The role of systemic risk spillovers in the transmission of Euro Area monetary policy

Alexandros Skouralis

Bayes Business School, City, University of London

E-mail: alex.skouralis@city.ac.uk

December 2022

Abstract

This paper empirically investigates the transmission of systemic risk across the Euro Area by employing a Global VAR model. We find that a union aggregate systemic risk shock results in a sharp decline in output, with two thirds of the response to be attributed to cross-country spillovers. The results indicate that peripheral economies have a disproportionate importance in spreading systemic risk compared to core countries. Then, we incorporate high-frequency monetary surprises into the model and we find evidence of the *risk-taking channel of monetary policy*. However, the relationship is reversed in the period of the ZLB, when expansionary shocks mitigate systemic risk, since they reduce market uncertainty and funding risk. Cross-country spillovers account for a significant fraction (17.4%) of systemic risk responses' variation. We also show that near term guidance reduces systemic risk, whereas the initiation of the QE program has the opposite effect. Finally, the effectiveness of monetary policy exhibits significant asymmetries, with core countries driving the union response.

Keywords: *Systemic risk ; Global VAR ; Euro Area ; Unconventional Monetary Policy*

JEL classification: C32 ; E44 ; F36 ; F45

Cite as: Skouralis, Alexandros (2023), "The Role of Systemic Risk Spillovers in the Transmission of Euro Area Monetary Policy", *Open Econ Rev* . https://doi.org/10.1007/s11079-022-09707-0

Acknowledgements: I am grateful to my PhD supervisors Ivan Paya and Efthymios Pavlidis for their comments and guidance. I also want to thank Mirela Miescu, Manfred Kremer and Arnab Bhattacharjee for their useful suggestions. Finally, I thank the participants at the IFABS Oxford 2021 Conference, the 25th International Conference on Macroeconomic Analysis and International Finance (ICMAIF/2021), the 11th RCEA Money, Macro and Finance Conference, the 2021 Irish Economic Association Conference and at the Central Bank of Ireland Economic Seminar series, for their helpful comments.

1. Introduction

In the aftermath of the 2008 financial crisis, the international transmission of financial risk has been a focal point of research and policy analysis. In 2011, Christine Lagarde, the then Managing Director of the IMF, argued that international financial exposures were "*transmitting weakness and spreading fear*" across markets and countries. Similarly, Grant (2016) suggests that the cross-country financial linkages (and not the trade relationships) were the main stress transmission mechanism in both the US subprime mortgage and the Eurozone debt crises.[1] Euro Area is a special case because, on the one hand there is significant heterogeneity amongst countries and on the other hand, there is a single monetary authority and high financial integration. The latter, despite all the direct and indirect benefits, could lead to more costly crises, since economies are exposed to both domestic and currency union shocks. A country level systemic risk event may become aggravated, due to strong financial contagion in the euro banking system, and lead to a widespread adverse effect on the union-wide financial stability (Allen et al. 2011).

The aim of this paper is twofold. First, we provide an empirical investigation of the transmission of systemic risk across the monetary union. The analysis quantifies the size and identifies the direction of the spillovers. This is one of the first papers that looks at systemic risk cross-country spillovers, whereas most of the existing literature focuses on stock market financial stress and analyses the monetary union as a whole or it only focuses on the largest economies (Dovern & van Roye 2014). Second, there is extent literature on how monetary policy affects systemic risk (Faia and Karau 2019 ; Kapinos 2020) and another strand of literature that examines the role of spillovers on the transmission of monetary policy (Burriel and Galesi 2018 ; Georgiadis 2015). This paper lies in the intersection of these two topics and it sheds light on the non-linear relationship between monetary policy and systemic risk and empirically investigates the role of cross-country spillovers in the transmission of monetary policy shocks.

According to the joint report of Financial Stability Board (FSB), International Monetary Fund (IMF) and Bank for International Settlements (BIS), systemic risk is defined as the disruption of the flow of financial services, caused by an institution or by a part of the financial system, that could have an adverse effect on the real economy. To capture systemic risk, we adopt the $\Delta CoVaR$ risk measure, introduced by Adrian & Brunnermeier (2016).[2] We extend the methodology to the country level by employing an aggregate version for a market capitalization weighted portfolio of financial institutions. $\Delta CoVaR$ is one of the most widely used measures and its main advantage is that is based on micro-data, so it is more informative than country-level measures that are based on government securities.[3] For robustness purposes, we also employ as an alternative indicator, the market-based

---

[1] Brutti & Sauré (2015) argue that cross-border financial exposures were an important transmission channel and they argue that a fragile foreign banking system could constitute a liability to the rest of the union members.

[2] Numerous studies focus on the estimation of systemic risk, however there is no commonly accepted measure in the literature. Bisias et al. (2012) present an extended survey of the different measures grouped by their features. Each group captures a different aspect of systemic risk, such as contagion, volatility, liquidity, macroeconomic environment and institution-specific measures.

[3] For the estimation we include financial firms beyond the banking sector such as insurance companies, real estate firms and financial services institutions. See also the recent work from Jin & De Simone (2020) and Pavlidis et al. (2021) who expand the analysis of the euro systemic risk beyond the banking sector by focusing on investment funds and real estate firms respectively.

Composite Index of Systemic Sovereign Stress (henceforth *SovCISS*). The index was created by Garcia-de Andoain & Kremer (2017) and the data series are provided by the ECB Statistical Data Warehouse.[4]

We then incorporate this systemic risk index in a Euro Area Global VAR (GVAR) model to allows us to capture the cross-countries spillovers. There are different methodological approaches in the literature to capture interconnectedness among firms or countries, such as market data-based (systemic risk) measures (Billio et al. 2012 ; Gómez-Puig & Sosvilla-Rivero 2014) and network analysis (Hüser 2015 ; Covi et al. 2019). Our approach differs from the other papers in the literature since we capture contagion by analysing (exogenous) shocks amongst member countries or union regions. The GVAR framework is a common approach to model financial linkages amongst countries (Galesi & Sgherri 2009 ; Dovern & van Roye 2014)[5] and has been extended to the Euro Area financial markets.[6] More specifically, Bicu & Candelon (2013) apply the model based on balance sheet data and sectoral CDS premia, to estimate the interconnectedness of the Eurozone banking sectors. Moreover, Caporale & Girardi (2013) uses the GVAR framework to find a strong link between Euro Area spreads and they show how the fiscal imbalances lead to financial imbalances.

All of the papers in the Euro Area GVAR literature argue that there are significant spillovers in terms of economic activity and financial stability. To measure the degree of interconnectedness and its drivers, we quantify the impact of country-level systemic risk shocks to the union aggregate level. Our empirical evidence suggests that Italy, Spain and Germany are the most systemically important countries in the monetary union. However, shocks in some of the smaller countries (Ireland) can also have a sizeable impact at the union level. We observe that core countries are highly interconnected but their spillovers to the rest of the union members are low. On the other hand, systemic risk shocks in the peripheral countries have a considerably larger effect on all the EMU members.[7] Therefore, the main transmission channel of systemic risk is running from peripheral to core countries. Our findings are consistent with Gorea & Radev (2014) who estimate the market-perceived probability of joint default of the Euro Area countries and they find evidence of an active contagion transmission channel from the Periphery towards the Core region. In addition, we examine the impact of systemic risk shocks on the macroeconomy. The results indicate that an unexpected increase in the Euro Area aggregate systemic risk leads to a slowdown in economic activity, of which two thirds of its variation can be attributed to cross-country spillovers.

The second part of the paper focuses on the role of spillovers on the *systemic risk-taking channel of monetary policy*. Central banks have a pivotal role in supervising and supporting financial stability. An extensive literature has focused on the *risk-taking channel of monetary policy* that suggests that accommodative monetary policy encourages more risk-taking behaviour of financial institutions (Borio & Zhu 2012). However, there is no extended literature in terms of financial stability and the "*systemic risk-taking channel*". Kabundi & De Simone

[4] ECB Statistical Data Warehouse also provides time-series data for the Composite Index of Systemic Stress (*CISS*) by Holló et al. (2012), but not for all the examined countries in our sample.

[5] Other papers also analyse the financial spillovers by focusing on the transmission of liquidity and credit shocks (see Chudik & Fratzscher 2011 and Eickmeier & Ng 2015).

[6] The GVAR literature has also been extended to the various Euro Area-focused contexts such as fiscal policy (Hebous & Zimmermann 2013 and Ricci-Risquete & Ramajo-Hernández 2015), monetary policy (Burriel & Galesi 2018) trade (Bussière et al. 2009) and house prices (Vansteenkiste & Hiebert 2011).

[7] Eller et al. (2017) apply a GVAR model to examine the international impact of a fiscal policy shock in Germany. Similarly to our findings they found that mostly core economies affected by the positive cross-border spillovers. The effect is positive but weaker for Periphery. They also argue that the transmission of the shock is through the financial channel.

(2020) identify this gap in the literature and analyse the systemic risk responses following conventional and unconventional monetary policy shocks identified using sign restrictions and they find evidence of *the risk-taking channel*.[8] Similarly, Faia & Karau (2019) include systemic risk measures in a VAR model and shadow rates as instruments of monetary policy. They present similar results but also evidence of a price puzzle, which indicates that the identification of the monetary shock is problematic. In addition, in the period of the ZLB the empirical evidence is mixed and another strand of the literature argues that expansionary unconventional monetary policy supported the financial system during the crisis (see Gambacorta et al. 2014, Boeckx et al. 2017).[9]

We adopt the high-frequency monetary surprises by Altavilla et al. (2019) that overcome the price puzzle issue and also allow us to examine the impact of other forms of monetary policy (such as forward guidance and QE) on systemic risk. This is the first paper, to the best of our knowledge, that incorporates high-frequency shocks into the GVAR framework. We divide the sample period into two sub-periods[10] with the cutting point being when the shadow rate becomes negative and the results indicate that the impact of monetary policy is not homogeneous across time. For the first sample period, our results below are in line with the *risk-taking channel*, whereas in the second period of the ZLB and of the unconventional monetary policies, expansionary policy shocks lead to a decline in systemic risk. Most importantly, we isolate the systemic risk response coming from the spillovers channel. The results indicate that cross-country spillovers play an important role in the transmission of monetary policy shocks accounting for more than 17% of the systemic risk and 13% of GDP responses' variation. Our findings suggest that there are significant asymmetries amongst countries with core economies to benefit the most in terms of growth and financial stability. We also find that the effect is also heterogeneous across the different types of surprises. An expansionary near term guidance (*timing*) shock to mitigate systemic risk, whereas QE shocks to have the opposite effect.[11]

