debt crisis gathered pace. One illustrative example is the introduction of the European Financial Stability Facility (EFSF) on 10 May 2010 which accounts for the pronounced surge that can be seen in most correlations on that day. Finally, these scenarios are mirrored in the correlation implied by sovereign shocks. It increases from 0.5 to 0.9 as the relative importance of sovereign shocks grows over the sample period. In contrast, the importance of bank shocks remains relatively stable (see upper panel).

4.2 Overall effects in individual euro area member countries

As suggested by Figure A1, which shows rolling correlations between bank risk and sovereign risk in individual member countries, there is considerable heterogeneity in the relationship between sovereign and bank risks across countries. In this subsection, we therefore estimate the model using country-specific endogenous variables to detect commonalities and differences across countries and vis-à-vis the euro area en bloc.

Table 2 contains the results. We focus on the bi-directional overall effects between sovereign risk and bank risk.[10] The first column in the upper part of the table repeats the results for the euro area for comparison. In Austria, Belgium, Germany, Spain, and France there is a significant positive effects in both directions. For the first three countries, the bi-directional effects are smaller than for the euro area, whereas they are of similar magnitude in Spain and France. As with the euro area, the effect from sovereign risk on bank risk tends to be larger than vice versa. There is a second group of countries with no or uni-directional effects. In Greece and Italy, there is an effect from sovereign risk on bank risk, reflecting that credit risks in these countries originated mainly in sovereigns' balance sheets, while in the Netherlands only the reverse effect is significantly positive. Overall, the country results provide further evidence in favour of Hypothesis 1 and 3.

Two underlying features seem relevant for understanding the grouping of countries. First, broadly speaking, the larger the bailout package for the banking sector, the tighter the link between banks and sovereigns. In the first group, bank support indeed ranged from 18% in France to 47% in Belgium in terms of GDP (see Stolz and Wedow, 2010). In the second group, Italy, for example, provided only 4%. An exception to the 'rule' is Netherlands with large bank support of 52% but only a small uni-directional effect. Yet, for Ireland, Greece, and Portugal there seems to be a second mechanism that breaks this rule. All three sovereigns were bailed out. As a consequence, bank risk on their balance sheets was, at least partly, forwarded to other sovereigns, breaking the link between domestic banks and their sovereign; even in Ireland with bank support of 319%.

Overall, the grouping coincides well with a widely used classification of euro area countries into core and periphery. We investigate this issue further below. Moreover, the findings square well with previous studies and

[10] By and large, the signs of the other coefficients in the *A* and A^{-1} matrices are as expected. For example, credit risks across all three credit sectors tend to be positively related, while the effects between the term spread and other asset prices vary across country. In periphery countries, the credit component mostly dominates, inducing a positive relation with credit markets and a negative with the equity market, whereas in many core countries the business cycle part prevails, implying opposite co-movements.

narrative evidence on the severity of banking and sovereign debt problems in individual member states (see, for example, Alter and Schüler, 2012, Mody and Sandri, 2012).

4.3 Overall effects in sub-samples

In this subsection, we assess the relation between sovereign risk and bank risk in recursive sub-samples to see whether it changes over time and in particular during bailout periods. This also allows us to test Hypotheses 2a and 2b against each other. We hold the starting point fixed and extend the estimation window in steps of the pre-defined regimes. The first window consists of regimes 1-2, the second of regimes 1-3, and so on. Over each window, we standardise the endogenous variables. [11]

Figure 4 contains the results. Again, we report only the overall effects between sovereign risk and bank risk. The upper left graph in the upper panel shows the results for the euro area. In the first window, there is no significant effect in either direction. Subsequently, however, there is a significant positive effect of sovereign risk on bank risk in the range of 0.45 to 0.59 (solid line). The reverse effect (dashed line) is significantly negative in windows 2 and 3 at −0.04 and −0.18, respectively. This finding supports Hypothesis 2a. The various bailout packages implemented during this period came as a series of bank risk shocks that drove bank risk and sovereign risk in opposite directions. According to the point estimates, a bailout shock that lowers bank spreads by 100 basis point leads to an increase in sovereign spreads by 12 basis points on average. From window 3 onwards, however, actual bailouts cease to occur and the post-bailout channel seems to gain importance which implies a positive effect from bank risk on sovereign risk, providing additional evidence for Hypothesis 1. Stanga (2011), Dieckmann and Plank (2012), and Acharya et al. (2015) find a similar, sign-changing correlation pattern between bank and sovereign spreads during and after bailout periods.

Looking at single countries, we find a similar sign pattern for the bi-directional effects in most core countries (see upper panel), further supporting Hypothesis 2a. In periphery countries, there is no clear pattern (lower panel), however. The grouping of countries corresponds largely to that of the previous subsection. It underpins the interpretation that the link between banks and sovereigns, existing in many core countries, reflects a transfer of credit risks. The results for Greece and Ireland underline the explanation of what breaks the link. While the transmission from banks to sovereigns is negative in windows 2 (and 3), echoing bank bailouts, it turns insignificant afterwards, reflecting a risk transfer of domestic banking risk on the balances of domestic sovereigns to other sovereigns.[12]

Finally, we define contagion as a significant increase of asset market interdependence after a shock or trigger event, following Forbes and Rigobon (2002) and Constâncio (2012). Specifically, and applied to the relationship between sovereign risk and bank risk, we define as contagion the emergence of a statistically and economically significant effect in either direction where no such effect existed beforehand. According to this definition, there was contagion between sovereign risk and bank risk since 2008 both at the euro area level and in nearly all analysed member countries.

4.4 Credit risk spillovers between euro area core and periphery

We now return to the euro area specification and, based on the previous results, split the sovereign and bank variable each into core (CO) and periphery (PE) to investigate cross-country spillovers.[13] Table 3 shows the overall effects, which generally back Hypotheses 1 and 3. Concerning the transmission of credit risk shocks, the cross-

[11] Due to data limitations, for Ireland the first window consists of regimes 2-3 and for Greece the last window only contains regimes 1-6. Moreover, estimation of rolling windows generally did not yield meaningful results. This probably reflects the importance of the strong volatility shifts between regimes 1 and 4 for identification, whereas later on changes in volatility are smaller, and the need for having sufficient observations in each sub-sample.

[12] While in Italy and Portugal there is a positive effect from bank risk to sovereign risk during bailout periods, we do not read this as supporting Hypothesis 2b. Both countries provided the smallest bailout packages in the euro area of only 4% and 12% of GDP, respectively, such that the positive effect rather mirrors the credit supply channel than the bailout channel.

