The Aggregate and Country-Specific Effectiveness of ECB Policy: Evidence from an External Instruments VAR Approach*

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This paper studies the transmission of ECB policy, both at the aggregate euro-area level and the country level. We estimate a VAR model for the euro area in which monetary policy shocks are identified using an external instrument that reflects unexpected changes in the policy stance. For that purpose, we use changes in German bunds at meeting days of the Governing Council and selected intermeeting announcements. We also decompose policy shocks into pure policy surprises and information shocks. The resulting impulse responses are robust with respect to the choice of the instrument. Expansionary monetary policy affects prices and real activity but remains ineffective in pushing credit and stock markets. We show that pure policy shocks, i.e., shocks net of the new information revealed on meeting days, also have a significant effect on credit and stock prices. The identified monetary policy shock is then put into country-specific local projections in order to derive country-specific impulse responses. The transmission is heterogeneous across member countries with credit and financial markets being unevenly affected by monetary policy.

JEL Codes: E52, E44, E32.

*We are grateful to the editor of this journal and an anonymous referee for very helpful comments. This paper is based on our project "Does Unconventional Monetary Policy Contribute to Economic Recovery in the Euro Area? A New Approach to Evaluating the Transmission of Monetary Policy," which was funded by a 2016/17 research fellowship of the European Commission (DG ECFIN). We thank seminar participants at DG ECFIN's annual research conference 2016, the EEA conference (Lisbon 2017), the Money, Macro and Finance group conference (London 2017), and David Fink and other researchers at the University of Gießen for valuable feedback. Lemke and Vladu (2017) kindly provided their estimated shadow rate for the euro area. Author e-mails: lucas.hafemann@wirtschaft.uni-giessen.de and peter.tillmann@wirtschaft.uni-giessen.de.

1. Introduction

In the aftermath of the 2008–09 financial crisis and the subsequent European debt crisis, the European Central Bank (ECB) adopted a series of unconventional policy measures. More precisely, with short-term interest rates at the effective lower bound, the ECB used unconventional monetary policy such as the Asset Purchase Programme (APP) and the targeted longer-term refinancing operations (TLTROs) to provide additional stimulus. Given the persistently low level of inflation and the sluggish recovery despite several years of expansionary monetary policy, the assessment of ECB policy is controversial. Only very recently, the recovery in the euro area gained momentum. Since 2008, analyzing monetary policy has become more difficult, as the overall policy stance is no longer appropriately summarized by the short-term policy rate. In fact, the ECB uses several instruments at the same time. Moreover, with a large share of monetary policy being transmitted through asset markets and this share becoming larger over the recent years, identifying monetary policy shocks has become more difficult. The traditional triangular identification scheme applied to vector autoregressive (VAR) models that imposes restrictions on the contemporaneous interaction among the variables is not suitable with financial data. Sign restrictions, a popular alternative to the Cholesky ordering, require imposing more or less controversial restrictions onto the dynamic interaction.

In this paper, we study the monetary policy transmission in the euro zone, both at the aggregate euro-area level and the disaggregated country level. For that purpose, we use an external instruments VAR approach to identify an ECB policy shock. The external instruments approach, which has recently been made popular by the work of Stock and Watson (2012), Mertens and Ravn (2013), and Gertler and Karadi (2015) identifies the simultaneous dynamics of monetary policy and asset prices with the help of the behavior of an instrument on central bank meeting days. The assumption is that around an ECB announcement, the instrument reflects only the policy surprise, which is orthogonal to other potential shocks driving the VAR system.

Based on the identified policy shock, we make the following contributions: First, we provide evidence on the effects of a monetary policy shock at the aggregate euro-area level for a full 2002–16 and a post-crisis sample. Expansionary monetary policy affects consumer prices and real activity and leads to a depreciation of the euro in real terms. While the shock also compresses the corporate bond spread, monetary policy remains ineffective in pushing credit and stock markets.

Second, we take account of the recent literature on information shocks, highlighting the fact that policy decisions by central banks also reveal information about the central bank's assessment of the economy (Jarocinski and Karadi 2018, Miranda-Agrippino and Ricco 2018, and Nakamura and Steinsson 2018). Under incomplete information, these information shocks are distinct from the pure monetary policy component of shocks. We use a principal component analysis to decompose the monetary policy shock into an information shock and a pure policy shock and find plausible impulse responses to both shocks. Based on this decomposition, we are able to show that the baseline results remain robust when we exclude the information revealed on meeting days from the monetary policy surprise.

Third, we use the identified euro-area policy shock to estimate several country-specific impulse response functions from local projections (Jordà 2005). This provides us with the effects of the common monetary policy on individual countries and excludes the feedback from the country level to ECB policy. The assumption is that the ECB is, in line with its mandate, directing policy to the euro-area aggregate, not to specific countries. The results show homogenous cross-country responses for consumer prices and industrial production but heterogeneity in the effects of monetary policy across members on unemployment, credit, and the stock market. In several countries the transmission through equity prices and through the banking system in terms of bank lending is severely dampened. The cross-country heterogeneity in the effects of bank lending and stock markets reflects the insignificant responses of both variables at the euro-area level.

Our project connects several strands of the recent literature: Hachula, Piffer, and Rieth (2019) and Andrade et al. (2016) also use an external instruments approach to estimate euro-area VAR models. However, their focus is different. The first paper estimates the effects of monetary policy shocks on fiscal policy variables in the euro area and studies whether fiscal discipline deteriorates after a monetary policy easing. The authors indeed find an increase in public expenditure after an expansionary policy shock. Andrade et al. (2016) focus on the ECB's Asset Purchase Programme, implemented since January 2015.[1] Two other recent papers, namely Cesa-Bianchi, Thwaites, and Vicondoa (2016) and Ha (2016), use the external instruments approach for shock identification in an open-economy VAR model and put the shock series into local projections.[2]

Furthermore, Wieladek and Pascual (2016) use a Bayesian VAR model with a battery of alternative identification schemes to study the euro area in 2012–16. Counterfactuals for the euro-area and for the country level show that monetary policy has a very large effect. Since January 2015, it has led to real gross domestic product (GDP) being 1.3 percent higher than in the absence of quantitative easing (QE). The same policy has benefited Spain the most and Italy the least. Boeckx, Dossche, and Peersman (2017) use a sign-restricted VAR model to study the effects of unconventional monetary policy shocks that drive up the ECB's balance sheet.[3] Based on a Bayesian VAR model, Mandler, Scharnagl, and Volz (2016) provide evidence for heterogeneous ECB policy transmission across the four largest economies of the euro area.

While the previously mentioned papers work with monthly or quarterly data, Fratzscher, Lo Duca, and Straub (2016) use daily data to study the responses of a broad range of asset prices to ECB announcements prior to 2013. They find that unconventional policy boosts asset prices and spills over to other economies' equity markets but not to other bond markets. The work by Burriel and Galesi (2018) also focuses on euro-area and country-specific effects of policy. The authors estimate a global VAR model for the euro area which allows for spillovers among euro-area countries. They find these intra-EMU spillovers to be sizable. In addition, they document a large heterogeneity of cross-country effects of monetary policy shocks.

[1] A very useful survey of the transmission channel of unconventional ECB policy is provided by Fiedler et al. (2016).

[2] Altavilla, Darracq Paries, and Nicoletti (2015) construct an indicator of credit supply tightening in the euro area and include it as an external instrument in a VAR model.

[3] Hristov et al. (2014), Altavilla, Giannone, and Lenza (2016), and De Santis (2016) provide additional evidence on selected ECB programs, such as the Outright Monetary Transactions program and the Asset Purchase Programme.

This paper proceeds as follows: section 2 outlines the VAR model with an external instrument, which is our benchmark model, as well as the data used. The section also discusses our findings for the aggregate euro area, presents results for variables that describe specific transmission channels of monetary policy, and also introduces the decomposition of policy surprises into pure policy shocks and information shocks. Section 3 introduces the local projections approach and discusses the country-specific results. Section 4 draws on these findings and discusses policy implications.

2. A Euro-Area VAR Model with External Instruments

2.1 Methodology

In this subsection, we describe how we combine the conventional VAR methodology with the event-study approach. We build upon the methodology of Stock and Watson (2012), Mertens and Ravn (2013), and Gertler and Karadi (2015) in order to overcome the problems of endogeneity without imposing sign or zero restrictions. The endogeneity issue is particularly relevant for financial variables, which are supposed to react instantly to a monetary policy shock. In line with, e.g., Gambetti and Musso (2017), we expect unconventional monetary policy to influence financial variables. Therefore, a Cholesky ordering can potentially provide misleading results. It is also hard to argue in favor of sign or zero restrictions. Upon imposing restrictions, presumptions about the behavior of the included variables have to be made. This is problematic in the case of unconventional monetary policy, where we know very little about its transmission. However, under the assumption that an accurate instrument can be found, we are able to capture the transmission of the complete set of monetary policy tools.

Our goal is to derive the structural VAR model according to equation (1):

$$S^{-1}Y_t = C + \sum_{j=1}^{p} B_j Y_{t-j} + \sum_{k=0}^{q} D_k X_{t-k} + u_t. \tag{1}$$

Hereby, Y_t represents the endogenous and X_t the set of exogenous variables at time t. While C captures constants, the matrices B_j and D_k contain the coefficients on the lags of the endogenous and exogenous variables up to lag length j and k, respectively. The simultaneous effect of one endogenous variable to another is captured by S^{-1} and u_t stands for the vector of error terms.