The positive relationship between monetary policy and systemic risk is driven by three main transmission channels. Firstly, during this period of the ZLB and unconventional monetary interventions, further expansionary polices restore market confidence and reduce uncertainty in the market (see Leitner et al. 2021). In 2012, Mario Draghi gave the famous "*whatever it takes*" speech, in which he expressed a strong commitment to Europe and the euro area. This speech alone reversed prior risk-taking in volume, price, and loan credit ratings (Alcaraz et al. 2019). The results also support that monetary policy, especially in the period of the ZLB, exhibit significant cross-country heterogeneity, since it affects primarily the Core region. Output and price level increase following a negative monetary policy shock, with only the results for core economies being statistically significant. Secondly, another transmission mechanism that results in the inversion of the relationship between monetary policy and systemic risk is through market expectations. When ECB's asset purchases reduce sovereign bond yields, investors consider institutions with a substantial balance sheet exposure to a risky sovereign as less risky (Szczerbowicz 2015). Thirdly, the Euro Area banking sector relied on the wholesale money market for its marginal

[8] Neuenkirch & Nöckel (2018) argue that Euro Area expansionary monetary policy shocks lead to a decrease in the banks' lending standards and consequently to an increase in systemic risk.
[9] Both papers use the assets of the ECB balance sheet as an instrument of monetary policy and they argue that these policies do not increase the volatility of the financial system (VIX) or systemic stress (*CISS*) respectively.
[10] The specific sub-samples are being selected so we can analyse the impact of the monetary policy before and after the period of the ZLB.
[11] Our findings are in line with Leitner et al. (2021) who find that in the period after 2007, expansionary conventional monetary policy, near term guidance and forward guidance result in a decline in systemic risk whereas QE shocks increase systemic risk and Kapinos (2020) who finds that expansionary monetary news shocks lead to a decrease in systemic risk in the US.

funding needs, which by itself posed serious risks to the financial system (Giannone et al. 2012). During the period of low interest rates, expansionary monetary policies increased liquidity in the market and therefore reduced funding (Darracq-Paries and De Santis 2015) and default risk (Eser and Schwaab 2016).

According to Altavilla et al. (2019), *"target"* surprises were dominant in the policy decision announcement window, however they extend the analysis to capture press conference window surprises: "*timing*" and "*forward guidance"*, which capture the market expectations channel and QE. Our results indicate that expansionary forward guidance announcements lead to a systemic risk reduction[12].The Euro Area systemic risk response is predominately driven by core economies, whereas peripheral countries experience in some cases higher systemic risk, inflationary pressures and weak growth. The findings are consistent with Fendel et al. (2020), who document that ECB communication affects the economies differently. Most specifically, economies with a low solvency rating are affected across different maturities, whereas the impact for countries with a high solvency rating is significant only in short term. On the other hand, QE shocks have the opposite effect. In 2016, Mario Draghi, the then president of the ECB, recognized this adverse effect and he clarified that is not the goal of the ECB to ensure the profitability of any particular institutions. More specifically, QE programs can reduce the profitability of financial institutions such as insurance companies which are exposed to the decline in interest rates.[13] Part of the literature also emphasizes the negative impact of QE on financial stability. Gern et al. (2015) and Claeys & Leandro (2016) support that prolonged expansionary monetary policies encourage risk-taking beyond the socially desirable. Additionally, it may result in asset prices disconnecting from the fundamentals and fuelling asset price bubbles, which can trigger a banking crisis in the medium or long term. In conclusion, the different channels of unconventional forms of monetary policy present mixed results regarding their impact on systemic risk. Despite the increase in systemic risk caused by the adoption of the QE program, expansionary monetary policy shocks (signalling and *"target"* /policy rate surprises) appear to be an important tool for mitigating systemic risk.[14]

The remainder of the paper proceeds as follows. In Section 2, we present the $\Delta CoVaR$ methodology and the construction of the systemic risk index. Sections 3 and 4 describe the GVAR methodology and discuss the empirical findings on the transmission of systemic risk shocks. Section 5 focuses on the relationship between systemic risk and monetary policy. Finally, Section 6 concludes and discusses the main policy implications.

2. Measuring systemic risk

A number of different systemic risk measures have been proposed in the literature, however there is not a commonly accepted approach. For our analysis, we construct a systemic risk country index by employing one of the most popular systemic risk methodologies, $\Delta CoVaR$, proposed by Adrian & Brunnermeier (2016). $\Delta CoVaR$ is a widely-used measure and has been applied in a variety of contexts such as measuring the systemic importance of the Eurozone financial sub-sectors (Bernal et al. 2014) and the European sovereign debt markets (Reboredo &

[12] See Zlobins (2020) who examines the macroeconomic effects of the ECB's forward guidance (FG) in the Euro Area and Möller (2020) studies the role of ECB communication as a determinant of Eurozone's banking system systemic risk.

[13] In In our sample insurance companies account for 26\% of the firms' Market Capitalization, therefore we expect that the asset purchase program will result to a deterioration of the financial sector index. In Appendix, Table A2 presents the composition of the portfolio of financial firms that are being used for the systemic risk index.

[14] Similarly to Claeys & Darvas (2015) who support that the overall benefits of the UMP outweight the potential risks.

Ugolini 2015).[15] The method builds on the concept of Value-at-Risk (*VaR*), which is arguably one of the most widely used risk measures for investors and policymakers. However it cannot be used for macroprudential purposes since it does not take into consideration the links amongst firms. To capture this aspect of risk, Adrian & Brunnermeier (2016) develop the concept of $CoVaR_q^{s|i}$, defined as the VaR_q of the entire financial system when the firm *i* is under distress (returns equal to its VaR_q). The VaR_q of an institution at q%, is defined by:

$$P\left(R^i \leq VaR_q^i\right) = q \quad (1)$$

$CoVaR_q^{s|i}$ is defined as:

$$P\left(R^s \leq CoVaR_q^{s|i} \mid R^i = VaR_q^i\right) = q \quad (2)$$

In Equation (2), R_i and R_s denote the returns of institution i and of the financial system index respectively. For our analysis, we focus on the 5th quantile (q = 0.05). The systemic importance of an institution can be measured by its marginal contribution to financial system's risk. For this purpose they define Δ*CoVaR* as the difference between the $CoVaR$ with the one estimated in normal times (q = 0.5). Δ*CoVaR* captures the risk spillovers from a firm across the financial system. For the cross-country analysis, we estimate the level of systemic risk at the country level by introducing an aggregate version of the Δ*CoVaR* measure. Therefore, we compute the systemic risk for a market capitalization weighted portfolio of financial firms including banks, financial services, real estate and insurance companies.[16] A similar approach has been adopted by Rodríguez-Moreno & Peña (2013) for a portfolio of European and US stocks. The estimation of systemic risk is at the national and not the European level, to isolate potential cross-border externalities at this stage, since we do not want the market variation of the other union members included in the aggregate union index to affect the country level estimation of systemic risk. [17]

[Insert Figure 1]

Figure 1(i) compares the Euro Area Δ*CoVaR* index and the *SovCISS* index from the ECB database. The estimation of *SovCISS* integrates yield and liquidity spreads along with volatility into an overall measure of sovereign market stress. Although the estimation methods are different, we observe that they provide a similar pattern. Figure 1(ii) illustrates the systemic risk index for the ten examined economies divided into two union regions, Core and Periphery. We observe that the Great Recession in 2008 and the sovereign debt crisis in 2012 both led to a considerable increase in systemic risk. The definition of the two union regions depends on two distinctive patterns that are observed in individual countries systemic risk variation. Core countries, namely Germany, France, the Netherlands, Belgium and Austria, affected mostly by the 2008 global financial crisis, whereas the increase in 2012 was considerable weaker in those countries. These countries present a very high degree of interconnectdness and co-movement for the entire examined period. On the other hand, for peripheral countries, namely Italy, Spain, Greece, Portugal and Ireland, present high level of risk in both periods, with the peak values to be observed in 2012.

[15] Varotto & Zhao (2018) examine the characteristics of US and European banking institutions and their systemic importance. They support that banks size is a primary driver of the most common systemic risk indicators.

[16] See Appendix, section A for the detailed estimation steps. The data series are provided by Datastream and for the selection of the financial institutions we used the constituents of the countries' DS Financials Index. For robustness, we use weights based on a 6 month moving-average Market Capitalization and the systemic risk indices is identical. In addition, we remove REITs from our sample and this does not change our results

[17] See Buch et al. (2019) for the differences and the drivers of Euro Area systemic risk at the national and European level.

3. The GVAR framework

The GVAR methodology is a multi-country model that allows us to take into consideration the international financial spillovers across the Euro Area. The framework was introduced by Pesaran et al. (2004) and extended by Dees et al. (2007). This is the first paper, to the best of our knowledge, that includes systemic risk/risk measures to account for financial stability. We incorporate ten Euro Area countries[18] and three macroeconomic variables for each economy (Y) ; logGDP[19], Prices (logHICP) and the systemic risk index. As shown in the Equation (3), each country is modelled as a small open economy with an error-correction model that includes domestic and foreign variables. The mathematical representation of the VAR model with exogenous variables is:

$$Y_{i,t} = a_i + \sum_{j=1}^{p} A_{i,j} Y_{i,t-j} + \sum_{j=0}^{p} B_{i,j} Y_{i,t-j}^{*} + \sum_{j=0}^{q} C_{i,j} X_{t-j} + e_{i,t} \quad (3)$$

In Equation (3), i stands for each country and $A_{i,j}$ is a matrix of coefficients related to the lags of the domestic variables. To capture spillovers across the monetary union, each national economy is also affected by a weighted matrix of foreign variables (Y*) as presented in Equation (4). The foreign variables include all three domestic variables weighted by the level of GDP for the examined period.[20] The GVAR model also allows for global variables (X_t) that are included in all country models. $B_{i,j}$ and $C_{i,j}$ are the matrices of coefficients for foreign and global variables respectively. Country specific shocks ($e_{i,t}$) are assumed to be serially uncorrelated mean zero with a nonsingular covariance matrix. In line with the literature, to ensure consistency, the foreign variables are treated as weakly exogenous, which implies that each country is treated as a small economy with the domestic macroeconomic variables to have no long-run impact to foreign variables, allowing however short-run feedback effects. Therefore, the international spillovers could have a short-term effect but not a long-term impact on the examined domestic economy.

$$Y_{i,t}^{*} = \sum_{i \neq j}^{N=10} w_{i,j} Y_{j,t} , \qquad with \ \sum_{i \neq j}^{N=10} w_{i,j} = 1 \quad (4)$$

Monetary policy, captured by the shadow rate by Wu & Xia (2016), is the common factor (X_t) for all the countries and can affect the real economy directly and indirectly through spillovers from the other Euro Area members. It is modelled as a function of a set of union aggregate variables ($\tilde{Y}$) such as output, prices and systemic risk to capture the ECB's response to macroeconomic developments in the union.[21]

$$X_t = b_x + \sum_{j=1}^{p_x} D_j X_{t-j} + \sum_{j=1}^{q_x} \tilde{Y}_{t-j} + u_{x,t} \quad (5)$$

The novelty of this paper is that we additionally incorporate high-frequency monetary surprises in the framework. In this case, when we analyse monetary policy shocks, the surprises enter the model as exogenous variables, allowing no feedback from the domestic macro-financial environment and ordered first in the model. The modelling approach is based on Paul (2020) that show that the structural estimation of a proxy SVAR model could

[18] These ten economies account for around 95% of Euro Area GDP for period 2002-2018.