[13] We classify as core Austria, Belgium, France, Germany, and Netherlands and as periphery Ireland, Italy, Portugal, and Spain.

effects among all credit variables are highly statistically and economically significant and have the expected positive signs. To rank the strength of the transmission, we sum columnwise over the top four rows of the table. The largest effects on other sovereigns and banks has periphery sovereign risk (2.65), followed by core sovereign risk (2.19), periphery bank risk (1.84), and core bank risk (1.56).

For the sovereign-bank relation within each country groups, we find significant bi-directional effects both within the core and periphery. The magnitude of effects is similar to the euro area specification with stronger effects of sovereign shocks on banks than vice versa. The reverse effect is larger in core countries than in the periphery, where it is barely significant. Again, bank credit risk is more important in core countries, whereas in periphery countries sovereign risk plays a larger role.

Regarding spillovers between core-periphery, we observe strong links both within and across banks and sovereigns. Within each credit sector, spillovers are larger from the periphery to the core than the other way around. At first this finding is surprising given the relative sizes of the corresponding economies and debt markets. But it reflects the large exposure of core banks to periphery sovereigns. Across sectors, the effect of sovereign on bank risk is stronger than vice versa, similar to the results within each country group.

To further investigate the economic significance of the structural shocks, we compute one day ahead forecast error variance decompositions. They yield the percentage that each shock type contributes to the variance of the endogenous variables. Given that shock variances are regime specific, we calculate the weighted average variance decomposition over all regimes, using the number of observations per regime as weights.

Table 4 contains the results. Altogether, they echo the overall effects. First, sovereign risk is more important in explaining bank risk than vice versa. Combined sovereign risks explain 24% and 11% of the variability in periphery and core bank risk, respectively. In contrast, combined bank risk shocks contribute only 3% and 4% to sovereign risk variability. Second, the dominance of sovereign risk shocks is particularly strong in the periphery where they contribute 16% to bank risk variance. Third, periphery shocks contribute more to the variance of core variables than vice versa. Fourth, partly implied by the first two observations, other than own shocks play an important role for bank risk variability, whereas for sovereign risk variability their contributions are smaller. Regarding non-financial risk shocks, they explain relatively large shares of bank risk but have only a limited impact on sovereign risk. Stock market shocks contribute between 3% and 8% to the variability in credit risks. In Appendix 2, we provide a detailed analysis and interpretation of the estimated structural shocks.

Finally, we investigate whether there is evidence for a flight-to-safety within the euro area. In particular, we explore whether adverse shocks to euro area asset markets trigger a flight of investors to the safe haven of German sovereign bonds. To this end, we employ the German CDS spreads to measure core sovereign risk and we replace the euro area term spread by the ten year Bund yield. Table 5 shows the overall effects.

We indeed find evidence for this phenomenon in the euro area. Except of core banks, all credit risk shocks entail significant negative effects on Bund yields. Non-financial risk shocks have the largest negative impact, followed by shocks to periphery sovereign risk. Shocks to periphery bank risk are less influential. Interestingly, even shocks to German sovereign risk trigger flows to the presumably safe haven of Bunds. Reversely, Bund yield shocks significantly lower both sovereign risk and bank risk in the periphery which indicates that in Bund yields the business cycle component dominates.

Comparing the first columns of Tables 3 and 5, we see that the effect of German sovereign risk on the other variables is always smaller (in absolute value) than that of (average) core sovereign risk. Moreover, shocks to periphery sovereign risk do not impact on German sovereign risk. This stands in contrast to their effect on core sovereign risk which is highly statistically and economically significant. Overall, this suggests that the credit market perception of Germany is different to that of the average core sovereign.

5 Monetary policy and bank bailout announcements

In this section, we first analyse the effects of specific ECB measures on asset prices in the euro area, and in particular on the credit risk of sovereigns and banks. Then, we estimate the announcement effects of specific bank bailout schemes on those risks. Throughout, the endogenous variables are in basis and in percentage points, respectively.

5.1 Monetary policy, credit risks, and other asset prices

In this subsection, we first analyse the effects of non-standard monetary policies on credit risks and other asset prices at the euro area level. Then, we look at individual countries, focusing on the effects on sovereign risk and bank risk.

5.1.1 Monetary policy and euro area asset prices

In this subsection, we return to the five-variable VAR specification for the euro area en bloc. We extract the estimated coefficients on the exogenous monetary policy variables and compute additional statistics which are shown in Table 6. The endogenous variables are in columns. The upper part reports implementation effects. Specifically, it contains point estimates and cumulative effects. The latter are the product of the point estimate, if significant, and the total volume of the respective programme. The lower part of the table contains the announcement effects which are the sum of the contemporaneous effect and its first ten lags. The p-value refers to the F-test of their joint significance. Generally, all monetary policy measures each drive sovereign risk and bank risk in the same direction. This commonality holds both for implementation and announcement effects. It underscores the strong interdependence between bank and sovereign risk.

Regarding LTROs with maturity of 6-12 and 36 months, respectively, the results for the announcement effects are surprising. While announcements regarding the former reduce sovereign spreads by 6 basis points and bank spreads by 1 basis point, the announcement of the latter actually increases them by 40 and 26 basis points, respectively. There are two complementary explanations for the positive effect. First, market participants were disappointed as they expected the announcement of a reactivation of SMP during the ECB press conference on that day. Second, they underestimated the volume that was going to be allotted within this scheme which, ultimately, exceeded one trillion euro.

Turning to the implementation effects of LTROs, we find the expected negative effects on bank risk which are highly statistically significant. For 6-12 months LTROs, the allotment of one billion euro lowers bank CDS spreads by 0.01 basis points. Given that overall 979 billion euros were tendered, the cumulative effect is −7.8 basis points. The implementation effect of 3-year LTROs is substantially stronger at −0.05 basis points per billion. The cumulative effect (of a total volume of 1,020 billion euros) is −47.9. Netting the latter with the positive announcement effect yields an overall effect of −21.9 basis points. All in all, the results speak in favour of Hypotheses 4 that LTROs lower bank risk.

Turning to SMP and OMTs, the announcements significantly reduce credit risks, as expected. SMP announcements induce a decline by 52 and 40 basis points in sovereign and bank spreads, respectively. Similarly, OMTs announcements lower them by 56 and 34 basis points, respectively. The stronger effects on sovereign spreads are consistent with the programmes' primary goal of reducing tensions in public debt markets. Overall, these findings support Hypothesis 5 that SMP and OMTs reduce sovereign credit risk.