Due to the endogenous nature of the variables in Y_t, we are not able to solve the structural VAR uniquely. Hence, we first estimate the reduced-form VAR, which results after multiplying each side of equation (1) by S:

$$Y_t = S \cdot C + \sum_{j=1}^{p} S \cdot B_j Y_{t-j} + \sum_{k=0}^{q} S \cdot D_k X_{t-k} + \varepsilon_t. \tag{2}$$

The reduced-form innovations are then given by equation (3):

$$\varepsilon_t = S \cdot u_t. \tag{3}$$

Here S is a square matrix with the dimension equal to the number of endogenous variables. The i-th column in S captures the response of the vector of reduced-form innovations, ε_t, to an increase in the i-th element of the matrix of structural shocks u_t. As we are only interested in the responses to a structural monetary policy shock u_t^{MP}, we just have to identify the column s in S that captures the impact of u_t^{MP} on the vector ε_t. Now let ε_t^{MP} be the reduced-form innovation of the monetary policy equation and s^{MP} be the element of s that describes its response to the structural shock, u_t^{MP}, such that equation (4) holds:

$$\varepsilon_t^{MP} = s^{MP} \cdot u_t^{MP}. \tag{4}$$

Accordingly, ε_t^q and s^q are reduced-form error terms and the respective elements in s that correspond to other variables:

$$\varepsilon_t^q = s^q \cdot u_t^{MP}. \tag{5}$$

Solving for u_t^{MP} in equations (4) and (5) leads to

$$u_t^{MP} = \frac{\varepsilon_t^{MP}}{s^{MP}} = \frac{\varepsilon_t^q}{s^q}, \tag{6}$$

which can be rearranged to

$$\varepsilon_t^q = \frac{s^q}{s^{MP}} \varepsilon_t^{MP}. \tag{7}$$

Finally, with the reduced-form error terms as both the dependent and the explanatory variable, respectively, an estimate for $\frac{s^q}{s^{MP}}$ can be found. In order to overcome the possible endogeneity of ε_t^q and ε_t^{MP}, we apply a two-stage least-squares approach. From the first stage we receive $\widehat{\varepsilon_t^{MP}}$ as an estimate that only captures changes in monetary policy that do not stem from a simultaneous change in ε_t^q. In the second stage, we then simply run the following ordinary least-squares (OLS) regression:

$$\varepsilon_t^q = \frac{s^q}{s^{MP}} \widehat{\varepsilon_t^{MP}} + \xi_t. \tag{8}$$

Given these estimates and the variance-covariance matrix of the reduced-form VAR model, we are able to uniquely identify all components of s. The crucial point in this framework is to find an accurate instrument Z_t which is, by definition, correlated with ε_t^{MP} but orthogonal to ε_t^q.

2.2 Data

For our baseline euro-wide model, the vector of the endogenous variables consists of the log of industrial production (excluding construction), the log of the Harmonised Index of Consumer Prices (HICP), a corporate bond spread, and the (shadow) short rate.[4] Following Sims (1992), we further add (the log of) oil prices as an exogenous variable in order to avoid the price puzzle.

Prior to the financial crisis, the ECB conducted open market operations in order to move the key policy rate. With the zero lower bound (ZLB) and the introduction of unconventional monetary

[4]In the baseline model, the corporate bond spread is the spread between the yield on BBB-rated and AA-rated bonds. However, spreads between corporate bonds with other ratings lead to similar results.

policy, the ECB extended its policy toolkit. It is for this reason that we use the (shadow) short rate provided by Wu and Xia (2016) for the interval available (i.e., from 2004:M9 until the end of our sample) as the measure of the monetary policy.[5] Until 2004:M8 the euro overnight index average (EONIA) rate represents the monetary policy stance, which we receive from Thomson Reuters Datastream. We generally draw on seasonally adjusted data for the changing composition of the European Economic and Monetary Union (EMU). Financial variables that are not expected to contain seasonal patterns are not adjusted. A complete list of all variables, their adjustment, and their sources can be found in table A.1 in the appendix. The sample consists of monthly data from 2002:M1 until 2016:M10.[6]

We include six lags as suggested by the Akaike information criterion and the final prediction error. However, as outlined below, choices of other lag lengths lead to similar results.

After estimating the baseline four-variable model, we add a fifth variable to our baseline model to shed light on several aspects of the transmission process. This fifth variable is taken from the following list of variables: euro-area government bond yields, the unemployment rate, the log of the real exchange rate, the log of the Euro Stoxx 50, the log of the rent component of the HICP, the log of the loan volume granted by financial institutions, and the net percentage change of credit standards and credit demand, both obtained from the Bank Lending Survey.[7]

[5]We also apply the shadow rates provided by Krippner (2012) and Lemke and Vladu (2017) as well as the zero-coupon one-year German government bond rate. As will be outlined below, the results from the three different short rates are indeed complementary.

[6]Data from the ECB's Bank Lending Survey as well as loan data are only available from 2003 onward. Hence, a shorter sample size is used for models containing these variables.

[7]Within the Bank Lending Survey the banks answer whether they tightened lending standards "considerably" or "somewhat," eased "somewhat" or "considerably," or left the standards unchanged. The net percentage change is the difference in the percentage of banks that tightened their lending standards (either "somewhat" or "considerably") and the share of banks that eased them. Accordingly, the net percentage change in the credit demand is the share of banks that expect an increase in the demand for loans (either "considerably" or "somewhat") minus the share that expect a decrease in the demand.

2.3 Choosing an Instrument

The choice of the instrument deserves special attention. We use changes in the German 10-year government bond yield on meeting days and a small number of other selected dates as the instrument.

The rationale behind the use of daily changes, rather than intraday data, lies in the timing of ECB communication on meeting days of the Governing Council. The press release at 13:45 CET on every meeting day is followed by a press conference at 14:30 CET. Since our instrument has to capture the market response to the press conference as well, we cannot apply the widely used 30-minute window.[8] The data of all external instruments stem from Thomson Reuters Eikon.

The financial crisis and the subsequent European debt crisis opened up an interest rate spread between government bonds of various euro-area countries. While the yield on German government bonds serves as a risk-free rate throughout the entire sample, the status of government bonds of other countries switches from a risk-free to an exposed asset. With the choice of German government bonds, we avoid the issue of a structural break within our instrument variable. Furthermore, we consider 10-year bonds since our applied instrument also has to reflect changes in investors' expectations through unconventional monetary policy measures such as forward guidance.

Our identification method rests on the efficient market hypothesis (EMH). The EMH states that movements in asset prices only appear if new information is received. Thus, under the assumption that news other than the monetary policy decisions on the meeting days and the selected special events are white noise, the changes in German bond yields on these days represent changes in the monetary policy stance. For example, an increase in the German bond yield on these days, i.e., a positive surprise component, reflects a monetary tightening.

[8] In fact, Gürkaynak, Sack, and Swanson (2005) find that daily changes in federal fund futures on Federal Open Market Committee meeting days are akin to changes in a 30-minute window around the release in the time span from 1994 to 2004. Thus, they conclude that "the surprise component of monetary policy announcements can be measured very well using daily data."

With the adoption of unconventional policies, important news about monetary policy also emerged on nonmeeting days. Hence, we supplement the set of meeting days by three additional events. These are the announcement of the two tranches of the Securities Markets Programme (SMP) on May 10, 2010 and August 7, 2011, respectively, as well as President Draghi's "whatever-it-takes" speech on July 26, 2012. The monthly series for our instrument consists of the change in German yields on these specific days—that is, if the Governing Council meets on one Thursday in a given month, the yield change on this day is used as the monthly entry in the instrument series. If there is both a Governing Council meeting and one of the additional events in a given month, we sum up the yield changes on these two days in order to get an estimate for the surprise component of that month.

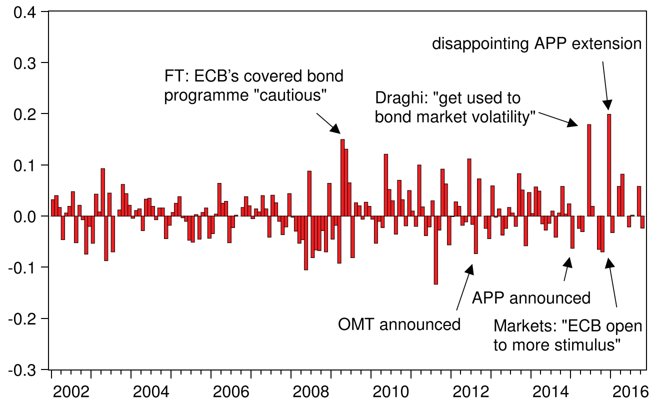
This measure for the monetary policy stance has several advantages. First, the surprise component serves as a consistent measure for the entire monetary policy toolkit. With the ECB adopting unconventional policies, it extended its set of policy instruments. By having one measure reflecting the entire set of policy instruments, we do not face the problem of disentangling the effects of each instrument, which is particularly challenging as those have been used simultaneously.

Second, the focus on market reactions allows us to directly measure the unanticipated part of a policy change. This is better suited for identifying a policy shock, as according to the EMH only those should influence asset prices. For example, an increase in the interest rate that is lower than expected is recognized as an expansionary monetary policy in the view of market participants. Finally, the external instruments approach clearly defines an unexpected monetary policy shock, which is the starting point of every analysis within the VAR model.

The series of the surprise component from 2002 until 2016 is plotted in figure 1. As the surprise component fluctuates around zero, it can be concluded that there is no systematic bias in the market expectations.[9] The largest swings are found after the financial crisis in 2007. President Draghi's remark "get used to market volatility"

[9] On a 10 percent significance level, a t-test confirms that the mean of the surprise component is not different from zero.

Figure 1. Monetary Policy Surprises Obtained from 10-Year Bunds



Notes: Policy surprises are defined as the change in the yield on 10-year German bunds on ECB meeting days and selected other days. This series is used as an external instrument in the VAR identification. The annotation refers to the *Financial Times* (FT), the Outright Monetary Transactions (OMT) program and the Asset Purchase Programme (APP).

on June 2015 and the disappointment about the size of the additional stimulus adopted in December 2015 account for the peaks in the surprise component. In contrast, the announcements of the Outright Monetary Transactions (OMT) program in September 2012 and the APP in January 2015 are reflected in negative surprises. In other words, monetary policy was surprisingly expansionary.

Before we turn to the results of our VAR model, we check if the considered instrument is accurate. First, we test for the information content of the instrument in an event study. We run the regression

$$\Delta y_t^{daily} = \alpha + \beta \cdot \Delta Z_t^{events} + \epsilon_t, \tag{9}$$

where the daily changes in asset prices, y_t^{daily}, are regressed on a constant and the surprise component, i.e., the changes in the German 10-year bond yield Z_t^{events}, using OLS. For this estimation we *only* consider the selected events, i.e., meeting days of the Governing Council and three selected special events, which leaves us with a total of 175 observations. The list of dependent variables consists of the log of the U.S. dollar exchange rate to the euro, the euro-area

Table 1. Monetary Policy Surprises in an Event Study

y_t		Coef.	*p*-value
(log) Exchange Rate	$\hat{\alpha}$	0.000	0.43
	$\hat{\beta}$	0.071	0.00
EURIBOR Future	$\hat{\alpha}$	−0.006	0.15
	$\hat{\beta}$	0.890	0.00
Corporate Bond Spread	$\hat{\alpha}$	−0.005	0.12
	$\hat{\beta}$	0.192	0.00

Notes: Results from an event-study regression of y_t on policy surprise series with the slope coefficient β and a constant α.

interbank offered rate (EURIBOR) futures rate,[10] and the corporate bond spread.[11]

The results of the regressions are presented in table 1. An unexpected increase in the government bond yield on meeting days, i.e., a surprise tightening, leads to an appreciation of the euro and increases in the EURIBOR future and the corporate bond spread. This suggests that changes in the German bond yield indeed contain information about unexpected changes in the ECB's monetary policy stance.