[19] We estimate the monthly GDP based on Chow-Lin interpolation using the quarterly GDP data provided by Eurostat and the (monthly) industrial production index provided by Fed of St. Louis.

[20] See Appendix, Table A3. The weights are adjusted for the sub-period analysis. Additionally, in line with Dovern & van Roye (2014), we use an alternative weighting scheme based on cross-country claims from the Consolidated Banking Statistic provided by BIS. The data present some missing values, which are filled with zeros or the claims of the other counterpart to the examined country if available. Both weighting schemes provide similar findings.

[21] Similar approach has been adopted by Burriel & Galesi (2018) and Georgiadis (2015).

be carried out by using the shock series ordered first in a standard recursive VAR model. With regards to the estimation steps, we firstly estimate each individual country's VARX separately (see Equation 3).

We select the lag order based on the Akaike Information Criterion (AIC) and we impose a limit to the number of lags for both domestic (p_{max}= 4) and foreign variables (q_{max} = 1) to secure model stability.[22] In the second step, all the country models are stacked in to create the GVAR model where all the variables are endogenous.

Specifically, Z_t is a vector of all variables included (Y_t, $Y_t{}'$,):[23]

$$A_{i,0}Z_{i,t} = a_0 + \sum_{j=1}^{p} A_{i,j}Z_{t-j} + e_{i,t} \quad (6)$$

We then use the weights (w), that capture bilateral exposure across countries, to express $Y_t{}'$ as function of Y_t and we define G = $A_I w_i$ to obtain:

$$G_0 Y_{i,t} = a_0 + \sum_{j=1}^{p} G_j Y_{t-j} + e_{i,t} \quad (7)$$

Multiplying both parts of Equation (7) by Go−1 , we obtain the autoregressive representation of the model:

$$Y_{i,t} = b_0 + \sum_{j=1}^{p} F_j Y_{t-j} + \eta_{i,t} \quad (8)$$

where $b_0 = G_0^{-1} a_0$, $F_j = G_0^{-1} G_j$ and $\eta_t = G_0^{-1} e_t$.

The dynamic properties of the model are analysed by using Generalized Impulse Response Functions (GIRFs), introduced by Koop et al. (1996) and adapted to VAR framework in Pesaran & Shin (1998). We follow Smith & Galesi (2017) SGIRF methodology, who identify structural shocks in a country by using the triangular approach by Sims (1980). Country shocks ($e_{i,t}$) are assumed to be uncorrelated with shocks in the common variable equation ($u_{x,t}$). Alternative ordering of the variables should not affect the outcome as long as the contemporaneous correlations remain unrestricted. For a more detailed description of the model, we refer to Smith & Galesi (2017) and Chudik & Pesaran (2016).[24]

4. Systemic risk spillovers

In this section we present the empirical findings on the transmission of systemic risk shocks across the Euro Area. We employ monthly data for the period 2004m09 to 2018m09 to take advantage of the fact that all the countries had adopted the common currency and they appertain to the ECB's monetary authorities' regulations.[25] This is one of the first papers to look at cross-country spillovers, whereas most of the existing literature analyses the monetary union as a whole or it only focuses on the largest economies. Our results shed light on the systemic importance at regional and country level and the direction of the risk transmission. For the identification of the systemic risk shock, we use the standard Cholesky decomposition similarly to Dovern & van Roye (2014) who

[22] In the Appendix, Table A4 presents the optimal ordering based on the Akaike information criterion (AIC). The results are robust to different lag selection based on the Schwarz Bayesian criterion (SBC).
[23] We neglect the global variables (X_t) for simplicity and we only use the domestic lags (p) since by construction are always greater than the foreign variables lags (q).
[24] For the estimation of the model, we use the Matlab codes from the GVAR Toolbox by Vanessa Smith.
[25] In the Appendix, Table A1 describes the data series and their sources. The main data limitation comes from the shadow rate series that starts at 2004m09.

adopt this approach to identify financial stress shocks in the GVAR framework.[26] Initially, we analyse the macroeconomic impact of an unexpected increase in the aggregate Euro Area systemic risk, in other words when all countries experience an unexpected one standard error (s.e.) increase in the level of risk. We then decompose the effect coming from domestic and foreign developments to examine the importance of cross-country spillovers. Finally, we investigate which countries drive the union systemic risk by presenting the peak responses after a country and a euro-regional shocks.

4.1 *The impact of a Euro Area systemic risk shock and the role of spillovers*

The 2008 financial crisis highlighted how a systemic event, such as the collapse of Lehman Brothers, can substantially affect real economic activity. Monitoring financial stress has become a major concern for regulators especially since the Great Recession and the European sovereign debt crisis. The relationship between financial stress and business cycles is widely-documented in the literature (Kremer 2016). To examine the relationship between the systemic risk in financial markets and economic activity, we analyse the responses of output and prices following an unexpected increase in the aggregate level of systemic risk in the Eurozone. Our empirical findings in Figure 2 indicate that an unexpected increase in systemic risk results in a persistent slowdown in economic activity. To decompose the effect coming from foreign developments, we present the responses when there is no direct spillover effect amongst countries with the red line and confidence interval. The findings indicate that spillovers account for two thirds of GDP's response, which highlights the importance of the spillovers that amplify the impact of systemic risk shocks.[27] Prices present a similar pattern. Finally, by construction, the effect of foreign systemic risk shocks have a simultaneous impact on the union aggregate systemic risk. In both cases, we apply a shock to all Euro Area countries, however the initial aggregate response is almost twice as large in the presence of spillovers.

[Insert Figure 2]

The results suggest that spillovers play an important role in the transmission of a systemic risk shock. To investigate the exposure of Eurozone economies to the rest of the union members, we look into the country SGIRFs.[28] The results for both systemic risk measures, $\Delta CoVaR$ and *SovCISS* indices suggest that there is an unambiguous strong contagion amongst Eurozone economies. In the case of the micro-data based $\Delta CoVaR$, the transmission of the shock has immediate effect on the union members' financial systems and it fades out 10 periods after its occurrence. The initial response is similar for the market-based *SovCISS* with the only difference to be that the effect is more long lasting in the case of output. The degree of interconnectedness is considerably higher in core countries, which are more exposed to systemic risk shocks at the union level. The responses of the countries in the Periphery are also significant but smaller in magnitude on average. The responses in this region are driven mostly by domestic factors, whereas the exposure to core economies and the spillover effect are weak

[26] They examine the international transmission of a US and a global financial stress shock on 20 major economies and its effect on economic activity. The shock is identified by imposing identification conditions based on Sims (1980) triangular approach.
[27] One of the important costs of financially integrated markets is that domestic economies are exposed to foreign credit shocks (Allen et al. 2011).
[28] See Appendix, Figure A1a and A1b.

or insignificant. Therefore, our results support that the main transmission channel of systemic risk is running from peripheral to core countries.

The most exposed country, both in terms of the increase in systemic risk and output losses, is Greece, which was vulnerable due to the government debt crisis (see Grammatikos & Vermeulen 2012). In the vast majority of countries, the spillover effect plays an important role and results in deeper recessions. Italy and Spain present also considerable exposure to the union shock, which is, however, mostly driven by domestic factors, whereas the spillover effect has an insignificant or negative effect at the countries' risk level. On the other hand, the decline in GDP of France and Germany is close to the Euro Area average. When we introduce the foreign variables matrix and the spillovers channel, their output losses are significantly higher than the rest of the union members. It is worth noticing that in some core economies, namely the Netherlands, Belgium and Austria, when we mute the foreign variables from the country equation, the impact of systemic risk shocks on output is insignificant or even positive. Our findings are in line with the previous empirical evidence which indicates that core economies are exposed to systemic risk spillovers from the Periphery, whereas the latter is more affected by the domestic macro-financial environment. Most importantly, we find that systemic risk shocks have a sizeable adverse effect on the economic activity and that the high degree of financial contagion is a strong mechanism through which domestic shocks are propagated to other economies.[29] Spillovers play an important role in the transmission of the shock, which highlights the need for close monitoring of systemic risk at the country level but also the financial contagion across the union members.[30]

4.2 Which countries drive Euro Area systemic risk contagion?

In this section we examine the systemic importance of two Euro Area regions and individual countries. Table 1 illustrates the peak systemic risk responses following regional and country specific shocks. A shock in the two Euro Area regions has a quantitatively similar effect on the union aggregate, however, Periphery only accounts for 22% of union's cross-country claims (based on BIS data) and one third of the union's GDP that indicates that they are disproportionately systemically important in comparison to core countries. In line with our findings in previous sections, we observe that spillovers are stronger from periphery to core economies than from core to the periphery. Italy is the most systemically important country in the Euro Area, followed by Spain.[31] The two largest economies in the monetary union, Germany and France, are also systemically important, especially across core countries. We observe that core countries are highly interconnected with a country level shock having a strong impact on the rest of the economies of the region but a weak effect on peripheral economies.

On the other hand, peripheral economies' shocks affect both regions. It is worth noticing that small economies appear to be also systemically important. Portugal and Ireland account together for less than 4% of Eurozone's GDP,[32] but their contribution to aggregate systemic risk is significant. The results are qualitatively similar if we

[29] However, as noted by Allen et al. (2011), spillovers should not undermine the rationale of financial integration in the Euro Area since the gains from diversification and risk sharing outweight potential costs. In addition, they support that some of the costs arisen from the contagion effects can be attributed to the lack of policy coordination and they can be avoided.
[30] Holló et al. (2012) document a sharp decline in economic activity following a *CISS* shock, especially in period of distress.
[31] To quantify the systemic importance of a country, we look at the increase of the Euro Area aggregate systemic risk index following a country level shock as depicted in the first column of Table 1.
[32] The percentage is estimated based on the average quarterly GDP for the examined period 2001-2018.

use *SovCISS* instead of $\Delta CoVaR$. Overall, the evidence suggests that peripheral countries are a significant source of systemic risk for the Euro Area. The need for monitoring the spillovers from the periphery has been documented before in the literature. According to Constancio (2012), contagion from the peripheral countries has contributed to union-wide financial stress, especially after July 2011 and the sovereign debt crisis. He also highlighted the strong degree of stress transmission from Italy and Spain to Greece, Portugal and Ireland's government bonds. Similarly, Caporale & Girardi (2013) analyse the spillovers in terms of borrowing cost from fiscal imbalances in the Euro Area economies. They find that negative externalities from Italy and other peripheral countries could lead to crowding out effects for the Euro Area consumption and an increase in the government bond rates in all countries and regions.