Finally, one surprising finding emerges regarding the effect of SMP purchases. They significantly increase bank spreads, by approximately 1 basis point per billion, mirroring a crowding out of privately held claims. Given that the ECB bought government bonds worth 218 billion euro, the cumulative effect is 209 basis points. Subtracting the effects of two announcements, the programme's overall effect on bank risk is 129 basis points.[14]

Altogether, OMTs announcements were most successful in reducing credit risks. One of the programme's most appealing features seems to be that it was never activated or put to a test by markets. In contrast, while SMP had quantitatively similar effects on sovereign spreads, this came partly at the expense of increasing bank risk.

5.1.2 Monetary policy effects in member countries

Next, we explore the effects of monetary policy on sovereign and bank CDS spreads at the country level. They largely mirror those for the aggregate level, backing Hypothesis 4 and 5. Table 7 shows the effects on sovereign spreads, based on the corresponding country-VAR equations. For comparison, the first column repeats the euro area results.

As to LTROs, while the announcement effect is mostly negative for 6-12 months operations, it is positive for three year operations in all countries. An interesting difference also emerges regarding their implementation effects. While the former significantly lower sovereign spreads in most core countries and in Ireland, the latter have strong negative effects in Spain and Italy. This asymmetry reflects the timing of each liquidity scheme. The shorter dated LTROs were mainly implemented in 2008-2010 when banks in core countries and Ireland were hit hardest by the global financial crisis. The extra liquidity reduced risks in these countries' banking sectors and thereby negative spillovers to domestic sovereigns. On the other hand, the longer dated LTROs were implemented at the turn 2011/2012 when the European debt crises escalated in Italy and Spain. These estimates complement the findings of Acharya and Steffen (2015), based on bank equity returns, who show that in particular Italian and Spanish banks engaged in carry trades, using LTRO-liquidity to buy domestic government bonds.

For SMP and OMTs, the announcement effects are highly statistically significant in all countries. Being stronger in the periphery, the effects of SMP announcements are between –80 basis points in Spain an –2140 in Greece. For OMTs the range is –80 in Ireland to –124 in Portugal. The findings for Italy, Spain and Portugal complement existing evidence from the cash bond market. In particular, they support the conclusions of Krishnamurthy et al. (2014) that these two programmes reduced government bonds spreads mainly by lowering sovereign credit risk.

Table 8 shows the effects on bank spreads. The implementation of LTROs with maturity 6-12 months mainly reduces bank risk in core countries. Regarding 3-year LTROs, the implementation effect is significantly negative in almost all countries. The impact tends to be stronger in the periphery where it lowers Portuguese, Spanish, and Italian bank spreads by –138, –67, and –53 basis points, respectively. Moreover, in all cases where both the implementation and the announcement effect are statistically significant, the former dominates such that the overall effect of 3-year LTROs is always negative. Contrary, purchases within SMP tend to increase credit risk in Germany, Austria, Italy, and Greece. In addition, the cumulative implementation effect always outweighs the cumulative announcement effect. Finally, OMTs announcements have the strongest effect in Italy and Spain. Here, bank spreads decrease by 71 and 55 basis points, respectively.

5.2 Bank bailout announcements, sovereign risk, and bank risk

In this subsection, we analyse explicitly the effects of specific bank bailout announcements on sovereign risk and bank risk in the euro area. We consider three types of bailout announcements by federal governments, following (CGFS & BIS, 2010): (a) debt guarantees, (b) deposit guarantees, and (c) capital injections. The announcement dates correspond to the very first official announcement of the bailout type. This does not preclude that at later stages new information regarding the timing, scale, and scope of these bailouts was released. We use dummy

[14] When interpreting announcement and implementation effects of SMP separately, one needs to keep two things in mind however. The first announcement regarding SMP occurred on the same day as the announcement of the establishment of the EFSF. Moreover, both announcements regarding SMP fall within the respectively same week when the ECB actually started buying sovereign bonds.

variables at the country level to indicate the announcement dates. Then, we average over countries to assess the effects at the euro area level. An analysis at the country level is prohibited by the fact that most member states announced more than one bailout type on the same day and that the composition of jointly announced bailout types differs across countries.

We use dummy variables instead of measures that aim at capturing the magnitude of the announced programmes because such measures would be difficult to compare across countries. In addition, several announcements are relatively general without specifying the overall implied amounts. Further, we neglect the implementation of bailouts as the details vary substantially across countries, complicating a meaningful aggregation.

We resort to the five-variable VAR specification for the euro area and include, one at a time, the announcement variables as additional exogenous variable. Including all announcement types jointly did not yield meaningful results due to problems of multicollinearity. Therefore, to cleanly trace out the specific effects, we use 20 lags. The lag length also accounts for the fact that scale and scope of the announced measures were relatively unprecedented in the euro area at that time and that information processing and learning by market participants probably took several weeks.

The bottom of Table 9 shows the cumulative effects of the announcements. Columns (1)-(3) contain the results for the sovereign risk equation, columns (4)-(6) for the bank risk equation. The upper part of the table shows the effects of monetary policy for comparison. They are largely unaffected by the inclusion of the bailout announcements.

All bailout announcements are highly statistically significant. The effects on bank spreads are all negative. For deposit guarantees and capital injections, respectively, they are similar in magnitude at about –75 basis points. For debt guarantees, the effect is still sizeable at –46. These effects are always larger in absolute value than those on sovereign risk. While the announcement of debt guarantees and capital injections slightly increase sovereign CDS spreads by 1 and 4 basis points, respectively, the announcement of deposit guarantees has a negative effect of 31 basis points. The latter might reflect the broader nature of this measure which targets not only the banking sector but also partly shields households and their savings decisions from spillovers.

Overall, the results confirm that the announcements of bank bailouts reduced credit risk of the banking sector. However, the results for sovereign risk provide a more subtle picture, partly modifying our interpretation of Section 4.3 of the negative effect of bank risk shocks on sovereign risk during bailout periods. While the point estimates for debt guarantees and capital injections support Hypothesis 2a, the negative effect of deposit guarantees is evidence in favour of Hypothesis 2b, that is, depending on the specific type, some bailouts increase sovereign risk while others indeed lower it.

6 Conclusions

The paper finds evidence in favour of a close and a much higher sovereign-bank risk nexus during the European financial crisis than compared to the pre-2008 tranquil period. Using a structural VAR that exploits the heteroskedasticity of the underlying daily series of financial market data, the analysis shows that sovereign risk shocks had an important and dominant impact on bank risk in the euro area. While also shocks to bank risk had an adverse impact on sovereign risk within the own country, sovereign risk overall appears to have been the more important driver of the sovereign-bank risk nexus.

