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Yields on sovereign debt, fragmentation and monetary policy transmission in the euro area: A GVAR approach

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Abstract

The divergence in sovereign yields has been presented as a reason for the lack of traction of monetary policy. We use a GVAR framework to assess the transmission of monetary policy in the period 2005-2016. We identify sovereign yield divergence as a key mechanism by which the leverage channel of monetary policy worked. Unconventional monetary policy was successful in mitigating this effect. When exploring the channels through which yields may affect the heterogeneous transmission of monetary policy, we find that the reaction of bank leverage depended substantially on where the sovereign yield originated, thus providing a mechanism that explains this heterogeneity. Second, large spillover effects meant that yield divergence decreased the traction of monetary policy even in anchor countries. Third, the heterogeneity in the transmission mechanism can be in part attributed to contagion from euro area wide sovereign stress. Fiscal credibility, therefore, may be an appropriate tool to enhance the output effect of monetary policy. Given the importance of spillovers, this credibility may be achieved by changes in the institutional make-up and policies in the euro area.

Keywords: monetary policy, spillovers, euro area crisis

JEL clasificación: E52, E63, F45, H63

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1. Introduction

"Within our mandate, the ECB is ready to do whatever it takes to preserve the euro area. And believe me, it will be enough.

(…)

Then there's another dimension to this that has to do with the premia that are being charged on sovereign states borrowings. These premia have to do, as I said, with default, with liquidity, but they also have to do more and more with convertibility, with the risk of convertibility. Now to the extent that these premia do not have to do with factors inherent to my counterparty - they come into our mandate. They come within our remit.

To the extent that the size of these sovereign premia hampers the functioning of the monetary policy transmission channel, they come within our mandate" (Draghi, 2012).

These words by the President of the European Central Bank (ECB) meant a turning point in the euro area crisis. Sovereign spreads declined, and funding conditions started normalizing across the euro area (see Figure 1). As many authors have confirmed, this speech, and ulterior actions, in particular the implementation of the Outright Monetary Transactions (OMT), provided the basis to avoid the breakup of the euro area (Hodson, 2013; Acharya and Steffen, 2015).

[Insert Figure 1 around here]

We test the effects of financial market fragmentation in the euro area using a Global Vector Autoregression (GVAR) framework, allowing us to explicitly link the euro area and member countries keeping the number of estimated coefficients to a minimum, avoiding the curse of dimensionality traditionally associated to Vector Autoregression (VAR) estimations. The GVAR modelling approach provides a relatively simple yet effective way of modelling complex high-dimensional systems, allowing us to set up counterfactuals to test whether the rise in sovereign yields that hampered monetary policy transmission was due to a worsening of fundamentals or to spillover effects from other countries or to euro area-wide stress or, finally, perceptions of euro area credibility. Finally, the GVAR deals with country heterogeneities and allows for an assessment of asymmetries in the transmission of monetary policy shocks. As a result, we can shed light on the sort of changes to fiscal policy and institutions that can lead to a higher traction of monetary policy.

The divergence in sovereign yields is shown to play an important role in the transmission of monetary policy. Some authors have claimed that this divergence can be interpreted like currency regimes what lack credibility. In this context, sovereign spread were analogous to fluctuations in the exchange rate (Sosvilla-Rivero and Maroto, 2003). The implication is that the lack of credibility alone, without a worsening in fiscal fundamentals, can lead to a rise in sovereign spreads (see, e. g., Obstfeld, 1996; or Gómez-Puig and Sosvilla-Rivero, 2014). In fact, the peg may eventually break up.

One aspect that can accelerate the process is the fact that the rise in the interest rate on sovereign debt, in turn, can reduce the traction of monetary policy, as shown by Al-Eyd and Berkmen (2013) and Zoli (2013).

We find evidence that the rise in sovereign bond risk premia lowered the real effect of conventional monetary policy (CMP), and that the leverage channel was impaired as a result of the rise in these premia. This is in line with Goretti and Souto (2013), who provide evidence of this by showing that corporate lending was more affected by sovereign yields and unemployment than by developments in the Euribor.

We focus on the leverage channel of the transmission of monetary policy may be impaired in a context of sovereign stress. This channel has been shown to be a powerful transmission channel for monetary policy (see, Bernanke and Gertler, 1995; De Niccolo *et al.*, 2010; and Bruno and Shin, 2015, among others). Dellarricia *et al.* (2013) show that lower monetary policy rates lead banks to increase risk and so facilitate corporate indebtedness. This relationship is also found in Bauer and Granziera (2016). This is an avenue by which monetary policy stimulates output (with some caveats, like those explained in Bech and Malkhozov, 2016).

We show under which conditions this leverage channel may work in the euro area[1]. We find that, indeed, the leverage effect of monetary policy in the presence of tensions in the sovereign, is limited. Furthermore, strong real spillover effects across the euro area mean that yield convergence increases the output effect of CMP even in those countries where yields did not increase on the face of turmoil, such as Germany and, in general, core euro-area countries.

In this setting, we find an increased role for unconventional monetary policy (UMP), as it can have a higher effect on sovereign yields. Given the strong output effect of sovereign yields estimated, we show that UMP, by pushing down yields in countries, may have induced a greater output effect by enabling the leverage channel.

The results regarding the substantial yield effect of UMP has been shown by a number of studies for the United Kingdom and the United States. In general, yield effects can be shown to be quite substantial in the United States (Krisnamurthy and Vissing-Jorgensen, 2012), although the uncertainty around the estimated effects is large, probably owing to the differences in the methodology used (see Gagnon *et al.*, 2011; Christensen and Rudebusch, 2012, Bauer and Rudebusch, 2014)[2]. This result is in line with those reported in Ciccarelli *et al.* (2013), Giannone *et al.* (2012) and Gambacorta *el al (*2014), who find that UMP had substantial real effects. Our paper provides an explicit channel for the transmission of sovereign yields into output, and finds that the sovereign yield effect was also large in the euro area.

Our results add to the study of the interactions between fiscal and monetary policy go beyond the effect of fiscal fundamentals on sovereign debt premia, and so the transmission of monetary policy. As other authors have shown, sovereign debt premia

[1] See Angeloni *et al.* (2015) for evidence of the existence of a risk-taking channel in the United States, and Robstad (2017) for evidence for Norway.

[2] See also D'Amico *et al.* (2012), Bauer and Rudebusch (2014), Santor and Suchanek (2013), Bridges and Thomas (2012), Joyce *et al.* (2011), Goodhart and Ashworth (2012) or Churm *et al.* (2015) for estimation of the effects in the United Kingdom and the United States of the respective Quantitative Easing measures

react, fundamentally, to external effects.[3] Indeed, when we insulate country variables from euro area wide stress, we find that the output effect of CMP is somewhat larger. In other words, negative spillovers from euro area-wide stress account for the hindering of the pass through from monetary policy.

This suggests that improvements in domestic fundamentals would have been of limited use when facing euro-area wide stress. The solution must lie, therefore, in the improved design of the euro area, which would in turn help facilitate improved fiscal fundamentals. Indeed, to the extent that the worse transmission of monetary policy has an output cost, it may lead to a worsening of fiscal fundamentals, even if at the onset the fiscal position was healthy.

This paper is organized as follows. Section 2 presents the GVAR model employed in the empirical analysis. Section 3 describes the data used and explains the specification of the model. Section 4 reports our results. Finally, Section 5 summarizes the findings and offers some concluding remarks.

2. The GVAR model

The starting point for this GVAR model is, conceptually, the standard Christiano *et al.* (1999) monetary policy VAR, which includes output, inflation and a monetary policy variable. We augment the traditional monetary policy VAR first by setting up a GVAR framework based on Pesaran *et al.* (2004) and Dees *et al.* (2007). This framework allows consistent modeling of international interdependencies and transmission channels across countries and the evaluation of different economic policies in counterfactual analyses.

Figure 2 depicts a stylized graph of the structure of the GVAR model. As can be seen, the model consists of two blocks: (i) a system of 11 national VAR models in which cross-country interactions are explicitly modeled; and (ii) a VAR model for common factors which affect all euro area countries, for instance the ECB's monetary policy. Therefore, each country VAR has a set of domestic variables, foreign variables and global variables. These countries are consistently linked into a single multi-country model using weights relating to the international linkages of each country with the other countries in the sample. In this way, international interdependencies can be modeled in a transparent fashion and in a way that is both consistent with the theory and consistent with the data.

