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Abstract

We explore the effects of the ECB's unconventional monetary policy on the banks' sovereign debt portfolios. In particular, using panel vector autoregressive (VAR) models we analyze whether banks increased their domestic government bond holdings in response to non-standard monetary policy shocks, thereby possibly promoting the sovereign-bank *nexus*, i.e. the exposure of banks to the debt issued by the national government. Our results suggest that euro area crisis countries' banks enlarged their exposure to domestic sovereign debt after innovations related to unconventional monetary policy. Moreover, the restructuring of sovereign debt portfolios was characterized by a home bias.

JEL-Codes: C320, E300, E520, E580, G210, H630.

Keywords: European Central Bank, unconventional monetary policy, panel vector autoregressive model, sovereign-bank nexus.

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1 Introduction

The European Central Bank (ECB) responded to the global financial crisis by conducting a number of unconventional monetary policy measures in addition to lowering the policy rate. The aim of these measures was to reduce potential risks for price stability in the euro area by counteracting distortions on the interbank market and reducing impairments in the monetary policy transmission induced by financial market fragmentation across member states during the sovereign debt crisis (ECB, 2011, 2013).[1]

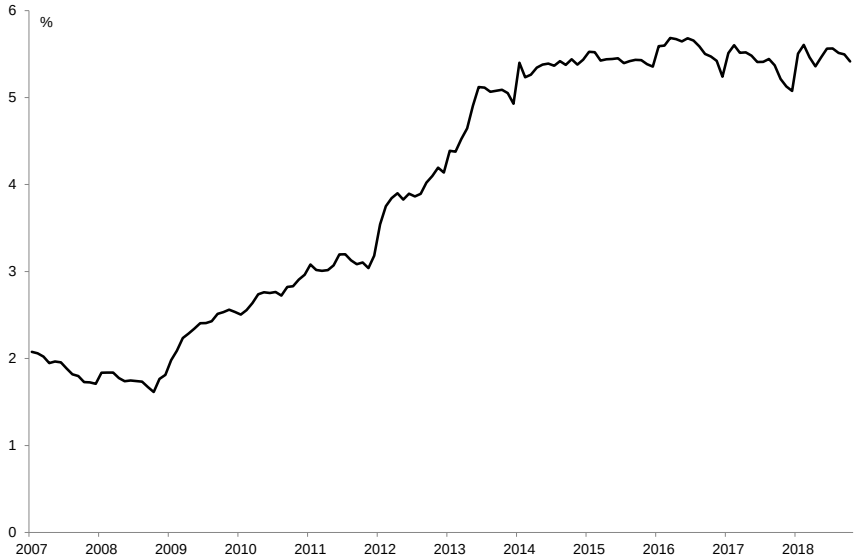
In this paper, we explore the effects of the ECB's unconventional monetary policy on the balance sheet exposure of a country's banking sector to the debt issued by the national government, i.e. the so-called *sovereign-bank nexus*. The nexus is considered of primary importance for the medium-term stability of the financial system (Basel Committee on Banking Supervision, 2017; IMF, 2018; Battistini et al., 2014; Brunnermeier et al., 2016; Farhi and Tirole, 2018, among others). On the one hand, a higher share of bond holdings is typically associated with a better liquidity position of banks, thus being favourable for the soundness of the banking system (Walther, 2016; Richter et al., 2017; Hoerova et al., 2018), and may even reduce the incentives for the sovereign to default (Gennaioli et al., 2018; Basel Committee on Banking Supervision, 2017). On the other hand, a stronger nexus may harm financial stability by making the national banking sector more sensitive to deteriorations in the sovereign's creditworthiness and may even contribute to the emergence of *diabolic loops* as repeatedly observed since the outbreak of the global financial crisis (Brunnermeier et al., 2016; Farhi and Tirole, 2018; Dell'Ariccia et al., 2018a). For example, many euro area countries experienced such a loop as the market value of banks' holdings of domestic government bonds dropped due in the deterioration in the sovereign's creditworthiness, thus putting a strain on the solidity of the banking sector. Governments responded by giving safety guarantees or even implementing substantial rescue packages, which, however, might potentially increase sovereign risk further and reinforce the impairment of banks' balance sheets.[2] Meanwhile, Battistini et al. (2014) and Brutti and Saure (2015) consider the distortion created and intensified by the nexus as one of the core problems associated with the euro crisis.

