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THE MACROECONOMIC EFFECTS OF THE SOVEREIGN DEBT CRISIS IN THE EURO AREA

By Stefano Neri* and Tiziano Ropele*

Abstract

This paper uses a Factor Augmented Vector Autoregressive model to assess the macroeconomic impact of the euro-area sovereign debt crisis and the effectiveness of the European Central Bank's conventional monetary policy. First, our results show that in the countries most affected by the crisis, the tensions in sovereign debt markets made credit conditions significantly worse and weighed on economic activity and unemployment. The disruptive effects of the sovereign tensions propagated to the core economies of the euro area through the trade and confidence channels. Second, 'modest' (in the sense of Leeper and Zha, 2003) counterfactual simulations suggest that the accommodative monetary policy stance of the ECB helped to moderate the negative effects of the sovereign debt tensions.

JEL Classification: C32, E44, E52, F41.

Keywords: sovereign debt crisis, FAVAR models, Bayesian methods, monetary policy.

Contents

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1 Introduction[1]

The onset of the euro area sovereign debt crisis in early 2010 has had severe macroeconomic consequences. Diverging sovereign bond yields across euro area countries were, at least initially, accompanied by different macroeconomic developments. In countries where the sovereign yields markedly increased – such as in Greece, Ireland, Portugal, Spain and Italy (henceforth, the "peripheral countries") – access to banks' credit became more difficult, economic activity began to contract and labour market conditions deteriorated. In other economies – such as Germany, the Netherlands, France, Austria, Belgium and Finland (henceforth, the "core countries") – firms' and households' financing conditions remained broadly in line with the monetary policy stance of the European Central Bank (ECB), industrial production continued to expand and the unemployment rate remained stable at moderate levels. As the sovereign tensions persisted, the negative economic effects became more widespread, causing a mild recession at the euro-area level. Against this backdrop, the ECB and the national governments implemented extraordinary measures to restore confidence in financial markets, limit the spread of tensions across countries and support economic activity.

The goal of this paper is twofold. First, we seek to quantify the economic effects of the euro-area sovereign debt crisis on a large number of macroeconomic variables across the euro area as well as in individual countries. In particular, our interest in examining a large number of variables is motivated not only by the fact that the sovereign debt crisis affected different countries in different ways – a feature we want our econometric model to mimic – but also because we wish to investigate the transmission channels through which the crisis unfolded. Second, we want to evaluate the role of ECB conventional monetary policy in offsetting the negative macroeconomic impact of the crisis. To this end, we design two counterfactual simulations that are "modest" – in the sense of Leeper and Zha (2003) – to assess to what extent the effects of the sovereign debt tensions would have been different had the ECB either not reacted at all or followed a more aggressive interest rate policy.[2]

For the purposes of our analysis we have to address several issues. First, we

[1]We would like to thank Fabio Canova, Francesco Nucci, Giulio Nicoletti, Gabriel Perez Quiros, Frank Smets, Giancarlo Corsetti, Carlos Thomas, Sandra Eickmeier, Benjamin Born and participants at the seminar at Banco de España, Banque de France, Banca d'Italia, European Central Bank, at the 19^{th} Conference on Computing in Economics and Finance held in Vancouver on 10-12 July 2013, at the conference "The Sovereign Debt Crisis and the Euro Area" held at Banca d'Italia on 23 and 24 September 2013, at the conference on "Macrofinancial Linkages and Macroprudential Policies", held at the Bank of Korea on 9 and 10 December 2013 and at the University of Bonn and CEPR conference on "The European Crisis - Causes and Consequences" on 20 and 21 June 2014. The opinions expressed in this paper are those of the authors and do not necessarily reflect those of the Bank of Italy.

[2]Modest as defined by Leeper and Zha (2003) means that these counterfactual exercises do not significantly change private agents' beliefs about ECB policy. See Section 5 for more details.

need an indicator of the euro-area sovereign tensions from which to compute the unexpected changes, i.e. the sovereign debt tensions shocks. In a monetary union with many fiscal authorities – such as the euro area – the characterization of such an indicator is not trivial. The recent and fast-growing empirical literature on the euro-area sovereign debt crisis has explored various measures mostly based on sovereign bonds yield spreads, sovereign credit default swap (CDS) premia or sovereign ratings. In this paper we use as benchmark indicator the difference between the yield on Greek ten-year government bonds and the ten-year euro interest rate swap (the Greek sovereign spread). The rationale underlying this choice is that it was Greece that sparked the euro-area sovereign debt crisis in the autumn of 2009, leading to contagion following the so-called "wake-up call". Second, a thorough investigation of the many propagation channels of the crisis means considering a great number of macroeconomic series. In the present study we use a data set that consists of 173 variables (151 country-level and 22 euro-area wide) pertaining to: bank rates, credit aggregates, monetary aggregates, industrial production, unemployment rates, inflation rates, intra-EMU exports, confidence indices, and other real and financial variables. For this we use a Factor Augmented Vector Autoregressive ('FAVAR') model, which is a particular case of the more general class of structural dynamic factor models by Forni et al. (2009). Forni and Gambetti (2010) and Luciani (2013) use these models to study the effects of monetary policy in the U.S., Barigozzi et al., (2014) in the euro area. FAVAR models have been extensively used in the literature to study the effects of monetary policy (see Bernanke, Boivin, and Eliasz, 2005, for the U.S. and Ellis, Mumtaz and Zabczyk, 2014, for the UK). Third, and last, another potential problem is the small sample size as the tensions in the sovereign debt markets in the euro area surfaced in early 2010. In this regard, we expand the number of time observations by starting the sample in January 2007 - thereby including the first phase of the global financial crisis - and using monthly data.[3] Furthermore, we estimate the FAVAR with Bayesian techniques that allow us to conduct inference even in small samples as they do not rely on asymptotic results.

Our main results can be summarized as follows. In response to an unexpected increase in the Greek sovereign spread, our estimated FAVAR model delivers country-level as well as euro-area wide macroeconomic adjustments that closely resemble the actual unfolding of the sovereign debt crisis and suggest several propagation channels. The shock is immediately transmitted –albeit with different intensities – to the sovereign spreads in Portugal, Ireland, Italy and Spain while leaving those of the other countries virtually unaffected.[4] These developments give rise to a marked heterogeneity in banks' funding conditions and in the cost and availability of credit to non-financial corporations (NFCs) and households (HHs) between peripheral and core countries. These results provide support to the tight nexus between sovereigns and banks being one of the key transmission mechanisms of the sovereign debt crisis in the euro area. Notwithstanding the marked heterogeneity in credit market de-

[3]Indeed, financial tensions in the euro-area sovereign debt markets were already seen after the Lehman Brothers' bankruptcy in September 2008.

[4]Sovereign spreads are calculated in the same way as for Greece.

velopments, the decline in industrial production turns out to be widespread across countries. According to our simulations this could be by two other propagation channels, namely the confidence channel and the trade channel. In fact in the wake of a Greek sovereign spread shock, consumer and business confidence indices drop significantly, indicating a weakening in domestic demand, in both the peripheral and the core countries. Further, intra-EMU exports plummet in nearly all countries suggesting a decline in foreign demand. Against this backdrop, the ECB responds by immediately lowering the policy rate, which in our baseline FAVAR specification is the rate on the main refinancing operations(MRO), and by pursuing a long-term expansionary policy.

Turning to the assessment of the ECB's "conventional"monetary policy, our counterfactual simulations show that the cut in the MRO rate helped to stabilize economic activity. Had the central bank kept the policy rate unchanged, lending rates would have increased more, industrial production would have declined more and labour market conditions would have deteriorated more, whereas, had the ECB been more aggressive, the increase in the cost of credit would have almost been offset and the decline in industrial production would have been minimized.

As discussed in Section 6 which deals with robustness, our main results are not due to specific modelling choices. In particular, we show that the impulse responses and the counterfactual simulations are robust to the use of other indicators of sovereign debt tensions, identification of a sovereign shock, different monetary policy rates, data transformations, sample periods and choice of priors.

The outbreak of the sovereign debt crisis in the euro area has spurred great interest among central banks, international institutions and researchers in understanding how the crisis unfolded within and across countries and in shedding light on its economic consequences. Among the theoretical works, Gennaioli, Martin and Rossi (2010) present a model of sovereign debt in which government default risk is costly because it destroys the balance sheet of domestic banks thus leading to a contraction in lending to the private sector. These spillover effects from the sovereign to the banking sector are greater in countries where banks hold more government bonds. Corsetti et al. (2013) use a closed-economy New Keynesian model to study how the "sovereign risk channel" affects macroeconomic variables and the conduct of monetary policy. The authors show that a rise in sovereign risk drives up private sector borrowing costs and if monetary policy cannot offset this increase because of the zero lower bound, then the sovereign risk can amplify the effects of cyclical shocks. Guerrieri, Iacoviello and Minetti (2012) develop a two-country DSGE model to investigate the transmission of government defaults abroad, through the financial sector. The authors assume that capital constrained banks grant loans to firms and invest in bonds issued by the domestic and the foreign governments. Under these circumstances, a sovereign default in one country may have sizeable spillover effects in another country through a drop in the volume of credit extended by the banking sector. Bi (2012) develops a closed economy general equilibrium model to study the interaction between sovereign risk premia and the so-called fiscal limit, which measures the government's ability to service its debt. Bi (2012) shows that the relationship between sovereign risk premia and government debt is non-linear and varies over time. More recently, Bi and Traum (2014) have estimated the distribution of the fiscal limit and the associated sovereign default probability for Greece. The authors find that the probability of default by Greece on its public debt had remained close to zero from 2001 to 2009 and then rose sharply to between 60 and 80 per cent by the end of 2011.

Empirical studies on the euro-area sovereign debt crisis have addressed a broad range of questions. Oliveira, Curto and Nunes (2012) show that during the crisis markets have penalized fiscal and other macroeconomic imbalances much more heavily than before. Furthermore, they suggest that markets not only attached a higher weight to fiscal imbalances, but also started putting a price on their interaction with the international risk factor. Caceres, Guzzo and Segoviano (2010), Arghyrou and Kontonikas (2012) and Beirne and Fratzscher (2013) document the existence of contagion effects in the bond markets of several euro-area countries. Brutti and Saure (2013) examine the role of financial linkages for the transmission of sovereign risk during the debt crisis and conclude that cross-border financial exposures are important transmission channels: without any exposure to Greek debt, the sovereign credit-default swap (CDS) of the average country would have reacted very much less to a shock to Greek sovereign risk. Gorea and Radev (2014) calculate joint default probabilities using CDS contracts for euro-area countries over the period 2007–2011 and find that financial linkages are an active contagion transmission channel only in the case of troubled peripheral economies. Real economy linkages play a more important role in transmitting shocks from peripheral to core countries. The authors show that countries that have stronger trade relations with the peripheral ones tend to have a higher expected joint default probability. Other studies have specifically examined the effect of sovereign risk on bank interest rates and credit developments.[5] Neri (2014) finds that during the euro-area debt crisis the surge in sovereign spreads significantly increased lending rates in the peripheral countries. De Marco (2014) finds that banks that were more exposed to the sovereign tensions tightened credit supply more than banks that were less exposed. Similarly, Popov and Van Horen (2014), using syndicated loan data, find that lending by European banks with sizeable balance sheet exposure to the sovereign debt of stressed countries was negatively affected by the onset of the sovereign crisis.

This paper contributes to the growing literature on the euro-area sovereign debt crisis as regards two dimensions. First, it represents an attempt to examine in a systematic way the effects of the sovereign debt crisis on a large number of macroeconomic variables by modelling their interdependences through a FAVAR model. To the best of our knowledge this is the first study of its kind. While these models have been extensively employed to examine the effects of monetary policy in

[5] Albertazzi et al. (2014), Bofondi, Carpinelli and Sette (2013) and Del Giovane, Nobili and Signoretti (2013) quantify the effects of the sovereign debt crisis on the Italian credit market.

the U.S. (Bernanke, Boivin and Eliasz, 2005), few have examined the euro area (Boivin, Giannoni and Mojon, 2008). Second, we assess the effectiveness of the ECB's "conventional" policy in stabilizing the euro-area economy. An evaluation of the effectiveness of the various non-standard measures adopted by the ECB is beyond the scope of this paper. Darracq-Parries and De Santis (2013) quantify the effects of the three-year long-term refinancing operations introduced at the end of 2011.

The remainder of the paper is organized as follows. Section 2 briefly describes the unfolding of the sovereign debt crisis and discusses the main transmission channels. Section 3 presents the methodology and Section 4 discusses the empirical findings. Section 5 presents the results of counterfactual simulations to assess the role of the conventional monetary policy of the ECB in mitigating the impact of the sovereign crisis. Section 6 briefly describes a set of robustness checks and Section 7 draws the conclusions.

2 The euro-area sovereign debt crisis: key facts and propagation channels

In this Section we briefly review the key macroeconomic developments that characterized the unfolding of the euro-area sovereign debt crisis. For a more thorough discussion of the causes at the origin of the sovereign debt tensions and an overview of the fiscal and structural measures implemented during the crisis see Lane (2012) and Moro (2014) and the references therein.

The euro-area sovereign debt crisis started in October 2009 when the freshly elected Greek government announced that its budget deficit for 2009 had been revised to around 14 per cent of GDP from the previously published figure of around 6. This immediately sparked doubts about the country's debt sustainability and in December 2009, rating agencies downgraded Greek debt below investment grade and government bond yields soared to unprecedented levels. By the end of April 2010 Greece turned to the European Union and the International Monetary Fund to activate a €45 billion bailout package. By early May 2010 the rescue package had to be increased to an amount of €110 billion over three years. Since then, the 10-year sovereign spread rose sharply in Greece and, albeit with different intensities and timings, in other peripheral countries too. In some core countries, notably in Germany and the Netherlands, the 10-year sovereign spread declined, possibly reflecting flight-to-quality phenomena. These patterns are clear in Figure 1.

Existing studies on financial crises have emphasized three main transmission channels through which sovereign risk can affect the real economy.

The first, and perhaps the most important, is the *banking channel*. Due to the pervasive role of government debt in modern financial systems, banks and sovereigns are tightly intertwined. A deterioration in sovereign creditworthiness makes bank funding more costly and difficult to obtain.[6] Such funding difficulties can then translate in a higher cost of credit and give rise to an outright reduction in the availability of loans through the traditional bank lending channel. During 2010 and 2011 in most peripheral countries banks' cost of funding substantially increased and so did the cost of new loans to non-financial corporations and households. As shown in Figure 2 (bottom-left panel) the dispersion in the interest rate on new loans to firms rose sharply throughout 2011, mainly reflecting developments in Italy, Spain, Greece and Portugal. In Germany the rise was remarkably smaller and substantially in line with the increase in the EONIA (Euro OverNight Index Average) money market rate. Likewise, the interest rate on new loans for house purchase went up rapidly in peripheral countries. Cross-country heterogeneity also characterized bank lending.