[Insert Figure 2 around here]

Each national economy i in the GVAR is represented by a VAR model that consists of a constant (c_i); a vector of domestic variables ($Y_{i,t}$), representing the domestic macroeconomic and financial conditions of the economy; a vector of foreign-specific and exogenous variables ($Y^*_{i,t}$), capturing the relative spillovers.; a vector of common variables ($Xi_{,t}$), such as monetary policy:

[3] See De santis (2014), Arghyrou and Kontonikas (2012), Antonakakis and Vergos (2013), Afonso *et al*. (2012), Beirne and Fratzscher (2013), Kalbaska and Gatkowski (2012) for different estimates of the sources of sovereign spreads. The consensus suggests, to varying degree, a substantial role for international determinants.

$$Y_{i,t} = c_i + \sum_{j=1}^{p_i} A_{ij} Y_{i,t-j} + \sum_{j=0}^{q_i} B_{ij} Y^*_{i,t-j} + \sum_{j=0}^{q_i} C_{ij} X_{t-j} + u_{it}$$

In order to avoid the curse of dimensionality, the key assumption of the GVAR model is that the foreign variables are treated as weakly exogenous and summarize developments in foreign countries and thereby reduce the number of parameters in each VAR model. In particular, the foreign variables are defined as the weighted average of the corresponding domestic variables of other countries:

$$Y^*_{i,t} = \sum_{j=1}^{N} w_{i,j} Y_{j,t} \qquad \text{with} \quad w_{i,i} = 0 \quad \forall i = 1, \ldots, N, \quad \sum_{j=1}^{N} \tilde{w}_{i,j} = 1$$

In this paper, the weights of the foreign variables are determined by the importance in trade flows of each of the countries with each other, as reported by the International Monetary Fund (IMF) direction of trade statistics. These foreign variables are assumed to be weakly exogenous. Since the GVAR model is designed to be used in applications with a large cross-sectional dimension, this exogeneity assumption can be interpreted as no long-run feedback from any individual country to the dynamics of the foreign factor.

As for the set of global exogenous variables (X), they follow the process

$$X_t = c_x + \sum_{j=1}^{p_X} D_j X_{t-j} + \sum_{j=1}^{q_X} F_j \tilde{Y}_{t-j} + u_{x,t}$$

where c_x is a vector of intercepts; D_j and F_j are matrices of coefficients, and the vector $\tilde{Y}_{i,t}$ is composed by weighted averages of all countries' domestic variables, being weights based on gross domestic product (GDP) shares.

As a result, the system can be expressed as follows

$$G_{i0} Y_{i,t} = c_i + \sum_{j=1}^{p_i} G_{ij} Y_{i,t-j} + \sum_{j=0}^{q_i} C_{ij} X_{t-j} + u_{it}$$

:

Once the model is solved, the dynamic properties are examined making use of impulse-response functions. In particular, we will use generalized impulse response functions (GIRF) proposed by Koop *et al.* (1996) and Pesaran and Shin (1998). The advantage of these is that the results are not sensitive to variable ordering. This is particularly important in a GVAR framework. While we may be able (and indeed willing) to impose exogeneity conditions on certain variables (such as the policy variable) within each country, we are agnostic in terms of which country is exogenous to others. As a result, we prefer the GIRF instead of the Ordinary Impulse Response Functions (OIRF) of Sims (1980). The estimated impulse responses can be thought of as the statistically most likely response following a shock to a variable in the system. However, we cannot give any structural interpretation to the shocks as they have not been identified as in the case of OIRF.

3. Data and specification of the model

3.1 Data

In our analysis we use monthly data covering the period January 2005- December 2015. Therefore, the sample period covers a first, relatively calm period, where the ECB monetary policy was mainly carried out through interest rates, and where, although access to finance may have been an issue at the individual level, it was not at a country level. In addition, our sample also covers episodes of turbulence: the Global Financial Crisis and the European Sovereign Debt Crisis. The final months of the sample, characterized by relatively easier financing conditions and subdued growth and inflation in the euro area, provide the ground for testing the different types of UMP.

Our sample includes the 11 out of the 12 founding euro area countries[4]: both central (Austria, Belgium, Finland, France, Germany, Luxemburg and the Netherlands) and peripheral countries (Greece, Italy, Portugal and Spain)[5].

We use several variables to describe monetary policy decisions. CMP is captured by the rate on MRO (Main Refinancing Operations), the ECB´s main instrument of CMP. As for the UMP, we use two variables: (i) balance sheet changes of the ECB, which have been shown to be an appropriate measure of the UMP (Boeckx *et al*., 2016), and (ii) the shadow interest rate for the euro area developed in Wu and Xia (2016). The latter is used because forward guidance and other aspects may have induced a relaxation of financial conditions that are not captured by the size of the balance sheet. One way to measure all th e aspects of UMP is by using yield curve models to measure the amount of easing carried out by the central bank, and so assigning a level of the short term rate (and so shadow rate) consistent with those unconventional policies.

In terms of the real variables, we follow the Christiano *et al.* (1999) and subsequent models, and the base is provided by output, inflation and the monetary policy variables. Output is taken as real GDP as reported by Eurostat. Give that GDP is at quarterly frequency, we construct a monthly measure of real GDP using interpolation procedure proposed by Chow and Lin (1971), where monthly industrial production and the volume of sales in wholesale and retail trade are the reference series.. Regarding inflation, we use the rate of inflation measured by the Harmonised Index of Consumer Prices (HICP),

[4] Ireland is not included in our sample because Eurostat only reports corporate leverage data for this country from 2012.

[5] This distinction between European central and peripheral countries has been used extensively in the empirical literature. The two groups we consider roughly correspond to the distinction made by the European Commission (1995) between those countries whose currencies continuously participated in the European Exchange Rate Mechanism (ERM) from its inception and which maintained broadly stable bilateral exchange rates with each other over the sample period, and those countries whose currencies either entered the ERM later or suspended their participation in the ERM, as well as fluctuating widely in value relative to the Deutschmark. These two groups are also roughly the ones found in Jacquemin and Sapir (1996), who applied multivariate analysis techniques to a wide set of structural and macroeconomic indicators, to form a homogeneous group of countries. Moreover, these two groups are basically the same as the ones found in Ledesma-Rodríguez *et al.* (2005) according to economic agents' perceptions of the commitment to maintain the exchange rate around a central parity in the ERM, and those identified by Sosvilla-Rivero and Morales-Zumaquero (2012) using cluster analysis when analysing permanent and transitory volatilities of EMU sovereign yields.

employed by the ECB in its quantitative definition of price stability and calculated with data reported by Eurostat.

In our case, we focus on the effect from financial fragmentation: its origins, its effects and its role in the transmission of monetary policy. In our model, therefore, we include 10-year sovereign bond yields and corporate leverage in each of the euro area countries. The former is a indication of the degree of financial frictions in the euro area (see Mayordomo *et al.*, 2015 or Zoli, 2013), while the latter provides a channel of the transmission of monetary policy (see Bech and Malkhoroz, 2016) and one that is particularly sensible to financial tensions and potential lack of credibility of the euro area. Finally, we include a measure of euro area turmoil in financial markets: a composite indicator of systemic stress (CISS) calculated and published by the ECB (see, Holló et al., 2012).

Appendix 1 summarizes the variables employed in the GVAR and data sources.

3.2. Specification of the model

We impose no further restrictions other than exogeneity of the monetary policy variable with respect to the various other variables employed in the model. This is a more agnostic scheme than that of Burriel and Galesi (2016), or other papers, which impose certain effects for these monetary policy variables, but in line for instance with Ciccarelli *et al.* (2013). To the extent that our purpose is to understand the effect of monetary policy, we prefer to keep the shock identification procedure as agnostic as possible. The only restriction we impose deals with the type of monetary policy shock, so as to guarantee that we isolate the effect from a certain type of monetary policy. We impose, in each case, that they are the only monetary policy shock used.

Second, we run an exercise with restrictions and one where each country is isolated from euro-area wide turmoil. In the first case, this is done by imposing the restriction that all sovereign yields equal that of Germany. This exploration is designed to assess the dynamic properties of the global model if the investors had not priced in the default risk in the periphery. In other words, we are interested in evaluating a counterfactual scenario for the euro area under full credibility throughout the period.

Third, a slightly less extreme assumption deals with the effect of euro area turmoil. Therefore, we impose a 0 coefficient on the term of euro area turmoil (the CISS). Doing so, we block the effect completely, for all countries and all variables. This is meant to capture the impact of a decline in credibility in the euro area. However, we still allow for contagion across euro area. Spillovers, which are shown to be significant, can still be present across countries.

In order to investigate the responses of variables to different shocks, we compute impulse response functions and discuss their impact.

4. Results

4.1. Estimation

Due to the large amount of coefficients of the GVAR, the direct estimation is practically unfeasible with standard techniques. To overcome the curse of dimensionality, we conduct the estimation of the model on a country-by-country basis. First, we estimate each country-specific model under the assumption that foreign-specific and common factors are weakly exogenous. Then, we estimate the model for the common factors, taking into account that the feedback variables $\tilde{Y}_t$ are predetermined as they enter with a lag.

The econometric specification, based on using four lags, seems appropriate. Autocorrelation tests reject the presence of autocorrelation in the GVAR residuals, confirming that the model captures the persistence of the data.

We undertake unit root tests to be sure the all the variables in the model have the same order of integration. As can be seen in Table 1, all variables are integrated of order 1. We also test for cointegration tests prior to calculating the corresponding long run relationships.

[Insert Table 1 around here]

Finally, we test the weak exogeneity assumption, which, as mentioned before, is essential to solve the GVAR model. Results in Table 2 confirm weak exogeneity for each of the variables that enter each country equation, suggesting that we can carry out the impulse response analysis with plausible assurances. We follow Belke and Osowsly (2016) and exclude the foreign variables for which the weak exogeneity in those countries for which the test fails, which mainly involve Germany.

[Insert Table 2 around here]

4.2. Effects of conventional monetary policy

In order to investigate the responses of variables to identified shocks, we compute impulse response functions and discuss their impact.