This link has intensified significantly over time, with it being much weaker within Europe during the global financial crisis than the subsequent European crisis. We find evidence for larger spillovers of sovereign risk and bank risk in the euro area periphery to the euro area core than vice versa, despite the latter being much larger in magnitude. We also present suggestive evidence for a flight-to-safety phenomenon towards Germany.

The core analysis of the paper focuses on whether and how bank bailout policies and monetary policy by the ECB have affected this sovereign-bank risk nexus. Bank bailout policies, such as capital injections into ailing banks and debt and deposit guarantees, exerted a significant impact on both sovereign risk and bank risk. Importantly, we find evidence that in some instances such bailout policies actually raised sovereign risk. As to monetary policy, our results show that OMTs were most successful, insofar as they reduced credit risks among both sovereigns and banks. In contrast and surprisingly, the actual implementation of SMP tended to increase credit risk of banks. The 3-year LTROs effectively reduced bank risk while their effect on sovereign risk was at best ambiguous.

Overall, these findings suggest that both rescue policies of the banking system and monetary policy exerted a significant impact on sovereign and bank risk as well as on risks and prospects of the real economy. The empirical estimates also indicate that neither of the two policies was unanimously effective. Thus, this entails a note of caution to policymakers that policies that are intended to reduce risk can in fact lead to an intensification of the negative feedback loop between sovereigns and banks.

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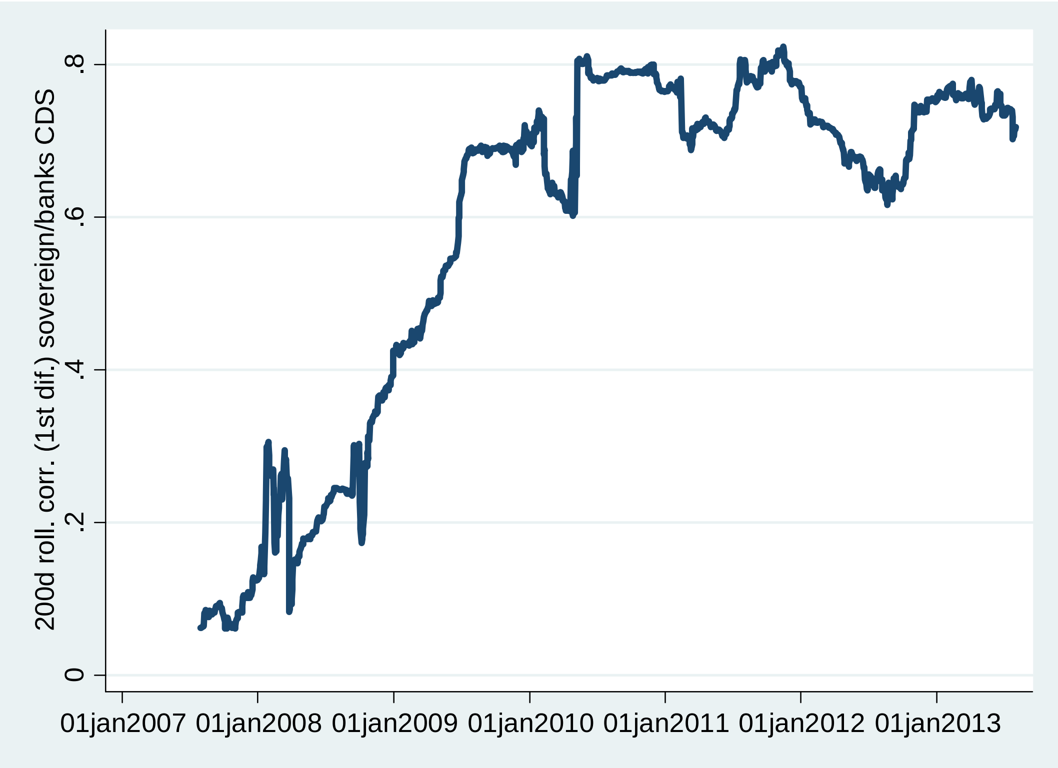
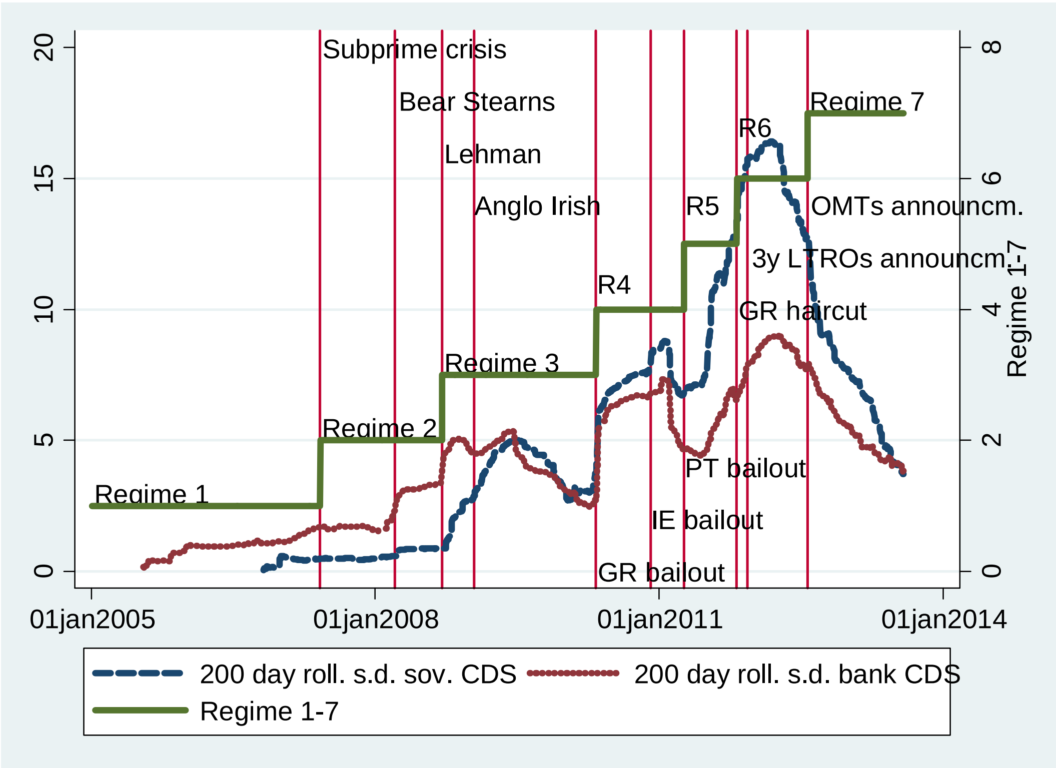
8 Figures