The second propagation mechanism is the *confidence channel*. The transmission of higher sovereign risk to the real economy may be accelerated and/or amplified through the deterioration in businesses' and consumers' confidence. During the euro-area sovereign debt crisis, confidence worsened in virtually all countries - though with different timing - possibly reflecting many factors: the announcement and implementation of fiscal consolidation policies (i.e. government spending cuts and/or tax increases) in stressed countries to restore the sustainability of public finances; the negative developments in equity and bond markets which made the internal and external financing of investment more costly and affected consumption via negative wealth effects and the deterioration of the economic outlook.

The third mechanism is the *trade* and *financial linkages channel*. The effects of tensions in sovereign debt markets can quickly propagate across countries through international trade and financial linkages. As for the trade linkages, during the sovereign debt crisis intra-EMU exports declined substantially, mainly reflecting falling imports in the countries most affected by the sovereign tensions. Sovereign tensions in one country may spill over to banks in other countries, either through banks' direct exposure to the distressed foreign sovereign debt, or indirectly, as a result of cross-border interbank exposures or banks claims on non-financial entities in countries affected by sovereign tensions. Popov and Van Horen (2014) document a direct link between deteriorating creditworthiness of foreign sovereign debt and lending by banks holding such debt. The authors find that banks with substantial holdings of peripheral sovereign debt reduced syndicated lending by about 20% relative to banks with marginal holdings.

Through the working of these channels, the tensions in sovereign debt markets in stressed economies brought about a significant decoupling of macroeconomic developments between peripheral and core countries. While in some core countries (such as in Germany) industrial production continued to grow and unemployment

[6] As discussed in Bank for International Settlements (2011).

rate slightly declined, in the periphery industrial activity severely contracted and labor market conditions deteriorated markedly.

The effects of the euro-area sovereign debt crisis were also mirrored in the TARGET2 net balances of the Eurosystem's national central banks (NCBs), as percentages of banking sectors total asset (Figure 2 top-left panel).[7] Prior to the global financial crisis, TARGET2 positions were almost balanced as cross-border payments were flowing in and out among countries. The beginning of the global financial crisis in August 2007 led to one-direction flows from peripheral countries to core countries, as banks in the latter ones started selling securities issued by banks and government in the periphery of the euro area. This widening of TARGET2 balances intensified with the outbreak of the sovereign debt crisis. Cecioni and Ferrero (2012) find that in Portugal, Italy and Spain the increase of TARGET2 liabilities was mostly related to private capital outflows in securities and interbank markets while in Greece also to the current account deficit and deposit runs.

In early 2012 banks' funding difficulties in peripheral countries were to a large extent alleviated by the ECB's decisions to reduce the official rates in November and December 2011 (each time by 25 b.p.) and to launch the two 3-year longer-term refinancing operations.[8] Uncertainty in financial markets temporarily retreated leading to an improvement in markets' confidence. The sovereign spreads declined in several stressed countries and the financing conditions became slightly more favorable, yet standing at levels considerably higher than those prevailing in core countries. This notwithstanding, in 2012 the economic outlook remained negative in most peripheral countries - possibly also reflecting the drag on growth induced by the large fiscal adjustments implemented during the sovereign crisis - and started deteriorating in core economies, confirming the relevance of the trade channel as an important propagation mechanism of shocks within the euro area. These developments are visible in the increased heterogeneity in industrial production since 2011 (Figure 2, top-right panel) and unemployment (Figure 2, bottom-right panel).

3 Empirical analysis

3.1 Measuring the euro-area sovereign debt tensions

In order to measure the euro-area sovereign debt tensions we take a market perspective and look at how financial market partecipants priced sovereign debt risk

[7]TARGET2 is the real-time gross settlement system owned and operated by the Eurosystem for large-value cross-border payments. For more details see https://www.ecb.europa.eu/paym/t2/html/index.en.html

[8]During the global financial crisis the ECB introduced a plethora of non-standard policy measures tailored to support the market liquidity and restore the correct transmission of monetary policy impulses. For a detailed description see Eser et al. (2012).

during the crisis. Our baseline indicator of the euro-area sovereign debt tensions is the Greek sovereign spread.[9] The rationale for using the Greek spread hinges on the so-called "wake-up call" contagion hypothesis. Within the debate on the origins of the euro-area sovereign debt crisis several studies have emphasized the role of contagion. Giordano, Pericoli and Tommasino (2013) find evidence of a "wake-up call" contagion, to be intended as the situation where the outbreak of a crisis in one country releases new information that triggers investors and market participants to revise their default risk assessment for other countries. De Santis (2012) shows that rating events concerning the Greek sovereign bonds led to substantial increases in the Irish and Portugues sovereign bond yields; the effects were less noticeable, but still statistically significant, for the Italian, Spanish, Belgian and French sovereign bond yields. Hence, these findings suggest that spillover effects from Greece were predominant. Likewise, Arghyrou and Kontonikas (2012) find that several euro-area countries experienced contagion from Greece endorsing the view that the sharp increase in Greek bond yield became a proxy for euro-area systemic risk.

While several recent studies have used the ten-year German Bund yield as a proxy for the free-risk rate (e.g. Beber, Brandt and Kavavejc, 2009; Arghyrou and Kontonikas, 2012; Haugh, Ollivaud and Turner, 2009), the computation of the sovereign spread in deviation from the ten-year euro interest rate swap has two advantages. First, the euro interest rate swap was less affected by flight-to-quality phenomena, which during the global financial and sovereign debt crises undoubtedly favoured the German Bunds (De Santis, 2012). Hence, using the German Bund yield as a reference rate would overestimate the sovereign debt risk in peripheral countries. Second, proxying the risk-free rate with the yield on interest rate swap contracts allows us to retain the sovereign spread of Germany in the analysis.

Before proceeding with the discussion of the data it is useful to clarify that for the purposes of our analysis we do not need to thoroughly disentangle the determinants of the euro-area sovereign bond yields. As shown in many studies, sovereign spreads are mostly driven by three risk factors: a global factor that reflects investors' changing attitudes towards risk, a country-specific sovereign credit risk and a country-specific sovereign bond liquidity risk. In our view, among these three factors the only one we need to be careful of is the global risk factor.[10] As a matter of fact, we are interested in using a measure of euro-area sovereign debt risk that is not affected by global forces and whose innovations (shocks) can be thought as

[9] In Section 6 on robustness we present other indicators of the euro-area sovereign debt tensions: the first is based on a Principal Component Analysis (PCA) of eleven ten-year sovereign spreads, the second on sovereign CDS premia, which are commonly used to measure the credit risk.

[10] During the sovereign debt crisis the "redenomination" risk, which arose in the summer of 2012 in the context of mounting fears of a break-up of the euro area, was an important factor behind the increase in sovereign spreads of the peripheral countries. To counter this risk the ECB introduced the Outright Monetary Transactions in August 2012. While it is difficult to control for the "redenomination" risk, we take care of the global risk factor using the U.S. VIX including this variable as an exogenous regressor in a robustness check. The results are similar to those in the baseline specification of the model.

truly originating within the euro area.

3.2 Econometric framework and estimation

In order to examine the macroeconomic effects of the euro-area sovereign debt crisis we use a FAVAR model. One of the main advantages of the FAVAR approach is to efficiently deal with high-dimension dataset. As thoroughly documented in the recent literature on the effects of monetary policy shocks (e.g. Bernanke and Boivin, 2003; Bernanke, Boivin and Eliasz, 2005), the FAVAR builds on the idea that the information embedded in a large number of economic series can be accurately summarized in a small number of unobservable latent factors extracted using the principal component analysis (henceforth, PCA) and whose joint dynamics, together with those of other observable factors, are described by a VAR model.

We estimate the FAVAR model following a two-step procedure, whereby the factors are estimated by principal components prior to the estimation of the FAVAR.[11] This procedure has the advantage of being computationally simple and easy to implement but it also implies the presence of "generated regressors" in the second step. However, as discussed in Bai and NG (2002), when N_X (i.e. the number of series) is large relative to T (the length of the times series) then the uncertainty surrounding the estimate of factors in the first step can be ignored.

FAVAR model: the first step

Let X_t denote an $N_X \times 1$ vector (with N_X large) of stationary series for which we want to trace the dynamic response to a sovereign debt tensions shock. Furthermore, let $\widehat{X}_t$ denote the stationary series normalized by their sample mean and standard deviation. The first step of the FAVAR approach consists in expressing $\widehat{X}_t$ as:

$$\widehat{X}_t = \mathbf{\Lambda}^F F_t + \xi_t \tag{1}$$

where F_t is an $N_F \times 1$ vector of unobservable latent factors estimated with the PCA (N_F is typically a small number), ξ_t is an $N_X \times 1$ vector of idiosyncratic components and Λ^F is an $N_X \times N_F$ matrix of factor loadings. In order to identify uniquely the factors and the associated loadings we use the restriction on the factors such that $F'F/T = \mathbf{I}$ where T is the number of time periods and $\mathbf{I}$ is the identity matrix. Thus, $F = \sqrt{T}Z$, where the Z_t are the eigenvectors corresponding to the N_F largest eigenvalues of $\widehat{X}'\widehat{X}$ sorted in descending order. This approach identifies the factors against any rotations.[12]

[11] Alternatively one could also use a computationally more burdensome one-step method and estimate the factors and the VAR simultaneously (Bernanke, Boivin and Eliasz, 2005).

[12] One can also choose to restrict the loadings by setting $\left(\mathbf{\Lambda}^F\right)' \left(\mathbf{\Lambda}^F\right) / N_X = \mathbf{I}$. Both approaches deliver the same common component $F \left(\mathbf{\Lambda}^F\right)'$ and the same factor space.

Since the twofold goal of this paper is to examine the effects of the euro-area sovereign debt crisis and evaluate the ECB conventional monetary policy, we assume that the indicator of sovereign debt tensions and the monetary policy rate are observable factors. Consequently, we re-write equation (1) as:

$$\widehat{X}_t = \widetilde{\mathbf{\Lambda}}^F \widetilde{F}_t + \mathbf{\Lambda}^Y Y_t + \widetilde{\xi}_t \tag{2}$$

where Y_t is a 2×1 vector with the observable factors, Λ^Y is an $N_X \times 2$ matrix of factor loadings. Note the "$\sim$" added on top of Λ^F, F_t and ξ_t which indicates that the unobservable factors are orthogonalized with respect to Y_t. In particular, $\widetilde{F}_t = F_t - \widehat{\beta} Y_t$, where $\widehat{\beta} = (Y_t' Y_t)^{-1} F_t' Y_t$. The matrix of unobservable factor loadings and the vector of idiosyncratic components are then re-estimated accordingly. For this procedure to work one has also to ensure that the idiosyncratic components are contemporaneously orthogonal to Y_t.[13] Ensuring that $\widetilde{F}_t$ and Y_t are contemporaneously orthogonal is necessary to examine the effects of a shock to an element in Y_t onto $\widetilde{F}_t$ and then onto X_t (Bernanke, Boivin and Eliasz, 2005).

FAVAR model: the second step

In the second step of the procedure we setup a VAR model:

$$Z_t = \sum_{j=1}^{p} \mathbf{A}_j Z_{t-j} + \sum_{j=1}^{q} b_j w_{t-j} + \varepsilon_t \tag{3}$$

where $Z_t \equiv \begin{bmatrix} \widetilde{F}_t & Y_t \end{bmatrix}'$, w_t is a measure of world demand, $\mathbf{A}$'s and b's are respectively conformable matrices and vectors, and ε_t is the zero-mean normally distributed error term with covariance matrix $\mathbf{\Sigma}_\varepsilon$.[14] The inclusion of the exogenous variable serves two purposes. First, it allows us to control for global external factors such as the collapse in international trade that occurred during the global financial crisis and that could have affected the euro-area economy. Second, the measure of world demand can be viewed as a proxy for the degree of global risk aversion of investors that typically increases in worldwide economic downturns.[15]

We estimate the VAR model (3) using Bayesian methods assuming a normal-diffuse prior for the coefficients (Kadiyala and Karlsson, 1997). Let c be a vector

[13] Following Bai and Ng (2004), we tested for the stationarity of the idiosyncratic components using the augmented Dicky-Fuller unit root test. For all the variables in our dataset, the test suggested no unit root in the idiosyncratic components $\widetilde{\xi}_t$.

[14] World demand is made stationary by taking first-differences and standardised by its sample mean and standard deviation.

[15] In the literature on the determinants of the sovereign credit risk, the degree of investors' risk appetite is typically proxied by the U.S. stock market implied volatility (VIX) or US corporate bond spreads (e.g. Gerlach, Schulz and Wolf, 2010). Longstaff et al. (2011) show that for an extensive cross-section of developed and emerging-market countries the patterns in sovereign credit risk can be linked to global market factors. Our results are robust to including the U.S. VIX index as an exogenous variable together with world demand.

that stacks the reduced-form coefficients present in $\mathbf{A}$'s and b's. We assume a normal prior for c and a diffuse one for the variance-covariance matrix of the shocks $\mathbf{\Sigma}_\epsilon$:

$$
\begin{aligned}
c &\sim N\left(\bar{c}, \bar{\mathbf{\Sigma}}_c\right) &\quad (4)\\
p(\mathbf{\Sigma}_\epsilon) &\sim |\mathbf{\Sigma}_\epsilon|^{-\frac{N+1}{2}} &\quad (5)
\end{aligned}
$$

where $\bar{c}$ and $\bar{\mathbf{\Sigma}}_c$ indicate respectively the mean and the variance covariance matrix of the prior, and $N = N_F + 2$ denotes the number of endogenous variables in the VAR. We impose the restrictions of the so-called Minnesota prior (Litterman, 1986) on c (Doan, Litterman and Sims, 1984): the variables of the VAR are assumed to follow a univariate first order autoregressive process with correlated innovations, rather than unit root processes as in the original formulation. All coefficients in $\bar{c}$ are equal to zero except the first own lag of the dependent variable in each equation. The variance-covariance matrix $\bar{\mathbf{\Sigma}}_c$ is assumed to be diagonal: the $\bar{\sigma}_c^{ij,\ell}$ element, corresponding to lag ℓ of variable j in equation i, is equal to:

$$
\bar{\sigma}_c^{ij,\ell} = \begin{cases} \frac{\phi_0}{h(\ell)} & \text{if i = j, } \forall \ell \\ \phi_0 \frac{\phi_1}{h(\ell)} \left(\frac{\sigma_j}{\sigma_i}\right)^2 & \text{if i} \neq \text{j, } \forall \ell \text{, j endogenous} \\ \phi_0 \phi_2 & \text{if j exogenous/deterministic} \end{cases}
$$

The hyperparameter ϕ_0 represents the overall tightness of the prior; ϕ_1 the relative tightness of other variables, ϕ_2 the relative tightness of the exogenous variables and $h(\ell)$ the relative tightness of the variance of lags other than the first one (we assume that $h(\ell) = \ell$, that is a linear decay function). The term $(\sigma_j / \sigma_i)^2$ is a scaling factor that accounts for the different scale of the variables of the model.[16]

The posterior distribution of the reduced-form parameters of the VAR, obtained by combining the (normal) likelihood of the VAR with the prior distribution, is normal conditional on the covariance matrix of the residuals, which has a Wishart distribution. Inference is conducted using the Gibbs sampling algorithm.[17]

Compared to classical estimation, the Bayesian approach has several advantages. First, it provides a natural framework for conducting inference even in small samples as it does not rely on asymptotic results. The posterior distribution of the parameters of the model contains all the necessary information to compute probability intervals for any function of these parameters (Canova, 2007). Second, it easily allows incorporating a priori information and hence dealing with short sample periods. Finally, in-sample over-fitting is less problematic with Bayesian VAR models that have also good forecasting properties (Doan, Litterman and Sims, 1984).