[Insert Table 1]

5. Monetary policy and systemic risk

5.1 Identification of monetary policy shocks

In our analysis, to account for changes in the monetary policy stance, we use the shadow rate by Wu & Xia (2016), which is being modelled as a common (global) variable. However, the identification of a monetary policy shock using the shadow rate as a policy instrument and Cholesky decomposition is problematic, since it results in a price puzzle (see Sims, 1992) as in Faia & Karau (2019). In other words, an expansionary monetary policy shock to result in lower prices and in a drop in economic activity. To address this issue we follow the new strand of the literature that uses the central bank's announcements to identify monetary policy shocks. For that purpose, we use data from Altavilla et al. (2019) who construct a Euro Area event-study database of monetary surprises (EA-MPD) by measuring the asset price changes following a policy announcement window. By looking at the press release window and the very short-end of the yield curve, they identify the "*target"* surprises following the work of Gurkaynak et al. (2004). The main advantage of this methodology is that it identifies more precisely monetary surprises by capturing new policy tools, such as Forward Guidance (FG) and QE.

This is one of the first papers that incorporates high-frequency shocks into the GVAR model.[33] For that purpose, we include the externally identified shock in the model as an exogenous variable that has a contemporaneous effect on the macroeconomic variables and systemic risk.[34] Since all the variables in the model are also expressed in levels and not in differences, in line with Coibion (2012) and Barakchian & Crowe (2013), we use the cumulative shock series to identify the policy shocks and we let the series to take values equal to zero for months with no announcements.

[Insert Figure 3]

[33] Goodhead (2021) uses the EA-MPD surprises in a Proxy SVAR to study the effect of forward guidance and yield curve compression surprises on Euro Area macro-financial variables. Alzuabi et al. (2020) use monetary policy shocks series constructed based on the shocks series by Romer & Romer (2004) for the US economy in the GVAR framework.

[34] See Paul (2020) who employ high-frequency surprises into a vector autoregressive model as an exogenous variable. Plagborg-Møller & Wolf (2021) show that the structural estimation of a proxy SVAR model could be carried out by using the monetary policy shock series ordered first in a standard recursive VAR model. Similar analysis has been carried by Miranda-Agrippino (2016) who also incorporate high-frequency surprises ordered first in a VAR model.

Figure 3 presents the responses following an expansionary monetary policy shock for the two examined time periods. "*Target*" monetary surprises used for the estimation capture the market expectations about changes in policy rates. By incorporating the high-frequency shocks into the model the price puzzle disappears. For the first period, an accommodative policy shock results to an increase in GDP and prices. In accordance with the results shown above, the regional and country responses are not homogeneous. The impact is stronger in core countries and drive the Euro Area aggregate response, whereas the peripheral economies present insignificant results. The consequence of an unexpected monetary expansion is the increase in systemic risk in both regions, which is line with the *risk-taking channel*. In the second period, when shadow rates become negative, the empirical evidence underlines the asymmetric transmission of monetary policy across the Euro Area, not only in terms of output, but also with regards to financial stability. A negative monetary policy shock, as captured by *"target"* surprises, mitigates systemic risk significantly in both regions. In other words, an unexpected monetary expansion from the ECB leads to a reduction of the Euro Area systemic risk aggregate.

This paper contributes to the literature of monetary policy's transmission asymmetries. Georgiadis (2015) apply a GVAR model for the Euro Area to analyse the impact of monetary policy on output and inflation. He finds significant heterogeneity amongst countries driven by structural characteristics such as the industry structure and more specifically the percentage of output associated with sectors sensitive to interest rate but also labour market variables. Burriel & Galesi (2018), in a euro-area GVAR model, find union-wide significant asymmetries in the transmission of monetary policy with countries with less fragile banking system to benefit the most.[35] Other characteristics such as the ease of doing business or the low level of GDP per capita result in higher output gains. However, the literature is limited regarding the potential asymmetries of ECB's monetary policy on the financial variables. According to the aforementioned literature, the reasons that could explain the heterogeneity of responses is the structure of the financial system and the domestic macroeconomic environment, since core economies were not affected considerably by the sovereign debt crisis.

For robustness purposes, we employ *SovCISS* as an alternative indicator for systemic risk. The results using an alternative measures of systemic stress such as *SovCISS*. In both cases similar patterns are being observed. The main difference in the responses between the two different specifications is the timing of the responses. The micro data-based, $\Delta CoVaR$, leads to an immediate decrease of systemic risk, whereas in the case of *SovCISS* the lowest point was reached after 2 quarters. In addition, we control for macroprudential policies which could impact systemic risk. We employ the data series index constructed by Cerutti et al. (2017) which enters the model as a domestic variable for the eleven examined economies. We re-run the model for the two sub periods and in both cases the inclusion of the new variable does not change the results. Although the analysis of macroprudential policy shocks is out of the scope of this paper, it is worth noticing that prudential policies appear to effectively mitigate systemic risk.[36] Cross-country spillovers of prudential policies account for a significant fraction of these responses and is a topic that is worth exploring further in future research.

[35] Ciccarelli et al. (2013) find asymmetries on the effect of monetary policy on output across countries and they suggest that the monetary transmission mechanism depends on the financial fragility of the sovereigns, banks, firms and households.

[36] Cerutti et al. (2017) suggest that macroprudential policies have a significant effect on credit development. Similarly, Fernandez-Gallardo & Paya (2020) find that macroprudential policy results in a decline in *CISS* and credit growth.

5.2 The role of systemic risk spillovers

In previous sections we showed that there are considerable systemic risk spillovers across the monetary union. Contagion and interconnectedness amongst financial institutions play an important role in the transmission of the monetary policy (see Kabundi & De Simone 2020). For that reason, we re-run the model when muting the cross-country spillovers across countries to decompose the effect of monetary policy into the direct and the indirect component.[37] Figure 4 illustrates the importance of taking into consideration the potential cross-country risk spillovers for the conduct of monetary policy. We present the Euro Area responses following an expansionary monetary policy shock for the period after 2009. In the first column, the spillovers account for 13% of the variation of the Euro Area GDP aggregate response. The role of spillovers however varies across the two regions. In core economies, the interconnectdness appears to be beneficial in terms of output gains with spillovers to account for a fraction of 40% of GDP SGIRFs.

[Insert Figure 4]

On the other hand, peripheral countries that suffered from severe recessions during the examined period, present negative externalities across the region. When we take into consideration the spillovers channel the impact is insignificant and less than half than before. With regards to the impact on systemic risk, spillovers account for 17.4% of the response. In this case the contagion channel has a positive effect across both regions. In core economies, a fraction of more than 20% can be attributed to the cross-country spillovers, whereas in the case of the peripheral economies this percentage is at 11.6%. Our empirical findings highlight how misleading can be, for the policymakers, to ignore the spillovers across the monetary union, both in terms of the macroeconomic impact but also the response of the financial markets.

5.3 Do QE shock affect systemic risk?

"Target" surprises were dominant in the policy decision announcement window, however Altavilla et al. (2019) extend the analysis to capture press conference window surprises. The first two factors are "*timing*" and "*forward guidance"*, which capture the market expectations channel in the short run and medium run respectively. They also isolate the QE surprises by using the method of Swanson (2017) in the post-2014 period. Following their work, we focus on the period after 2014 and we incorporate one instrument at a time to extrapolate each component separately and to examine how they affect systemic risk. The modelling approach is identical to the *"target"* surprises as the cumulative shock series are modelled as exogenous variables in the GVAR model structure.

Our results indicate that the expectation channel has a positive relationship with systemic risk. In other words, expansionary monetary policy announcements lead to a systemic risk reduction. The effect of the "*timing*" shock, that refers to the short-term expectations has an immediate strong effect and it results to an increase in output and a decrease in systemic risk, but also causes inflationary pressures. The "*forward guidance*" factor presents similar results leading to a decline in systemic risk a few months after the occurrence of the shock.[38] It is worth noticing

[37] Similarly, Burriel & Galesi (2018) attribute a considerable fraction of the monetary shocks' impact on the spillovers amongst countries, which amplifies the aggregate effect.
[38] See Zlobins (2020) who examines the macroeconomic effects of the ECB's forward guidance (FG) in the Euro Area and Möller (2020) studies the role of ECB communication as a determinant of Eurozone's banking system systemic risk.

though that in both channels we observe considerable heterogeneity across regions, in line with the previous findings. Core economies drive the Euro Area systemic risk response, whereas peripheral countries experience in some cases higher systemic risk, inflationary pressures and weak growth.

[Insert Figure 5]

The findings from QE shocks indicate that the asset purchases program led to an increase in the aggregate systemic risk. Figure 5.A presents the systemic risk responses following a QE shock, which is increasing across the Euro Area with the highest responses observed in core economies providing evidence of the *risk-taking channel* similarly to expansionary shocks in normal times. In terms of output, the shock results to a positive but statistically insignificant effect in most of the countries.[39] Our findings indicate that the initiation of the QE program creates a trade-off for the ECB between economic growth and financial stability.

Finally, we decompose the response coming from domestic factors and the spillovers channel. The empirical evidence, as presented in Figure 5, highlights the important role that contagion plays on the transmission of the signalling shocks. In both cases of "*timing*" and "*forward guidance*", if we do not take into consideration the spillover effect the systemic risk responses, become insignificant. When the contagion effect is muted, the effect of a QE shock also becomes insignificant. Therefore, similarly to policy rate announcements, cross-country spillovers play an important role in the transmission of conference window surprises.

6. Conclusions

Since the financial crisis, systemic events have become a major concern for regulators and policymakers. According to the ECB report (2009), the analysis of systemic risk should consider both endogenous and exogenous sources of risk. In this paper we quantify the financial exposure of Euro Area economies to other union members and its impact on economic activity. To capture systemic risk, we present a new country-level index based on micro-data and the $\Delta CoVaR$ methodology, which we then incorporate into a GVAR model to examine the spillovers across Euro Area economies. Our empirical evidence suggests that there are considerable systemic risk spillovers across the union. More specifically, we observe high degree of financial contagion amongst core countries, which is not spreading out to the Periphery. On the other hand, peripheral economies are affected mostly by domestic factors and they are a source of systemic risk for the EA. At the country level, systemic risk shocks in small economies have a sizeable effect on the other member countries, which highlights the need for monitoring financial risk not only at the aggregate level. Additionally, we study the impact of systemic risk on economic activity. Our findings suggest that a Euro Area systemic risk shock results in a significant drop in GDP across the union and that the responses are mostly driven by the spillovers channel that accounts for around two thirds of the responses' variation.

Our results indicate that spillovers also play an important role in the transmission of monetary policy. We find that in normal times a monetary contraction reduces systemic risk. However, during the ZLB period, when the unconventional forms of policy were introduced, the relationship is reversed, and expansionary monetary shocks lead to a decrease in the risk level by reducing market uncertainty. We also find that during the conference window

[39] Detailed results available upon request.

surprises, near term guidance mitigates systemic risk, whereas the opposite effect is being observed for QE shocks. Most importantly, the evidence suggests that neglecting cross-country spillovers would underestimate the impact of monetary policy shocks, since they account for a substantial fraction of the systemic risk responses.

References

Adrian, T. & Brunnermeier, M. K. (2016), "CoVaR", *American Economic Review,* 106 (7), pp. 1705–41.

Alcaraz, C., Claessens, S., Cuadra, G., Marques-Ibanez, D. & Sapriza, H. (2019), 'Whatever it takes. what's the impact of a major nonconventional monetary policy intervention?', ECB Working paper series (No.2249) .