Figure 1: Rolling correlation between sovereign credit risk and bank credit risk in the euro area



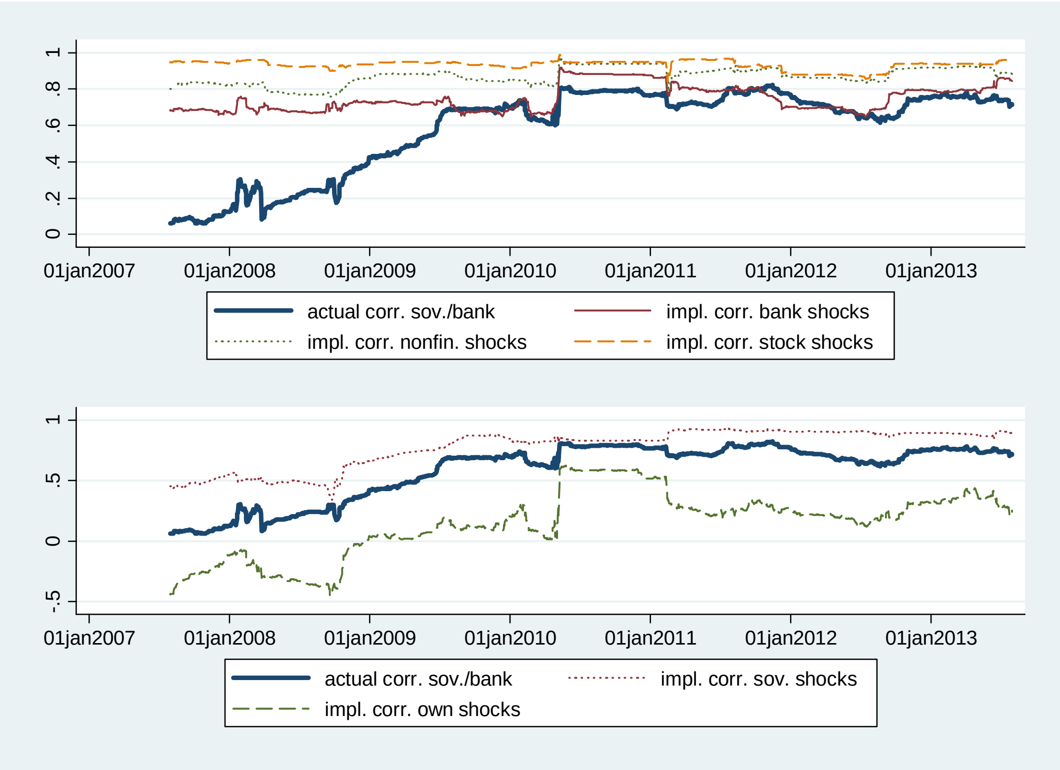
The figure shows the 200 days rolling correlation between the first differences of the average credit default swap spread (five year, senior) of the sovereigns of the euro area and banks over the sample period.

Figure 2: Time line, regime definition, and rolling standard deviations of sovereign risk and bank risk of the euro area



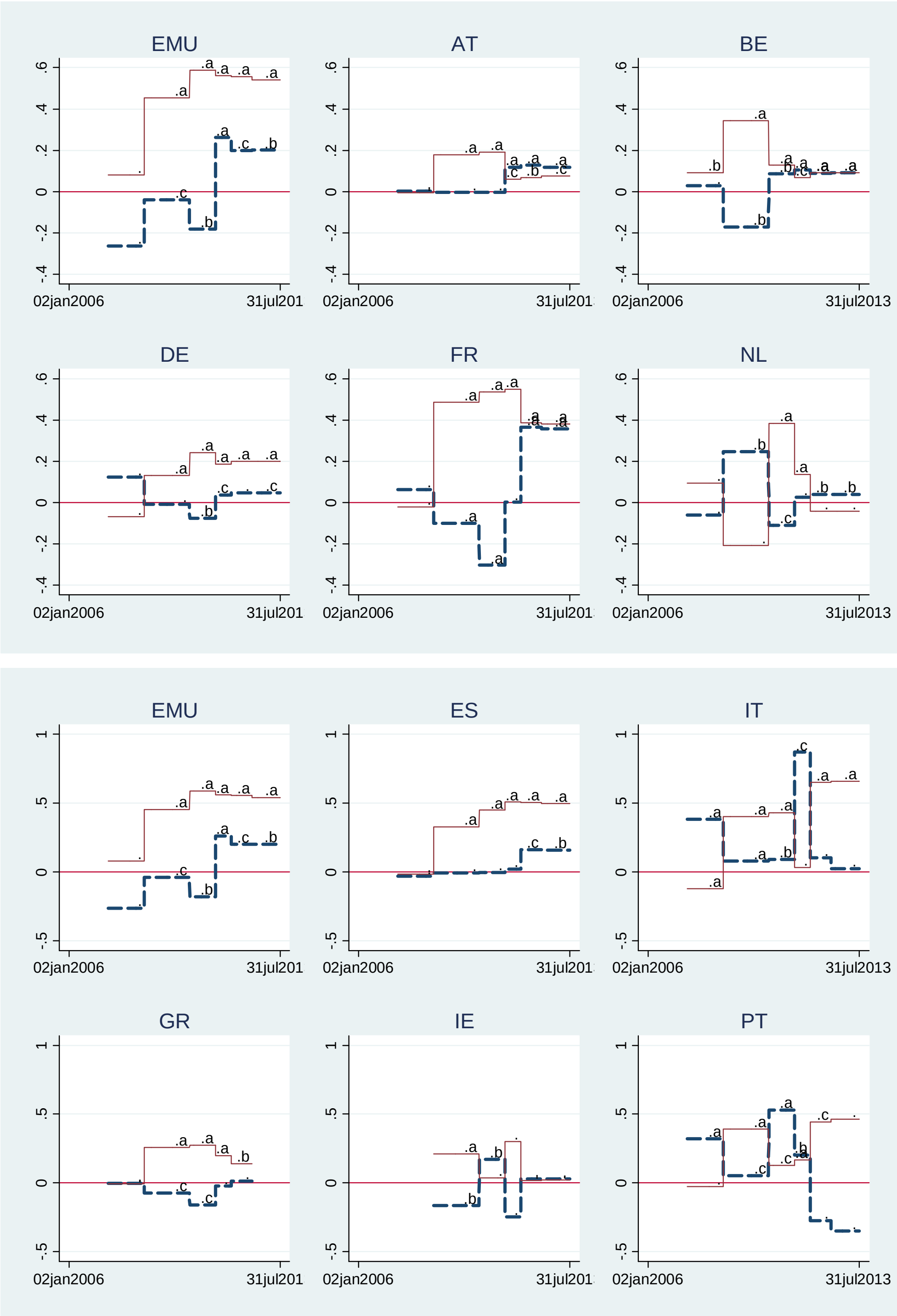
The figure shows (a) a time line of the global financial and the European debt crisis, (b) the definition of volatility regimes 1-7 (green solid line, right axis), and (c) the 200 days rolling standard deviations of the first difference of the average credit default swap spread (senior, five year) of sovereigns of the euro area and banks, respectively (blue dashed and red dotted line, left axis).