[16] In our benchmark specification of the FAVAR model we set $\phi_0 = 0.1$, $\phi_1 = 0.5$ and $\phi_2 = 1000$ as in Canova (2007). We perform some robustness exercises on the relevance of the prior tightness for our results in Section 6.

[17] Draws from the posterior distribution for which the eigenvalues of the companion matrix of the VAR are larger than one in absolute value are discarded.

Identification of the shocks in the VAR

In line with the long tradition in macroeconomics of applying a recursive ordering strategy to identify monetary policy shocks (e.g. Christiano, Eichenbaum and Evans, 1999), we use the Cholesky decomposition of the variance-covariance matrix $\mathbf{\Sigma}_{\varepsilon}$ to identify sovereign debt tensions shocks.[18] The recursive identification scheme implies that the shock to one variable affects contemporaneously only the variables that are ordered after. In our benchmark specification of the VAR the variables are then ordered as follows $Z_t = \begin{bmatrix} \widetilde{F}_t & S_t & R_t \end{bmatrix}'$, where S_t denotes the Greek sovereign spread and R_t the monetary policy rate. Hence, the identification strategy implies that innovations to the sovereign debt tensions indicator do not have a contemporaneous effect on the factors while they do on the policy rate, which also responds on impact to the factors. The sovereign debt tensions indicator reacts to the policy rate with one-month lag. In Section 6 on robustness we also discuss an alternative identification scheme.

4 Data and econometric results

In the empirical analysis the data set X_t consists of a balanced panel of 173 monthly macroeconomic time series spanning the period from January 2007 through December 2012. The complete list of series, their transformation to induce stationarity and data sources are reported in Table 1. All the data with a clear seasonal pattern are either available already seasonally adjusted or are seasonally adjusted with TRAMO. As shown there, many variables are transformed by taking the one-month log difference while others are kept in levels.[19] For instance, the interest rates on deposits and loans are not transformed and this is in line with what is usually done in most of FAVAR studies on the effects of monetary policy. Accordingly, we keep in level also the ten-year sovereign spreads. Also the confidence indices are not transformed, as these indicators have a bounded range of variation, and the TARGET2 net balances.

Regarding the first step of the FAVAR procedure we select the number of unobservable latent factors using two criteria. First, we use the so-called *scree plot criterion*. The scree plot charts the eigenvalues of a covariance matrix (in our case $\widehat{X}_t'\widehat{X}_t$) in descending order. Typically, the curve that connects the eigenvalues in the scree plot is at first very steep and then flattens out. According to this criterion the number of factors to be retained corresponds to eigenvalue at which the curve straightens out. The scree plot shown in Figure 4 suggests using four factors that

[18] In the recent literature on the effects of the sovereign debt crisis other identification strategies beyond Cholesky have also been used in VAR models. For example, de Groot and Leiner-Killinger (2013) and Stanga (2011) use sign restrictions.

[19] For robustness check we also try with three-month differences. The results are discussed in Section 6.

overall explain about 65% of the cross-sectional variance of the data; each of the factor from the fifth onward explain no more than 3 per cent. Second we used the criteria suggested by Ahn and Horenstein (2013), that are based on the distance between two adjacent eigenvalues of the covariance matrix $\widehat{X}_t'\widehat{X}_t$, and obtained the same number of factors.

Figure 5 reports the unobservable latent factors F_t and the orthogonalized ones $\widetilde{F}_t$. The first unobservable factor closely resembles the MRO rate, suggesting that the co-movements among the series in our data set are to a large extent driven by the monetary policy. The second unobservable factor appears to track well the development in euro-area economic activity and turns out to be highly correlated with the one-month growth rate of euro-area industrial production. The third and fourth unobservable factors do not seem to mimic any particular macroeconomic series in the data set. After the procedure of orthogonalization of F_t with respect to the ten-year Greek spread and the MRO rate, the first factor loses its correlation with the ECB policy rate, while the second and fourth factor are basically unaffected; the third factor instead changes somewhat and most notably from the beginning of the euro-area sovereign debt crisis.

Turning to the second step of the FAVAR procedure, we estimate the VAR using four orthogonalized factors, the ten-year Greek sovereign spread as indicator of the euro-area sovereign debt tensions, the MRO rate as monetary policy rate and the world demand as an exogenous regressor. All the variables are stationary (the MRO rate at 10 per cent, the others at least at 5 per cent) according to the Augmented Dickey-Fuller test. Moreover, the eigenvalues of the companion matrix of the VAR lie all within the unit circle, indicating that the model is stationary. We set the mean of the prior distribution of the first lag of each variable to 0.75. This value is close to the average estimated AR(1) coefficient for the six series included in the VAR. Based on the Schwarz's Bayesian information criterion and the outcome of residuals serial correlation tests, the optimal lag of the VAR turns out to be three. Standard formal tests on the residuals do not reveal any sign of heteroskedasticity nor of serial correlation.

4.1 Impulse responses to a sovereign debt tension shock

In what follows we examine the impulse responses for the variables in X_t to a 400 b.p. unexpected increase in the ten-year Greek spread. Roughly speaking, the size of the shock corresponds to the rise in the Greek sovereign spread between August and September 2011, after the announcement of the private sector involvement in the solution to the Greek crisis.[20] Inference on the distribution of the impulse responses is based on 10,000 draws from the Gibbs sampling algorithm. Figures 6-10 and

[20]The size of the shock corresponds roughly to 2.5 times the standard deviation of the residuals of the equation of the sovereign spread.

Figure 11 show respectively the median impulse responses of country-specific and euro-area wide variables over a simulation horizon of 36 months.[21] For the series that are transformed using the one-month difference the impulse response are cumulated. Table 2 reports the probability that at a given horizon the response of a variable is either positive or negative.

4.1.1 Country-level results

As shown in the top panels of Figure 6 in the wake of an unexpected increase in the Greek sovereign spread the sovereign spreads in all peripheral countries rise instantaneously while are virtually unaffected throughout the entire simulation horizon in the core countries. On impact, the largest increase occurs in Portugal (slightly less than 200 b.p.), followed by Ireland, Italy and Spain (each by around 60 b.p.). In all cases the responses of the sovereign spreads are very persistent and return gradually to the baseline. As reported in the bottom panels of Figure 6, TARGET2 net balances in peripheral countries decline sharply largely mirroring the adjustment paths of sovereign spreads while in the core countries, especially in Germany, the Netherlands and Finland, net balances increase significantly. These developments square well with the capital outflows observed during the sovereign crisis from the peripheral towards the core countries.

Figures 7 and 8 document the prominent role of the banking channel as a transmission mechanism of the sovereign debt tensions. Except for Ireland, in all the peripheral countries banks raise the interest rate charged on new loans to non-financial corporations. On impact, the increase is large in Greece and Portugal (about 40 b.p.) and more moderate in Italy and Spain (about 20 b.p.). The probability for these responses to be greater than zero is close to 1 (Table 2). Thereafter, the cost of new loans to non-financial corporations starts declining reflecting both the dying out of the initial shock as well as the reduction in the policy rate by the ECB. As one could expect, in core countries the adjustment of the interest rates on new loans to firms inherits the pattern followed by the monetary policy rate and thus we find a persistent decline in the cost of lending. As Table 2 shows the probability that these impulse responses are positive is close to zero, but then they increases throughout the horizon as the ECB reduces the policy rate, bringing down the cost of credit. Apart from some small differences, similar results hold true also for the interest rate charged on new mortgages and for the remuneration of new households' deposits.

Figure 8 shows an important result regarding the peripheral countries. For these economies the impulse responses suggest the working of a bank lending channel: when hit by shock to government bonds which worsen banks' funding conditions, lenders reduce their supply of credit. As shown in the figure, in the wake of a sovereign tension shock the monetary aggregate M3 starts declining and so do lend-

[21]We use 68% probability intervals as suggested by Sims and Zha (1999), who show that these intervals for impulse responses are more accurate and reliable than 0.95 ones.

ing to non-financial corporations and to households for house purchases. After one year loans to non-financial corporations and to households in Greece, Portugal, Spain and Italy decline by around 2 per cent. As for the core countries, lending to non-financial corporations in Germany and Finland moderately expands while in Austria, France and the Netherlands it initially stagnates and then declines; in Belgium lending starts falling immediately after the shock. In all core countries, but Germany, lending to households slightly declines while the monetary aggregate M3 is virtually unaffected.

Figure 9 reports the impulse responses of country-level industrial production, unemployment rate and HICP inflation. Unlike the previous results, with the exceptions of Greece, Portugal and Finland the responses of industrial production to the sovereign shock are qualitatively similar between peripheral and core countries.[22] In either group of countries the shock leads to significant contraction in industrial activity. One year after the shock the fall in industrial production is about 2 per cent in Italy, Ireland, Germany and the Netherlands, and 1 per cent in Spain, Austria and Belgium. Regarding the core countries the decline in economic activity, notwithstanding the more favorable access to credit for firms and the virtually unaffected unemployment rate (see middle panels in Figure 9)[23], can be rationalized with the working of the confidence and trade channels.

As illustrated in Figure 10, in all countries (except Germany) the sovereign debt tensions shock leads to an immediate and sizeable deterioration in consumer confidence (bottom panels); business confidence in core countries initially increases but then quickly declines turning negative and flattening one year after the shock (middle panels). Intra-EMU exports substantially decline in nearly all countries, with the puzzling exception of Greece where they increase substantially (Figure 10; top panels).[24]

Inflation (measured with the HICP and expressed in terms of annualized monthly changes) increases in all countries but Greece (Figure 9 bottom panels). While in core countries this result could reflect that expansionary monetary and credit market conditions in a context of low unemployment, in peripheral countries the increase in inflation may be due to other factors. As discussed in Fernández-Villaverde et al. (2011) heightened fiscal policy uncertainty might have "stagflationary" effects as firms in the face of possible future higher marginal costs due to higher labour and capital taxes increase prices.

[22] The increase in Greek industrial production, which at first sight might appear as a puzzling finding, can be explained by the sizeable expansion in within-EMU exports (Figure 10). As discussed in Provopoulos (2014), between 2001 and 2009 Greece lost about 30% in terms of cost competitiveness against its major trading partners and then in just three years, from 2010 through 2012, 80 per cent of that loss was recovered, mostly through an internal devaluation and structural reforms (which have brought about reductions in domestic wages and prices). Also in Finland, the rise in industrial production can be in part attributed to the expansion of exports.

[23] Unemployment rate increases in all peripheral countries but Ireland.

[24] Also in Ireland within-EMU exports increase. However, as reported in Table 2, the probability that this impulse response is positive is nearly zero throughout the entire simulation horizon.

4.1.2 Results for the euro area

Figure 11 reports the impulse responses for a selection of euro-area aggregate series. The shock significantly affects the financial sector: the spread between the 3-month Euribor and the three-month EONIA swap - an indicator of money market tensions - immediately increases, the aggregate volume of overnight (EONIA) unsecured lending transactions falls sharply, the composite indicator of systemic stress (CISS) rises and banks' stock market evaluations decrease markedly. Bank's funding difficulties affect their lending policies: the cost of new loans rises and lending to non-financial corporations and households falls. The sovereign shock constrains the supply of credit and propagates to the real economy through the banking sector: industrial production falls gradually and the unemployment rate slowly increases. The impact on inflation is negligible.

Against a background of weakening economic activity and limited inflationary pressures, the ECB gradually reduces the policy rate (Figure 11 bottom-right panel). While the reaction of the ECB might seem quantitatively small given the adverse economic consequences brought about by the shock, one has to bear in mind that during the sovereign debt crisis (and also during the global financial crisis) the ECB has adopted a range of unconventional monetary policy measures tailored to ease banks' funding difficulties, restore the monetary policy transmission mechanism and stimulate lending. The evidence on the impact of these measures is still limited. Regarding the three-year longer-term refinancing operations introduced in December 2011, Darracq-Paries and De Santis (2013) find, using the Bank Lending Survey of the Eurosystem, that the refinancing operations had a significant and positive impact on real GDP and loan provision to non-financial corporations. In Section 5 we assess the effectiveness of the ECB interest rate policy.

4.1.3 Forecast error variance decomposition

Other than impulse response functions, another revealing exercise typically performed in the standard VAR context is the forecast error variance decomposition. This consists of determining the fraction of the variance of the forecast error of a variable at a given horizon that is accounted for by a given shock. We focus our attention on the contribution of the shock to the Greek spread shock for the variability of the macroeconomic series in our data set.

As discussed in Bernanke, Boivin and Eliasz (2005) in the FAVAR framework part of the variability of the macroeconomic variables (see equation (2)) comes from their idiosyncratic component, which might in part reflect measurement errors. As a result, the relative importance of a structural shock is assessed with regard only to the portion of the variable explained by the common factors. More precisely, the forecast error variance decomposition for X_{it}, i.e. the i-th element of X_t, can then be expressed as:

$$\frac{\Lambda_i \left[var\left(Z_{t+k} - Z_{t+k|t}|shock\right)\right] \Lambda_i'}{\Lambda_i var\left(Z_{t+k} - Z_{t+k|t}\right) \Lambda_i'}$$

where Λ_i is the *i-th* line of $\Lambda_i = \left[\Lambda^F, \Lambda^Y\right]$, and $\frac{var\left(Z_{t+k} - \widetilde{Z}_{t+k|t}|shock\right)}{var\left(Z_{t+k} - \widetilde{Z}_{t+k|t}\right)}$ is the standard VAR variance decomposition.

Table 3 reports the results for selected variables at the 12, 24 and 36 month horizons, which is computed using the mean of the posterior distribution of the reduced form coefficients and of the covariance matrix of the VAR residuals.The table shows that the sovereign shock has been an important driver of sovereign spreads and TARGET2 net balances. As for the latter variable, the shock accounts for nearly 70 per cent of the variance of the forecast error for Italy and Germany. Sovereign shocks account for a small fraction of the variability of the cost of loans to non-financial corporations. The contribution of the shock to economic activity and unemployment is, on average, larger for the peripheral countries. As for Italy, the shocks explain 15 per cent of the variability of industrial production at the two-year horizon, while the same figure for Germany is 9 per cent. The contributions to the volatility of unemployment are larger, on average, than those to industrial production; the shock accounts for a large fraction of the variability of unemployment in Greece, Italy and Portugal. At the euro-area level, the shock explains, respectively, 9 and 13 per cent of the volatility of industrial production and unemployment at the two-year horizon.