We further evaluate the properties of the instrument by testing for the occurrence of a weak instruments problem. The explanatory power of the instrument can be examined by regressing the reduced-form VAR residuals of the monetary policy equation on a constant and the external instrument. As described by Li and Zanetti (2016), this equals the first stage in our two-stage least-squares regression from equation (8). For the changes in the German 10-year bond yields, the corresponding F-statistic in the baseline case is 10.44. Following Stock, Wright, and Yogo (2002), a value for the F-statistic lower than 10 indicates a weak instrument issue. With the

[10] At any point in time, we consider the future that is the eighth next to deliver. Note that the first six delivery months are consecutive in time. Given that the subsequent delivery months—namely March, June, September, or December—settle on a quarterly frequency, the delivery of the future that we consider is roughly in one year. Our presented results are robust to other continuation futures.

[11] The corporate bond spread presented here is the spread between A- and BBB-rated bonds.

German bond yields avoiding the weak instrument problem and showing plausible results for the event-study regression, we are confident about our choice of an accurate instrument. Hence, we are able to estimate the impulse responses from our VAR model. The results are discussed below.

2.4 Results

We start by estimating the effect of an expansionary monetary policy that leads to a 25 basis point (bp) drop in the shadow rate. All results are presented as impulse response functions together with a 90 percent confidence interval.

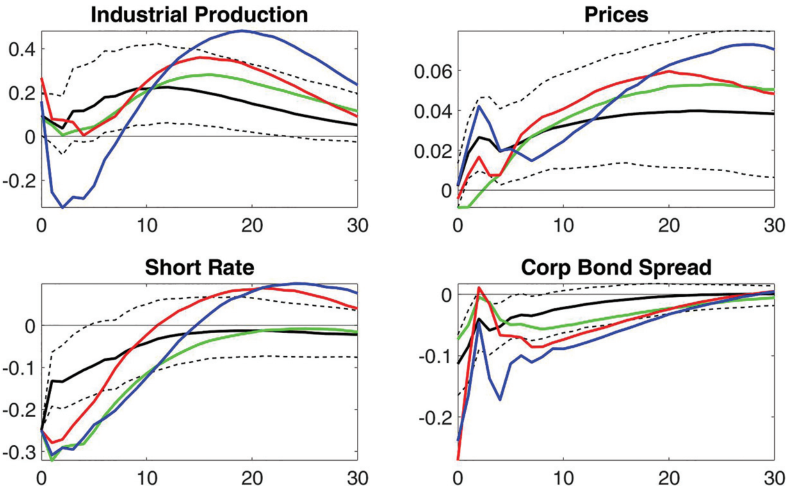
2.4.1 Baseline Model

The results from the baseline VAR model are presented in figure 2. As indicated by the black lines, the responses of industrial production, prices, and the corporate bond spread to an expansionary shock have the expected sign and are statistically significant. As noted above, we circumvent the price puzzle by adding oil prices as an exogenous variable, so that a monetary easing immediately increases prices. The responses of the consumer price index (CPI) and the industrial production index indicate that ECB policy stimulated both inflation and real economic activity. Boeckx, Dossche, and Peersman (2017) find similar results by imposing sign restrictions in a euro-area VAR model. Following Zhu (2013), the corporate bond spread reflects the external finance premium and, hence, the credit channel of monetary policy transmission. We find that spreads narrow immediately upon the monetary easing, which is consistent with the presence of the credit channel.

Further on, we review the accuracy of our outcome by altering the shadow rate and the lag length. In this respect, the green and blue lines in figure 2 show the impulse responses based on the shadow rates of Krippner (2012) and Lemke and Vladu (2017), respectively.[12] The results turn out to be similar. Gertler and Karadi (2015) have used a safe interest rate with a maturity of one year,

[12]For color versions of the figures, see the online version of the paper on the IJCB website (http://www.ijcb.org).

Figure 2. Baseline VAR Model



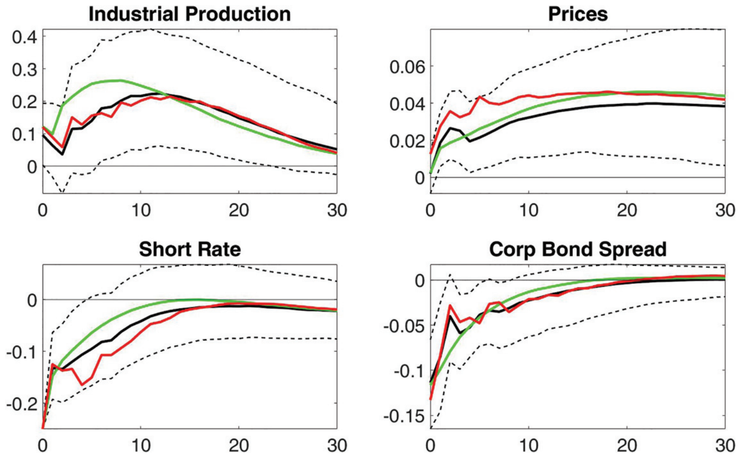
Notes: Responses to an expansionary monetary policy shock of 25 bp obtained from the baseline VAR model with external instruments and 90 percent confidence band. The black line is the response in the model based on the Wu-Xia (2016) shadow rate, the green line is based on the shadow rate of Krippner (2012), the blue line is based on the shadow rate of Lemke and Vladu (2017), and the red line is estimated based on the one-year German government bond zero-coupon rate.

proxied by the U.S. government bond rate, instead of the shadow rate. For reasons of comparability, we also present results based on the interest rate on a zero-coupon one-year German government bond (red line). Again, the outcomes for industrial production, the price level, and the interest rate are very similar. Only the negative response of the corporate bond spread is more pronounced. Since corporate financing is more dependent on long-term credit conditions, this finding does not come as a surprise. However, one has to keep in mind that, in contrast to shadow rates, the short-term government bond rate hits the zero lower bound during the financial crises. As displayed in figure 3, altering the lag length does not change the results qualitatively.

2.4.2 Cholesky Identification

For a comparison, we apply a Cholesky identification instead of the external instruments approach. The implied ordering of the

Figure 3. Baseline VAR Model: Alternative Lag Structure



Notes: Responses to an expansionary monetary policy shock of 25 bp obtained from the baseline VAR model with external instruments and 90 percent confidence band. The black line represents the baseline model with a lag length of four. The green (red) line is the impulse response for the model with two (six) lags.

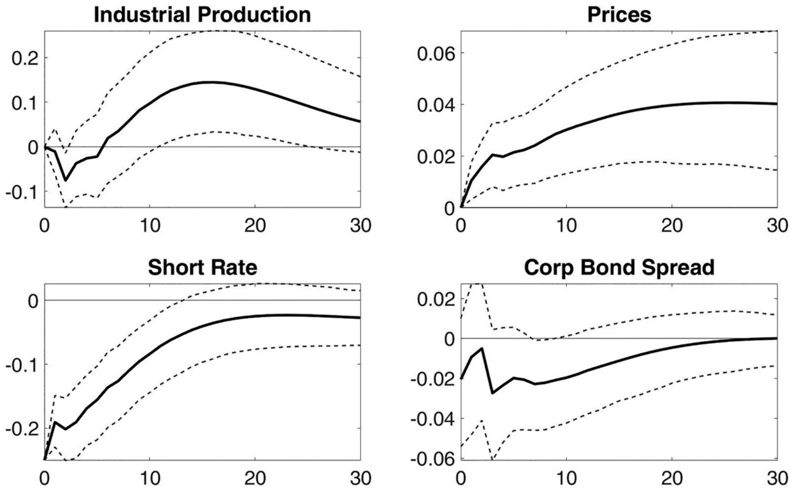
variables is the following: log of industrial production, log of consumer prices, the shadow short rate, and the corporate bond spread. The restriction imposed implies that monetary policy affects the spread contemporaneously, but all other variables with a time lag of one month.

The results are shown in figure 4. While prices and industrial production exhibit responses which are very similar to the baseline findings, the corporate bond spread does not react significantly. This might be the result of the endogenous nature of both the shadow rate and the bond spread, which is not adequately captured by the Cholesky identification. This also lends support to the external instruments approach that we use for identification in our baseline model.

2.4.3 Extending the Baseline Model with Other Real and Nominal Variables

We now turn to the responses of additional variables which were not included in our baseline model. As outlined in the previous

Figure 4. Baseline VAR Model: Cholesky Identification

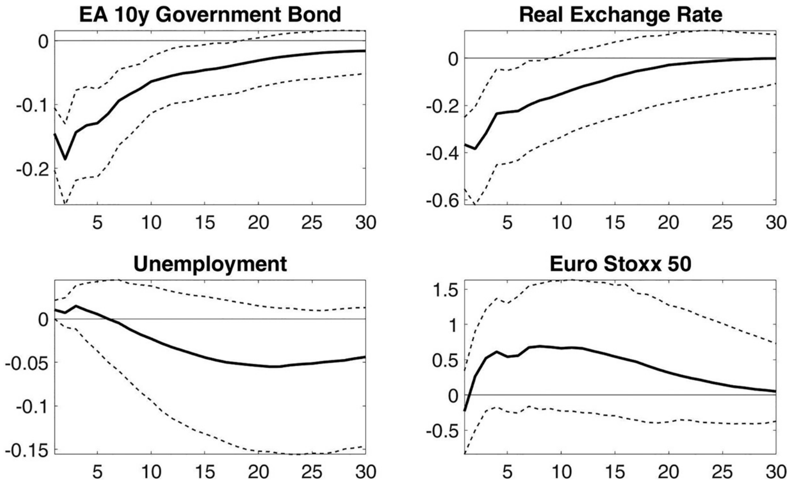


Notes: Responses to an expansionary monetary policy shock of 25 bp obtained from the baseline VAR model identified recursively and 90 percent confidence band.

subsection, we add one variable at a time as a fifth variable to our model. To save space, we only report the impulse response for the fifth variable.[13] Figure 5 shows the results for euro-area government bond yields, the real exchange rate, unemployment, and the Euro Stoxx 50. Bond yields immediately fall after a monetary easing. Furthermore, the instant depreciation of the euro indicates the existence of the exchange rate channel. Surprisingly, the increase in industrial production found before is not accompanied by a significant decrease in the unemployment rate. Though the sign of the unemployment response is negative, on a 10 percent confidence level, it cannot be ruled out that its response is actually zero. One explanation for the modest decrease in unemployment might be the heterogeneity of business cycles in the euro area. Our results might reflect that, since

[13]Throughout the different VAR models the responses of the four variables in the baseline model remain qualitatively unchanged.