Figure 3 plots the impulse responses on output to an exogenous, 1% increase, in the monetary policy rate at the euro area level, while Figure 4 shows the effects of the CMP shock at the country level. As can be seen, during the period analyzed, CMP was barely effective in raising output on average. The coefficients shown are in line with other papers that study the heterogeneous transmission of monetary policy, and the country ordering is line with the results from other GVAR studies. Countries like Austria or Belgium show relatively high passthrough, whereas Spain and Greece, for instance, are at the bottom of the spectrum. In some cases, the sign is different than what would be expected. This result is consistent with that of Burriel and Galesi (2015) and Georgiadis (2015). These authors attribute the higher pass through of monetary policy in these countries to better bank capitalization and better institutions, as shown in higher spots on rankings like ease of doing business.

[Insert Figures 3 and 4 around here]

Second, we find that the leverage channel was impaired during the period. In particular, the effect of a CMP shock is rarely significant, and we only find it is only significant at the 5% level in Austria (as shown Figures 5 and 6). These results are consistent with the activation of the risk taking channel during times of stress (Dell'Aariccia *et al.*, 2013). It would be consistent with the result that banks in stress time tend to take less risk when rate decrease. In turn, the loosening in monetary conditions is not passed on to businesses. This tends to be the case when borrowing is constraint.

[Insert Figures 5 and 6 around here]

Next, we examine the relationship between the leverage effect and the GDP effect. We find some evidence of a positive relationship between leverage and GDP, as shown by the scatterplot in Figure 7. In other words, in those countries where leverage reacted more normally, we see more of an increase in GDP. This suggests that, even if the impulse response of GDP to leverage is heterogeneous across countries, the sign is usually positive and that the impairment of leverage, in turn, reduced the output effect of monetary policy.

[Insert Figure 7 around here]

In order to further investigate the role of sovereign constraints on leverage, we look at the effect of changes in sovereign bond yields on leverage. The higher the response depicted in Figure 8, the more binding sovereign yields become for firms decisions. This would suggest that, on the face of rising yields, leverage has to adjust. As expected, we find that the highest effects are detected in the peripheral countries. The implication is that the leverage channel of monetary policy, which we have shown to be heterogeneous across the euro area, was affected by developments in sovereign yields in the periphery. The estimated coefficients suggest that a rise of about 130 basis points in yields, such as the one that took place between pre crisis levels and the average in the period 2012-2013, would have induced a decline in leverage of about 3.5% of GDP in Italy (higher than in other studies in the literature, such as Iturriaga, 2000). The fact that this coefficient in higher in the periphery suggests that in safe assets, leverage is largely unconstraint (and also does not benefit) from swings in sovereign yields. However, it does seem to work in the periphery.

[Insert Figure 8 around here]

This is, in our view, evidence that financial fragmentation had real effects in the different countries within the euro area. This interpretation of the sensitivity of bank leverage to sovereign yields in stressed countries is consistent with the view of Acharya and Steffen (2015) and others that document how sovereign risk was passed on to bank funding conditions. It is also consistent with theory: in the presence of credit constraints, output is more sensitive to changes in the sovereign yield. The high transmission between sovereign and other borrowers instills the development of a `diabolic loop' (see, e. g., Brunnermeier *et al.*, 2011; and Reichlin, 2013. A collateral effect is that unless monetary policy can alter sovereign yields, the leverage effect will be limited.

In order to further test this hypothesis, we run the GVAR model as described above, but we impose an over-identifying restriction: all sovereign yields in the euro area are equal to that of Germany. By imposing that restriction, we intend to understand how monetary policy would have worked, had there been full credibility, which in turn would have led to lower sovereign bond yield spreads.

We find that the output effects increase in all countries, as shown in Figure 4. What is interesting, is that the increase in the output effects are not always larger in the periphery than in the core. Similarly, when wee study the transmission through corporate leverage, we find a much higher effect in all countries (see Figure 9). And even though some of the greatest beneficiaries are in the periphery (like Greece and Italy), we also find that other countries benefitted.

[Insert Figure 9 around here]

The fact that imposing yield equalization increases the output effect of monetary policy on all euro area countries, including the anchor countries for yields (in this case, Germany), suggests that spillover effects are substantial. Indeed, our estimates suggest that almost half the output effect on Germany can be attributed to spillovers. As one would expect, in particular in the case of Germany, the spillovers on leverage are much smaller. In fact yield equalization leads to decrease in the leverage effect of monetary policy. Therefore, the output effect is greater than the yield effect, on account of the larger spillovers in the former than in the latter.

In order to gain further insight into the drivers of this heterogeneity, we set out to control for different sources of increases in sovereign spreads. In particular, while we have seen that there are substantial positive spillover effects, we want to study the impact of negative spillovers from euro-area wide stress.

The implications are important, in particular when we show the appropriate policy response. Indeed, if the rise in sovereign stress and so the malfunctioning of the leverage channel is due to worsening fundamentals, the appropriate policy could be to improve those fundamentals. If the contrary is true, and the lack of traction of monetary policy stems from the contagion of euro area wide stress, then the appropriate policy might be dealing with the transmission of shocks across the euro area, by strengthening the monetary union.

We implement this exploration by setting the coefficient of euro area wide stress to 0 in all the country equations. This amounts to assuming that countries would be insulated to such stress, and so that country equations will only evolve through own factors and those of other countries.

This imposition introduces higher output effects, in particular in countries in the periphery. In fact, in countries like Spain or Portugal, the output effect would have been greater in this scenario that in the one with yield equalization (panel A in Figure 10). This suggests that the spillovers from euro-area wide stress were so large in these countries (both real and financial) that their elimination would have introduced very high output effects.

However, the leverage channel (panel B of Figure 10) would have not worked in many countries. This shows, therefore, that at least part of the lack of traction of monetary policy in the euro area can be explained by euro area wide specific factors. Had there been no contagion from these factors to the periphery, the effects would have been lower.

However, the impairment in leverage channel can only be attributed to this in some specific countries.

[Insert Figure 10 around here]

The peak responses estimated are in line with those in the literature for the period of heightened tensions for those studies that impose few restrictions of the effect of the shocks (which themselves are wide ranging, see for instance Uhlig, 2005). In particular they are lower than the usual effects found in the literature, but in line with those that for instance Ciccarelli *et al.* (2013) find when there are credit frictions. However, the increased traction when there is no divergence in sovereign rate is somewhat higher, although not as high the output effects of CMP in normal times, such as the coefficients in Ciccarelli *et al.* (2013) when they eliminate the effect of credit frictions.

4.3. Effects of unconventional policies

UMP can be characterized in two different ways. First, we can use an instrument based characterization. This can be done using the size of the balance sheet, as done in papers like Boeckx *et al.* (2016).

However, this is only a partial way of capturing the effect. Communication has become an essential instrument of monetary policy. The effect of forward guidance or other factors is essential. Indeed, the quintessential monetary policy decision taken in the period analyzed is Draghi´s July 2012 speech and the subsequent introduction of the OMT, which have not involved a change in the size of the balance sheet. We, therefore, want to include a measure of UMP that takes account of these policies. In order to do this, we use the shadow ECB rate as measured by Wu Xia (2016). They measure the degree of accommodation even if the policy rate does not move and the shadow policy rate that would be consistent with that degree of accommodation in financing conditions.

Indeed, we find that it had a positive effect on yields in the periphery, as well as in the core, and have a substantially higher yield effect than CMP, as shown in Figures 11 and 12. Note that some of the largest beneficiaries were countries in the periphery, although not always. In particular, the lack of traction in the case of Portugal can be explained by specific aspects. In fact, Portugal did not access markets while on a bailout, thus making its sovereign bond market less liquid and so, possibly, less responsive to factors that affected other countries. On average, UMP had more effect on these longer term yields.

[Insert Figures 11 and 12 around here]

Given that our previous results show that sovereign yields are a key transmission mechanism for monetary policy, this would suggest that UMP had a positive output effect (Figure 13). A key avenue for monetary policy, therefore, is that it has traction to reduce sovereign spreads. This suggests that policy measures that have been successful in this regard will have a substantially positive effect on output, although they were more so in the core. This result is consistent with the finding in Burriel and Galesi (2016). However, the incremental effect on output would be even larger.

[Insert Figure 13 around here]

Note that the effect is heterogeneous, more so than in normal times. We find that the countries that benefitted most from Wu and Xia (2016)'s shadow interest rate shocks were those that had a higher impact on sovereign yields from shadow interest rate shocks, supporting the importance of this channel in countries where leverage was constraint. However, the leverage channel remained impaired, as shown by the little effect of Wu Xia shocks on corporate leverage shown in Figure 14 and 15.

[Insert Figures 14 and 15 around here]

Indeed, yield equalization with Germany would have also led to higher output effects of UMP, helped by large output effects shown in Figure 16. This result suggests that, even though UMP was effective in lowering sovereign yields and so fostering output growth, it would have been even more effective if there had been a full passthrough from sovereign yields in Germany to those in other countries.

[Insert Figure 16 around here]

5. Concluding remarks

We make use of a GVAR framework to assess the transmission of monetary policy in the period 2005-2016, modelling the cross-country interactions through which shocks propagate.

We show how sovereign yields played an essential role in the transmission of monetary policy in the different euro area countries. This is consistent with the existence of friction in some countries, which limited the ability of agents to access financial markets and so benefit from the decline in yields.