5 Assessing the ECB interest rate setting

In this Section we assess the role of the ECB conventional monetary policy in counteracting the disruptive effects of the sovereign debt tensions. To this end, we construct impulse responses to an unexpected increase in the Greek sovereign spread for all the variables considered in our analysis conditional on two alternative scenarios for the policy rate, which are shown in Figure 12.

The first experiment (no rate cut scenario) quantifies the effects of the sovereign debt shock had the ECB not reduced the policy rate. Comparing the baseline responses with those under the zero-response policy then provides an assessment of the contribution of the ECB conventional monetary policy in stabilizing the economy.[25] The second experiment quantifies the effects of the sovereign shock under the assumption that the ECB is more aggressive than in the baseline simulation (more aggressive cut scenario). We assume that in response to the sovereign shock the ECB reduces the policy rate by 20 basis points on impact (i.e. roughly twice as much as in the baseline simulation) and then follows the path implied by the VAR.

[25] Technically we impose a sequence of monetary policy shocks such that the MRO rate remains constant at zero.

In both experiments we set the coefficients and residual covariance matrix at the mean of their posterior distributions.

To save on space, Figures 13 through 15 report the impulse responses of selected euro-area wide and country-specific variables. For the zero-response case, a 400 b.p. increase in the ten-year Greek spread would have led to a more pronounced rise in the money market spread and in banking rates in the euro area as a whole. The contraction of credit to households would have been larger while lending to non-financial corporations would have been smaller.[26] The Dow Jones Euro Stoxx Bank Index would have dropped substantially more while the increase in the CISS indicator would have been larger and more persistent. The nominal effective exchange rate of the euro would have depreciated less, in line with the predictions of the uncovered interest rate parity. Finally, the fall in industrial production would have been deeper and the rise in unemployment rate larger. Inflation would have behaved in a similar way in the two scenarios.

Turning to the larger euro-area countries, Figure 14 shows that the cost of new loans to non-financial corporations would have significantly risen in Spain and Italy and to a smaller extent in France, while it would have not declined in Germany, as in the baseline case (Figure 15, red solid lines). Industrial production would have fallen much more in all the four countries (Figure 15, green dashed lines).

Next we turn to the case of a more aggressive monetary policy. Interestingly, the cost of new loans to non-financial corporations and households would have slightly fallen while industrial production would have declined less in all the four countries (Figures 14 and 15, blue solid line). At the euro-area level, with a more aggressive policy the ECB would have offset the decline in industrial production and helped avoiding a large raise in the unemployment rate.

These counterfactual exercises show that the ECB conventional policy helped mitigating the negative effects of the sovereign debt crisis on the banking sector and the real economy in the euro area as a whole as well as in individual countries. It is important to reiterate that our analysis focuses exclusively on the ECB interest rate policy and does not take into account the unconventional measures that have been introduced during the global financial and sovereign debt crises. Hence, our findings have to be interpreted as a conservative assessment of the contribution of the monetary policy of the ECB.

Having assessed the contribution of the ECB monetary policy, we investigate, following Leeper and Zha (2003), whether the two scenarios are "modest" in the sense that they do not significantly change private agents' beliefs about the ECB policy. Leeper and Zha (2003) find that policy interventions such as those routinely considered by the Federal Reserve are modest in light of the Lucas critique but can

[26] This result may be related to the finding in Den Haan et al. (2009) for the U.S. and Canada according to which when policy rates change, banks adjust their portfolios in favor of business loans.

shift the probability distributions of the main macroeconomic variables in economically meaningful ways. The methodology consists of computing for each of the two policy interventions the following "modesty" statistic:

$$\eta_P^*(K) = \frac{\left|\sum_{s=0}^{K-1} C_s \widetilde{\epsilon}_{P,T+K-s}\right|}{\sigma\left(\sum_{s=0}^{K-1} C_s\right)} \tag{6}$$

where K is the number of steps in the simulations, C_s the coefficients of the structural moving representation of the VAR and $\tilde{\epsilon}$ the sequence of shocks in the counterfactual scenarios. The impulse responses in these scenarios are normalized by the standard deviation of the responses in the baseline simulation. If the resulting statistic is below 2 it means that the policy interventions do not give raise to changes in agents' beliefs that may undermine the results of the exercise.

Table 4 reports the statistic for a selection of aggregate euro-area variables that are relevant for the monetary policy of the ECB. In the case of the simulation in which the ECB does not reduce the policy rate (right column labeled "no rate cut"), the "modesty" statistic is above 2 only for industrial production at the end of the simulation (36 months). For the scenario in which the ECB immediately reduces the policy rate (right column labeled "more aggressive cut") the statistic is above 2 for none of the variables considered. Overall, the analysis suggests that the scenarios we have designed are not implausible and the associated policy interventions are "modest" in the sense of Leeper and Zha (2003).

6 Robustness analysis

This Section presents the results of various checks in order to assess the robustness of our findings. All the results - reported only for selected euro-area wide series - are shown in Figure 16.[27]

Alternative indicators of the euro-area sovereign debt tensions

Since the beginning of the European Monetary Union in 1999 many studies have investigated the determinants of government bond spreads (e.g. Manganelli and Wolswijk, 2009; Haugh, Ollivaud and Turner, 2009; Schuknecht, von Hagen and Wolswijk, 2010). A widespread finding is that euro-area sovereign yield spreads strongly co-move suggesting the presence of a common driver. Studies based on PCA typically find that the first component accounts for about 80 per cent of the total variation in the government yield spreads. In the light of these results we have constructed an indicator of sovereign debt tensions performing a PCA on the

[27] Results that are not reported in the paper are available upon request.

11 sovereign debt spreads from January 2007 through December 2012.[28] The first principal component explains 64 per cent of the variance of the spreads while the second and the third one account, respectively, for 23 and 6. Based on these results, and on the literature, we have taken the first principal component as indicator of the sovereign debt tensions.

As a further robustness check we have also considered the sovereign credit default swap (CDS) premia (e.g. Longstaff et al., 2011). In particular we have construced the median sovereign CDS premia out of the 11 country-level series.

As shown in Figure 3 the ten-year Greek sovereign spread (green dotted line), the first principal component of the sovereign spreads (black dashed line) and the median sovereign CDS premia (red dashed dotted) all behave in a very similar fashion, exhibiting a cross-correlation of about 0.9. These strong comovements suggest that using these two alternative indicators our baseline results should not affect in a significant way the results presented in Sections 4 and 5. Figure 16 shows, indeed, that the impulse responses of the main euro-area variables for these two robustness checks are remarkably similar.[29]

The EONIA as the monetary policy rate

Since October 2008 the EONIA rate has remained constantly below the MRO rate. This has been the result of the ample excess liquidity determined by the adoption of the fixed-rate full allotment procedures in all the main refinancing operations and the introduction of longer-term refinancing operations with maturity of one (May 2009) and three years (December 2011).

While a thorough analysis on the effects of the unconventional measures adopted by the ECB during the global financial crisis is left for future research, in this part of the analysis we check the robustness of our results by substituting the MRO rate with the EONIA. In this way we take into account the impact of the massive injections of liquidity by the ECB on the money market. In Figure 16 the blue solid lines represent the impulse responses of the FAVAR model in the case in which the Greek sovereign spread is the indicator of the euro-area sovereign debt tensions and the EONIA rate represents the ECB policy rate. Also in this case the comparison with the green dotted lines (the baseline case) suggests that our results are robust to the choice of the policy rate.

[28] Also in this case the ten-year sovereign spreads are calulated in deviation from the ten-year euro interest rate swap. For the PCA the level of the spreads are de-meaned and divided by the standard deviation.

[29] We do not report the results of the country-specific variables and those of the counterfactual simulations as they are remarkably similar to those obtained with the Greek sovereign spread. These results are available upon request.

An alternative ordering to identify sovereign spread shock

In Section 3.2 we have assumed that innovations to the sovereign debt tensions indicator do not contemporaneously affect the unobservable factors while they do affect immediately the policy rate. Furthermore, we have also imposed that the sovereign debt tensions indicator responds to the monetary policy with one-month lag. While we believe that this identification strategy is sensible, an alternative scheme may pose that policy rate responds with a one-month lag to the indicator of sovereign debt tensions. In this case the ordering of the variables in the VAR is $Z_t = \begin{bmatrix} \widetilde{F}_t & R_t & S_t \end{bmatrix}'$. The indicator of sovereign debt tensions is allowed to react contemporaneously to all the variables in the VAR. In practice, this identification scheme could capture the fact that although new information from financial markets is observable on a daily basis, the monetary policy decision process may require some time.

We repeated the whole analysis (estimation, impulse responses and the counterfactual exercises) using the above ordering and found very limited quantitative differences with respect to the baseline case. Figure 16 reports the impulse responses for selected euro-area variables: the grey dashed and dotted lines represent the impulse responses of the model in which the Greek spread is the indicator of sovereign debt tensions, the MRO is the policy rate and the ordering of the latter two variables is the one described above. Comparison with the baseline case (green dotted lines) shows that changing the identifying assumption does not affect the results.

Other checks

To further assess the robustness of our findings we conducted few other checks.[30] We estimated the model over the period from January 2008 to December 2012 and using three-month changes rather than first differences for the variables with a clear trend. The results are broadly in line with those obtained with the baseline case. Finally, we increased the prior parameter ϕ_0 from 0.1 to 0.25 and found no major difference in the impulse responses.

7 Concluding remarks

More than four years after the beginning of the sovereign debt crisis, the economic outlook in most of the euro-area countries remains weak and still marked by a great deal of uncertainty. Quite surprisingly, to date there is scarce evidence on the macroeconomic impact of the sovereign debt crisis on the euro area as a whole and on individual economies and on the stabilization role played by the ECB conventional monetary policy.

[30] The results are not reported but are available upon request.

In this paper we have sought to fill this gap by means of a FAVAR model, which represents a state-of-the-art econometric tool to deal with large dataset. The empirical results show that the sovereign tensions that started in Greece towards the end of 2009 initially, and quite rapidly, transmitted to those euro-area countries with weak fiscal and macroeconomic conditions but then later spread to the other euro-area countries less directly hit by the sovereign tensions, bringing about a deterioration in credit market conditions, a contraction in economic activity and an increase in unemployment. Next to the bank channel as the prominent propagation channel of the sovereign tensions in the peripheral countries, our results also give support to the working of the trade and confidence channels as mechanisms through which the sovereign tensions also affected core countries. Finally, based on counterfactual simulations ("modest" in the sense of Leeper and Zha, 2003) we show that the accommodative monetary policy of the ECB contributed to counteracting the disruptive effects of the sovereign debt crisis.

While our analysis helps understanding the real effects of the sovereign crisis, a lot more needs to be done, in particular along two dimensions. On the empirical side, more elaborated models, possibly allowing for time variation in parameters (Primiceri, 2005 and Koop and Korobilis, 2010), might be useful to enrich our analysis. The Large Bayesian VAR approach suggested by Bańbura, Giannone and Reichlin (2010) is an interesting and appealing alternative to deal with the large dimension of the data we are interested in using for our purpose.

On the theoretical side, structural models with open economy features allowing for the possibility of sovereigns' and banks' defaults may be extremely useful to analyse the channels through which the fear of unsustainable fiscal dynamics ends up hitting the real economy and spilling over to the rest of the global economy (Guerrieri, Iacoviello and Minetti, 2012). Needless to say, such models need to incorporate not only a "conventional" role for monetary policy but, most importantly, its "unconventional" dimension.

Our analysis falls short of considering the role of fiscal policy in preserving the sustainability of public finances and of the ECB unconventional measures in restoring confidence in financial markets and supporting the flow of credit to the real economy. Assessing the effectiveness of these policies is beyond the scope of our analysis and we leave it for future research.

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Tables and figures

Table 1 Data used in computation of the latent factors

Nr.	Series											Description	Transf.	Source
1-11	AT	BE	DE	ES	FI	FR	GR	IE	IT	NL	PT	Rate on new loans to NFCs with initial rate fixation <1 year	0	ECB
12-22	AT	BE	DE	ES	FI	FR	GR	IE	IT	NL	PT	Rate on new loans to HHs for house purchases	0	ECB
23-33	AT	BE	DE	ES	FI	FR	GR	IE	IT	NL	PT	Rate on new HHs' deposits with agreed maturity up to 1 year	0	ECB
34-44	AT	BE	DE	ES	FI	FR	GR	IE	IT	NL	PT	M3 monetary aggregate (national contributions)	1	ECB
45-55	AT	BE	DE	ES	FI	FR	GR	IE	IT	NL	PT	Loans to NFCs	1	ECB
56-66	AT	BE	DE	ES	FI	FR	GR	IE	IT	NL	PT	Loans to HHs for house purchases	1	ECB
67-77	AT	BE	DE	ES	FI	FR	GR	IE	IT	NL	PT	Industrial production index	1	Eurostat
78-88	AT	BE	DE	ES	FI	FR	GR	IE	IT	NL	PT	Unemployment rate	2	ECB
89-99	AT	BE	DE	ES	FI	FR	GR	IE	IT	NL	PT	HICP index	1	ECB
100-109	AT	BE	DE	ES	FI	FR		IE	IT	NL	PT	ten-year sovereign bond spread	0	ECB
110-120	AT	BE	DE	ES	FI	FR	GR	IE	IT	NL	PT	Within EMU exports	1	ECB
121-131	AT	BE	DE	ES	FI	FR	GR	IE	IT	NL	PT	TARGET2 net balances	0	ECB
132-141	AT	BE	DE	ES	FI	FR	GR		IT	NL	PT	Business confidence index	0	OECD
142-151	AT	BE	DE	ES	FI	FR	GR		IT	NL	PT	Households' confidence index	0	OECD
152	EA											Rate on new loans to NFCs with initial rate fixation <1 year	0	ECB
153	EA											Rate on new loans to HHs for house purchases	0	ECB
154	EA											Rate on new deposits from households with maturity up to 1 year	0	ECB
155	EA											Industrial production index	1	Eurostat
156	EA											HICP inflation	1	Eurostat
157	EA											HICP core inflation	1	Eurostat
158	EA											Monetary aggregates M1	1	ECB
159	EA											Monetary aggregates M2	1	ECB
160	EA											Monetary aggregates M3	1	ECB
161	EA											Loans to firms	1	ECB
162	EA											Loans to households	1	ECB
163	EA											Dow Jones Euro Stoxx Index	1	ECB
164	EA											Dow Jones Euro Stoxx Banks Index	1	ECB
165	EA											Oil prices in euro	1	ECB
166	EA											Unemployment rate	2	Eurostat
167	EA											3-month EURIBOR-EONIA spread	0	ECB
168	EA											Business confidence index	0	OECD
169	EA											Nominal effective exchange rate	0	ECB
170	EA											Aggregate volume in the overnight segment of the money market	0	ECB
171	EA											Composite Indicator of Systemic Stress (CISS)	0	ECB
172	EA											Option-implied volatility stock market (Dow Jones Euro Stoxx Index)	0	ECB
173	EA											Aggregate volume of interbank lending	1	ECB

Note: As for the transformation of the variables, 0 denotes no transformation of the variable, 1 first differences of the log of the variable, 2 = first differences of the variable. Inflation is annualised. NFCs = non-financial corporations; HHs = households.