Figure 5. Alternative Fifth Variable: Additional Real and Nominal Variables



Notes: Responses of alternative choices for the fifth variable to an expansionary monetary policy shock of 25 bp obtained from the baseline VAR model with external instruments and 90 percent confidence band.

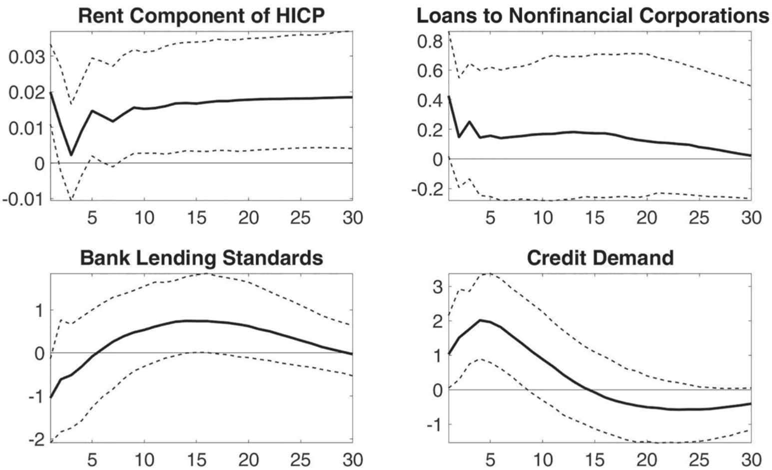
the European debt crisis, unemployment in core and periphery countries respond differently to a monetary policy shock. This hypothesis is supported by our country-specific results presented below.

Although the Euro Stoxx 50 has the expected positive sign, its response turns out to be insignificant. Hence, for the entire time span, we do not find evidence for a policy transmission through the stock market.[14] At a first glance, this seems surprising, as expansionary monetary policy leads to a bull market from a theoretical point of view.[15] However, as outlined in, e.g., Jarocinski and Karadi (2018), Nakamura and Steinsson (2018), and Romer and Romer (2000), a

[14]The reaction of the MSCI Euro Index is virtually identical to the one from the Euro Stoxx 50. These results, along with impulse responses from policy uncertainty, the VSTOXX, and the monetary base, are available on request.

[15]Indeed, Gambetti and Musso (2017) find evidence that the ECB's Asset Purchase Programme increased stock prices.

Figure 6. Alternative Fifth Variable: Credit Market

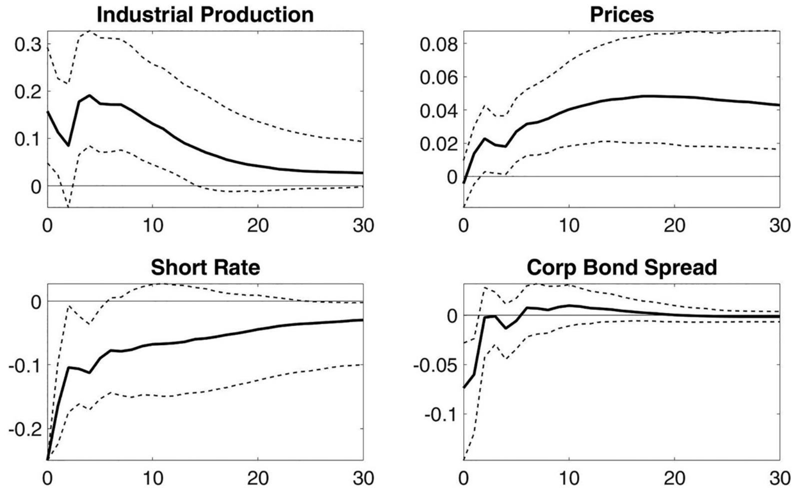


Notes: Responses of alternative choices for the fifth variable to an expansionary monetary policy shock of 25 bp obtained from the baseline VAR model with external instruments and 90 percent confidence band.

monetary policy shock also contains information about the policymakers' perceptions of the economic situation. Under the assumption that market participants value this information, the responses of (financial market) variables are also driven by the information component. While a decrease in the short rate due to monetary easing is expected to increase stock prices, a decrease in the policy rate due to weaker economic fundamentals potentially leads to a reduction in stock prices. Below, we follow Jarocinski and Karadi (2018) and further disentangle the information shock from the pure monetary policy shock. Indeed, we find that a pure monetary policy shock (information shock) increases (decreases) the Euro Stoxx 50.

According to figure 6, a monetary easing increases the rent component of the HICP, which serves as a monthly proxy for house prices. A monetary expansion relaxes bank lending standards, thus supporting the existence of a risk-taking channel. The demand for credit increases. A significant reaction in both bank lending and credit demand is also found by Ciccarelli, Maddaloni, and Peydro (2015). Furthermore, we find that the total loan volume to nonfinancial institutions increases.

Figure 7. Baseline VAR Model: 2008:M10–2016:M10



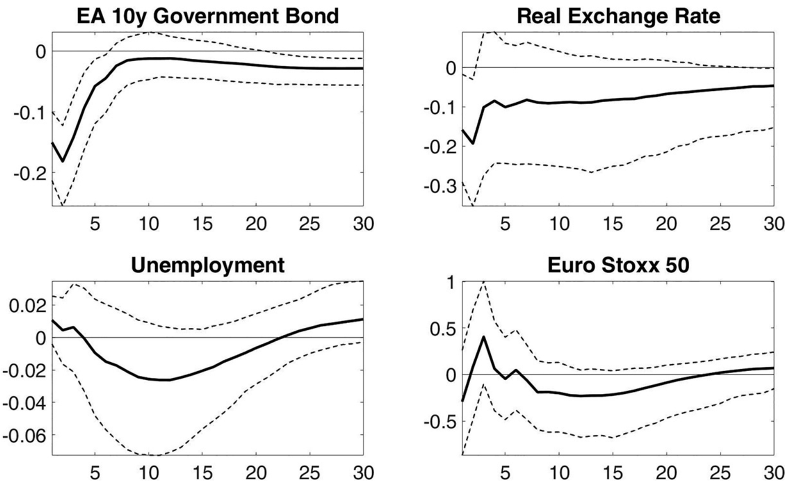
Notes: Responses to an expansionary monetary policy shock of 25 bp obtained from the baseline VAR model estimated over the post-crisis sample with external instruments and 90 percent confidence band.

2.4.4 The Post-2008 Sample

In order to address the question of how unconventional monetary policy is transmitted, we present evidence from the crisis period only. We interpret the sharp decrease in the ECB's key interest rate as the beginning of the era of unconventional monetary policy. The results based on a sample from 2008:M10 until 2016:M10 are shown in figures 7 and 8. With the shorter time span, we reduce our lag length to three as again indicated by the Akaike criterion and the final prediction error.

Overall the reactions remain similar to those from the full sample VAR model. However, figure 8 reveals a weaker reaction of the real exchange rate in the subsample. In the 2002–16 sample the responses of the unemployment rate and the Euro Stoxx 50 display the expected sign, although their responses are at no point significantly different from zero; see figure 5. In contrast to that, the sign of the reaction of the unemployment rate and the Euro Stoxx 50 in the 2008–16 sample is less clear, as the responses cross the zero line

Figure 8. Alternative Fifth Variable: Additional Real and Nominal Variables (2008:M10–2016:M10)

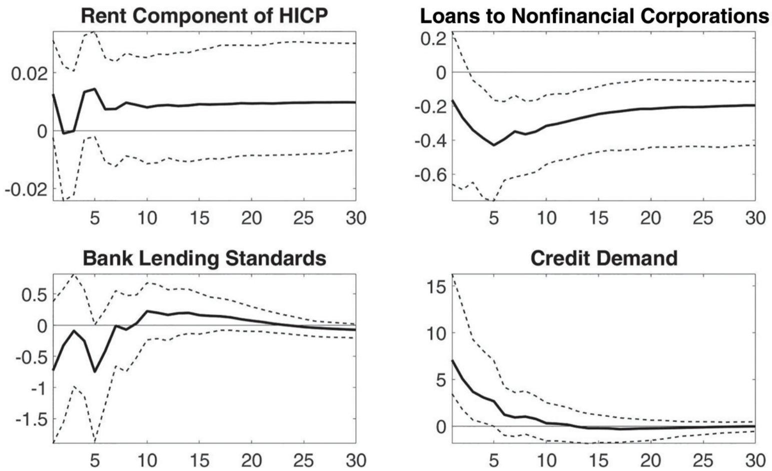


Notes: Responses of alternative choices for the fifth variable to an expansionary monetary policy shock of 25 bp obtained from the baseline VAR model estimated over the post-crisis sample with external instruments and 90 percent confidence band.

several times; see figure 8. Hence, we conclude that the policy transmission through employment and the stock market is particularly impaired in the post-2008 era. This era is characterized by sizable intra-euro-area government bond spreads, indicating that national characteristics play a major role for market participants during this time. This suggests that we can obtain more information from a country-specific perspective, which is pursued in the next section.

Figure 9 displays impulse responses for the credit market variables. Though not significant, the reaction of rent prices and lending standards are in line with the findings for the 2002–16 sample. In contrast, the increase in credit demand is substantially higher in the post-crisis sample. Interestingly, an expansionary monetary policy shock lowers the total loan volume to nonfinancial institutions. Our findings underpin the structural problems of the euro-area credit market: aggregate lending does not increase despite relaxed standards and higher credit demand.