The GVAR framework provides a link between the leverage and risk-taking channel and the credibility of the euro area. While better own country fundamentals maybe of use in the transmission of monetary policy, the spillover effects from elsewhere in the euro area are substantial. This is especially true in the periphery, where the impairment of the leverage channel had real effects and was related to the divergence in sovereign yields.

UMP can be viewed as a way of addressing those concerns that led to the divergence in sovereign yields. The results in this paper also shows that the need for these measures are related to the vagaries of conducting monetary policy in an imperfect monetary union. The rise in sovereign spreads hampers monetary policy and so has an output cost. This, in turn, places a greater burden on monetary policy, thus rendering the achievement of its objectives more difficult.

Our paper thus holds lessons regarding the interaction of fiscal policy and monetary policy. To the extent that sovereign spreads are costly, the policy and institutional design that limits those spreads is welcome. Market pricing of a sustainable debt (through lower sovereign yield spreads) can have added punch for growth: by reducing the sovereign spreads, it can help monetary policy have higher traction, and so increase the output overall.

Our results suggest that the reduction in sovereign spreads is not merely related to country-specific factors that determine the fiscal health of a country. Pass-through from other countries and from euro area-wide stress also plays a role. In that arena, a better functioning of the euro area and a better management of asymmetric shocks plays a crucial role. Our results confirm the finding in Corsetti *et al.* (2016) that OMT lowered the perception that sovereigns could default, thus decreasing funding costs. In their paper, the zero lower bound highlights the need for active fiscal policy to stabilize output. Our paper suggests that the current design of the euro area makes that need all the more urgent. By warranting further action from the central bank, sovereign debt premia make the zero lower bound more binding. Stabilization, therefore, can be achieved in two ways: stronger fiscal policy, or institutional arrangements that instill higher credibility on the euro area and so lower sovereign spreads.

Finally, our results are consistent with other recent studies (De Santis and Stein, 2016; Ehrmann and Fratzscher, 2017) highlighting the hypothesis of possible fragmentation on the European bond markets during the crisis.

We consider that the results presented in this paper should be of value to macro prudential and monetary policymakers trying to influence the transmission mechanism of monetary policy and to enhance the stability of the economic system.

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Appendix 1: Description of variables in the GVAR and data sources

Variable	Description	Source
Real growth rate	Year-on-year rate of growth of real GDP	Eurostat
HICP inflation	Year-on-year rate of growth of Harmonized Index of Consumer Price (HICP)	Eurostat
Corporate leverage	Non-Financial Corporate debt to GDP ratio	Eurostat
ECB total assets	Year-on-year rate of growth of ECB total assets	ECB Statistical Data Warehouse
MRO rate	Interest rate on marginal refinancing operations (MRO)	ECB Statistical Data Warehouse
CISS index	Index of Composite Index of Systemic Stress as developed in Holló *et al*. (2012)	ECB Statistical Data Warehouse
Shadow interest rate	ECB shadow rate computed by Wu and Xia (2016)	https://sites.google.com/site/jingcynthiawu/home/wu-xia-shadow-rates
Sovereign bond yields	10-year sovereign bond yields	Bloomberg

Table 1: Unit root test

Unit Root Tests for the Domestic Variables at the 5% Significance Level

Domestic Variables	Statistic	Critical Value	GERMANY	SPAIN	AUSTRIA	BELGIUM	FRANCE	ITALY	FINLAND	GREECE	PORTUGAL	NETHERLANDS	LUXEMBOURG
nfclever (with trend)	ADF	-3.45	-0.7	-2.9	3.4	-3.2	-3.0	-2.9	-0.4	-2.8	-3.1	-3.7 *	-2.1
nfclever (with trend)	WS	-3.24	-1.3	-3.0	1.1	-2.6	-2.6	-3.0	-1.0	-2.7	-3.3 *	-3.9 *	-2.2
nfclever (no trend)	ADF	-2.89	-1.6	-2.9 *	4.3	-3.4 *	-2.9 *	-2.9 *	0.6	-2.7	-2.9 *	-2.0	-2.2
nfclever (no trend)	WS	-2.55	0.1	-3.0 *	2.5	-2.2	-2.7 *	-2.9 *	-0.1	-2.7 *	-3.2 *	-1.8	-0.7
Dnfclever	ADF	-2.89	-4.1 *	-3.2 *	-2.2	-3.6 *	-2.9	-2.8	-3.7 *	-3.8 *	-4.1 *	-3.3 *	-3.4 *
Dnfclever	WS	-2.55	-4.3 *	-3.5 *	-2.4	-3.6 *	-3.1 *	-3.1 *	-3.9 *	-4.0 *	-4.3 *	-3.5 *	-3.6 *
DDnfclever	ADF	-2.89	-9.7 *	-10.5 *	-10.8 *	-6.3 *	-8.8 *	-9.7 *	-13.0 *	-7.8 *	-10.2 *	-9.9 *	-9.1 *
DDnfclever	WS	-2.55	-9.9 *	-10.7 *	-11.0 *	-6.5 *	-8.9 *	-10.0 *	-13.3 *	-8.0 *	-10.4 *	-10.2 *	-9.3 *
y (with trend)	ADF	-3.45	-3.7 *	-3.0	-1.7	-2.6	-2.7	-3.1	-3.8 *	-3.2	-3.0	-3.0	-2.3
y (with trend)	WS	-3.24	-3.4 *	-3.0	-1.3	-1.3	-2.5	-3.0	-3.2	-3.1	-2.2	-2.7	-2.0
y (no trend)	ADF	-2.89	-2.2	-2.0	-1.7	-0.6	-2.3	-2.2	-1.8	-1.6	-2.9 *	-2.2	-1.4
y (no trend)	WS	-2.55	-0.9	-1.1	-1.5	-1.1	-2.5	-1.1	-2.1	-0.6	-1.1	-0.8	-1.7
Dy	ADF	-2.89	-2.8	-3.5 *	-3.2 *	-2.3	-2.1	-3.0 *	-2.7	-2.5	-2.7	-2.6	-2.8
Dy	WS	-2.55	-2.9 *	-3.7 *	-3.4 *	-2.5	-2.2	-3.2 *	-2.8 *	-2.8 *	-3.0 *	-2.9 *	-3.0 *
DDy	ADF	-2.89	-7.4 *	-7.8 *	-12.2 *	-12.4 *	-5.1 *	-7.4 *	-7.5 *	-11.1 *	-8.6 *	-9.8 *	-8.4 *
DDy	WS	-2.55	-7.5 *	-8.0 *	-12.5 *	-12.7 *	-4.1 *	-7.6 *	-7.5 *	-11.3 *	-8.7 *	-9.9 *	-8.6 *
sov (with trend)	ADF	-3.45	-1.9	-1.3	-2.3	-2.0	-1.0	-2.1	-1.4	-1.7	-2.0	-1.1	-2.3
sov (with trend)	WS	-3.24	-1.7	-1.3	-2.1	-1.7	-1.3	-2.0	-1.7	-1.9	-1.8	-1.5	-2.1
sov (no trend)	ADF	-2.89	-0.4	-0.2	-0.6	-0.4	-1.5	-0.6	-1.5	-1.9	-0.4	-1.5	-0.6
sov (no trend)	WS	-2.55	-0.7	-0.6	-0.9	-0.7	-1.6	-0.9	-1.7	-2.0	-0.8	-1.6	-0.9
Dsov	ADF	-2.89	-8.0 *	-9.3 *	-7.5 *	-8.1 *	-8.4 *	-8.0 *	-4.0 *	-8.2 *	-8.3 *	-6.4 *	-7.5 *
Dsov	WS	-2.55	-8.2 *	-9.4 *	-7.6 *	-8.3 *	-8.6 *	-8.1 *	-4.2 *	-8.4 *	-8.5 *	-6.5 *	-7.6 *
DDsov	ADF	-2.89	-10.7 *	-9.5 *	-10.4 *	-11.1 *	-9.0 *	-11.5 *	-8.5 *	-8.6 *	-12.1 *	-8.3 *	-10.4 *
DDsov	WS	-2.55	-10.8 *	-9.7 *	-10.5 *	-11.2 *	-9.2 *	-11.6 *	-8.8 *	-8.8 *	-12.3 *	-8.5 *	-10.5 *
sov (with trend)	ADF	-3.45	-1.6	-1.2	-2.1	-1.7	-3.4	-2.0	-3.4	-3.5 *	-3.4	-3.6 *	-3.0
sov (with trend)	WS	-3.24	-1.6	-1.4	-1.9	-1.6	-3.5 *	-2.0	-3.0	-2.8	-3.4 *	-3.7 *	-2.8
sov (no trend)	ADF	-2.89	-0.6	-1.7	-0.8	-0.6	-1.8	-1.1	-1.5	-1.1	-1.9	-3.3 *	-1.2
sov (no trend)	WS	-2.55	-1.0	-1.9	-1.1	-1.0	-1.9	-1.4	-1.7	-1.4	-2.1	-3.5 *	-1.2
Dsov	ADF	-2.89	-7.2 *	-8.6 *	-6.5 *	-7.3 *	-7.3 *	-7.2 *	-6.0 *	-8.0 *	-5.2 *	-6.5 *	-6.4 *
Dsov	WS	-2.55	-7.4 *	-8.8 *	-6.7 *	-7.5 *	-7.5 *	-7.3 *	-3.8 *	-6.8 *	-4.1 *	-6.6 *	-5.2 *
DDsov	ADF	-2.89	-9.4 *	-11.7 *	-9.0 *	-9.7 *	-7.9 *	-10.3 *	-9.0 *	-8.4 *	-8.6 *	-9.9 *	-8.1 *
DDsov	WS	-2.55	-9.6 *	-11.9 *	-9.1 *	-9.8 *	-8.0 *	-10.4 *	-7.9 *	-7.6 *	-8.4 *	-10.1 *	-8.1 *

Notes:

D indicates first differences, while DD indicates second differences.