Table 2

Probability distribution of impulse responses of selected variables

Country	Rate on loans to NFCs: $Pr > 0$					Country	Rate on loans to HHs: $Pr > 0$				
	Horizon (months)						*Horizon (months)*				
	1	4	8	16	36		1	4	8	16	36
AT	0.23	0.24	0.16	0.07	0.06	AT	0.00	0.01	0.06	0.07	0.04
BE	0.16	0.19	0.13	0.07	0.06	BE	0.97	0.91	0.77	0.25	0.10
DE	0.06	0.07	0.05	0.06	0.05	DE	0.05	0.09	0.09	0.07	0.05
ES	1.00	0.97	0.85	0.27	0.12	ES	0.86	0.80	0.67	0.22	0.08
FI	0.52	0.43	0.26	0.10	0.07	FI	0.15	0.16	0.13	0.07	0.05
FR	0.74	0.59	0.40	0.12	0.08	FR	0.00	0.12	0.25	0.15	0.05
GR	1.00	1.00	1.00	0.90	0.77	GR	0.97	0.88	0.74	0.20	0.09
IE	0.48	0.42	0.28	0.10	0.07	IE	0.68	0.59	0.41	0.13	0.08
IT	1.00	1.00	0.97	0.46	0.19	IT	1.00	0.99	0.90	0.39	0.13
NL	0.52	0.42	0.24	0.09	0.07	NL	0.35	0.38	0.30	0.11	0.06
PT	1.00	1.00	1.00	0.90	0.55	PT	1.00	1.00	1.00	0.62	0.28
	Loans to NFCs: $Pr < 0$						**Loans to HHs:** $Pr < 0$				
AT	0.95	0.93	0.94	0.94	0.96	AT	1.00	1.00	0.99	0.99	0.94
BE	0.00	0.00	0.00	0.00	0.65	BE	0.00	0.00	0.00	0.00	0.00
DE	1.00	1.00	1.00	1.00	0.99	DE	1.00	1.00	1.00	1.00	0.99
ES	0.00	0.00	0.00	0.00	0.52	ES	1.00	1.00	1.00	1.00	0.97
FI	0.19	0.25	0.31	0.38	0.92	FI	1.00	1.00	1.00	1.00	0.99
FR	1.00	1.00	1.00	1.00	0.99	FR	1.00	1.00	1.00	1.00	0.99
GR	0.14	0.20	0.24	0.29	0.80	GR	0.29	0.39	0.47	0.55	0.91
IE	1.00	1.00	1.00	1.00	0.99	IE	1.00	1.00	1.00	1.00	1.00
IT	0.32	0.36	0.40	0.45	0.88	IT	0.93	0.91	0.90	0.89	0.68
NL	1.00	1.00	1.00	1.00	1.00	NL	1.00	1.00	1.00	1.00	1.00
PT	1.00	1.00	1.00	1.00	0.99	PT	0.96	0.97	0.98	0.98	0.79
	Industrial production: $Pr < 0$						**Unemployment rate:** $Pr > 0$				
AT	0.97	0.95	0.95	0.93	0.73	AT	1.00	0.95	0.92	0.93	0.91
BE	1.00	0.99	0.98	0.97	0.83	BE	0.81	0.96	0.98	0.98	0.94
DE	0.94	0.93	0.92	0.92	0.73	DE	0.20	0.82	0.93	0.95	0.92
ES	0.39	0.42	0.44	0.46	0.42	ES	1.00	0.98	0.97	0.96	0.85
FI	0.99	0.98	0.98	0.97	0.77	FI	0.00	0.00	0.07	0.61	0.61
FR	0.01	0.02	0.03	0.04	0.15	FR	0.45	0.86	0.93	0.94	0.92
GR	1.00	1.00	1.00	0.99	0.93	GR	1.00	1.00	1.00	1.00	1.00
IE	1.00	1.00	1.00	1.00	0.90	IE	0.00	0.00	0.00	0.01	0.03
IT	0.99	0.98	0.97	0.96	0.81	IT	1.00	1.00	1.00	1.00	0.99
NL	0.55	0.57	0.58	0.58	0.42	NL	0.42	0.78	0.92	0.95	0.94
PT	0.03	0.05	0.06	0.07	0.09	PT	1.00	1.00	1.00	1.00	1.00
	Intra-UE trade: $Pr < 0$						**TARGET2 net balances:** $Pr < 0$				
AT	0.97	0.94	0.93	0.92	0.68	AT	0.01	0.08	0.17	0.29	0.09
BE	0.93	0.91	0.91	0.91	0.72	BE	0.00	0.00	0.00	0.00	0.02
DE	0.89	0.86	0.83	0.81	0.54	DE	1.00	1.00	1.00	1.00	0.98
ES	0.35	0.35	0.36	0.37	0.32	ES	0.00	0.00	0.00	0.00	0.02
FI	0.73	0.73	0.71	0.72	0.48	FI	0.23	0.43	0.57	0.67	0.14
FR	0.18	0.17	0.17	0.16	0.17	FR	1.00	1.00	1.00	1.00	0.98
GR	0.00	0.00	0.01	0.02	0.28	GR	1.00	1.00	1.00	1.00	0.97
IE	0.93	0.92	0.91	0.91	0.59	IE	1.00	1.00	1.00	1.00	0.96
IT	0.56	0.60	0.62	0.63	0.52	IT	0.00	0.00	0.00	0.00	0.02
NL	0.96	0.94	0.92	0.91	0.49	NL	1.00	1.00	1.00	1.00	0.97
PT	1.00	1.00	1.00	1.00	0.96	PT	0.00	0.00	0.03	0.12	0.24

			Horizon (months)				
			1	4	8	16	36
Euro area	Rate on loans to NFCs	$Pr > 0$	0.78	0.65	0.45	0.14	0.08
Euro area	Rate on loans to HHs	$Pr > 0$	0.65	0.58	0.47	0.17	0.08
Euro area	Industrial production	$Pr < 0$	0.03	0.06	0.09	0.13	0.18
Euro area	Inflation rate	$Pr > 0$	1.00	0.94	0.78	0.51	0.82
Euro area	Loans to NFCs	$Pr < 0$	1.00	1.00	1.00	1.00	0.99
Euro area	Loans to HHs	$Pr < 0$	0.92	0.90	0.89	0.89	0.44
Euro area	Bank stock prices	$Pr < 0$	0.62	0.68	0.71	0.74	0.18
Euro area	Unemployment rate	$Pr > 0$	1.00	1.00	1.00	0.99	0.97
Euro area	Money market spread	$Pr > 0$	1.00	0.90	0.89	0.71	0.14
Euro area	Exchange rate	$Pr < 0$	1.00	1.00	1.00	1.00	0.97
Euro area	Interbank lending	$Pr < 0$	0.45	0.29	0.20	0.16	0.84

Note: probability, based on the posterior distribution of the VAR parameters, that the response at a given month of the impulse horizon is either positive or negative. NFCs = non-financial corporations; HHs = households.

Table 3

Variance decomposition of selected country-specific and euro-area variables

ten-year sovereign spread				**TARGET2 net balances**			
Country	*Horizon (months)*			*Country*	*Horizon (months)*		
	12	24	36		12	24	36
AT	14	22	24	AT	62	55	46
BE	61	59	57	BE	1	1	3
DE	11	10	9	DE	65	57	52
ES	66	57	51	ES	55	57	54
FI	2	3	4	FI	68	64	57
FR	38	43	44	FR	1	1	2
GR	-	-	-	GR	57	46	44
IE	35	30	30	IE	31	32	33
IT	68	65	60	IT	68	63	55
NL	1	4	5	NL	66	61	55
PT	64	59	54	PT	46	35	32
Rate on loans to NFCs				**Within-EMU exports**			
AT	1	5	9	AT	1	1	1
BE	1	5	10	BE	1	3	4
DE	3	7	11	DE	1	3	4
ES	2	2	5	ES	1	1	1
FI	1	4	8	FI	0	0	1
FR	0	3	7	FR	0	0	0
GR	33	25	20	GR	1	3	4
IE	0	4	8	IE	1	2	2
IT	6	4	5	IT	1	2	2
NL	1	4	8	NL	0	0	0
PT	29	19	17	PT	1	2	2
Industrial production				**Unemployment rate**			
AT	5	10	8	AT	2	7	11
BE	1	4	5	BE	3	11	18
DE	3	9	10	DE	1	6	11
ES	2	4	5	ES	3	9	11
FI	0	0	0	FI	1	1	1
FR	3	8	8	FR	1	6	11
GR	2	4	5	GR	28	33	36
IE	6	13	14	IE	14	13	15
IT	6	15	17	IT	13	21	25
NL	2	5	6	NL	2	7	14
PT	0	0	0	PT	17	33	47

Country	*Variable*	*Horizon (months)*		
		12	**24**	**36**
Euro area	Rate on loans to non-financial corporations	0	3	6
Euro area	Rate on loans to households	0	3	6
Euro area	Industrial production	3	9	10
Euro area	Inflation rate	1	1	1
Euro area	Monetary aggregate M3	1	0	1
Euro area	Loans to non-financial corporations	2	6	11
Euro area	Loans to households	7	19	30
Euro area	Unemployment rate	4	13	20
Euro area	Exchange rate	72	54	43
Euro area	Interbank lending	1	5	7

Note: the statistic is computed using the mean of the posterior distribution of the coefficients of the VAR. NFCs = non-financial corporations; HHs = households.

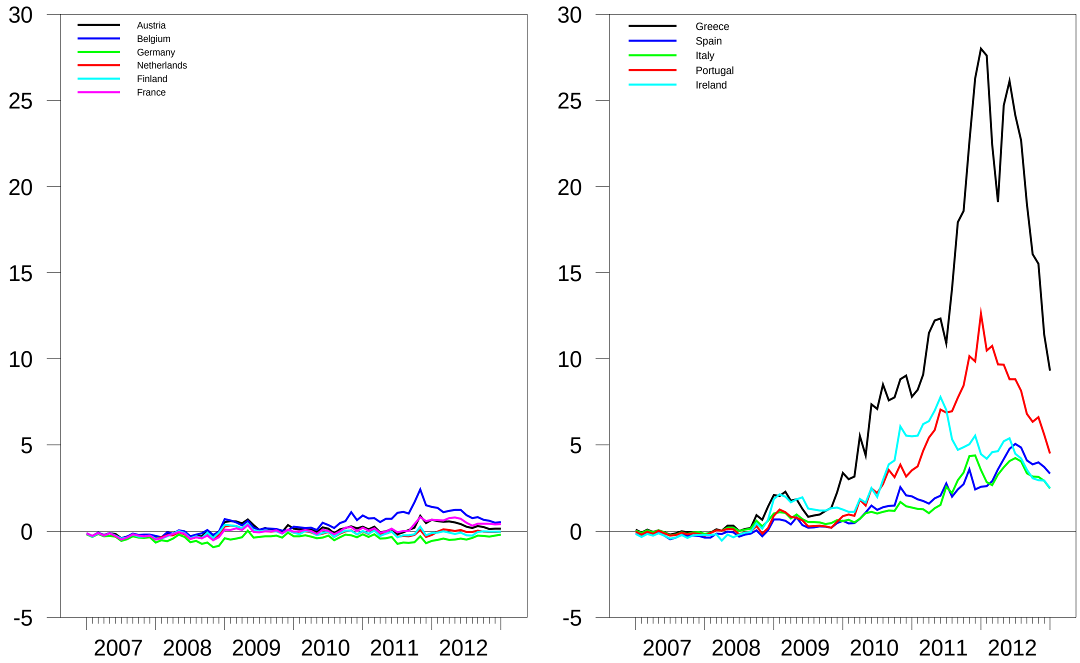
Table 4

Leeper and Zha (2003) "modesty" statistic

	no rate cut horizon			**aggressive rate cut horizon**		
	1 year	2 years	3 years	1 year	2 years	3 years
Cost of loans to NFCs	1.6	1.4	1.1	1.1	0.2	0.2
Cost of loans to HHs	1.8	1.6	1.3	1.3	0.2	0.2
Industrial production	0.8	1.5	2.3	1.4	1.1	0.7
Inflation rate	0.1	0.7	1.5	0.5	0.6	0.0
Monetary aggregate M3	1.1	1.1	1.1	1.6	0.5	0.2
Lending to NFCs	1.3	1.1	1.1	1.9	0.5	0.2
Lending to HHs	0.2	0.5	0.9	0.5	0.5	0.3
Unemployment rate	0.4	0.9	1.6	0.9	0.9	0.7
Exchange rate	0.6	1.4	1.9	1.1	0.9	0.2
Interbank volumes	1.1	1.4	1.4	0.8	0.1	0.1

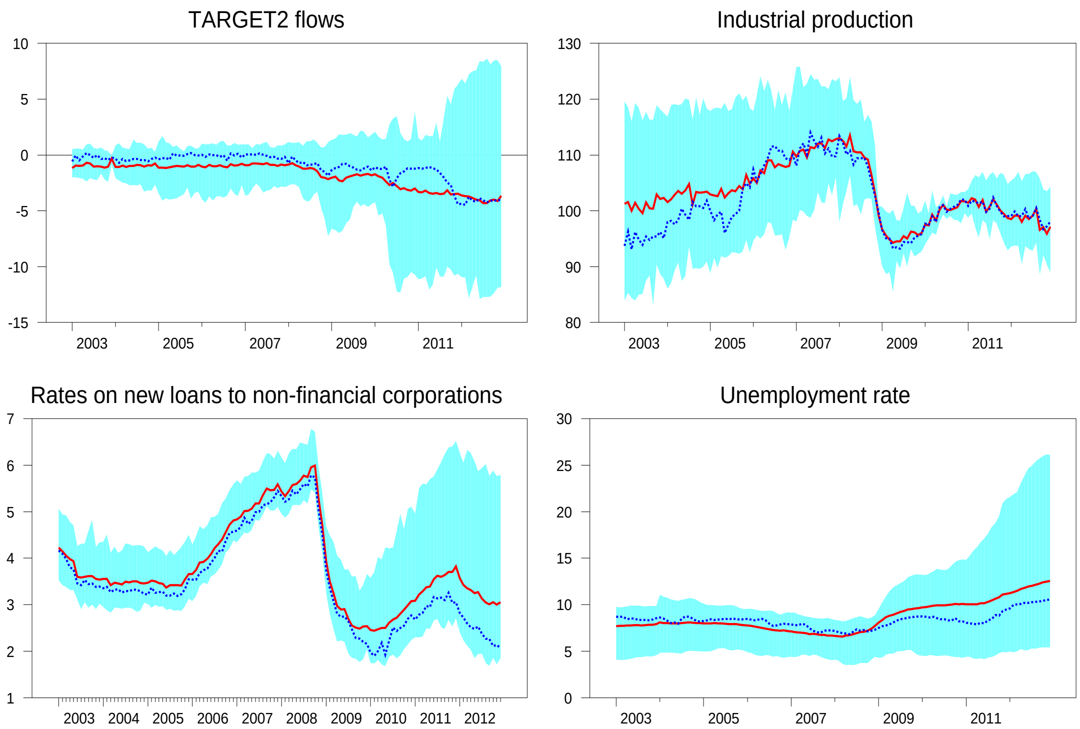
Note: the "modesty" statistic is computed using the mean of the posterior distribution of the reduced form coefficients of the VAR and of the covariance matrix of the residuals.
NFCs = non-financial corporations; HHs = households.