Figure 9. Alternative Fifth Variable: Credit Market (2008:M10–2016:M10)



Notes: Responses of alternative choices for the fifth variable to an expansionary monetary policy shock of 25 bp obtained from the baseline VAR model estimated over the post-crisis sample with external instruments and 90 percent confidence band.

2.5 Pure Monetary Policy Shocks vs. Information Shocks

Jarocinski and Karadi (2018), Miranda-Agrippino and Ricco (2018), Nakamura and Steinsson (2018), and Romer and Romer (2000), among others, have pointed out that Governing Council decisions also unveil information about variables that do not represent policy instruments. The rationale behind this argument is that policymakers react to economic conditions (i.e., inflation and unemployment). An unanticipated decrease in the main refinancing rate might indicate that inflation is lower than expected and/or unemployment is higher than expected.

Jarocinski and Karadi (2018) disentangle the information component of monetary policy shocks from the pure policy shock by differentiating between responses of interest rates and stock prices on Governing Council meeting days. While interest rates decrease and stock prices increase after a monetary policy easing, both financial market variables move in tandem after an information shock.

Table 2. Loadings on the First Two Principal Components

Variable	PC 1	PC 2
German Government Bond 2Y	0.4433	−0.2401
German Government Bond 3Y	0.4699	−0.2176
German Government Bond 5Y	0.4744	−0.2082
German Government Bond 10Y	0.4272	−0.1683
Euro Stoxx 50	0.3028	0.6337
FTSE Euro 100	0.2887	0.6494

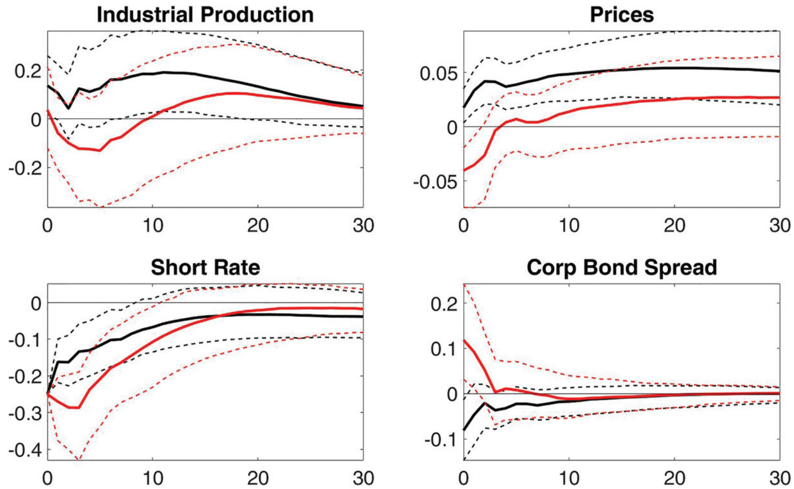
Therefore, Jarocinski and Karadi (2018) estimate a VAR model with instruments and impose sign restrictions in order to identify pure policy shocks and information shocks, respectively.

We follow their concept of discerning between movements of interest rates and stock prices on monetary policy announcement days. We incorporate changes in both variables into a principal component analysis. More precisely, we include standardized changes in the yield of German government bonds with maturities of 2, 3, 5, and 10 years on announcement days as well as standardized changes of the Euro Stoxx 50 and the Financial Times Stock Exchange (FTSE) Euro 100 stock price index.[16] By applying principal component analysis, we are more agnostic than Jarocinski and Karadi (2018), as we let the data speak without imposing restrictions. In fact, principal components and factor analyses are common empirical tools in the news announcement literature; see, e.g., Gürkaynak, Sack, and Swanson (2005) and Barakchian and Crowe (2013).

Table 2 displays the loadings on the first two components. The cumulative proportion of information explained by these two principal components is roughly 92 percent. While in the first component all variables are loaded with a positive sign, the second component loads changes in bond yields with a negative sign and changes in the stock market with a positive sign. Hence, we interpret the first component as the information shock and the second component as

[16] Each variable is standardized to have a mean of zero and a standard deviation of one.

Figure 10. Pure Policy and Information Shock



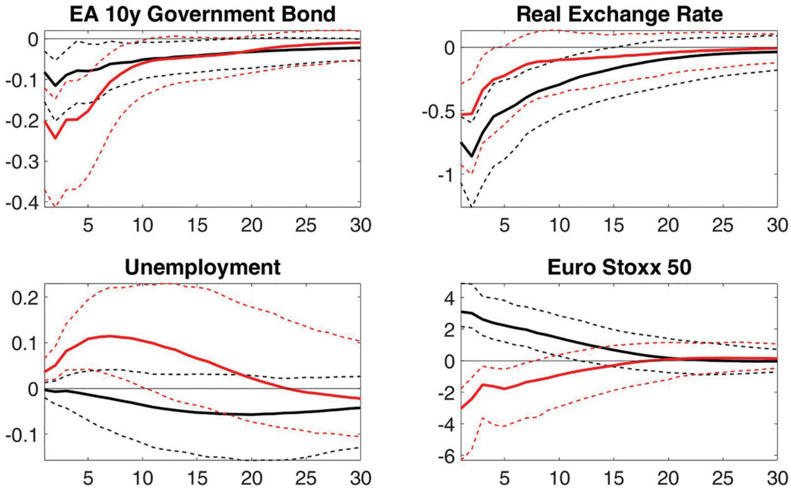
Notes: Responses to an expansionary monetary policy shock of 25 bp obtained from the baseline VAR model estimated with external instruments and 90 percent confidence band. The black (red) line indicates the impulse responses for the pure monetary policy shock (information shock).

the pure policy shock.[17] The interpretation of the pure policy shock is further supported by the fact that the loadings on the lower end of the yield curve are higher (in absolute terms). According to the pure policy shock, the two biggest surprises were the decision not to raise the volume of the APP in December 2015 and the announcement of the SMP in May 2010.

Figure 10 shows the results from the baseline model following a pure policy shock and an information shock, respectively. The pure policy shock displays results which are qualitatively similar to those following the monetary policy shock discussed before. A negative information shock means that policymakers lower the interest rate due to weak economic fundamentals. In line with the findings of Jarocinski and Karadi (2018), a negative information shock decreases the price level and increases the corporate

[17]We multiply the pure policy shock with -1 such that, in line with the monetary surprise component from above, a positive surprise represents a monetary tightening.

Figure 11. Pure Policy and Information Shock: Additional Real and Nominal Variables

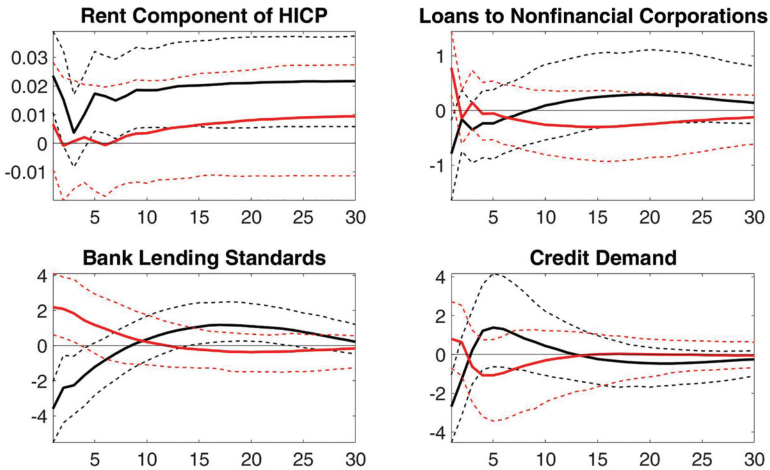


Notes: Responses to an expansionary monetary policy shock of 25 bp obtained from the baseline VAR model estimated with external instruments and 90 percent confidence band. The black (red) line indicates the impulse responses to the pure monetary policy shock (information shock).

bond spread immediately. We do not find evidence that this shock decreases industrial production. Nevertheless, we observe a reduction in economic activity as indicated by the hike in unemployment; see figure 11. The stock market reacts in line with our expectations, i.e., a drop in the interest rate due to a pure policy shock (information shock) increases (decreases) the Euro Stoxx 50 on impact. A depreciation of the euro as well as decreases in government bond yields can be the consequence of both types of shocks.

From figure 12 we observe that rents only respond to a pure policy shock. As before, lending standards decrease and credit demand strengthens after a pure policy shock. A negative information shock leads to tighter lending standards but has no effect on credit demand. Once again, the loans to the private sector respond counter-intuitively with respect to both shocks. Apart from loans, all impulse responses to both types of shocks are well in line with the theory and the findings in the literature.

Figure 12. Pure Policy and Information Shock: Credit Market



Notes: Responses to an expansionary monetary policy shock of 25 bp obtained from the baseline VAR model estimated with external instruments and 90 percent confidence band. The black (red) line indicates the impulse responses to the pure monetary policy shock (information shock).

Overall, we find that the pure policy shock leads to impulse responses that are in line with those observed from the VAR model, where changes in the yield on 10-year German bunds on ECB meeting days serve as an instrument. Thus, we conclude that our instrument in the baseline model captures policy surprises well and is not overly distorted by the revelation of new information on meeting days.

3. Country-Specific Effects of Euro-Area Monetary Policy

In this section, we study the country-specific responses to a common monetary policy shock. Hence, at this stage, we want to exclude the feedback from domestic economic conditions to euro-area monetary policy. Since we have identified a common monetary policy shock in the previous section, there is no identification problem to solve at this stage. Therefore, in order to derive country-specific responses to a common euro-area shock, we use local projections as suggested by Jordà (2005).

An impulse response is defined as the response of a variable h periods ahead to a monetary policy shock at time t. This response is not derived from a full-scale VAR model with interactions among all endogenous variables, but rather from a single-equation framework that does not allow for a feedback from the endogenous variable to monetary policy. We estimate a series of regressions of a dependent variable dated $t + h$ on the monetary policy shock in t as well as a set of control variables. The estimated model is the following:

$$y_{t+h} - y_{t-1} = \alpha_h + \beta_h mp_t^{EA} + \gamma_h' \sum_{s=0}^{q} \mathbf{x}_{t-s} + \varepsilon_{t+h}, \qquad (10)$$

where y_t is the dependent variable and $\mathbf{x}_t$ is a vector of country-specific control variables. We include up to q lags of control variables. The euro-area monetary policy shock is denoted by mp_t^{EA}. Hence, the coefficient β_h measures the impact of a change in policy at t on the dependent variable h periods ahead. Plotting β_h as a function of h provides us with an impulse response function.