ADF stands for Augmented Dickey Fuller and WS for Weighted-Symmetric Dickey Fuller test.

* indicates rejection at the 5% level.

Table 2: Weak exogeneity tests

Test for Weak Exogeneity at the 5% Significance Level

Country	F test	Fcrit_0.05	rs	levers	ys	sovs	wuxia	ciss
GERMANY	F(1,66)	3.99	1.54	0.40	2.90	0.47		
SPAIN	F(1,75)	3.97	0.87	3.22	2.87	0.04	0.49	0.09
AUSTRIA	F(1,75)	3.97	0.19	4.47	0.37	0.66	1.94	1.63
BELGIUM	F(1,75)	3.97	1.29	4.12	3.05	0.04	1.99	0.45
FRANCE	F(1,75)	3.97	2.33	0.06	0.55	1.26	0.00	0.68
ITALY	F(1,75)	3.97	1.29	3.75	1.06	0.32	0.03	0.00

Figure 1: Sovereign yields in the euro area, 2005-2016

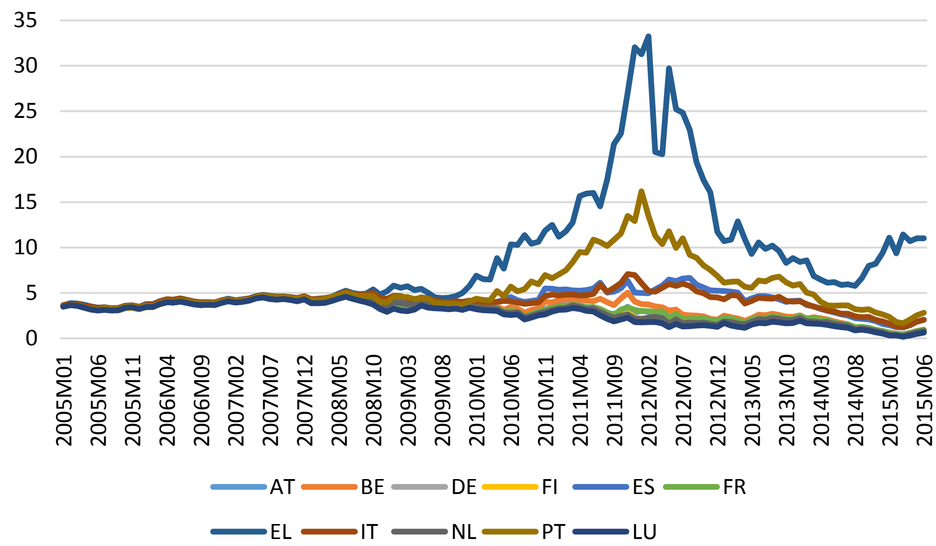


Figure 2: Structure of the GVAR model

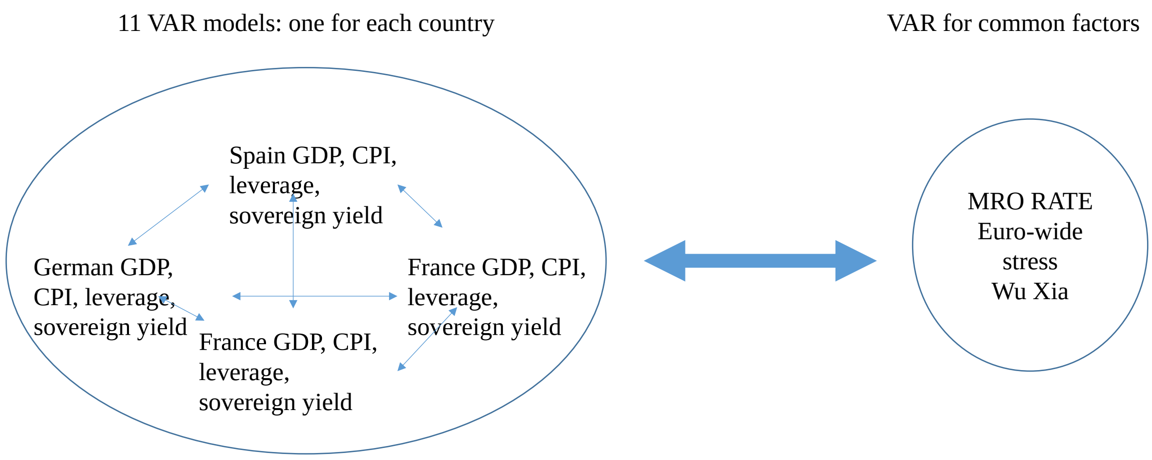
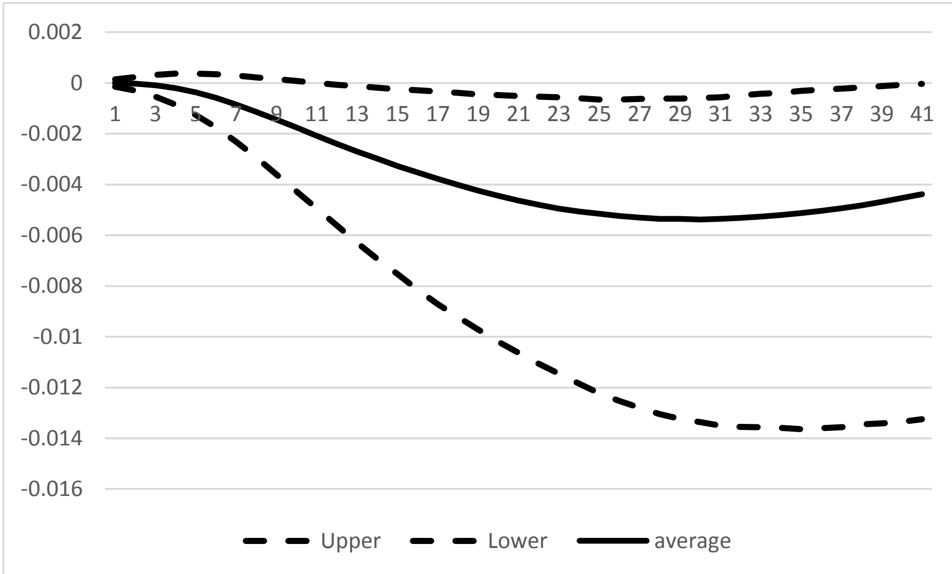
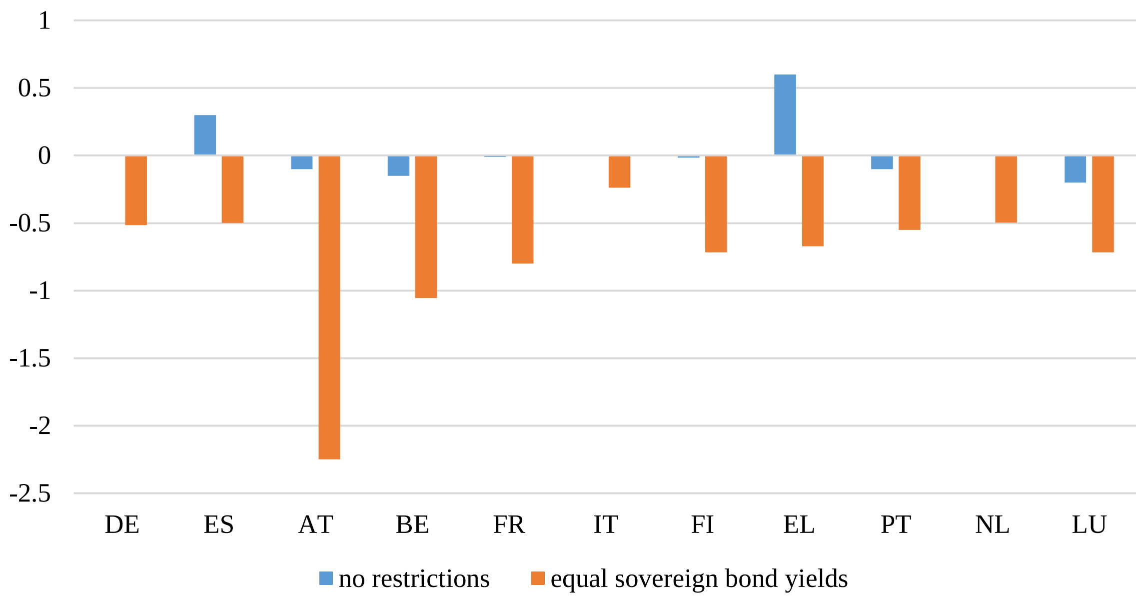