Fig. 1 Sovereign spreads



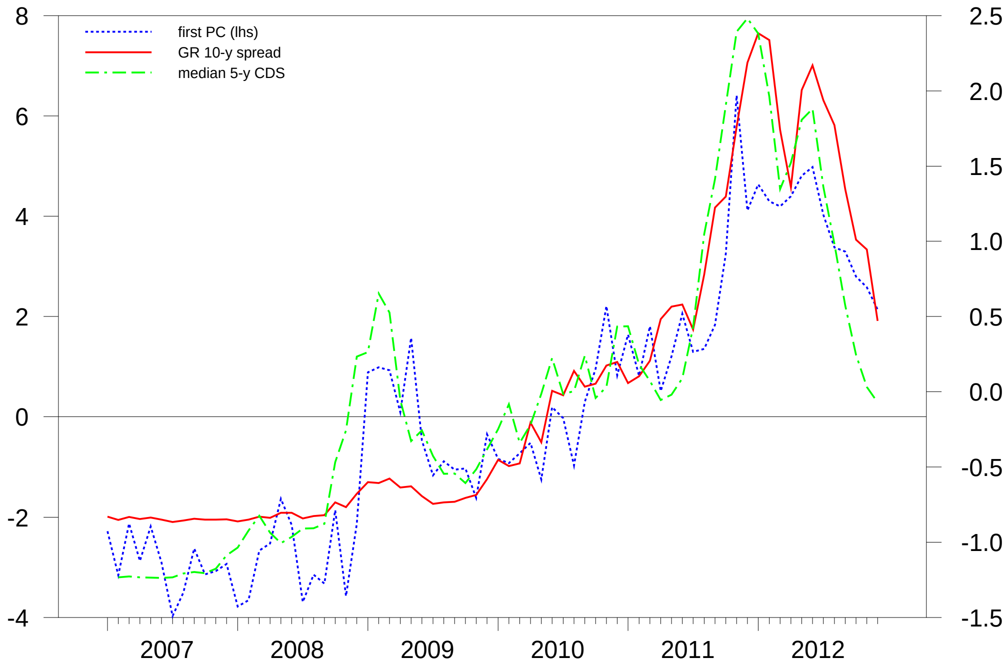
Note: The sovereign spreads are the differences between the ten-year government bond yields and the interest rate swap of the same maturity.

Fig. 2 Dispersion of selected macroeconomic variables



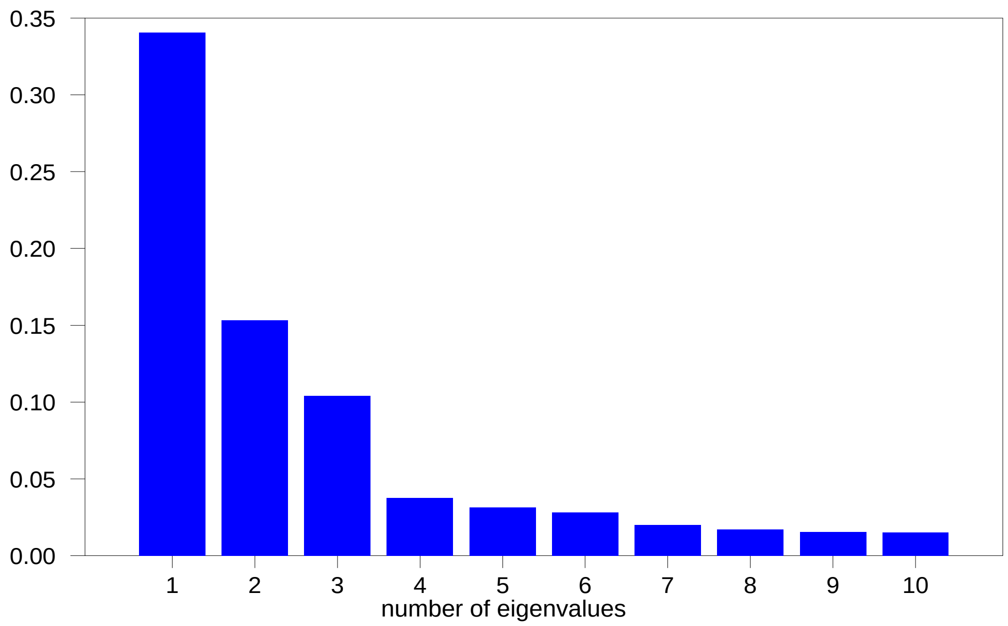
Note: blue area: 10^{th}-90^{th} percentiles; blue dotted line: median; red line: mean.

Fig. 3 Indicators of sovereign debt tensions



Note: the ten-year Greek spread and the median 5-year CDS (right-hand scale) are de-meaned and normalized by their standard deviation.

Fig. 4 Scree plot



Note: The plot reports the eigenvalues of a covariance matrix in decreasing order of magnitude. The number of factors is then chosen as the number of eigenvalue at which the bars straighten out.

Fig. 5 Estimated unobserved factors

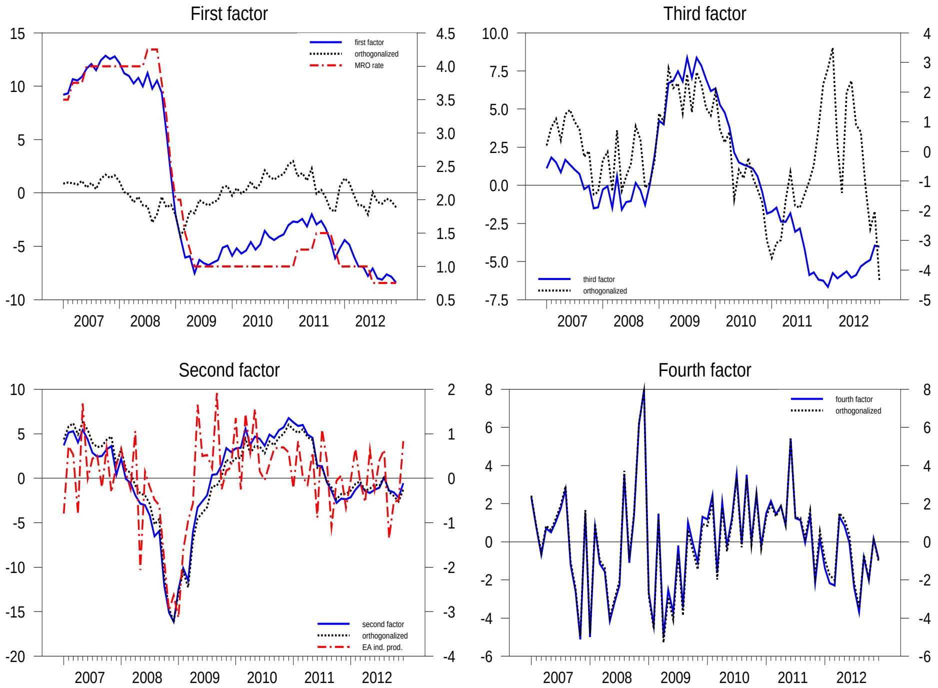
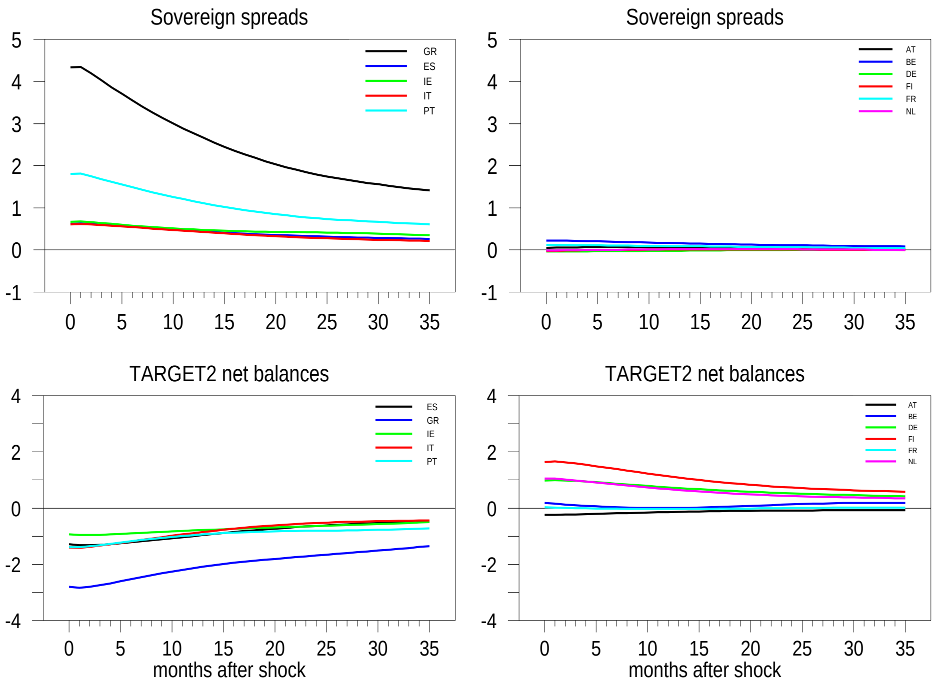
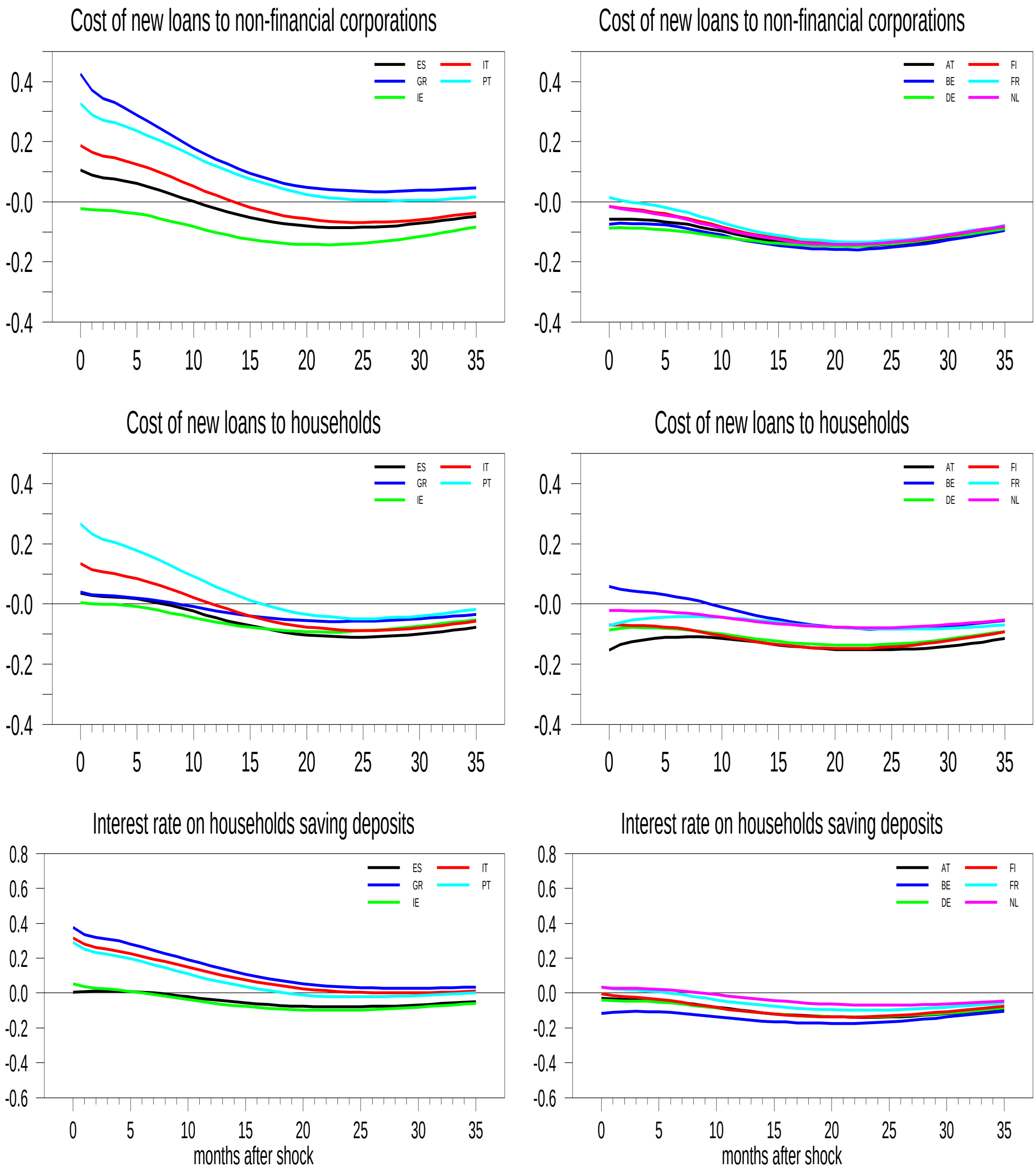