Against this background, we estimate panel vector autoregressive (VAR) models using Bayesian methods to assess how banks in a sample of euro area countries adjusted their domestic sovereign debt portfolios in response to a non-standard monetary policy shock. We focus on the period 2007-2014. According to Figure 1, the ratio of banks' domestic

[1] In particular, the ECB switched to regular open market operations with fixed rates and full allotment that were provided with longer maturities, relaxed collateral requirements, changed the modalities of its long-term refinancing operations and launched outright transactions, like the Securities Market Programme (SMP) in 2010 and the extended Asset Purchase Programme (APP) in 2015, or announced these - under the Outright Monetary Transaction (OMT) program in 2012. In addition, the central bank imposed a negative interest rate on its deposit facility. See Section 3 for more details.

[2] According to Acharya et al. (2014), in industrial countries there was essentially no sign of sovereign credit risk before the onset of the global financial crisis. Hence, the nexus was not considered to be problematic due to the prevailing view that sovereign credit risk was unlikely to be a concern in the near future. Rather, sovereign defaults were regarded as a problem of emerging economies.

Figure 1: Euro area banks' domestic government bond holdings ratio



Notes: Data taken from the ECB. Own calculations. Banks' domestic government bond holdings ratio is defined as domestic sovereign bond holdings relative to total assets. Euro area countries comprise Austria, Belgium, Germany, Spain, Finland, France, the Netherlands, Portugal and Italy. Euro area average is calculated by using countries' nominal GDP shares of the previous year as weights.

government bond holdings increased markedly during that time.

Following Canova and de Nicolo (2002), Peersman (2005), Uhlig (2005), Rubio-Ramirez et al. (2010) or Arias et al. (2014) we use sign restrictions on impulse responses to identify an unconventional monetary policy shock. In particular, in our benchmark model we refer to Boeckx et al. (2017) and relate a shock to non-standard monetary policy to an unexpected increase in the Eurosystem's total assets that is accompanied by a decrease in the spread between the EONIA and the policy rate as well as lower financial stress. We also assess alternative identification schemes that are related to changes in the composition of open market operations and the shadow rate of monetary policy.

Our results suggest the presence of a dichotomy between the core countries of the euro area, i.e. Germany, France, the Netherlands, Belgium, Austria and Finland, and the crisis economies Italy, Spain and Portugal. In particular, in the years 2007-2014, the banking sectors of the euro area crisis countries significantly shifted their asset portfolios towards domestic sovereign bonds in response to expansionary unconventional monetary shocks. These shocks appear to have been quantitatively important, as they explain around 19% of the variation in the national banking sectors' share of domestic government bonds in the group of distressed euro area economies. Moreover, banks seemed to manage their sovereign debt portfolios actively in response to sudden unconventional monetary expansions, as the rising holdings of domestic government bonds were accompanied by a reduction in the balance sheet share of bonds issued by other euro area member states. Thus, the reaction of banks' sovereign debt portfolios in the crisis countries was characterized by a home bias. By contrast, euro area core countries' banks seemed not to significantly increase their domestic government bond holdings relative to total assets in response to innovations related to unconventional monetary policy. Core countries'

banks rather restructured their sovereign bond portfolios by lowering their holdings of rest EMU government bonds. Furthermore, estimations using the approach by Jarocinski (2010) also provide support for the presence of a significant dichotomy between core and crisis economies with regard to the response of their banking sectors to unconventional monetary policy shocks. While in Italy, Spain and Portugal the change in the domestic government bond holdings ratio occurred swiftly, in none of the core countries can a significant response of the ratio be documented. Finally, a historical decomposition suggests that the ECB's asset purchases conducted within the Securities Markets Programme (SMP) contributed to an increase in banks' sovereign debt portfolios. In Portugal, the effect was immediately observable after May 2010, while in Italy and Spain it arose after February 2012. Furthermore, the announcement of the Outright Monetary Transactions (OMT) program in September 2012 seemed also to have contributed to a higher domestic government bond holdings ratio. Overall, we conclude that the crisis countries' banks enlarged their exposure to domestic sovereign debt in response to expansionary innovations stemming from unconventional monetary policy, which possibly made them more vulnerable to sovereign distress.