Figure 3: Actual and implied correlation between sovereign risk and bank of the euro area driven by different types of shocks



The figure shows the actual 200 days rolling correlation between sovereign risk and bank risk of the euro area and the implied correlations. The latter are explained by a specific shock type according to its estimated historical contribution to the sovereign risk variable and bank risk variable.

Figure 4: Overall effects between sovereign risk and bank risk of the euro area and in member states in recursive sup samples



The figure shows the overall effect from sovereign risk on bank risk (thin solid line) and vice versa (thick dashed line). They are extracted from corresponding A-1 matrices which are estimated on recursive sup samples of the euro area en bloc and single countries. The letters .a, .b, .c denote significance at the 1%, 5%, 10% levels.

9 Tables

Table 1: Direct and overall effects among endogenous variables at the euro area level: A and A-1 matrix

The table shows the estimated direct and overall effects of structural shocks of one standard deviation on the endogenous variables, based on a five-variable structural VAR for the euro area. Impulse variables are in columns, response variables are in rows. The sample period is 24 October 2006 until 31 July 2013.

	Impulse				
Response	Sov. risk	Bank risk	Nonfin. risk	Term spread	Stock market
			Direct effects		
Sov. risk	1.00	0.14	0.02	0.06	-0.11
p	.	.*c*	.	.*c*	.*a*
Bank risk	0.46	1.00	0.21	-0.09	-0.09
p	.*a*	.	.*a*	.	.*a*
Nonfin. risk	0.06	0.07	1.00	0.12	-0.33
p	.*a*	.*b*	.	.*a*	.*a*
Term spread	0.32	0.29	-0.31	1.00	0.09
p	.*a*	.*b*	.*a*	.	.
Stock market	-0.09	-0.12	-0.11	0.04	1.00
p	.*a*	.*a*	.*a*	.	.
			Overall effects		
Sov. risk	1.13	0.20	0.07	0.05	-0.16
p	.*a*	.*b*	.*a*	.	.*a*
Bank risk	0.54	1.12	0.29	-0.04	-0.26
p	.*a*	.*a*	.*a*	.	.*a*
Nonfin. risk	0.22	0.18	1.05	0.11	-0.37
p	.*a*	.*a*	.*a*	.*a*	.*a*
Term spread	0.44	0.32	-0.23	0.97	0.08
p	.*a*	.*b*	.*a*	.*a*	.
Stock market	-0.18	-0.16	-0.17	0.02	1.09
p	.*a*	.*a*	.*a*	.	.*a*

Notes: .a, .b, .c denote significance at the 1%, 5%, 10% levels; number of observations 1764.

Table 2: Overall effects between sovereign risk and bank risk in individual euro area member states

The tables show the contemporaneous overall effects between sovereign risk and bank risk in euro area member states, extracted from the corresponding country-level A-1 matrices.

	Country					
	EMU	AT	BE	DE	ES	FR
Bank on sov. risk	0.20	0.12	0.09	0.05	0.16	0.36
p	*.b*	*.a*	*.a*	*.b*	*.b*	*.a*
Sov. on bank risk	0.54	0.08	0.09	0.20	0.50	0.38
p	*.a*	*.b*	*.a*	*.a*	*.a*	*.a*
Observations	1764	2477	2142	2470	1765	2074

Notes: .a, .b, .c denote significance at the 1%, 5%, 10% levels.

	Country				
	GR	IE	IT	NL	PT
Bank on sov. risk	-0.00	0.03	0.03	0.04	-0.35
p	.	.	.	*.b*	.
Sov. on bank risk	0.12	0.02	0.66	-0.04	0.46
p	*.b*	.	*.a*	.	.
Observations	1571	1466	2454	1765	2003

Notes: .a, .b, .c denote significance at the 1%, 5%, 10% levels.

Table 3: Overall effects among euro area core and periphery sovereign risk and bank risk

The table shows the estimated overall effects of structural shocks of one standard deviation on the endogenous variables for the euro area core (CO) and periphery (PE) and other asset prices. They are extracted from the A-1 matrix of a seven-variable structural VAR. Impulse variables are in columns, response variables are in rows. The sample period is 24 October 2006 until 31 July 2013.

	Impulse						
Response	Sov CO	Bank CO	Sov PE	Bank PE	Nonfin EA	Term EA	Stocks EA
Sov CO	1.15	0.15	0.54	0.07	0.09	-0.11	-0.21
p	*.a*	*.a*	*.a*	*.c*	*.a*	*.c*	*.a*
Bank CO	0.36	1.12	0.34	0.52	0.40	-0.08	-0.37
p	*.a*	*.a*	*.a*	*.a*	*.a*	.	*.a*
Sov PE	0.29	0.08	1.18	0.11	0.06	0.02	-0.14
p	*.a*	*.a*	*.a*	*.c*	*.a*	.	*.a*
Bank PE	0.39	0.21	0.59	1.14	0.21	-0.03	-0.22
p	*.a*	*.a*	*.a*	*.a*	*.a*	.	*.a*
Nonfin EA	0.17	0.04	0.21	0.15	1.05	0.09	-0.36
p	*.a*	*.c*	*.a*	*.a*	*.a*	*.b*	*.a*
Term EA	0.30	0.08	0.46	0.25	-0.22	0.95	0.16
p	*.a*	*.c*	*.a*	*.a*	*.a*	*.a*	*.b*
Stocks EA	-0.18	-0.04	-0.14	-0.13	-0.17	0.01	1.09
p	*.a*	*.b*	*.a*	*.a*	*.a*	.	*.a*

Notes: .a, .b, .c denote significance at the 1%, 5%, 10% levels. 1764 observations

Table 4: Variance decomposition for euro area core and periphery specification

The table shows the weighted average (across regimes) of one day ahead forecast error variance decompositions, based on the seven-variable structural VAR. The weights are the number of observations per regime. The sample period is 24 October 2006 until 31 July 2013.