Fig. 6 Impulse responses of sovereign spreads and TARGET2 net balances



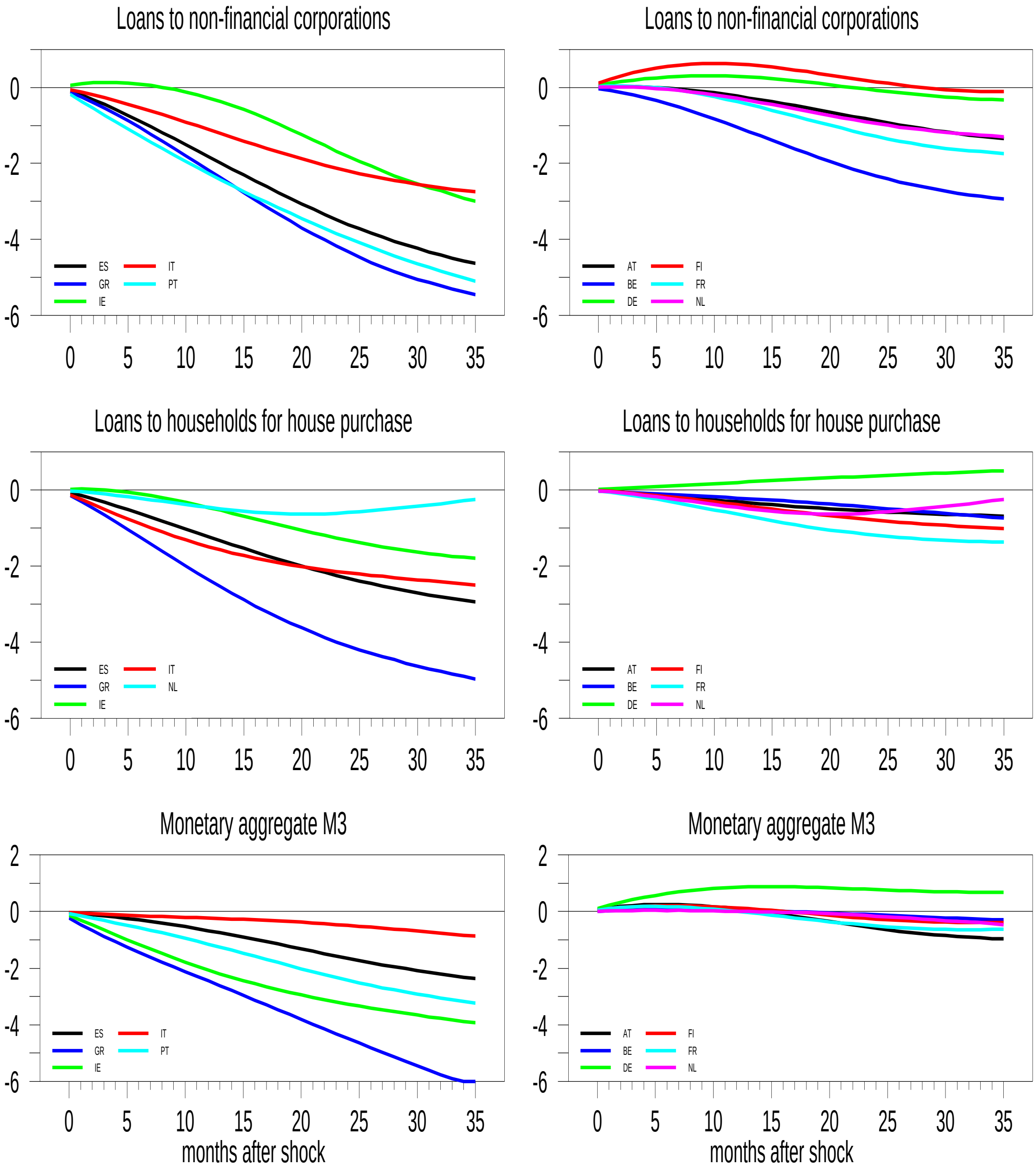
Note: impulse responses to a 400 basis points shock to the ten-year Greek spread. Median values of the posterior distribution of the response at each period. Deviations from the baseline in percentage points. TARGET2 net balances are in percentage of a country banks' total assets. DE = Germany, FR = France, NL = The Netherlands, BE = Belgium, IT = Italy, IE = Ireland, ES = Spain, GR = Greece, PT = Portugal.

Fig. 7 Impulse responses of banks' rates



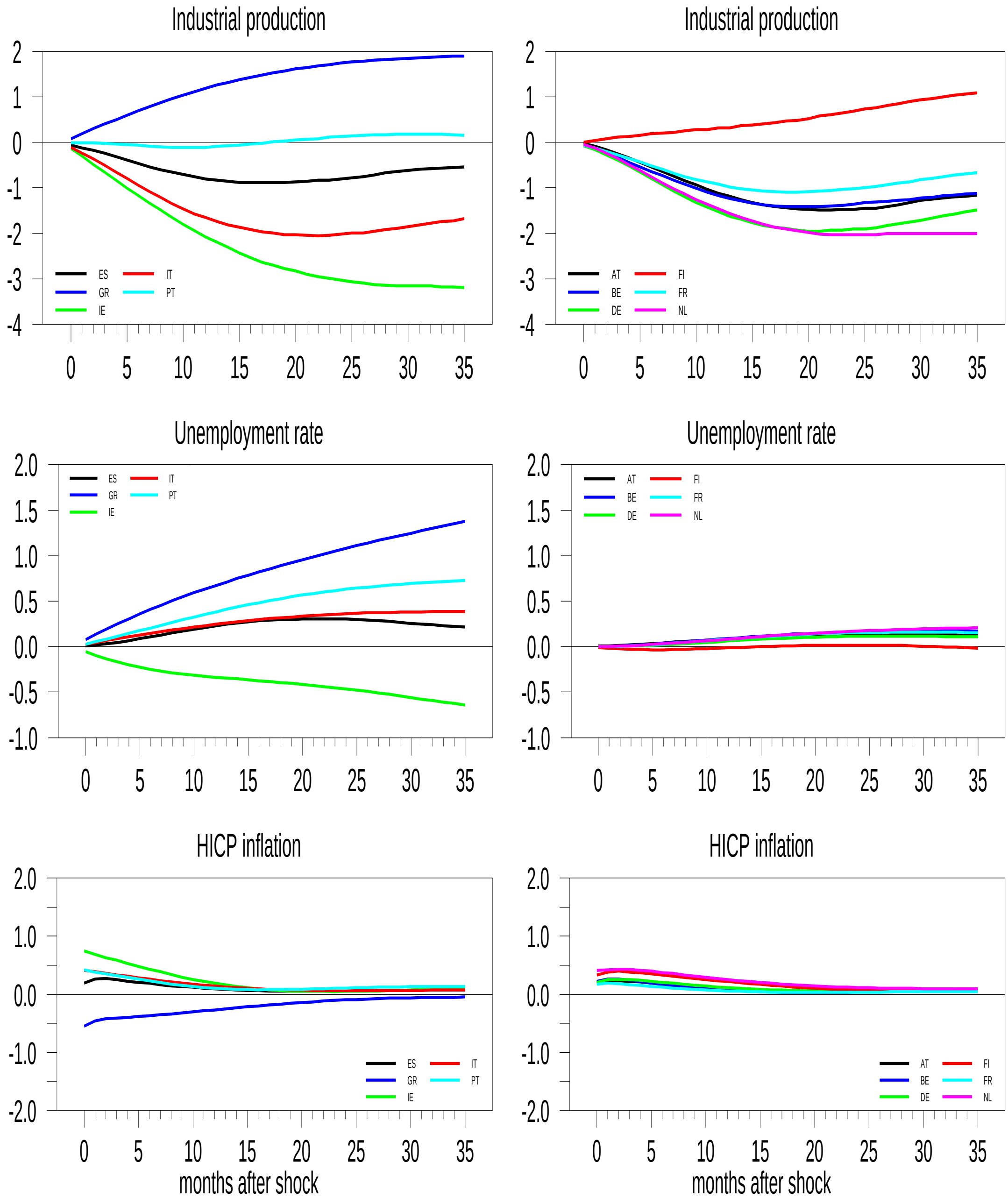
Note: impulse responses to a 400 basis points shock to the ten-year Greek spread. Median values of the posterior distribution of the response at each period. Deviations from the baseline in percentage points. TARGET2 net balances are in percentage of a country banks' total assets. DE = Germany, FR = France, NL = The Netherlands, BE = Belgium, IT = Italy, IE = Ireland, ES = Spain, GR = Greece, PT = Portugal.

Fig. 8 Impulse responses of credit to non-financial corporations and households



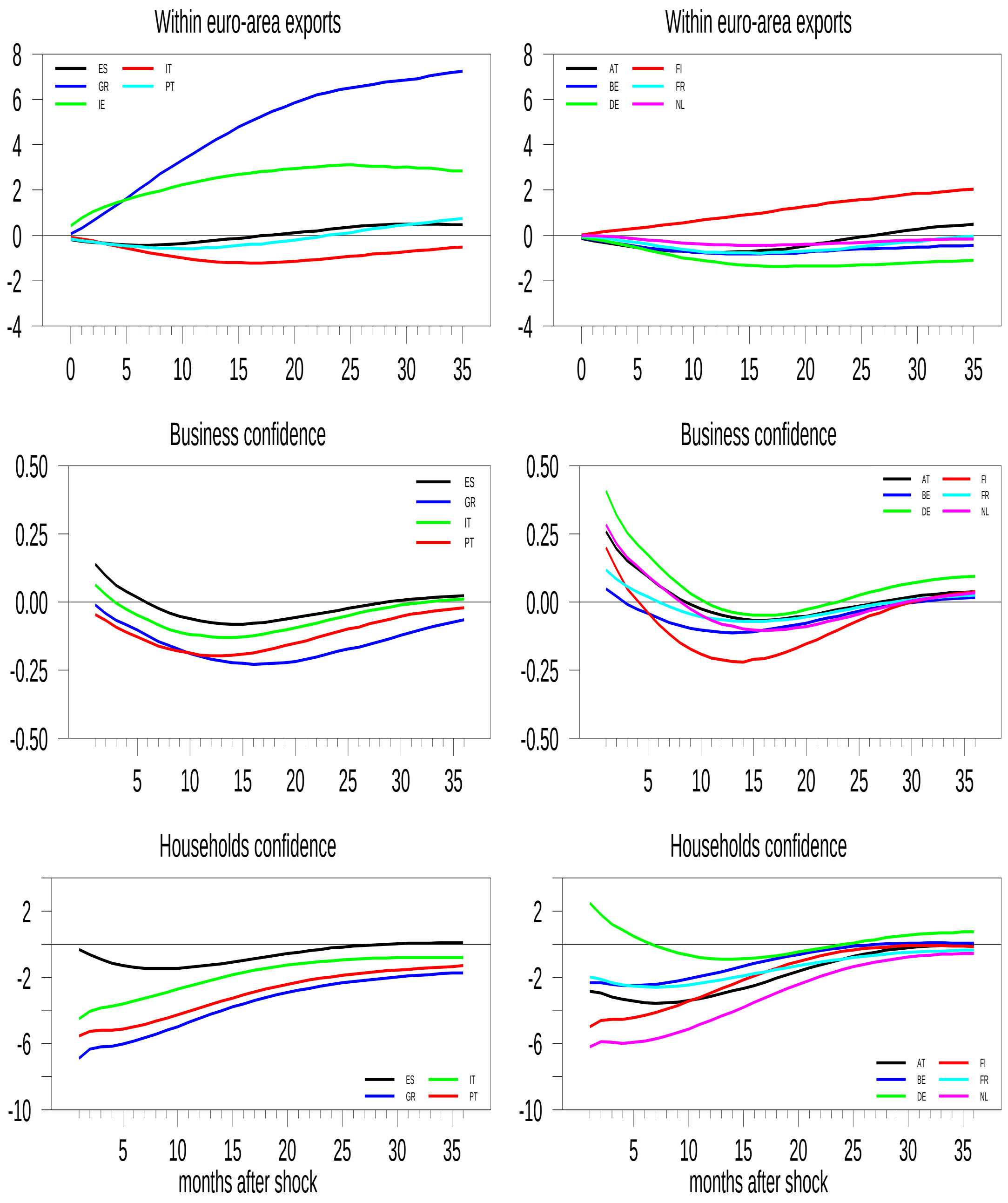
Note: impulse responses to a 400 basis points shock to the ten-year Greek spread. Median values of the posterior distribution of the response at each period. Deviations from the baseline in percentage points. TARGET2 net balances are in percentage of a country banks' total assets. DE = Germany, FR = France, NL = The Netherlands, BE = Belgium, IT = Italy, IE = Ireland, ES = Spain, GR = Greece, PT = Portugal.

Fig. 9 Impulse responses of industrial production, unemployment and inflation



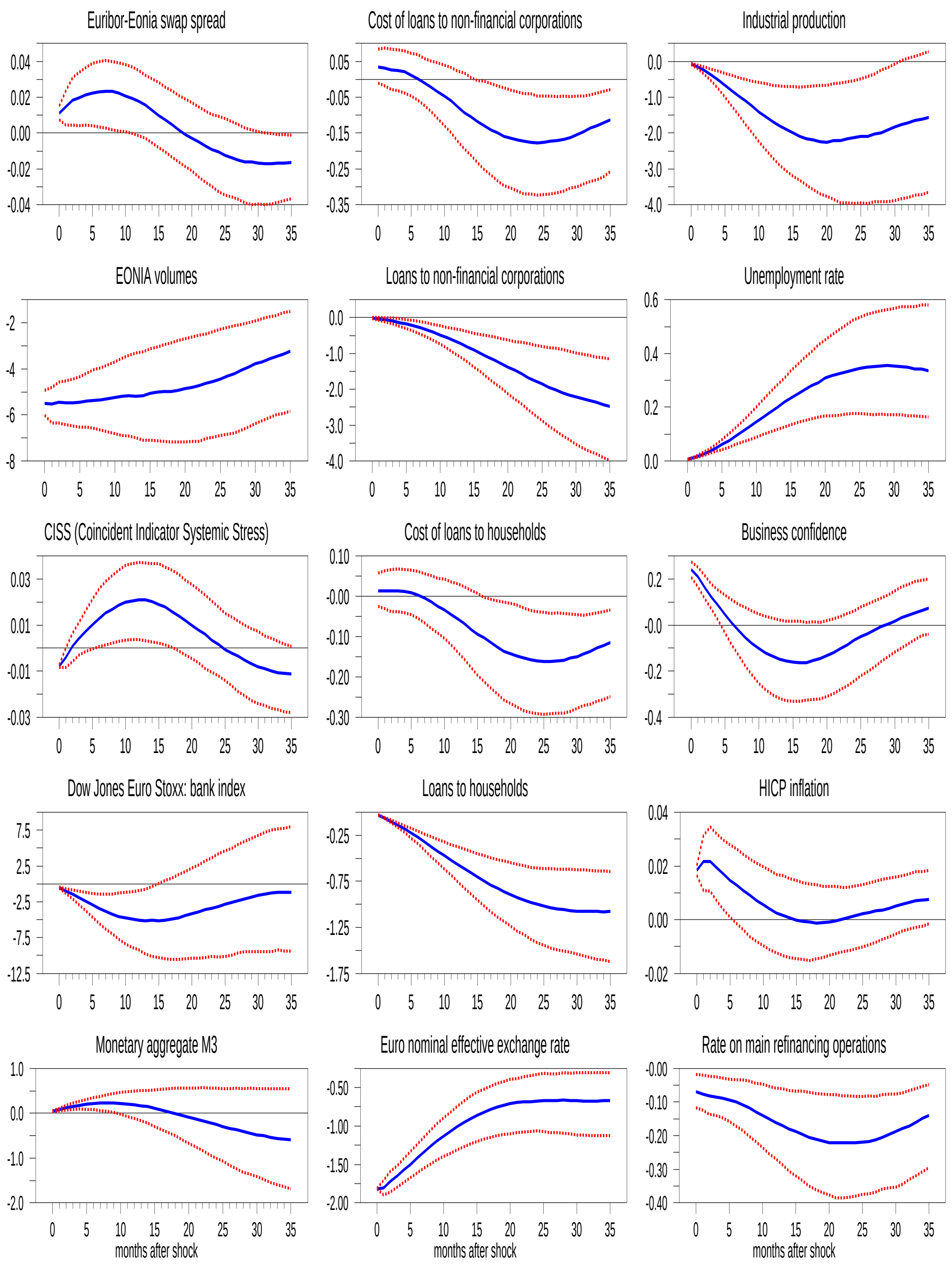
Note: impulse responses to a 400 basis points shock to the ten-year Greek spread. Median values of the posterior distribution of the response at each period. Deviations from the baseline in percentage points. TARGET2 net balances are in percentage of a country banks' total assets. DE = Germany, FR = France, NL = The Netherlands, BE = Belgium, IT = Italy, IE = Ireland, ES = Spain, GR = Greece, PT = Portugal.