Allen, F., Beck, T., Carletti, E., Lane, P. R., Schoenmaker, D. & Wagner, W. (2011), "Cross border banking in Europe: Implications for financial stability and macroeconomic policies", Centre for Economic Policy Research (CEPR).

Altavilla, C., Brugnolini, L., Gürkaynak, R. S., Motto, R. & Ragusa, G. (2019), "Measuring Euro Area monetary policy", *Journal of Monetary Economics,* 108, pp. 162–179.

Alzuabi, R., Caglayan, M. & Mouratidis, K. (2020), "The risk-taking channel in the United States: A GVAR approach", *International Journal of Finance & Economics,* pp. 1–24.

Available at: https://www.ecb.europa.eu/press/pressconf/2016/html/is160121.en.html .

Available at: https://www.imf.org/en/News/Articles/2015/09/28/04/53/sp082711 .

Barakchian, S. M. & Crowe, C. (2013), "Monetary policy matters: Evidence from new shocks data", *Journal of Monetary Economics,* 60 (8), pp. 950–966.

Bernal, O., Gnabo, J.-Y. & Guilmin, G. (2014), "Assessing the contribution of banks, insurance and other financial services to systemic risk", *Journal of Banking & Finance,* 47, pp. 270–287.

Bicu, A. & Candelon, B. (2013), "On the importance of indirect banking vulnerabilities in the Eurozone", *Journal of Banking & Finance,* 37 (12), pp. 5007–5024.

Billio, M., Getmansky, M., Lo, A. W. & Pelizzon, L. (2012), "Econometric measures of connectedness and systemic risk in the finance and insurance sectors", *Journal of Financial Economics,* 104 (3), pp. 535–559.

Bisias, D., Flood, M., Lo, A. W. & Valavanis, S. (2012), "A survey of systemic risk analytics", *Annu. Rev. Financ. Econ.,* 4 (1), pp. 255–296.

Boeckx, J., Dossche, M. & Peersman, G. (2017), "Effectiveness and transmission of the ECB's balance sheet policies", *International Journal of Central Banking,* 13 (1), pp. 297–333.

Borio, C. & Zhu, H. (2012), "Capital regulation, risk-taking and monetary policy: A missing link in the transmission mechanism?", *Journal of Financial Stability,* 8 (4), pp. 236–251.

Brutti, F. & Sauré, P. (2015), "Transmission of sovereign risk in the Euro crisis", *Journal of International Economics,* 97 (2), pp. 231–248.

Buch, C. M., Krause, T. & Tonzer, L. (2019), "Drivers of systemic risk: Do national and European perspectives differ?", *Journal of International Money and Finance,* 91, pp. 160– 176.

Burriel, P. & Galesi, A. (2018), "Uncovering the heterogeneous effects of ECB unconventional monetary policies across Euro Area countries", *European Economic Review,* 101, pp. 210–229.

Bussière, M., Chudik, A. & Sestieri, G. (2009), "Modelling global trade flows: Results from a GVAR model", *ECB Working Paper Series (no.1087)* .

Caporale, G. M. & Girardi, A. (2013), "Fiscal spillovers in the Euro Area", *Journal of International Money and Finance,* 38, pp. 84e.1–84e16.

Cerutti, E., Claessens, S. & Laeven, L. (2017), "The use and effectiveness of macroprudential policies: New evidence", *Journal of Financial Stability,* 28 pp. 203–224.

Christine Lagarde (2011), "Global risks are rising, but there is a path to recovery", Remarks at Jackson Hole, August 27, 2011.

Chudik, A. & Fratzscher, M. (2011), "Identifying the global transmission of the 2007–2009 financial crisis in a GVAR model", *European Economic Review*, 55 (3), pp. 325–339.

Chudik, A. & Pesaran, M. H. (2016), "Theory and practice of GVAR modelling", *Journal of Economic Surveys*, 30 (1), pp. 165–197.

Ciccarelli, M., Maddaloni, A. & Peydró, J.-L. (2013), "Heterogeneous transmission mechanism: Monetary policy and financial fragility in the Eurozone", *Economic Policy*, 28 (75), pp. 459– 512.

Claeys, G. & Darvas, Z. M. (2015), "The financial stability risks of ultra-loose monetary policy", *Bruegel Policy Contribution (Issue 2015 / 03)*.

Claeys, G. & Leandro, A. (2016), "The European Central Bank's Quantitative Easing programme: Limits and risks", *Bruegel Policy Contribution (Issue 2016 / 04).*

Coibion, O. (2012), "*Are the effects of monetary policy shocks big or small?*", *American Economic Journal: Macroeconomics*, 4 (2), pp. 1–32.

Constancio, V. (2012), "Contagion and the European debt crisis", *Financial Stability Review*, 16, pp. 109–121.

Covi, G., Montagna, M., Torri, G. et al. (2019), "Economic shocks and contagion in the Euro Area banking sector: A new micro-structural approach", *Financial Stability Review (1)* .

Darracq-Paries, M., & De Santis, R. A. (2015). A non-standard monetary policy shock: The ECB's 3-year LTROs and the shift in credit supply. *Journal of International Money and Finance*, *54*, 1-34.

Dees, S., Mauro, F. d., Pesaran, M. H. & Smith, L. V. (2007), "Exploring the international linkages of the Euro Area: A Global VAR analysis", *Journal of Applied Econometrics*, 22 (1), pp. 1–38.

Dovern, J. & van Roye, B. (2014), "International transmission and business-cycle effects of financial stress", *Journal of Financial Stability*, 13, pp. 1–17.

Draghi, M. (2016), "Introductory statement to the press conference (Q&A)",
ECB report (2009), "The concept of systemic risk", *Financial Stability Review*, pp. 134–142.

Eickmeier, S. & Ng, T. (2015), "How do US credit supply shocks propagate internationally? A GVAR approach", *European Economic Review*, 74, pp. 128–145.

Eller, M., Feldkircher, M., Huber, F. et al. (2017), "How would a fiscal shock in Germany affect other European countries? Evidence from a Bayesian GVAR model with sign restrictions", *Focus on European Economic Integration*, (1), pp. 54–77.

Eser, F., & Schwaab, B. (2016). Evaluating the impact of unconventional monetary policy measures: Empirical evidence from the ECB′ s Securities Markets Programme. *Journal of Financial Economics*, *119*(1), 147-167.

European Central Bank, Frankfurt am Main, 21 January,
Faia, E. & Karau, S. (2019) "Systemic Bank Risk and Monetary Policy", *International Journal of Central Banking*, 17(71) .

Fendel, R., Neugebauer, F. & Kilinc, M. (2020), "ECB's communication and the yield curve: Core versus Periphery effects", *Applied Economics Letters*, pp. 1–5.

Fernandez-Gallardo, A. & Paya, I. (2020), "Macroprudential policy in the euro area", *Lancaster University, Department of Economics, Economics Working Paper Series (No.2020/020)* .

Financial Stability Board (FSB), International Monetary Fund (IMF) and Bank for International Settlements (BIS) (2009), "*Report to G20 finance ministers and governors: Guidance to assess the systemic importance of financial institutions, markets and instruments: Initial considerations".*

Galesi, A. & Sgherri, S. (2009), "Regional financial spillovers across Europe: A Global VAR analysis", *International Monetary Fund*, No 9-23 .

Gambacorta, L., Hofmann, B. & Peersman, G. (2014), "The effectiveness of unconventional monetary policy at the zero lower bound: A cross-country analysis", *Journal of Money, Credit and Banking*, 46 (4), pp. 615–642.

Garcia-de Andoain, C. & Kremer, M. (2017), “Beyond spreads: Measuring sovereign market stress in the euro area”, *Economics Letters,* 159 pp. 153–156.

Garcia-de Andoain, C. & Kremer, M. (2018), “Beyond spreads: measuring sovereign market stress in the euro area”, *ECB working paper (No. 2185)*.

Georgiadis, G. (2015), “Examining asymmetries in the transmission of monetary policy in the Euro Area: Evidence from a mixed cross-section Global VAR model”, *European Economic Review,* 75, pp. 195–215.

Gern, K.-J., Jannsen, N., Kooths, S. & Wolters, M. (2015), “Quantitative Easing in the Euro Area: Transmission channels and risks”, *Intereconomics,* 50 (4), pp. 206–212.

Giannone, D., Lenza, M., Pill, H., & Reichlin, L. (2011). Non-standard monetary policy measures and monetary developments. ECB Working Paper Series (No. 1290).

Gómez-Puig, M. & Sosvilla-Rivero, S. (2014), “Causality and contagion in EMU sovereign debt markets”, *International Review of Economics & Finance,* 33, pp. 12–27.

Goodhead, R. (2021), “The economic impact of yield curve compression: Evidence from Euro Area conventional and unconventional monetary policy”, *Central Bank of Ireland, Research Technical Paper (Vol. 2021, No. 1).*

Gorea, D. & Radev, D. (2014), “The Euro Area sovereign debt crisis: Can contagion spread from the Periphery to the Core?”, *International Review of Economics & Finance,* 30, pp. 78–100.

Grammatikos, T. & Vermeulen, R. (2012), “Transmission of the financial and sovereign debt crises to the EMU: Stock prices, CDS spreads and exchange rates”, *Journal of International Money and Finance,* 31 (3), 517–533.

Grant, E. (2016), “Exposure to international crises: Trade vs. financial contagion”, *Technical report, ESRB Working Paper Series (no. 30)*

Gurkaynak, R. S., Sack, B. P. & Swanson, E. T. (2004), “Do actions speak louder than words? The response of asset prices to monetary policy actions and statements”, *FEDS Working Paper (No. 2004 / 66)* .

Hebous, S. & Zimmermann, T. (2013), “Estimating the effects of coordinated fiscal actions in the Euro Area”, *European Economic Review,* 58, pp. 110–121.

Holló, D., Kremer, M. & Lo Duca, M. (2012), “CISS-A composite indicator of systemic stress in the financial system”, *ECB Working paper series (no.1426).*

Hüser, A. (2015), “Too interconnected to fail: A survey of the interbank networks literature”, *SAFE working paper (No.91).*

Jin, X. & De Simone, F. N. (2020), “Monetary policy and systemic risk-taking in the Euro Area investment fund industry: A Structural Factor-Augmented Vector Autoregression Analysis”, *Journal of Financial Stability,* 49 (2020), 100749 .

Kabundi, A. & De Simone, F. N. (2020), “Monetary policy and systemic risk-taking in the Euro Area banking sector”, *Economic Modelling,* 91, pp. 736–758.

Kapinos, P. S. (2020), “Monetary policy news and systemic risk at the zero lower bound”, *International Journal of Finance & Economics,* pp. 1–14.

Koop, G., Pesaran, M. H. & Potter, S. M. (1996), “Impulse response analysis in nonlinear multivariate models”, *Journal of Econometrics,* 74 (1), pp. 119–147.