For our purpose, local projections are advantageous for two reasons: (i) they rest on a very small number of parameters to be estimated and (ii) since we estimate a single equation only, the results are more robust to misspecifications in other parts of the model. While we typically model dynamic systems of equations, e.g., VAR models, *because* we want to capture the feedback from the economy to policy, we deliberately exclude this feedback here.

Due to the fact that the dependent variable is h periods ahead, the error terms will exhibit serial correlation. We therefore apply a Newey-West correction to our estimation errors, which we use to construct a confidence band around the estimated series of β_h coefficients. As suggested by Jordà (2005), the maximum lag for the Newey-West correction is set to $h + 1$.

We estimate local projections for 10 member countries, which together account for more than 95 percent of euro-area GDP: Germany, France, Spain, Italy, Portugal, Greece, Ireland, Netherlands, Finland, and Austria. To contrast the country-specific responses with the area-wide responses, we also estimate the model for a synthetic euro area that consists of these 10 countries only.[18] The sample period is 2002:M1 to 2016:M1 and the data frequency is monthly. The sample is slightly shorter than the sample used in the previous section due to limited data availability. We estimate the model for each of the following variables: (log) industrial production, (log) price level as measured by the HICP, unemployment rate, (log) real exchange rate, (log) stock prices, and (log) loans to the private sector.

We keep the list of control variables relatively short and include country-specific cyclical variables such as unemployment, prices, industrial production, and the real exchange rate. We also include the shadow short-term interest rate to reflect monetary conditions. Note that the latter is supposed to reflect the level of policy accommodation, but not the policy shock, which is reflected by mp_t^{EA}. Changing the vector of control variables has no substantive effect on our estimated impulse response functions.

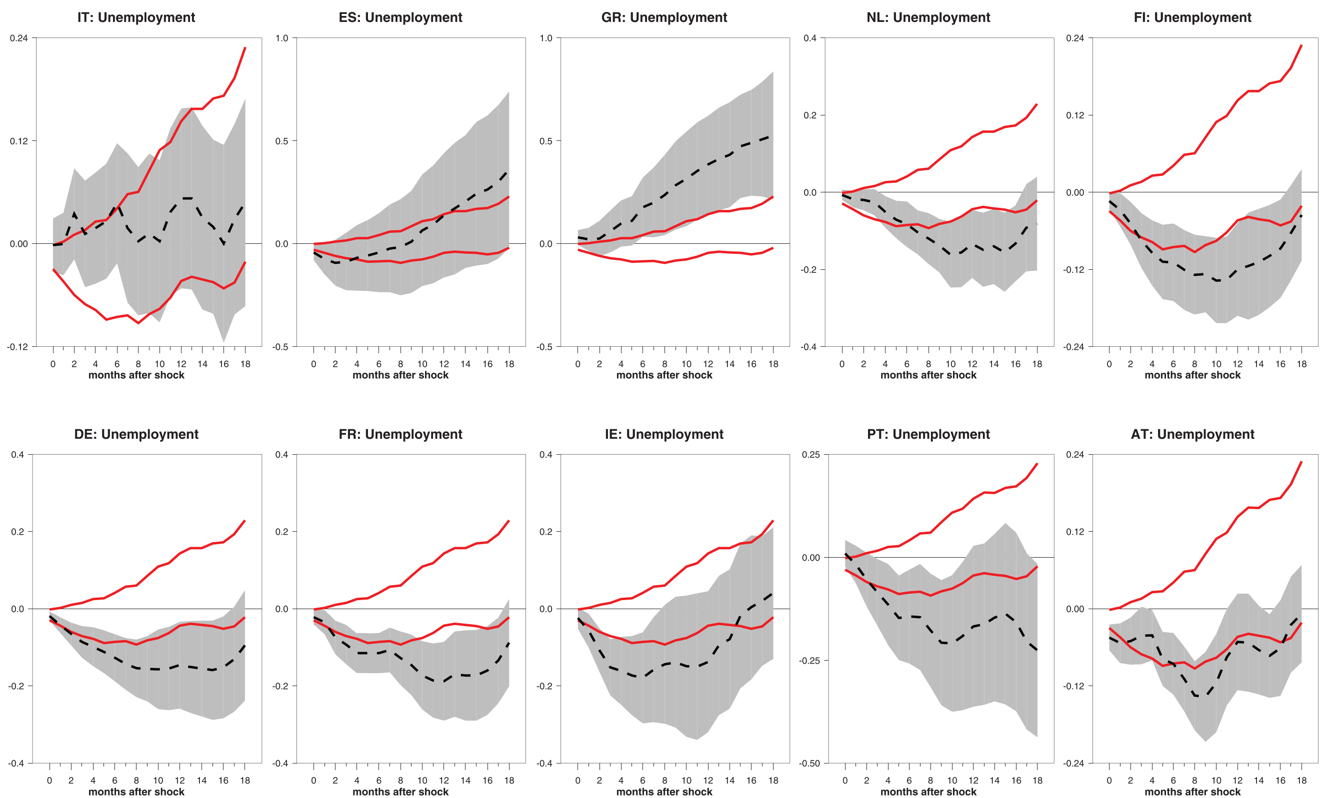
The euro-area monetary policy shock, mp_t^{EA}, is based on the identification of policy surprises discussed before. The relation between the structural shock u_t of the VAR model and the reduced-form shock ε_t is given by $U_t = S^{-1} \cdot \varepsilon_t$. From the estimation of the baseline model in 2.4, we receive the reduced-form error terms as well as the row in the matrix S^{-1} that captures the contemporaneous responses to the structural shock. With these variables at hand, we are thus able to uniquely identify our policy shock series, mp_t^{EA}.

3.1 Results

The results are presented in figures 13 to 18. In each figure, we plot the impulse response function following a monetary policy easing shock, the 90 percent error band around this impulse response, and, as a pair of red lines, the error band around the estimated impulse response for the synthetic euro-area variable. Thus, comparing the dotted country-specific impulse response and the red error

[18] The euro-area time series for each variable is constructed as the weighted average of the country-specific variables. For that purpose, the GDP weights from the ECB website have been normalized in order to account for member countries which are not included here, that is, the GDP weights for the 10 countries used here always add up to 100 percent.

Figure 13. Country-Specific Responses of Unemployment



Notes: Country-specific response to a euro-area monetary policy easing shock of 25 bp (dotted line) obtained from local projections and 90 percent error bands (shaded area). The solid lines are the error bands around the average euro-area response.

bands allows us to assess whether a given country's response deviates significantly from the response of the euro area as a whole.

We find that following a monetary policy shock, unemployment decreases significantly in core countries such as Germany, France, and the Netherlands; see figure 13. Some periphery countries—namely Italy, Spain, and Greece—in contrast, could not benefit from the monetary expansion implemented by the ECB. In these countries, unemployment does not fall. As a consequence of this heterogeneity, the area-wide unemployment rate does not respond significantly, which is consistent with the finding presented in the previous section.

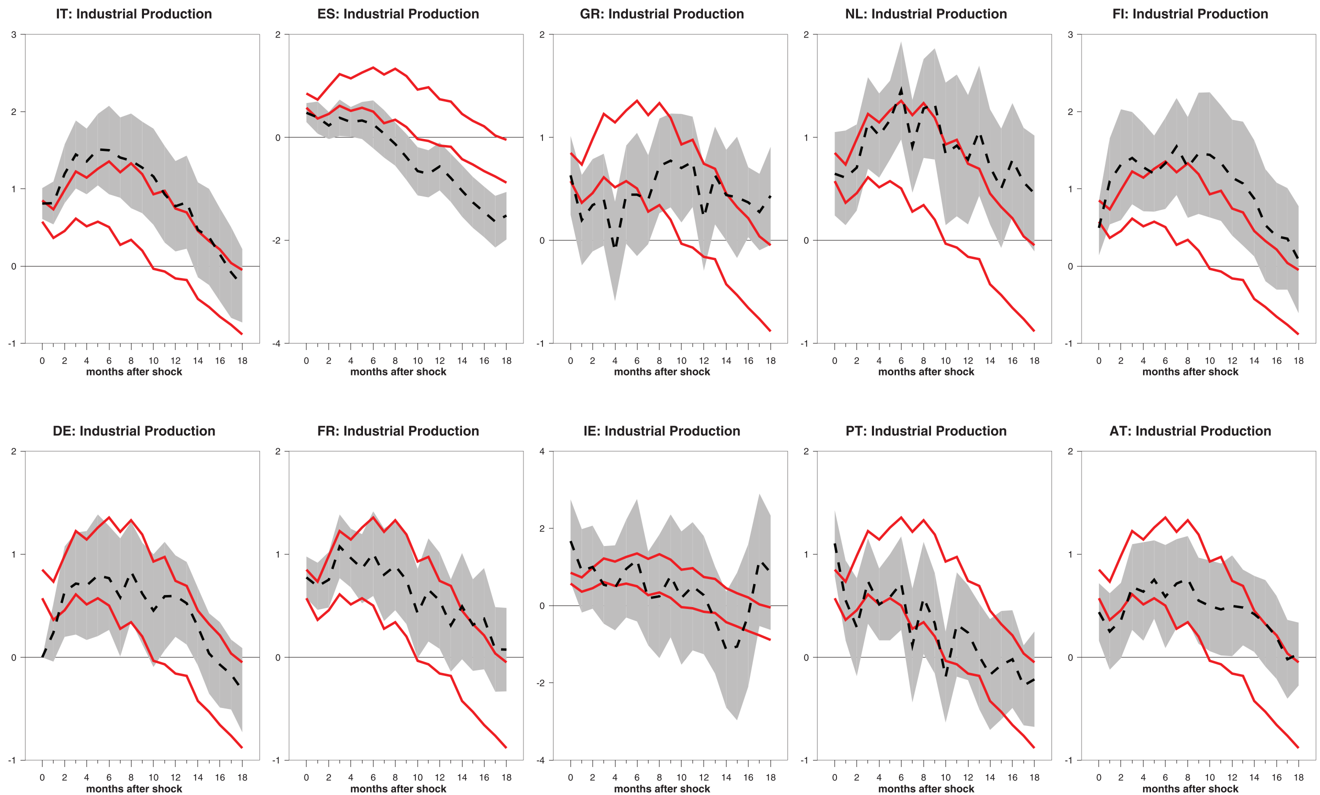
Figure 14 reports the responses of industrial production. Manufacturing activity improves in all countries following the expansionary policy shock. Interestingly, the responses are much more homogeneous across countries. Only the response of industrial production in Spain deviates markedly from the euro-area average response. In contrast to that, manufacturing activity rises in Italy and Greece after a monetary easing while employment does not improve. Possibly, unemployment rates in these countries are mainly driven by other sectors.[19] In a nutshell, we only observe heterogeneous effects on real activity if it is proxied by the unemployment rate and not by industrial production.