Figure 3. 1% shock of conventional monetary policy. Euro area average response



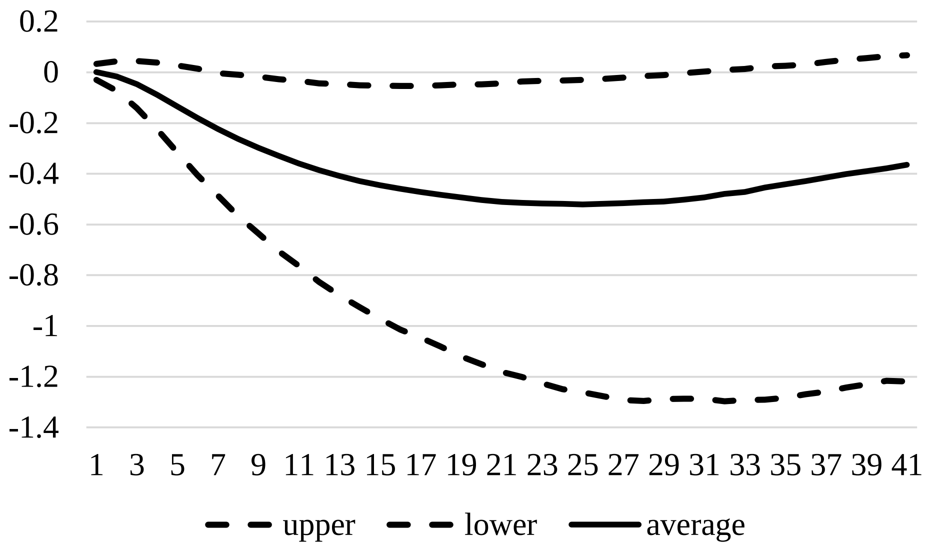
Note: The bounds represent the 16th and 84th percentiles

Figure 4. Peak response: 1% shock of conventional monetary policy on GDP



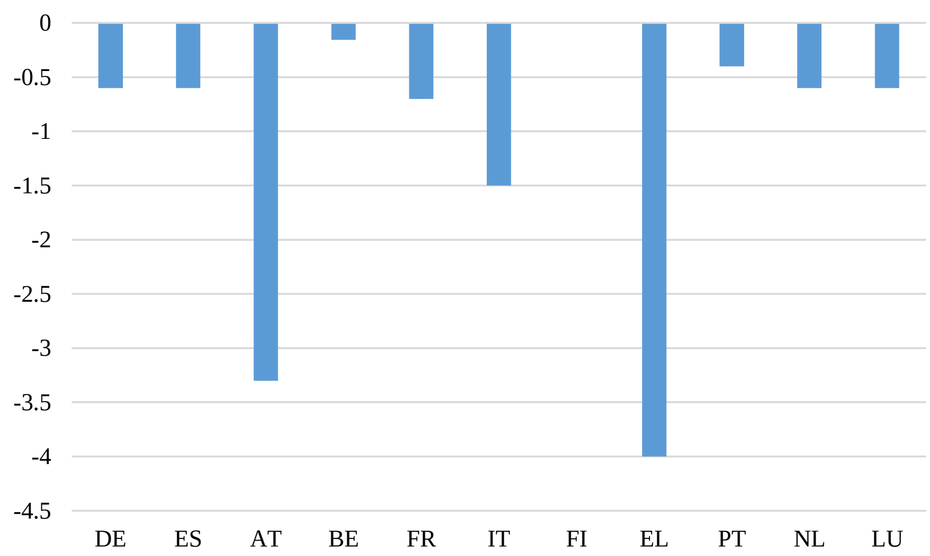
Note: AT, BE, DE, EL, ES, FI, FR, IT, LU, NL and PT stand for Austria, Belgium, Germany, Greece, Spain, Finland, France, Italy, Luxemburg, the Netherlands and Portugal, respectively.

Figure 5. Effect of 1% shock of conventional monetary policy on corporate leverage (% of GDP). Euro area average response



Note: The bounds represent the 16th and 84th percentiles

Figure 6. Effect of 1% shock of conventional monetary policy on leverage (% of GDP)



Note: AT, BE, DE, EL, ES, FI, FR, IT, LU, NL and PT stand for Austria, Belgium, Germany, Greece, Spain, Finland, France, Italy, Luxemburg, the Netherlands and Portugal, respectively.

Figure 7. Peak response of GDP (%, horizontal axis) and peak response of corporate leverage (% of GDP, vertical axis) to 1% shock of conventional monetary policy

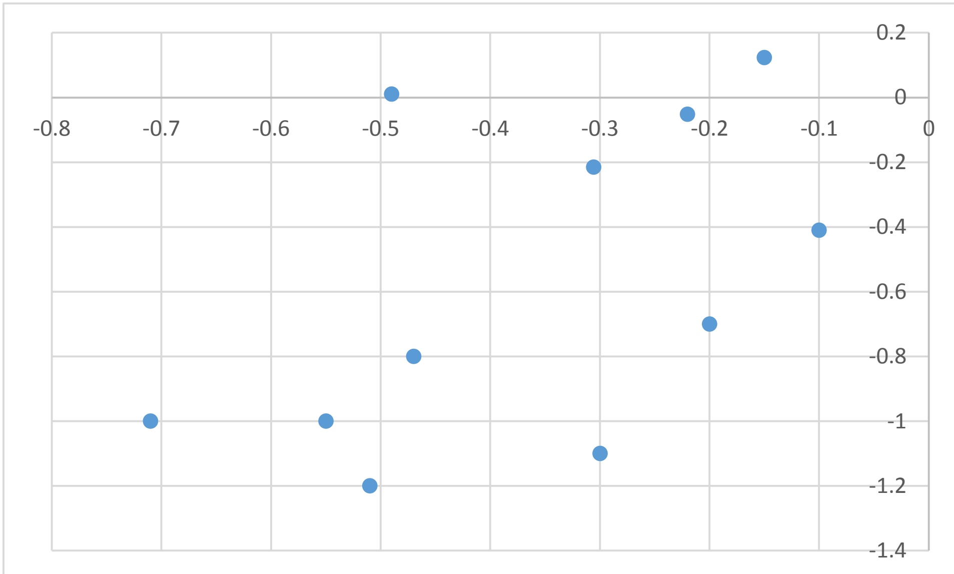
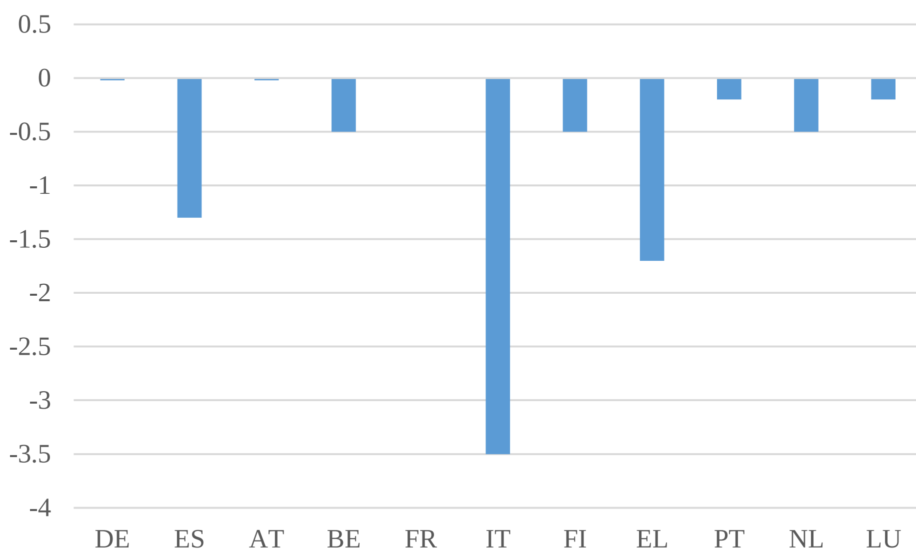
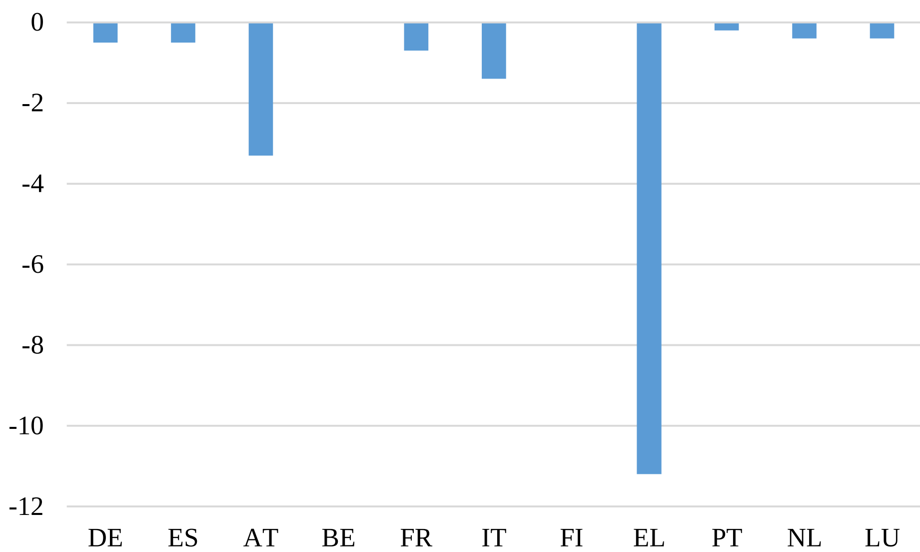


Figure 8. Effect of a shock to sovereign yields on own country leverage (% of GDP)



Note: AT, BE, DE, EL, ES, FI, FR, IT, LU, NL and PT stand for Austria, Belgium, Germany, Greece, Spain, Finland, France, Italy, Luxemburg, the Netherlands and Portugal, respectively.