Kremer, M. (2016), “Macroeconomic effects of financial stress and the role of monetary policy: A VAR analysis for the Euro Area”, *International Economics and Economic Policy,* 13 (1), pp. 105–138.

Leitner, G., Hübel, T., Wolfmayr, A. & Zerobin, M. (2021), “How risky is monetary policy? The effect of monetary policy on systemic risk in the euro area”, *Department of Economics Working Paper Series (No. 312), WU Vienna University of Economics and Business.*

Miranda-Agrippino, S. (2016), “Unsurprising shocks: information, premia, and the monetary transmission”, *Bank of England Working Paper (no.626)*.

Möller, R. (2020), "Systemic importance of central bank communication: ECB policy announcements and systemic risk in the Eurozone", Available at SSRN 3644439 .

Neuenkirch, M. & Nöckel, M. (2018), "The risk-taking channel of monetary policy transmission in the Euro Area", *Journal of Banking & Finance,* 93, pp. 71–91.

Paul, P. (2020), "The time-varying effect of monetary policy on asset prices", *Review of Economics and Statistics,* 102 (4), pp. 690–704.

Pavlidis, E., Paya, I. & Skouralis, A. (2021), "House prices,(un) affordability and systemic risk", *New Zealand Economic Papers,* 55 (1), pp. 105–123.

Pesaran, H. H. & Shin, Y. (1998), "Generalized impulse response analysis in linear multivariate models", *Economics letters,* 58 (1), pp. 17–29.

Pesaran, M. H., Schuermann, T. & Weiner, S. M. (2004), "Modeling regional interdependencies using a Global Error-correcting macroeconometric model", *Journal of Business & Economic Statistics,* 22 (2), pp. 129–162.

Plagborg-Møller, M. & Wolf, C. K. (2021), "Local projections and vars estimate the same impulse responses", *Econometrica,* 89 (2) pp. 955–980.

Reboredo, J. C. & Ugolini, A. (2015), "Systemic risk in european sovereign debt markets: A CoVaR-copula approach", *Journal of International Money and Finance,* 51, pp. 214–244.

Ricci-Risquete, A. & Ramajo-Hernández, J. (2015), "Macroeconomic effects of fiscal policy in the European Union: A GVAR model", *Empirical Economics,* 48 (4), pp. 1587–1617.

Rodríguez-Moreno, M. & Peña, J. I. (2013), "Systemic risk measures: The simpler the better?", *Journal of Banking & Finance,* 37 (6), pp. 1817–1831.

Romer, C. D. & Romer, D. H. (2004), "A new measure of monetary shocks: Derivation and implications", *American Economic Review,* 94 (4), pp. 1055–1084.

Sims, C. A. (1980), "Macroeconomics and reality", *Econometrica: Journal of the Econometric Society,* pp. 1–48.

Sims, C. A. (1992), "Interpreting the macroeconomic time series facts: The effects of monetary policy", *European Economic Review,* 36(5), pp. 975–1000.

Smith, V. & Galesi, A. (2017), "GVAR toolbox 2.0 user guide", CFAP & CIMF

Swanson, E. T. (2017), "Measuring the effects of federal reserve forward guidance and asset purchases on financial markets", *NBER Working Paper (No. 23311)*

Szczerbowicz, U. (2018), "The ECB unconventional monetary policies: have they lowered market borrowing costs for banks and governments?", *42th issue of the International Journal of Central Banking, December 2015*.

Vansteenkiste, I. & Hiebert, P. (2011), "Do house price developments spillover across Euro Area countries? Evidence from a Global VAR", *Journal of Housing Economics,* 20 (4), pp. 299–314.

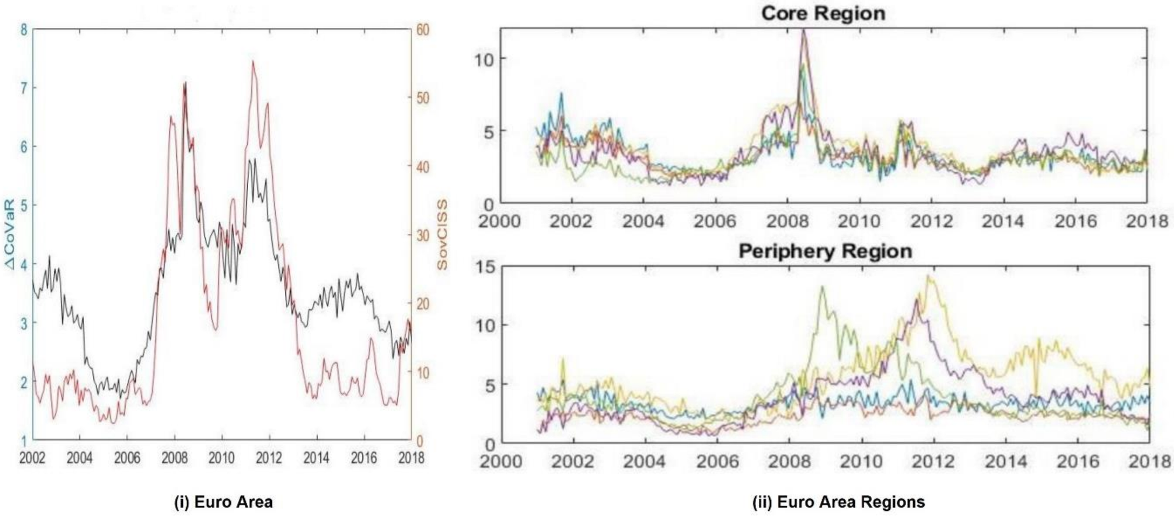
Varotto, S. & Zhao, L. (2018), "Systemic risk and bank size", *Journal of International Money and Finance,* 82, pp. 45–70.

Wu, J. C. & Xia, F. D. (2016), "Measuring the macroeconomic impact of monetary policy at the zero lower bound", *Journal of Money, Credit and Banking,* 48 (2-3), pp. 253–291.

Zlobins, A. (2020), "Macroeconomic effects of the ECB's forward guidance", *Empirical Economics,* pp. 1–25.

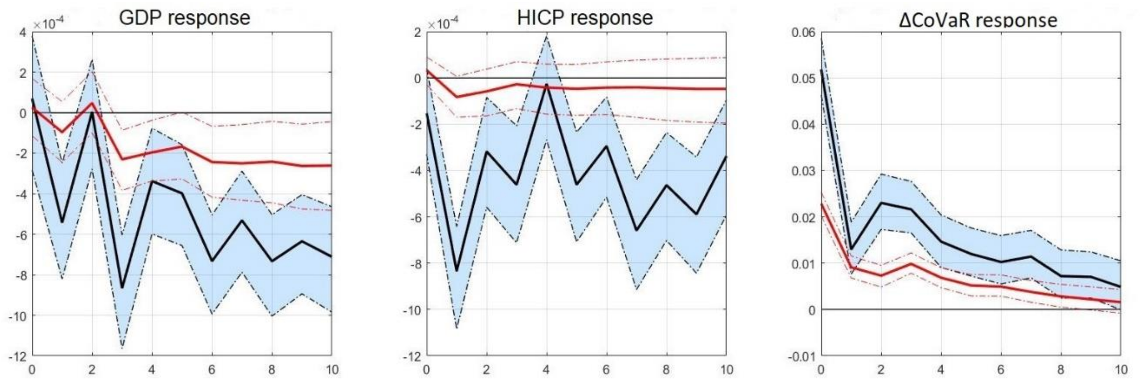
Figures & Tables

Figure 1: Systemic risk in the Euro Area



Note: The figure reports the systemic risk estimation for the Euro Area based on two alternative measures. The black line illustrates the ΔCoV aR country-level risk index and the red line, the SovCiss provided by ECB Statistical Data Warehouse. The examined period is 2001m1-2018m12. In (ii), we divide our sample of 10 Euro Area economies to two regions, namely Core and Periphery based on the systemic risk variation they exhibited in the examined time period.

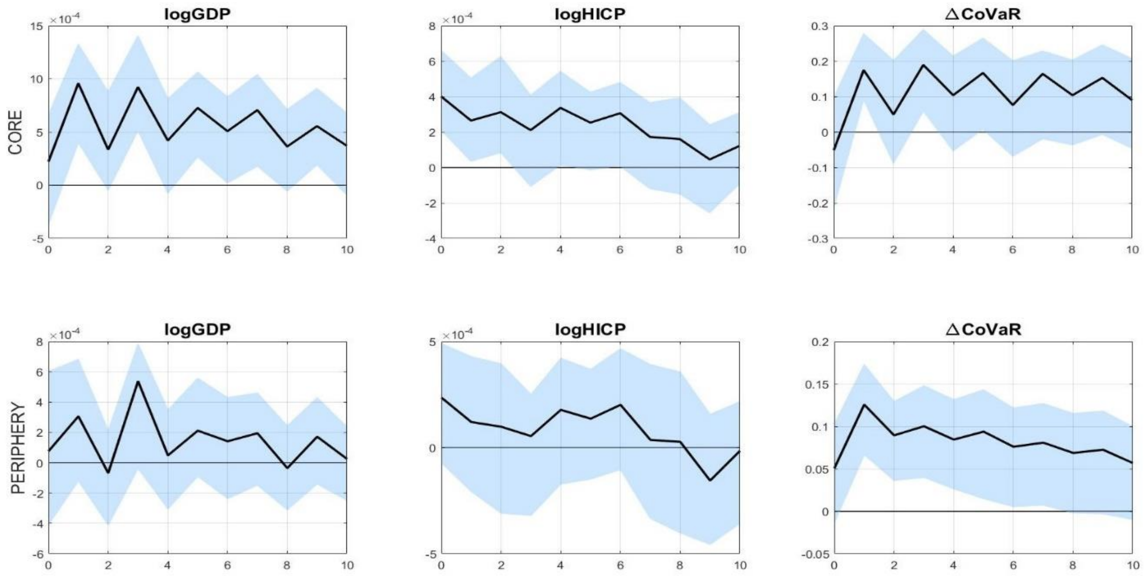
Figure 2: Euro Area systemic risk shock



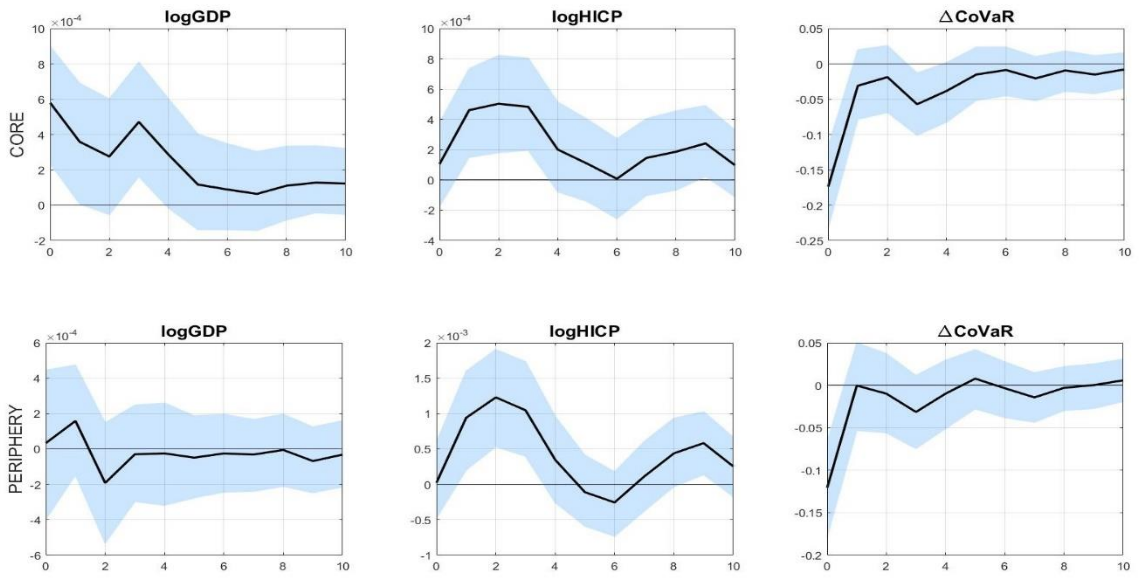
Note: The figure reports the SGIRFs of the Euro Area output, prices and systemic risk following a (positive) systemic risk shock. The identification strategy is based on the Cholesky decomposition. The lag selection is based on the Akaike information criterion (AIC). The shaded area represents the 68\% confidence level, which is based on 200 bootstrap iterations.