Figure 15 shows the responses of consumer prices, which increase moderately following a monetary policy shock. The responses are well in line with the average response of the euro-area price level and might be a result of the single European market.

In all countries, the real effective exchange rate depreciates on impact; see figure 16. Different responses of real exchange rates among EMU members can only occur when price levels react differently. As we find homogeneous responses of price levels to a monetary policy shock, we also observe homogeneous movements of the real exchange rate. The size of the depreciation for the euro area as a whole is in a range similar to the one observed in the VAR model (see figure 5). However, the confidence bands in the local projections framework are somewhat wider, suggesting that cutting the

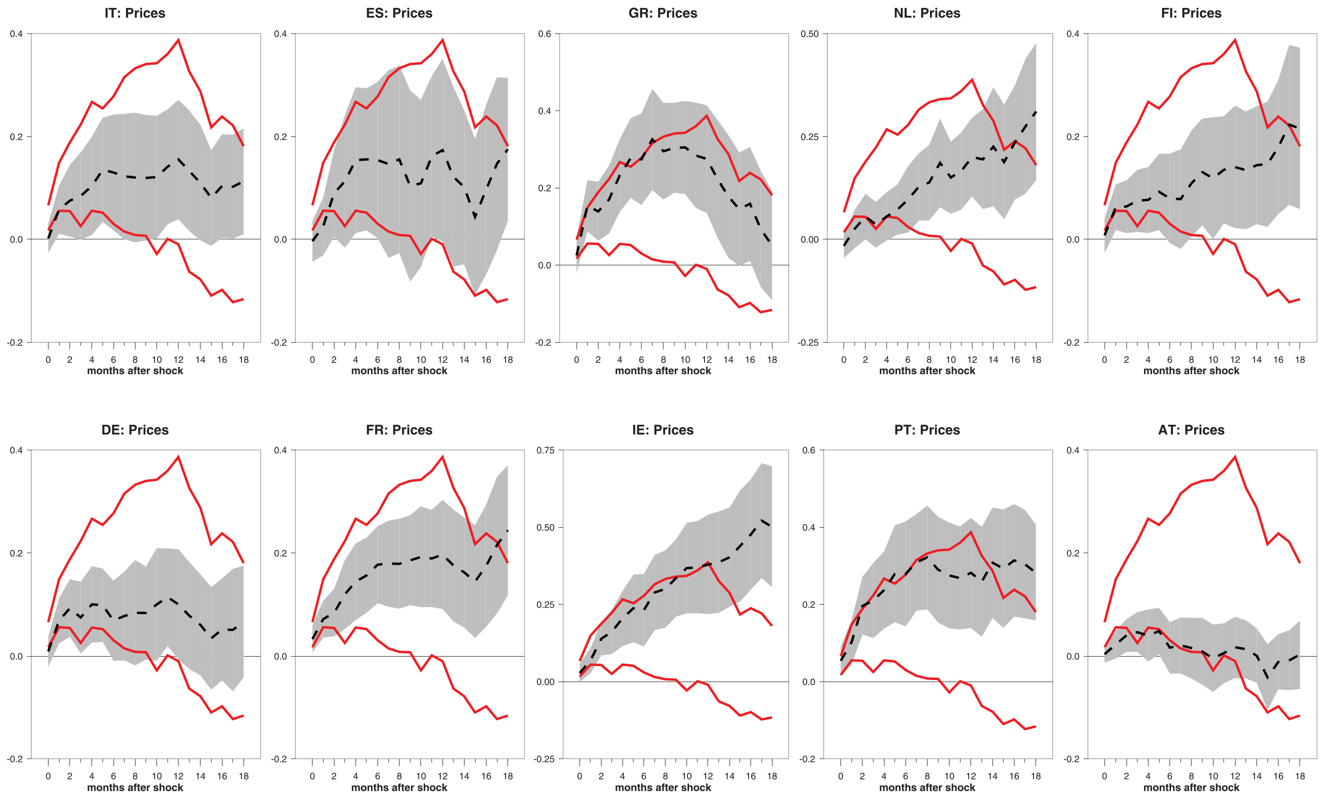
[19] In fact, the service sector accounts for more than two-thirds of GDP in both countries.

Figure 14. Country-Specific Responses of Industrial Production



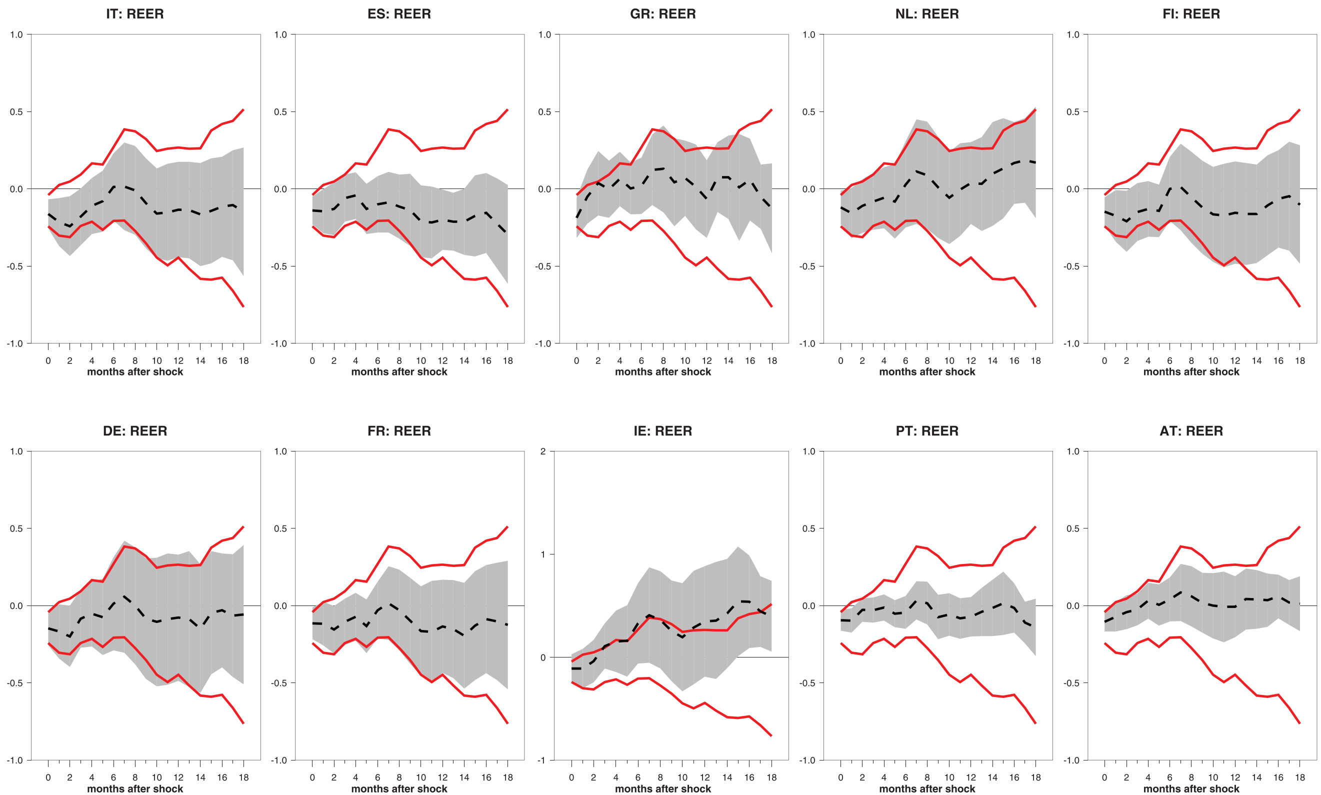
Notes: Country-specific response to a euro-area monetary policy easing shock of 25 bp (dotted line) obtained from local projections and 90 percent error bands (shaded area). The solid lines are the error bands around the average euro-area response.

Figure 15. Country-Specific Responses of Consumer Prices



Notes: Country-specific response to a euro-area monetary policy easing shock of 25 bp (dotted line) obtained from local projections and 90 percent error bands (shaded area). The solid lines are the error bands around the average euro-area response.

Figure 16. Country-Specific Responses of the Real Exchange Rate



Notes: Country-specific response to a euro-area monetary policy easing shock of 25 bp (dotted line) obtained from local projections and 90 percent error bands (shaded area). The solid lines are the error bands around the average euro-area response.

feedback from the real economy to monetary policy results in higher estimation uncertainty.

The response of the main stock price indexes (see figure 17) exhibits the expected positive sign for the overall euro zone in the short run. For some countries—i.e., Spain, Greece, the Netherlands, Ireland, Portugal, and Austria—the responses deviate negatively from the average euro-area response after about 10 months. The results are also in line with the country-specific findings provided by Wieladek and Pascual (2016). These authors also document an insignificant and even negative effect of a policy easing on stock prices in some euro-area countries.