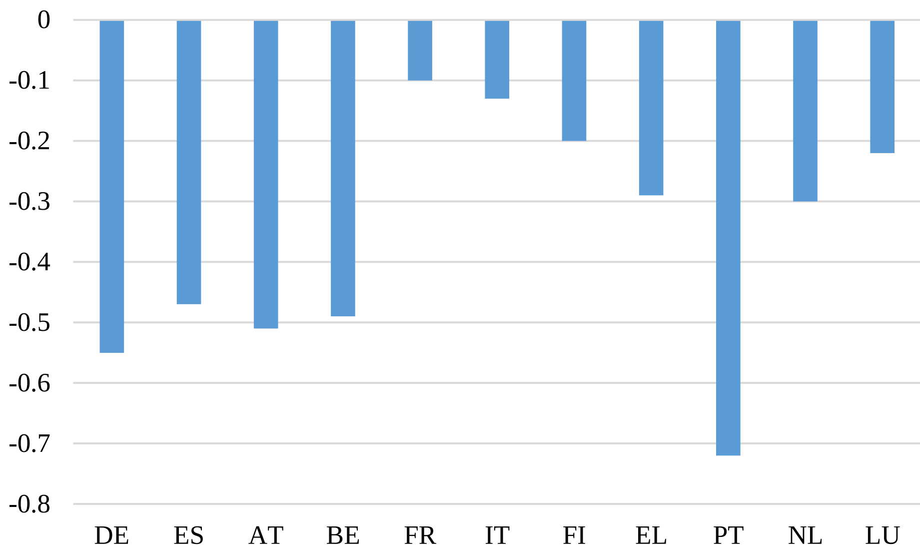
Figure 9. Effect of 1% conventional monetary policy shock on leverage if yields equal to Germany (% GDP)



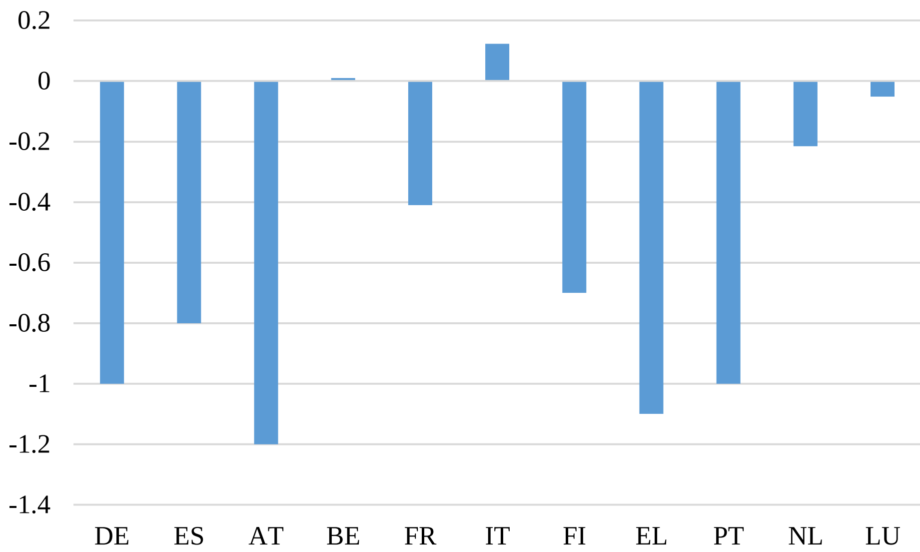
Note: AT, BE, DE, EL, ES, FI, FR, IT, LU, NL and PT stand for Austria, Belgium, Germany, Greece, Spain, Finland, France, Italy, Luxemburg, the Netherlands and Portugal, respectively.

Figure 10. Country peak responses to 1% shock of conventional monetary policy. Country equations isolated from euro area-wide stress.

Panel A: Effect on output

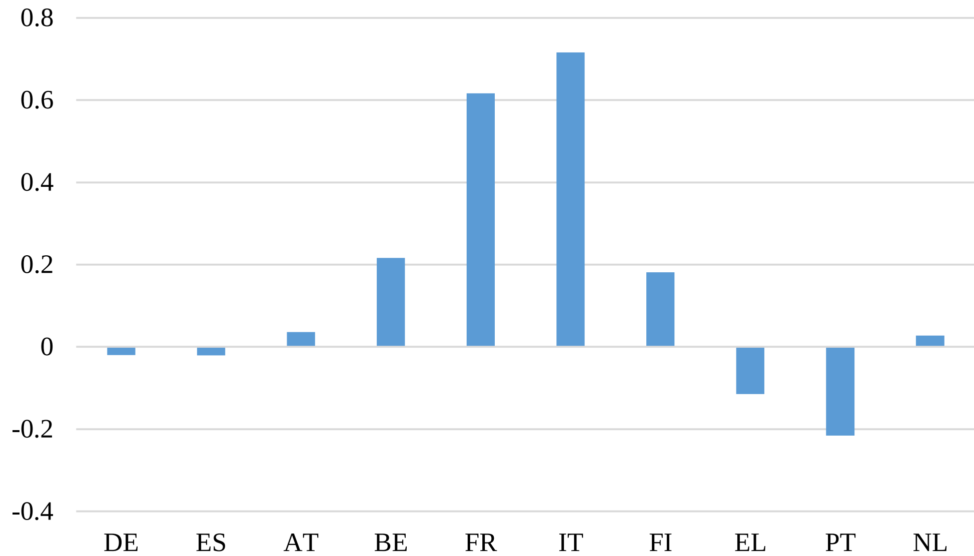


Panel B: Effect on corporate leverage



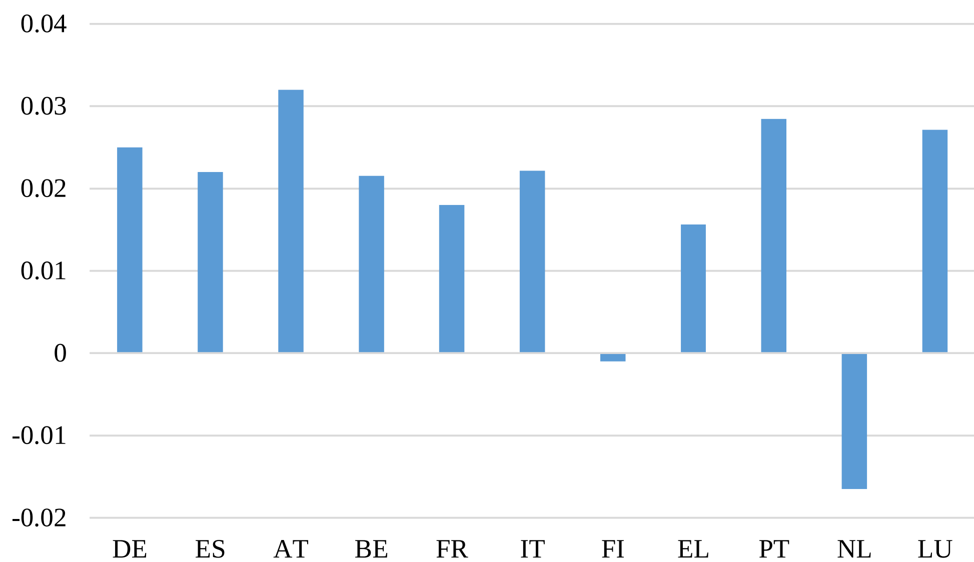
Note: AT, BE, DE, EL, ES, FI, FR, IT, LU, NL and PT stand for Austria, Belgium, Germany, Greece, Spain, Finland, France, Italy, Luxemburg, the Netherlands and Portugal, respectively.

Figure 11: Effect of a 1% shock to the Wu Xia shadow policy rate on sovereign yields (%)



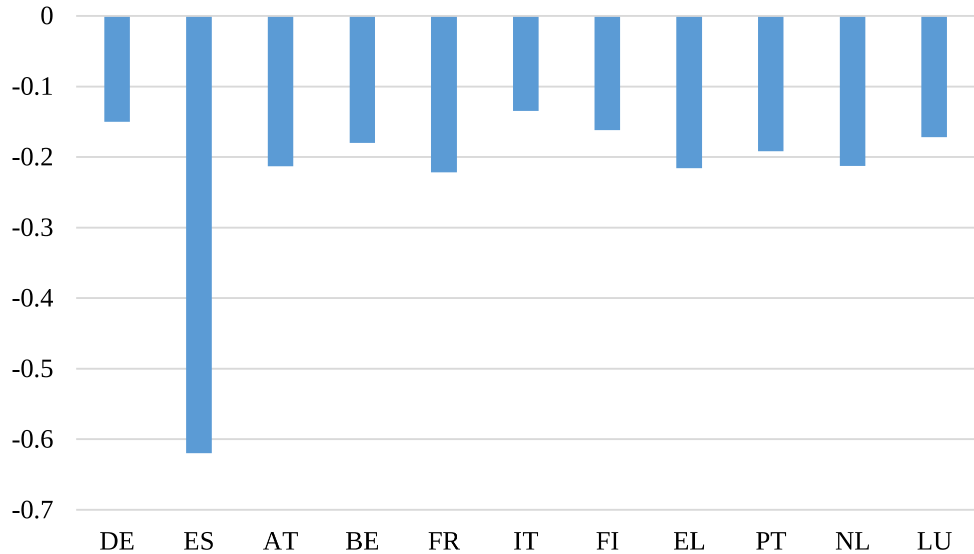
Note: AT, BE, DE, EL, ES, FI, FR, IT, LU, NL and PT stand for Austria, Belgium, Germany, Greece, Spain, Finland, France, Italy, Luxemburg, the Netherlands and Portugal, respectively.