Figure 3: Monetary policy shock: Sub-period analysis

Period A: 2002-2008

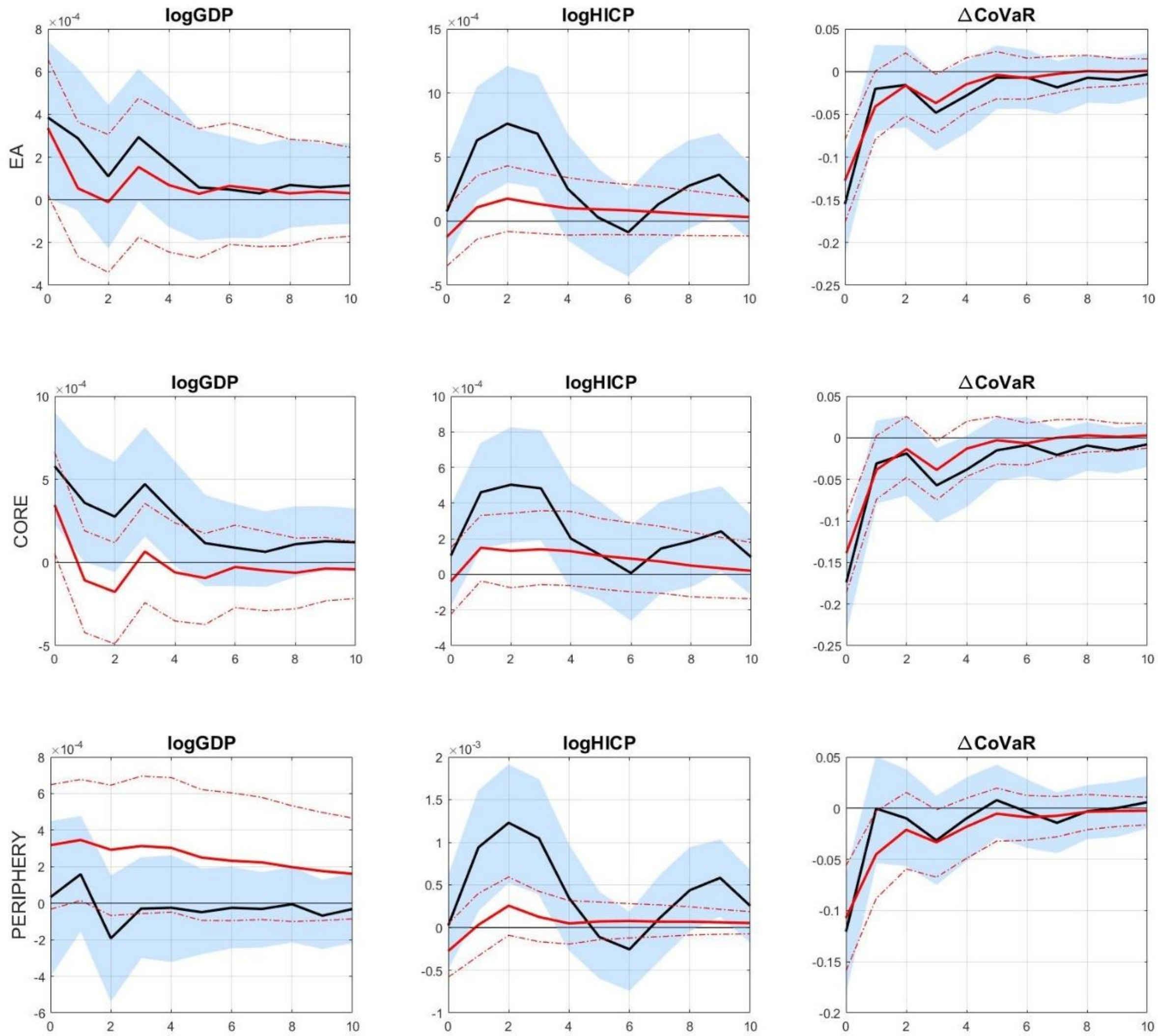


Period B: 2009-2018



Note: The figure reports the SGIRFs of output, prices and systemic risk following an expansionary monetary policy shock. The shock is defined as one s.e. decrease in the exogenous cumulative *target* surprises series provided by Altavilla et al. (2019) and the identification strategy is based on the Cholesky decomposition. The first two rows present the responses of thesub period 2002-2008 and the last two of the second sub-period until 2018. The lag selection is based on the Akaike information criterion (AIC). The shaded area represents the 68% confidence level, which is based on 200 bootstrap iterations.

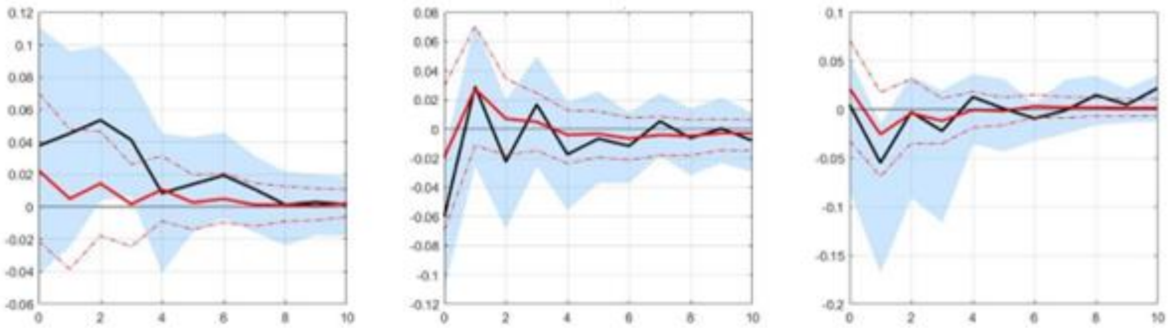
Figure 4: Monetary policy shock: Spillover effect



Note: The figure reports the SGIRFs of output, prices and systemic risk following an expansionary monetary policy shock. The shock is defined as one s.e. decrease in the exogenous cumulative *target* surprises series provided by Altavilla et al. (2019) and the identification strategy is based on the Cholesky decomposition. The black line stands for the benchmark model and the red line when we mute the cross-country spillovers. The responses include the aggregate Euro Area and two regions; core and periphery. The examined period is 2009m1-2018m9. The lag selection is based on the Akaike information criterion (AIC). The shaded area represents the 68\% confidence level, which is based on 200 bootstrap iterations.

Figure 5: Conference window surprises

A. Quantitative Easing (QE) B. Timing C. Forward Guidance (FG)



Note: The figure reports the SGIRFs of systemic risk following an expansionary monetary policy shock. The shock is defined as one s.e. decrease in the exogenous cumulative *target* surprises series provided by Altavilla et al. (2019) and the identification strategy is based on the Cholesky decomposition. Figure A refers to QE surprises followed by *timing* and *Forward Guidance* shocks. The examined period is 2014m1-2018m9. The lag selection is based on the Akaike information criterion (AIC). The shaded area represents the 68% confidence level, which is based on 200 bootstrap iterations.

Table 1: Country and regional systemic risk shocks

	ΔCoVaR			*SovCISS*		
Regional shocks	Euro Area	Core	Periphery	Euro Area	Core	Periphery
Core	3.32**	•	0.83**	2.04**	•	1.23**
Periphery	3.31**	3.52**	•	3.08**	2.34**	•
Country shocks	Euro Area	Core	Periphery	Euro Area	Core	Periphery
DEU	1.82**	3.10**	-0.36**	1.26**	1.77**	-0.30
FRA	2.19**	3.00**	0.73*	0.87**	1.42**	-0.10**
NLD	1.70**	2.51**	0.70*	1.06**	1.08**	1.03**
BEL	0.96**	1.23**	0.47*	0.81**	0.78**	0.87**
AUS	0.74**	0.94**	0.39*	0.62**	0.60**	0.67**
ITA	2.86**	2.96**	2.68**	2.74**	2.07**	4.06**
ESP	2.35**	2.84**	1.68**	2.07**	1.54**	3.25**
GRE	1.19**	1.32**	0.96**	0.90**	0.70**	1.26**
POR	0.70**	0.86**	0.49**	0.62**	0.48**	0.90**
IRE	1.50**	1.83**	0.94**	0.57**	0.45**	0.85**

Note: The table illustrates the (positive) peak regional SGIRF for systemic risk following an one standard error increase in the systemic risk at regional and country level. For the identification of the shock we apply the Cholesky decomposition with the ordering being GDP, Prices and systemic risk. For the vast majority of the cases, the impact of systemic risk is immediate and the peak response is being observed in the first period after the shock occurs. Notation of ** and * indicate statistically significant results at 90% and 68% respectively.

Appendix

A. ΔCoVaR methodology: *Static estimation*

Adrian & Brunnermeier (2016) developed the concept of *CoVaR* building on one of the most popular measures of a firm's risk is its value at risk, *VaR*. *CoVaR* captures the association between the risk of the overall financial sector and a particular institution's stress event.
The VaR_q of an institution *i* at q%, is defined by:

$$P\left(R^i \leq VaR_q^i\right) = q$$

where R^i stands for the return of institution *i*, and q denotes the estimated percentile. The paper by Adrian & Brunnermeier (2016) estimates firms' returns based on growth rates of market-valued total financial assets. In our approach since not all the financial firms provide high frequency data, the estimation is based only on Price and Market Capitalization data. The Conditional *VaR* (*CoVaR*) is, in turn, defined as the *VaR* of the financial system given that institution *i* is under distress.