Finally, figure 18 suggests that the ECB is not effective in stimulating credit to nonfinancial corporations. Germany, Austria, and Greece appear to be the only countries in which credit increases significantly following the monetary expansion. In most other countries, the response of bank credit remains insignificant. As derived from the VAR model and shown in figure 6, this is in line with the insignificant response of aggregate credit in the euro area.[20]

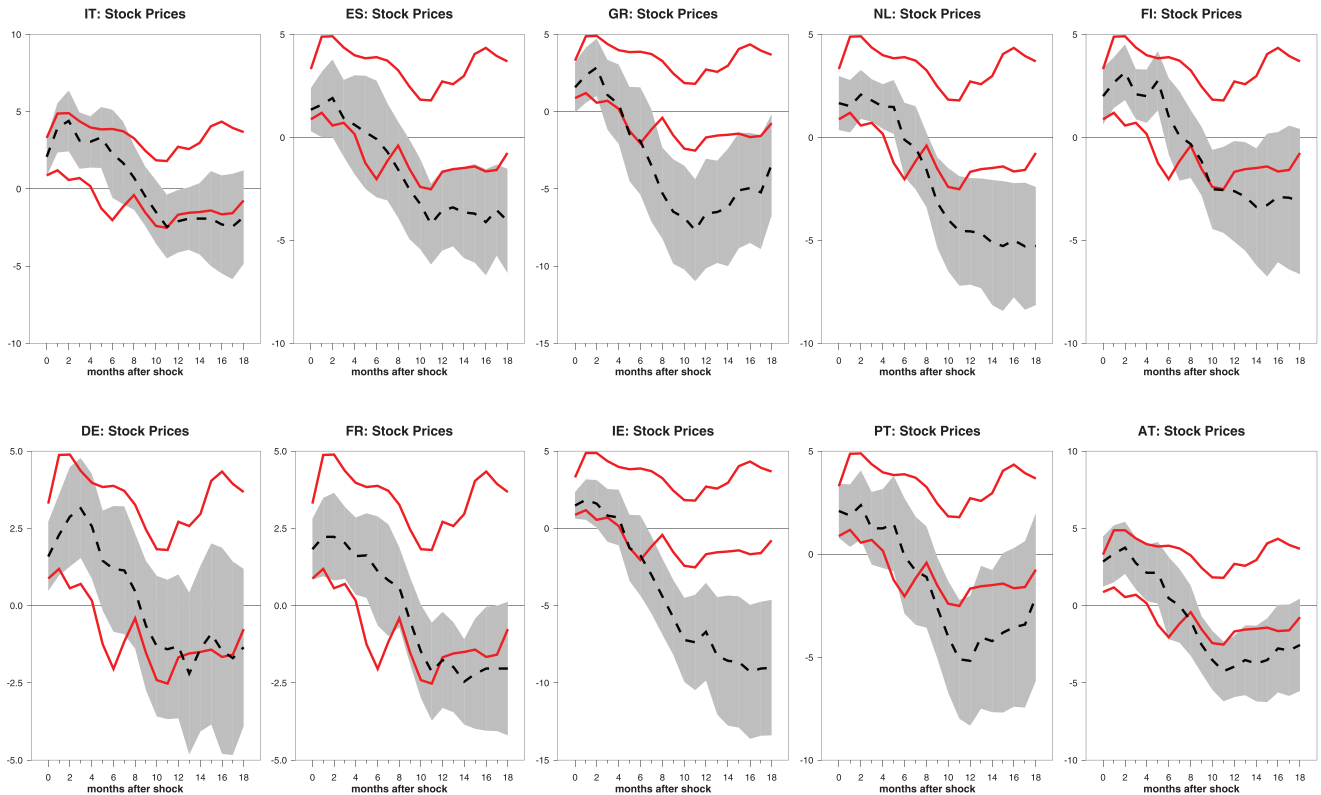
Overall, we find the responses of unemployment, stock prices, and bank lending to be different across member countries, while consumer prices and industrial production are much more homogeneous. The results suggest that the impaired transmission through the financial system, i.e., the stock market and the credit market, as well as structural frictions in the adjustment of the labor market, might hold the key to understanding the uneven transmission of ECB policy.

4. Conclusions

In this paper, we studied the monetary transmission mechanism in the euro area—both based on aggregate and country-specific data. To identify a monetary policy shock, we estimated an external instruments VAR that solves the contemporaneous correlation between monetary policy and financial variables in the euro area.

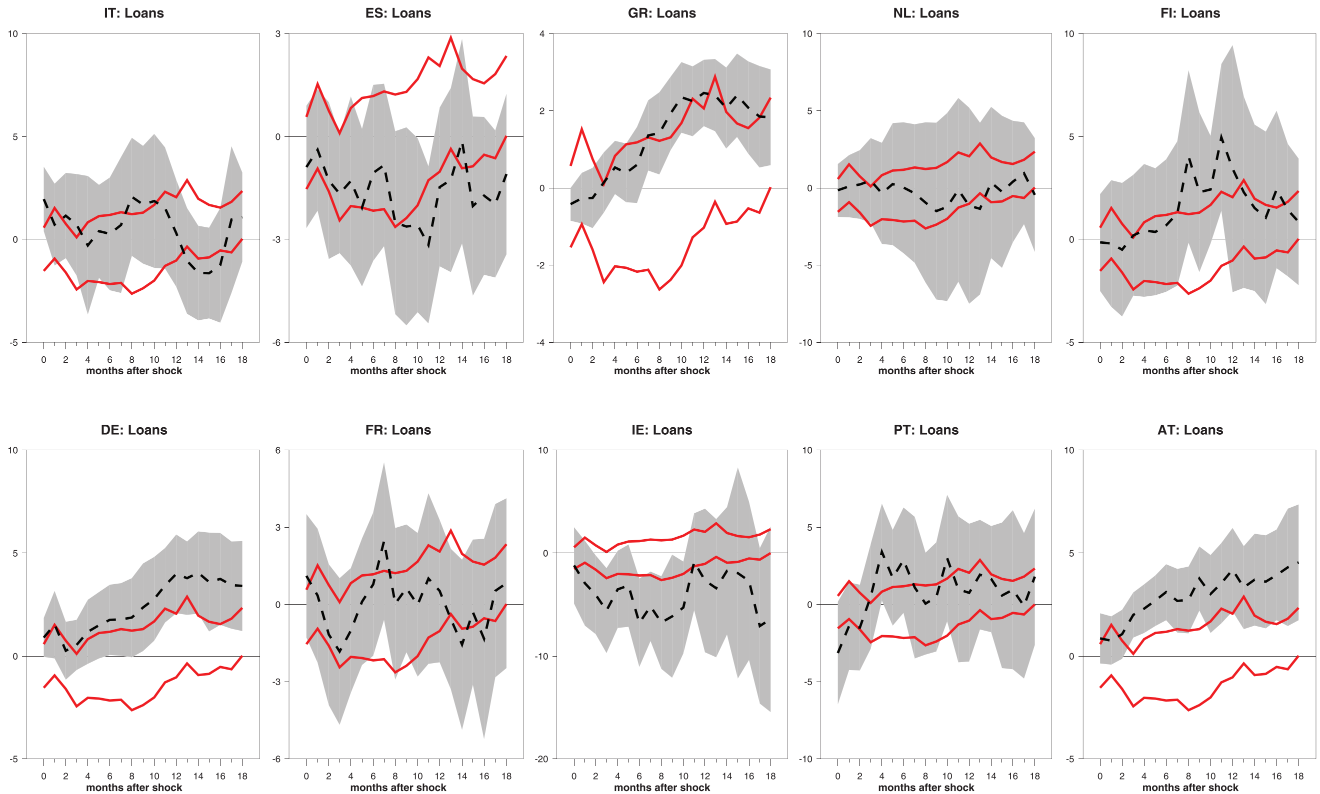
[20]This finding is in line with the results of Boeckx, Dossche, and Peersman (2017).

Figure 17. Country-Specific Responses of Stock Prices



Notes: Country-specific response to a euro-area monetary policy easing shock of 25 bp (dotted line) obtained from local projections and 90 percent error bands (shaded area). The solid lines are the error bands around the average euro-area response.

Figure 18. Country-Specific Responses of Loans



Notes: Country-specific response to a euro-area monetary policy easing shock of 25 bp (dotted line) obtained from local projections and 90 percent error bands (shaded area). The solid lines are the error bands around the average euro-area response.

Our findings are threefold: First, identifying a VAR with an external instrument helps to disentangle the simultaneous interaction of the ECB and the financial market. A principal component analysis of the responses of bond yields and stock prices combined with the interaction among the variables in the VAR model generates a plausible decomposition of policy surprises into the pure policy shock and the information shock arising from ECB decisions.

Second, we document the heterogeneity of the monetary transmission process across transmission channels. Overall, monetary policy is less effective with regard to stimulating bank lending and increasing the valuation of the stock market. These findings suggest that monetary transmission is severely hampered by the state of banking systems, e.g., the ongoing deleveraging and the burden of nonperforming loans.

Third, we shed light on the heterogeneity of policy transmission across member countries. For that purpose, we included the ECB's monetary policy shock in country-specific regressions. This makes sure that the policy shock is the same across countries and that a feedback from country-specific variables to euro-area monetary policy is excluded. We show that the responses of some variables, most notably prices and industrial production, are relatively similar across countries, while the transmission through the financial system, i.e., the responses of stock prices and bank lending, varies among member countries. Since our results are purely positive, we should be careful not to overemphasize the normative implications. Nevertheless, the results suggest that a "one-size-fits-all" monetary policy might not be the best tool to boost demand if national banking systems are blocked—not least since banks provide most financing in continental Europe. Over many years since the eruption of the European debt crisis, monetary policy was overburdened with the task of reviving economic activity. In light of the findings presented here, this has supported inflation throughout the euro zone. However, the effects on real activity are heterogeneous, especially if one focuses on unemployment, where core countries benefit from a monetary easing disproportionately.

Appendix. Data Sources and Definitions

Table A.1. Data Sources

Variable	Adj.	Source
Bank Lending Standards	nsa	Bank Lending Survey
Credit Demand	nsa	Bank Lending Survey
Crude Oil Prices (Brent Europe)	nsa	FRED
EONIA Rate	nsa	Datastream
EURIBOR Future	nsa	Eikon
Euro Stoxx 50	nsa	Datastream
Eurobond 10y All Ratings	nsa	ECB
FTSE Euro 100 Stock Price Index	nsa	Datastream
German Government Bond Yield	nsa	Eikon
Harmonised Index of Consumer Prices	sa	ECB
Industrial Production (excl. Construction)	sa	ECB
Loans to Nonfinancial Institutions	sa	ECB
Real Exchange Rate (vis-à-vis Group of 19 Trading Partners)	nsa	ECB
Shadow Rate	nsa	Wu and Xia (2016)
(Alternative) Shadow Rate	nsa	Krippner (2012)
(Alternative) Shadow Rate	nsa	Lemke and Vladu (2017)
S&P Eurozone Corporate Bond Yield	nsa	Datastream
Unemployment Rate	sa	ECB

Note: Seasonally adjusted data series are indicated by "sa." Data series not seasonally adjusted are indicated by "nsa."

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