Figure 12. ECB MRO positive shock on sovereign yields (%)



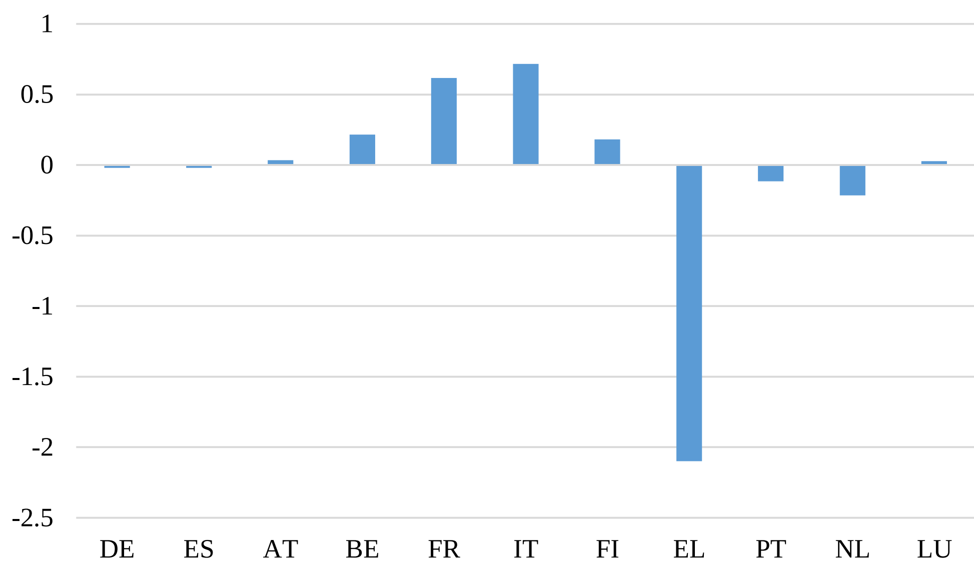
Note: AT, BE, DE, EL, ES, FI, FR, IT, LU, NL and PT stand for Austria, Belgium, Germany, Greece, Spain, Finland, France, Italy, Luxemburg, the Netherlands and Portugal, respectively.

Figure 13: Effect of a 1% shock to the Wu Xia shadow policy rate on output (%)



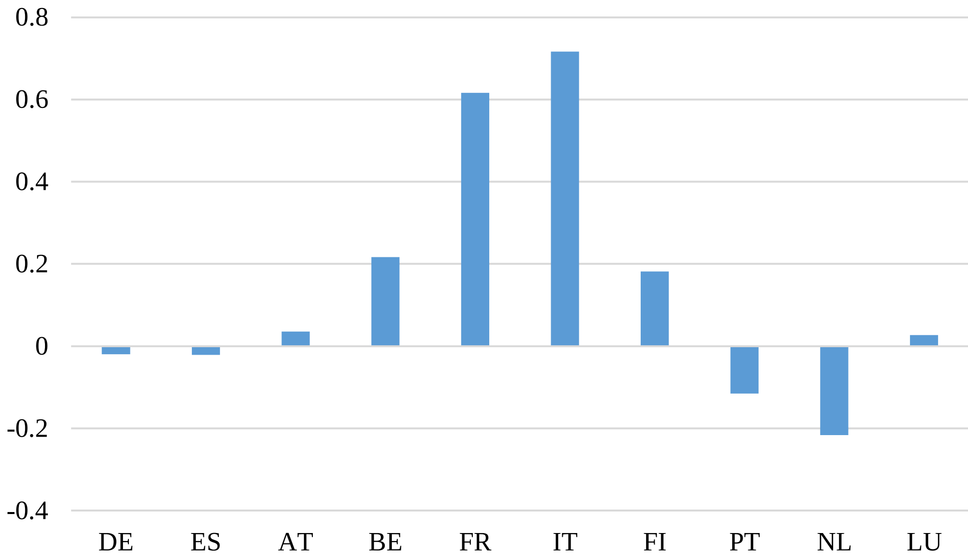
Note: AT, BE, DE, EL, ES, FI, FR, IT, LU, NL and PT stand for Austria, Belgium, Germany, Greece, Spain, Finland, France, Italy, Luxemburg, the Netherlands and Portugal, respectively.

Figure 14: Effect of a 1% shock to the Wu Xia shadow policy rate on leverage (% of GDP)



Note: AT, BE, DE, EL, ES, FI, FR, IT, LU, NL and PT stand for Austria, Belgium, Germany, Greece, Spain, Finland, France, Italy, Luxemburg, the Netherlands and Portugal, respectively.

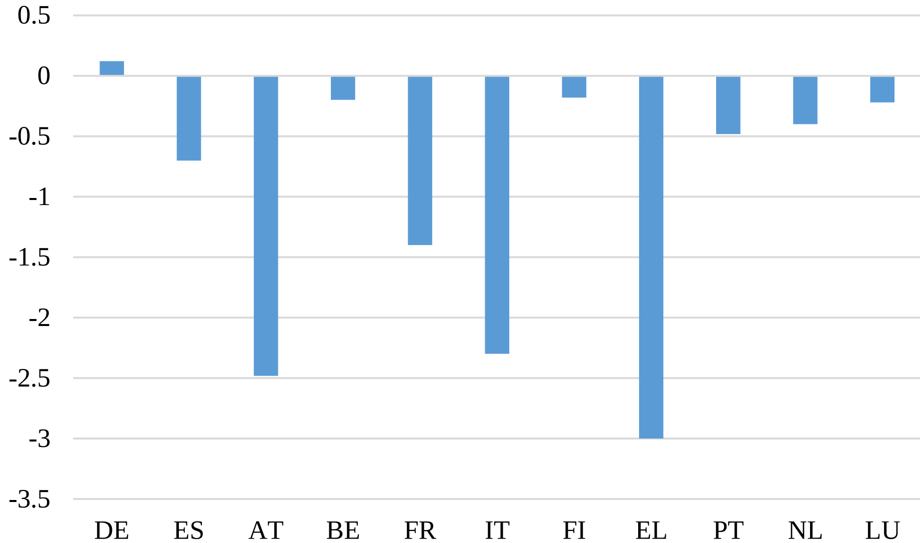
Figure 15: Effect of a 1% shock to the Wu Xia shadow policy rate on leverage, all countries except Greece (% of GDP)



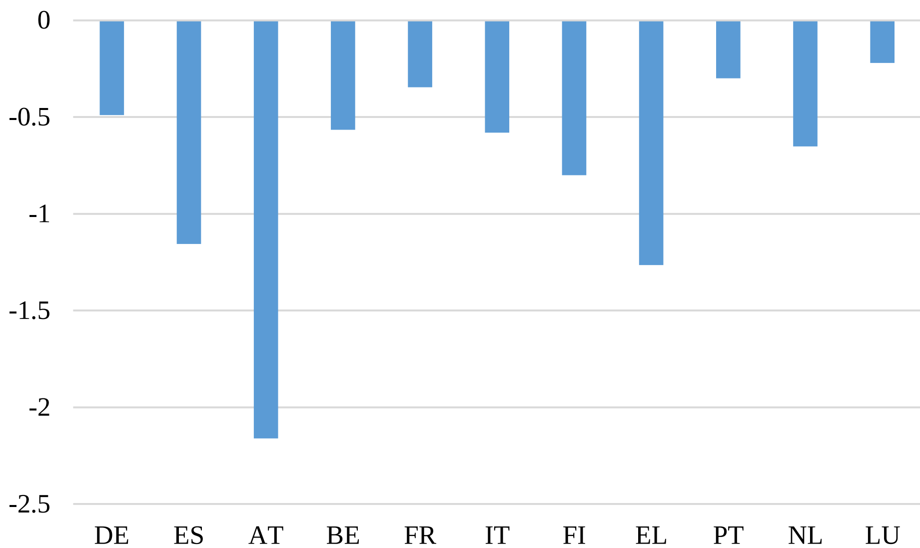
Note: AT, BE, DE, EL, ES, FI, FR, IT, LU, NL and PT stand for Austria, Belgium, Germany, Greece, Spain, Finland, France, Italy, Luxemburg, the Netherlands and Portugal, respectively.

Figure 16: Effect of a 1% shock to the Wu Xia shadow policy rate on with sovereign yields set to German yields

Panel A: Leverage effect:



Panel B: Output effect:



Note: AT, BE, DE, EL, ES, FI, FR, IT, LU, NL and PT stand for Austria, Belgium, Germany, Greece, Spain, Finland, France, Italy, Luxemburg, the Netherlands and Portugal, respectively.