Fig. 10 Impulse responses of within euro-area exports and confidence indicators



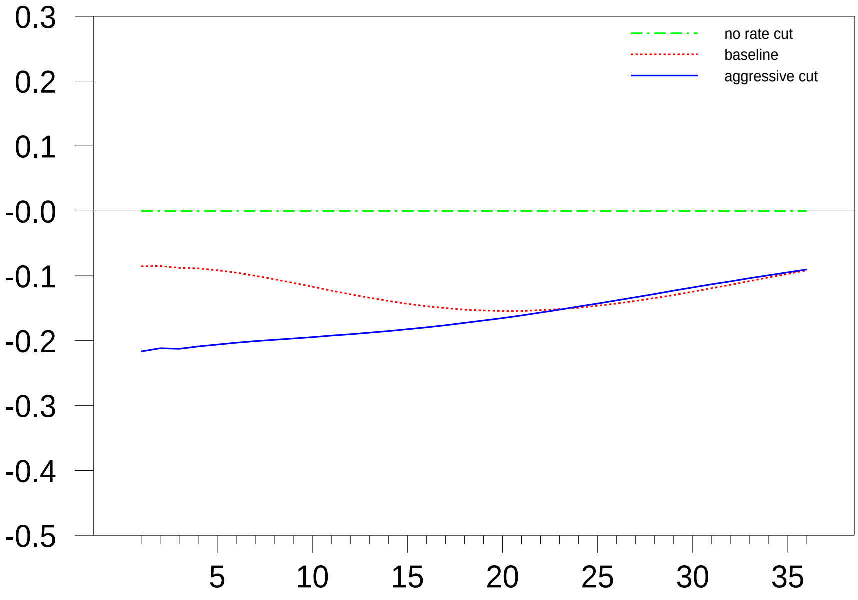
Note: impulse responses to a 400 basis points shock to the ten-year Greek spread. Median values of the posterior distribution of the response at each period. Deviations from the baseline in percentage points. TARGET2 net balances are in percentage of a country banks' total assets. DE = Germany, FR = France, NL = The Netherlands, BE = Belgium, IT = Italy, IE = Ireland, ES = Spain, GR = Greece, PT = Portugal.

Fig. 11 Impulse responses of euro-area selected variables



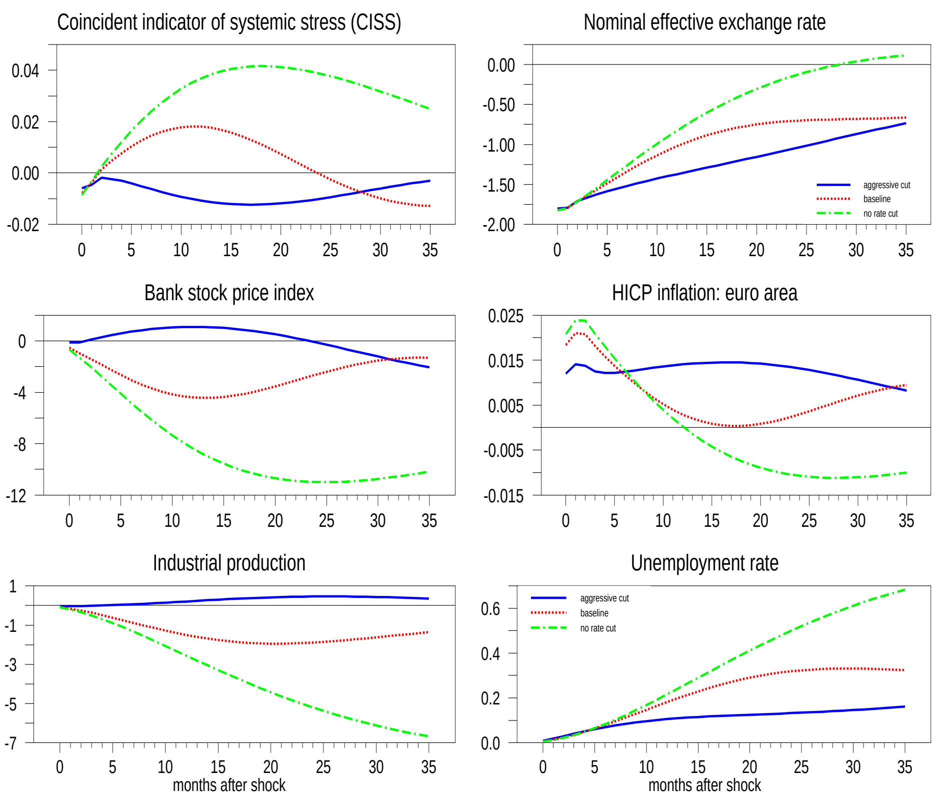
Note: impulse responses to a 400 basis points shock to the ten-year Greek spreadd. Blue solid line: median of the posterior distribution; red dashed line: 0.16 and 0.84 percentiles of the posterior distribution.

Fig. 12 Counterfactual exercise: response of MRO rate



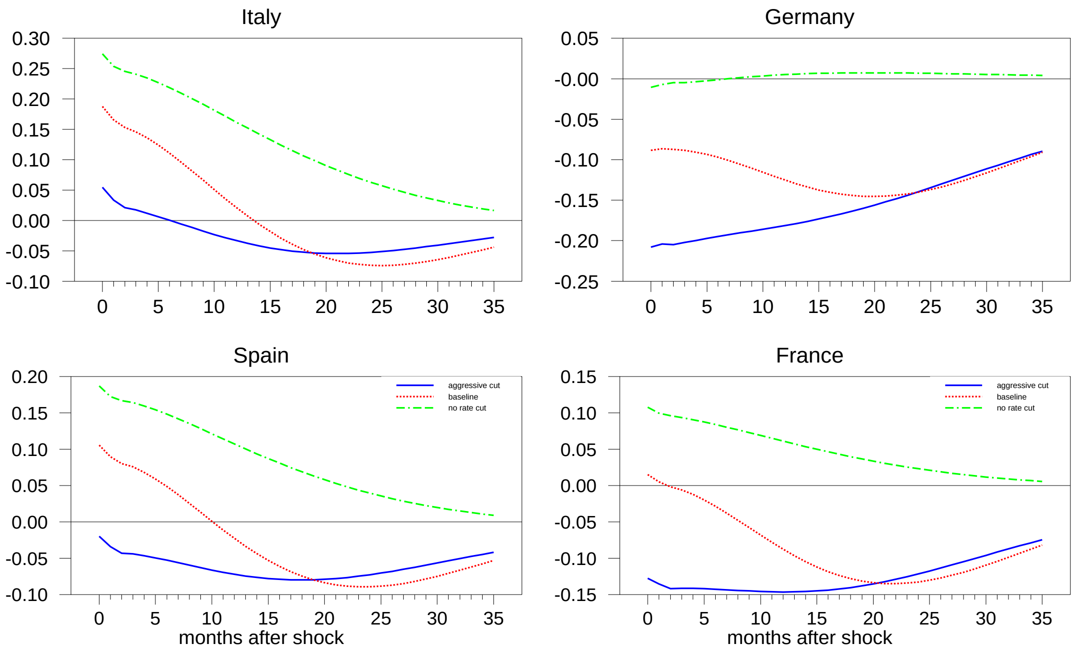
Note: impulse responses to a 400 basis points shock to the ten-year Greek spread. Median values of the posterior distribution of the impulse response at each period. Deviations from the baseline in percentage points.

Fig. 13 Counterfactual exercise: response of selected euro-area variables



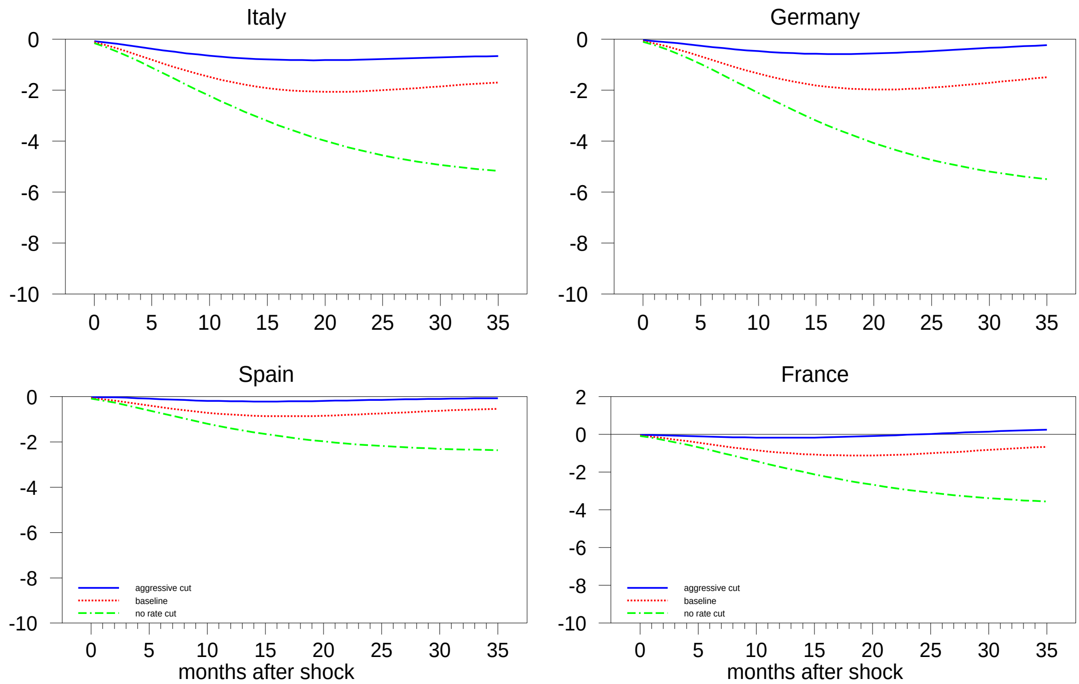
Note: impulse responses to a 400 basis points shock to the ten-year Greek spread. Median values of the posterior distribution of the impulse response at each period.

Fig. 14 Counterfactual exercise: response of cost of new credit to non-financial corporations



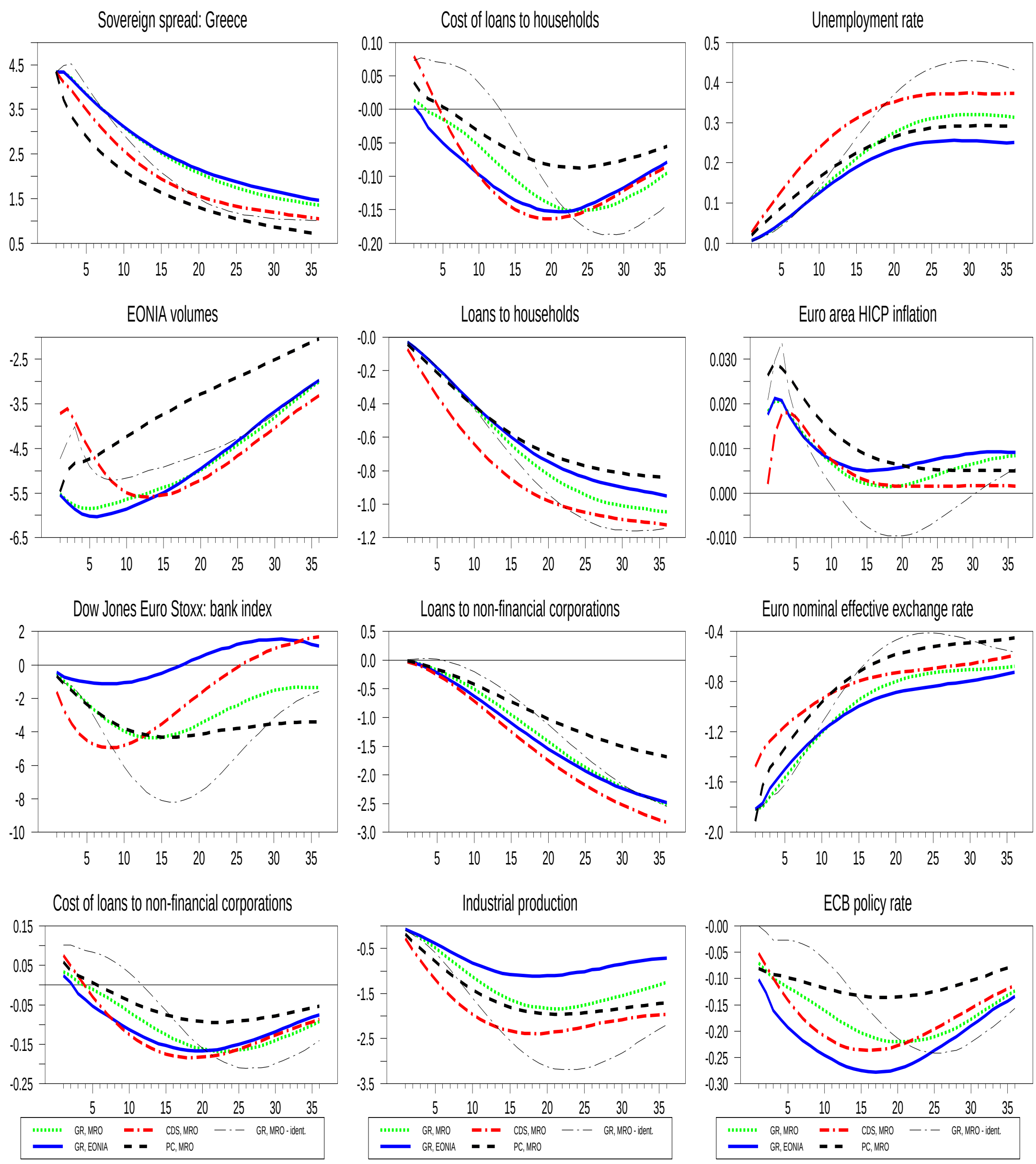
Note: impulse responses to a 400 basis points shock to the ten-year Greek spread. Median values of the posterior distribution of the impulse response at each period.

Fig. 15 Counterfactual exercise: response of industrial production



Note: impulse responses to a 400 basis points shock to the ten-year Greek spread. Median values of the posterior distribution of the impulse response at each period.

Fig. 16 Impulse responses of euro-area selected variables: robustness checks



Note: the size of the shock is the same in all models and it is equal to 400 basis points. Median values of the posterior distribution of the impulse response at each period. GR,MRO denotes the model in which the measure of sovereign debt tensions is the Greek spread and the ECB policy is described by the MRO rate; GR,EONIA denotes the model in which the measure of sovereign debt tensions is the Greek spread and the ECB policy is described by the EONIA rate; CDS,MRO denotes the model in which the measure of sovereign debt tensions is the median 5-year CDS spread and the ECB policy is described by the MRO rate; PC,MRO denotes the model in which the measure of sovereign debt tensions is the first principal component of sovereign spreads and the ECB policy is described by the MRO rate; GR,MRO ident. denotes the model in which the measure of sovereign debt tensions is the Greek spread, the ECB policy is described by the MRO rate and the spread is ordered before the policy rate.

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