The mathematical expression of the $CoVaR_q$ is:

$$P\left(R^s \leq CoVaR_q^{s|i} \mid R^i = VaR_q^i\right) = q$$

where $R^s$is the return of the financial system. The marginal contribution of a particular institution to the system's risk, Δ*CoVaR*, is computed by comparing the $CoVaR_q$ with the one in normal times, at the median (q = 0.5).

$$\Delta CoVaR_q^i = CoVaR_q^{s|R_i=VaR_q^i} - CoVaR_q^{s|R_i=R_{median}}$$

The estimation of the Δ*CoVaR* is done through quantile regressions.

The procedure is described in the following 3 steps:

1) Run the quantile regression: $R_t^s = a_q + b_q R_t^i + e_t$
2) Use the estimates of $a_q, b_q$to obtain: $CoVaR_q^{s|i} = \widehat{a_q} + \widehat{b_q} VaR_q^i$
3) Compute systemic risk: $\Delta CoVaR_q^{s|i} = CoVaR_q^{s|i} - CoVaR_{0.5}^{s|i}$

B. Adding time variation

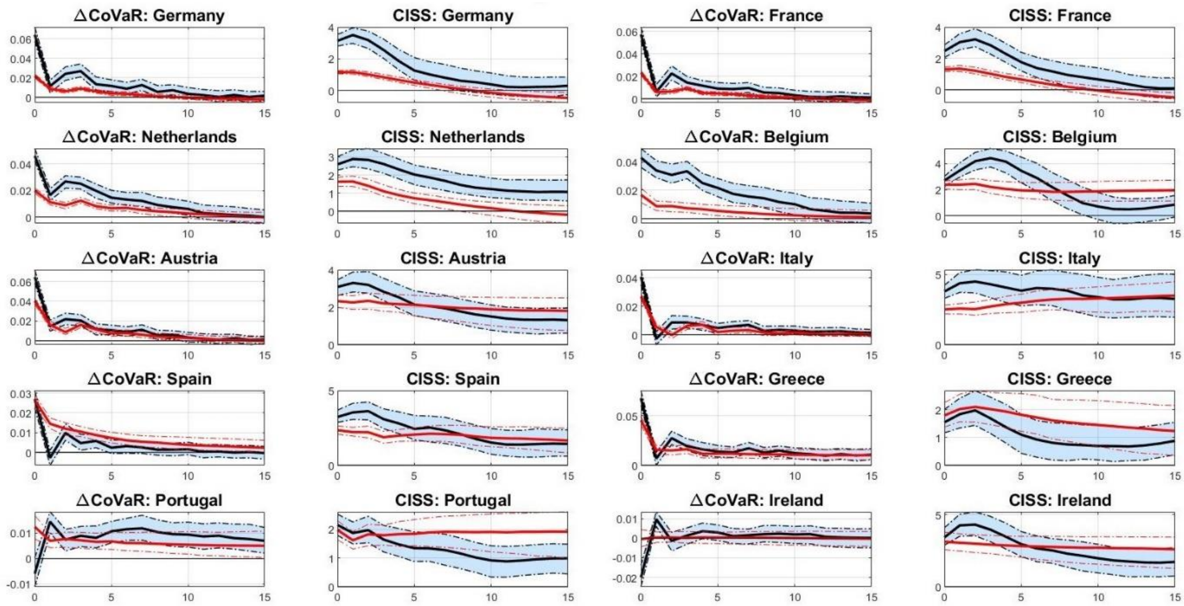
Following Adrian & Brunnermeier (2016), we allow the returns of the examined firms and of the sector as a whole to depend on a set of state variables, *St* . We note that these variables are not considered to be factors of systemic risk, but they are used because they can capture time variation in the conditional moments of the returns. These variables should be highly liquid and tractable and the choice of them depends on data availability. For our analysis we employ 4 variables: the term spread, the change in the 3 month interest rate, the difference between the government bond and EURIBOR and each country's stock market index (see Table A1).

The estimation procedure of the dynamic model for the $\Delta CoVaR$ is described by the following five steps:

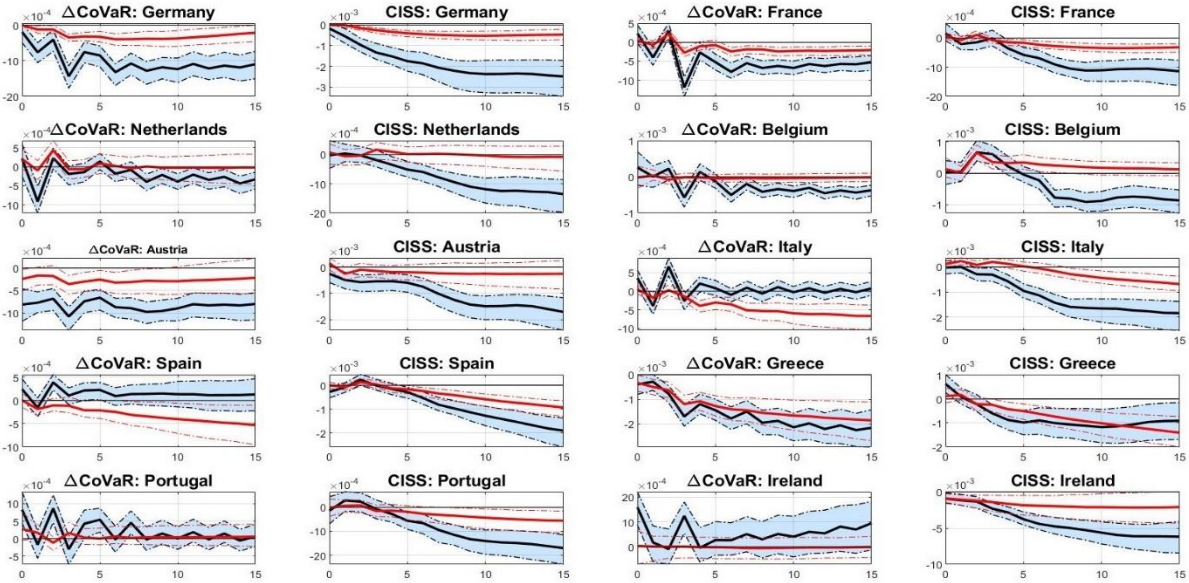
1) Run the quantile regression: $R_t^i = a_q + c_q S_{t-1}^i + e_t$
2) Use the estimates of a_q, c_q to obtain the dynamic $VaR_{q,t}^i = \widehat{a_q^i} + \widehat{c_q^i} S_{t-1}^i$
3) Run the quantile regression: $R_t^s = a_q^{s|i} + b_q^{s|i} R_t^i + c_q^{s|i} S_{t-1}^i + u_t$
4) Use the estimates of $a_q, b_q and\ c_q$ to obtain: $CoVaR_{q,t}^{s|i} = \widehat{a_q^{s|i}} + \widehat{b_q^{s|i}} VaR_{q,t}^i + \widehat{c_q^{s|i}} S_{t-1}^i$
5) Compute systemic risk: $\Delta CoVaR_{q,t}^{s|i} = CoVaR_{q,t}^{s|i} - CoVaR_{0.5,t}^{s|i}$

Figure A1: Euro Area systemic risk shock: Country responses

(a) Systemic risk responses



(b) GDP response



Note: The figure reports the SGIRFs of the Euro Area systemic risk (a) and output (b) following a (positive) systemic risk shock. The identification strategy is based on the Cholesky decomposition. The lag selection is based on the Akaike information criterion (AIC). The shaded area represents the 68% confidence level, which is based on 200 bootstrap iterations.

Table A1: Data Description

Variable series	Frequency	Source
Gross Domestic Product (GDP)	Quarterly	Eurostat
Industrial Production	Monthly	Fed of St. Louis
Harmonised Consumer Price Index (HCIP)	Monthly	Eurostat
Shadow rate	Monthly	Wu & Xia (2016)
High-Frequency Monetary Surprises	Monthly	Altavilla et al. (2019)
Sovereign Composite Systemic Stress Index	Monthly	Eurostat
Price & Market Capitalisation	Monthly	Thomson Reuters EIKON Datastream
State Variable		
3mo Government Bond	Monthly	Fed of St. Louis, Thomson Reuters EIKON Datastream and IMF
10y Government Bond	Monthly	Fed of St. Louis
EURIBOR	Monthly	Fed of St. Louis
Stock Market Index	Monthly	Thomson Reuters EIKON Datastream

Note: The table illustrates the sources of the economic and financial series used in the GVAR model estimation. We also report the state variables sources used for the systemic risk index estimation. For countries where the 3 month government bond is not available, we use alternatively the Datastream series: TR EURO GVT 3MO.

Table A2: Euro Area ΔCoVaR estimation: Data

	No.	MV (%)		No.	MV (%)
Banks	55	44.65%	Fin. Svs	81	13.52%
Insurers	25	26.05%	Real Estate	100	15.79%

Note: The table reports the data used to estimate the ΔCoVaR index. For that purpose, we collect Price and Market Capitalization data from Datastream for 261 active Euro Area financial firms. Data for 'dead' companies are not available, leading potentially to a survivorship bias. The sectoral division is based on Datastream reports. We observe that banks account for almost 45% of the Market Capitalization of the Euro Area financial system. We include firms that consists the (country) DS Financial sector as presented by the data source. The estimation period is 2001m1-2018m12.

Table A3: GVAR weights

	DEU	FRA	ITA	ESP	NLD	BEL	AUS	GRE	POR	IRE
DEU		0.37	0.35	0.32	0.31	0.30	0.29	0.29	0.29	0.29
FRA	0.31		0.27	0.25	0.24	0.23	0.23	0.22	0.22	0.22
ITA	0.25	0.22		0.20	019	0.18	0.18	0.18	0.18	0.18
ESP	0.16	0.15	0.14		013	0.12	0.12	0.12	0.12	0.12
NLD	0.10	0.09	0.08	0.08		0.07	0.07	0.07	0.07	0.07
BEL	0.06	0.05	0.05	0.04	0.04		0.04	0.04	0.04	0.04
AUS	0.05	0.04	0.04	0.04	0.03	0.03		0.03	0.03	0.03
GRE	0.03	0.03	0.03	0.03	0.03	0.02	0.02		0.02	0.02
POR	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02		0.02
IRE	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	

Note: The table illustrates the weights for the GVAR model. Each column illustrates the decomposition of the foreign variables matrix for the 10 Euro Area economies. The estimation is based on the average quarterly GDP data provided by Eurostat for the period 2001-2018.

Table A4: GVAR lag order selection

	Full Period	Period A	Period B	Foreign variables
DEU	3	3	3	1
FRA	3	3	3	1
ITA	4	3	4	1
ESP	3	4	2	1
NLD	4	4	2	1
BEL	3	3	3	1
AUS	3	1	1	1
GRE	3	3	3	1
POR	3	1	3	1
IRE	1	2	1	1

Note: The table reports the optimal lag selection for the GVAR model based on the Akaike information criterion (AIC) for the full time period (first column) and two sub-periods (second and third column). The last column stands for the lag of the foreign variables, which is set to be equal to 1 by construction in line with the GVAR literature.