	Impulse						
Response	Sov CO	Bank CO	Sov PE	Bank PE	Nonfin EA	Term EA	Stocks EA
Sov CO	0.72	0.04	0.16	0.00	0.02	0.03	0.04
Bank CO	0.05	0.61	0.06	0.12	0.10	0.00	0.05
Sov PE	0.07	0.02	0.86	0.01	0.01	0.00	0.03
Bank PE	0.08	0.08	0.16	0.56	0.08	0.00	0.04
Nonfin EA	0.02	0.00	0.04	0.02	0.82	0.01	0.08
Term EA	0.04	0.00	0.09	0.02	0.03	0.80	0.01
Stocks EA	0.03	0.00	0.02	0.02	0.04	0.00	0.89

Table 5: Flight-to-safety - Overall effects between Bund yields and other asset prices

The table shows the estimated overall effects of structural shocks of one standard deviation on the endogenous variables. It contains the A-1 matrix of a seven-variable structural VAR, using only German CDS spreads to measure core sovereign risk and the 10 year yield on German sovereign bonds. Impulse variables are in columns, response variables are in rows. The sample period is 24 October 2006 until 31 July 2013.

	Impulse						
Response	Sov DE	Bank CO	Sov PE	Bank PE	Nonfin EA	Bund yield	Stocks EA
Sov DE	1.04	0.06	0.11	0.16	0.05	0.05	-0.17
p	*.a*	*.b*	.	*.c*	*.c*	.	*.a*
Bank CO	0.23	1.09	0.29	0.58	0.39	-0.05	-0.31
p	*.a*	*.a*	*.a*	*.a*	*.a*	.	*.a*
Sov PE	0.26	0.05	1.07	0.09	0.06	-0.05	-0.10
p	*.b*	*.c*	*.a*	*.c*	*.a*	*.b*	*.a*
Bank PE	0.21	0.17	0.54	1.15	0.20	-0.05	-0.19
p	*.a*	*.a*	*.a*	*.a*	*.a*	*.b*	*.a*
Nonfin EA	0.07	0.05	0.19	0.17	1.07	0.05	-0.36
p	*.b*	*.c*	*.a*	*.a*	*.a*	.	*.a*
Bund yield	-0.14	0.03	-0.21	-0.07	-0.26	1.00	0.43
p	*.a*	.	*.a*	*.b*	*.a*	*.a*	*.a*
Stocks EA	-0.09	-0.04	-0.13	-0.15	-0.17	0.03	1.09
p	*.a*	*.c*	*.a*	*.a*	*.a*	.	*.a*

Notes: .a, .b, .c denote significance at the 1%, 5%, 10% levels. 1764 observations.

Table 6: Implementation and announcement effects of monetary policy on credit risks and other asset prices in the euro area

The table shows the effects of on non-standard monetary policy measures on the endogenous variables, based on the five-variable, structural VAR specification for the euro area. The dependent variables are in basis points in columns (1)-(4) and in percentage in column (5). The upper part of the table shows the point estimates and the cumulative implementation effects of monetary policy measures. The lower part shows the cumulative effects of specific ECB announcements together with the p-value of the F-test of joint significance of lags 0-10.

	(1) Sov. risk	(2) Bank risk	(3) Non-fin. risk	(4) Term spread	(5) Stock market
Implementation effects					
6-12m LTRO allotm. (bn.)					
Point estimate	-0.011	-0.008	-0.011	0.002	0.003
p	*0.003*	*0.006*	*0.000*	*0.695*	*0.000*
Cum. effect (979 bn.)	-10.7	-7.8	-10.7	-	2.9
3y LTRO allotments (bn.)					
Point estimate	-0.030	-0.047	0.006	0.004	-0.000
p	*0.431*	*0.001*	*0.257*	*0.803*	*0.846*
Cum. Effect (1,020 bn)	-	-47.9	-	-	-
SMP purchases (bn.)					
Point estimate	1.082	0.961	0.417	0.469	-0.111
p	*0.296*	*0.073*	*0.161*	*0.235*	*0.211*
Cum. Effect (218 bn)	-	209.3	-	-	-
Cum. announcm. effects					
LTROs 6-12 months	-5.9	-1.0	3.8	8.8	-0.6
p	*0.031*	*0.138*	*0.439*	*0.001*	*0.511*
3-year LTROs	39.7	26.0	9.6	-13.8	-8.1
p	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*
SMP	-52.0	-40.0	-16.2	-54.2	3.1
p	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*
OMT	-56.0	-33.7	-7.9	-15.2	5.1
p	*0.000*	*0.000*	*0.000*	*0.000*	*0.001*
R squared	0.24	0.33	0.37	0.24	0.60

Note: The p-values are based on heteroskedasticity robust standard errors; 1764 observations.

Table 7: Implementation and announcement effects of monetary policy on sovereign credit risk of euro area member states

The table shows the effects of non-standard monetary policy measures by the ECB on sovereign CDS spreads of euro area countries, based on the sovereign risk equation of the corresponding country-specific sVAR specification. The dependent variable is in basis points. The upper part of the table shows the implementation effects of specific monetary policy measures. The lower part shows the cumulative announcement effects of specific ECB measures together with the p-value of the F-test of joint significance of lags 0-10.

	EMU	AT	BE	DE	FR	NL	ES	IE	GR	IT	PT
Implementation effects											
6-12m LTRO allotm. (bn.)	-0.011	-0.017	-0.007	-0.003	-0.002	-0.010	-0.012	-0.020	-0.057	-0.022	-0.013
p	*0.003*	*0.000*	*0.064*	*0.074*	*0.171*	*0.005*	*0.012*	*0.002*	*0.429*	*0.000*	*0.214*
Cum. effect 6-12m LTROs	-10.7	-16.6	-6.9	-2.9	-	-9.8	-11.7	-19.6	-	-21.5	-
3y LTRO allot. (bn.)	-0.030	-0.016	-0.048	-0.009	-0.030	-0.011	-0.067	-0.015	-5.272	-0.092	-0.000
p	*0.431*	*0.112*	*0.192*	*0.254*	*0.137*	*0.253*	*0.001*	*0.809*	*0.149*	*0.086*	*0.999*
Cum. effect 3y LTROs	-	-	-	-	-	-	-68.3	-	-	-93.8	-
SMP purchases (bn.)	1.082	0.568	1.188	0.112	0.327	0.784	1.096	-0.504	61.756	2.137	3.542
	0.296	*0.595*	*0.190*	*0.852*	*0.567*	*0.107*	*0.391*	*0.740*	*0.019*	*0.186*	*0.323*
Cum. announcm. effects											
LTRO 6-12 months	-5.9	-3.6	1.2	-1.3	3.0	-4.6	-7.4	-3.6	-199.6	-6.4	-39.2
p	*0.031*	*0.075*	*0.006*	*0.087*	*0.020*	*0.000*	*0.387*	*0.019*	*0.857*	*0.070*	*0.204*
3-year LTROs	39.7	25.0	47.4	15.1	52.3	54.4	48.1	67.0	4971.8	42.8	75.4
p	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*
SMP	-52.0	-20.3	-40.6	-10.2	-11.5	-30.1	-79.8	30.9	-2139.9	-113.0	-132.1
p	*0.000*	*0.013*	*0.000*	*0.058*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*
OMT	-56.0	-10.9	-23.4	-8.2	-25.0	-21.9	-114.0	-80.0	0.0	-106.9	-124.2
p	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	-	*0.000*	*0.000*
Observations	1764	2477	2142	2470	2074	1765	1765	1466	1583	2454	2003
R squared	0.24	0.15	0.20	0.15	0.18	0.27	0.26	0.22	0.25	0.27	0.18

Note: The p-values are based on heteroskedasticity robust standard errors.

Table 8: Implementation and announcement effects of monetary policy on bank credit risk of euro area member states

The table shows the effects of non-standard monetary policy measures by the ECB on bank CDS spreads (in basis points) of euro area countries, based on the bank risk equation of the corresponding country-specific sVAR specification. The dependent variable is in basis points. The upper part of the table shows the implementation effects of specific monetary policy measures. The lower part shows the cumulative announcement effects.

	EMU	AT	BE	DE	FR	NL	ES	IE	GR	IT	PT
Implementation effects											
6-12m LTRO allotm. (bn.)	-0.008	-0.014	-0.002	-0.005	-0.013	-0.007	-0.007	-0.022	0.026	-0.010	-0.005
p	*0.006*	*0.004*	*0.855*	*0.184*	*0.001*	*0.030*	*0.152*	*0.211*	*0.569*	*0.079*	*0.254*
Cum. effect 6-12m LTROs	-7.8	-13.7	-	-	-12.7	-6.9	-	-	-	-7.8	-
3y LTRO allotments (bn.)	-0.047	-0.039	-0.080	-0.042	-0.031	-0.004	-0.066	-0.016	-0.356	-0.052	-0.134
p	*0.001*	*0.022*	*0.023*	*0.000*	*0.051*	*0.316*	*0.026*	*0.677*	*0.543*	*0.002*	*0.036*
Cum. effect 3y LTROs	-47.9	-39.8	-81.6	-42.8	-30.6		-67.3			-53.0	-137.7
SMP purchases (bn.)	0.961	1.666	1.509	0.749	1.016	0.331	0.622	-2.341	8.800	1.592	1.634
p	*0.073*	*0.033*	*0.134*	*0.077*	*0.196*	*0.448*	*0.391*	*0.481*	*0.024*	*0.084*	*0.314*
Cum. effect SMP	209.3	361.9	-	163.3	-	-	-	-	1,918.4	346.6	-
Cum. announcm. effects											
LTRO 6-12 months	-1.0	-1.9	18.7	6.7	4.2	-5.4	21.2	37.9	2.0	-14.6	-4.5
p	*0.138*	*0.087*	*0.085*	*0.021*	*0.555*	*0.614*	*0.001*	*0.613*	*0.280*	*0.142*	*0.154*
3-year LTROs	26.0	2.9	68.1	25.1	25.3	-0.3	38.9	-74.3	216.7	8.6	80.7
p	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*
SMP	-40.0	-43.4	-23.6	-33.1	-39.5	-0.5	-52.1	196.4	-473.5	-63.0	-79.1
p	*0.000*	*0.000*	*0.546*	*0.086*	*0.551*	*0.016*	*0.001*	*0.000*	*0.082*	*0.000*	*0.000*
OMT	-33.7	-39.7	-23.6	-5.6	-20.6	-14.0	-54.5	21.5	0.0	-71.2	-61.0
p	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.139*	-	*0.000*	*0.477*
Observations	1764	2477	2142	2470	2074	1765	1765	1466	1584	2454	2003
R squared	0.33	0.18	0.19	0.16	0.26	0.11	0.28	0.11	0.27	0.29	0.20

Note: The p-values are based on heteroskedasticity robust standard errors.

Table 9: Effects of bank bailout announcements on sovereign risk and bank risk in the euro area

The lower part of the table shows the effects of specific bank bailout announcements (debt guarantees, deposit guarantees, capital injections) by governments on sovereign CDS spreads (columns 1-3) and bank CDS spreads (columns 4-6). They are extracted from the sovereign risk equation and bank risk equation, respectively, of the five-variable sVAR for the euro area. Specifically, the table shows the 20 day cumulative announcement effects together with the p-value of the F-test of joint significance of lags 0-20. The dependent variables are in basis points. The upper part of the table shows the implementation effects of specific monetary policy measures. The lower part shows in addition the cumulative effect of the announcement of specific ECB measures together with the p-value of the F-test of joint significance.

	Sovereign risk			Bank risk		
	(1)	(2)	(3)	(4)	(5)	(6)
Implementation effects, point estimates						
6-12m LTROs allotm. (bn.)	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01
p	*0.009*	*0.000*	*0.001*	*0.044*	*0.008*	*0.003*
3y LTROs allotments (bn.)	-0.03	-0.03	-0.03	-0.05	-0.05	-0.05
p	*0.425*	*0.412*	*0.425*	*0.000*	*0.000*	*0.000*
SMP purchases (bn.)	1.10	1.11	1.10	0.97	0.95	0.96
p	*0.283*	*0.272*	*0.280*	*0.063*	*0.064*	*0.066*
Cum. announcement effects						
Monetary policy announcements						
LTROs 6-12 months	-6.5	-13.7	-5.4	1.6	-0.1	2.2
p	*0.110*	*0.024*	*0.058*	*0.431*	*0.184*	*0.091*
3-year LTROs	40.8	41.0	40.8	27.6	28.0	27.4
p	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*
SMP	-52.6	-50.0	-54.5	-42.0	-43.1	-43.2
p	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*
OMT	-54.4	-55.6	-54.6	-32.2	-32.1	-32.5
p	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*
Bank bailout announcements						
Debt guarantees	0.9			-46.6		
p	*0.006*			*0.000*		
Deposit guarantees		-31.0			-73.5	
p		*0.000*			*0.000*	
Capital injections			4.1			-76.0
p			*0.003*			*0.000*
R squared	0.26	0.26	0.26	0.37	0.39	0.37

Note: The p-values are based on heteroskedasticity robust standard errors; 1764 observations.

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