Our paper is related to several recent contributions that investigate the effects of the ECB's unconventional monetary policy on the sovereign-bank nexus by means of microeconometric methods (Altavilla et al., 2017; Drechsler et al., 2016; Peydro et al., 2017; Crosignani et al., 2017; Jasova et al., 2018, among others).[3] These studies have the advantage of exploiting the rich information revealed by the cross-sectional and time-series dimension of the large bank-level panels. The papers usually concentrate on the contemporaneous microeconomic effects of specific policy interventions on the individual bank, while largely abstracting from dynamic macroeconomic feedback effects. We contribute to the literature by basing our empirical analysis on aggregate data, thus taking a purely macroeconomic perspective and providing direct estimates of the reaction of the aggregate banking sector in several euro area countries to unconventional monetary policy shocks. While acknowledging that the use of aggregate data comes at the cost of losing cross-sectional information, it allows us to capture - albeit only implicitly - many macro-level interlinkages between banks' behavior and the rest of the economy.

The paper is organized as follows. Section 2 gives an overview of the related literature. In Section 3, we discuss our benchmark panel VAR model set-up. We outline the model framework, introduce the data and discuss the strategy to identify an unconventional monetary policy shock. In Section 4, we summarize our results. We present impulse response analysis, a decomposition of the forecast error variance, discuss alternative schemes to identify unconventional monetary policy shocks and also discuss the results for the single euro area countries derived from a panel of VAR models that are estimated by means of a hierarchical Bayesian panel model estimator. Section 5 provides concluding remarks.

[3]We discuss these contributions in greater detail in Section 2 below.

2 Related literature

Our work relates to a number of studies that use structural VAR models to investigate the effects of unconventional monetary policy shocks on the basis of aggregate data.[4] Most of the contributions focus on the transmission of such shocks to real activity and inflation and, in some cases, on credit market variables, e.g. different loan volumes and lending rates, or further financial market aggregates. Other papers take an explicit financial stability perspective by exploring how innovations to non-standard monetary policy affect risk-taking behavior (risk-taking channel) or certain finacial stress indicators.[5] The overall conclusion of the vast majority of these studies is that unexpected unconventional interventions induced by monetary policy tend to improve the cyclical situation as well as the refinancing conditions but might also be associated with an intensification of risk-taking in the economy. However, this literature does not discuss any possible effects on the sovereign-bank nexus.

A number of microeconometric studies explore the effects of the ECB's unconventional monetary policy on banks' sovereign debt portfolios using bank-level data. In particular, these papers focus on how certain bank-specific and/or country-specific characteristics affect the behavior of the individual bank. Most contributions focus on the episodes immediately following the introduction of the ECB's long-term refinancing operations (LTROs) conducted with extended maturities between 2011-2012 and 2013-2014. These studies mainly test *(i)* the *carry-trade* hypothesis (Acharya and Steffen, 2015), according to which banks go long on high-risk high-yield sovereign debt, which they fund either by borrowing from the ECB or by going short on low-yield debt and/or (ii) the *moral suasion* hypothesis (Ongena et al., 2016), according to which banks hold domestic government debt partly due to political pressure. Acharya and Steffen (2015) find support for the carry-trade hypothesis as, during 2007-2012, particularly large banks and those with low Tier 1 capital ratios and high risk-weighted assets exploited government guarantees, arbitrage in regulatory risk weights, and access to central bank funding. Ongena et al. (2016) show that during the euro area sovereign debt crisis, banks in fiscally stressed countries were considerably more likely than foreign banks to increase their holdings of domestic sovereign bonds in months with relatively high domestic sovereign bond issuance. Since the effect seemed not to be triggered by the ECB's liquidity provision, they conclude that their results reflect a moral suasion behavior.[6] Furthermore, according to Altavilla et al.

[4]See, for example, Baumeister and Benati (2013), Gambacorta et al. (2014), Weale and Wieladek (2016), Boeckx et al. (2017), Burriel and Galesi (2018).

[5]See, for example, Angeloni et al. (2015), Neuenkirch and Nöckel (2018) or Lewis and Roth (2019). Adrian and Liang (2018) provide a comprehensive review of the risk-taking channel of monetary policy. However, most of the empirical contributions dealing with the risk-taking channel are microeconometric in nature and focus on conventional monetary policy (Maddaloni and Peydro, 2011; Jimenez et al., 2014; Altunbas et al., 2014, for exapmple). Dell'Ariccia et al. (2017) and Delis et al. (2017) are examples of microeconometric studies also covering episodes of unconventional monetary interventions.

[6]Uhlig (2014) shows in a theoretical model that governments potentially facing refinancing difficulties typically have an incentive to allow domestic banks to accumulate more risky domestic bonds. The opposite is the case when public finances are healthy. Battistini et al. (2014) argue that sovereign stress strengthens this incentive, leading to a positive relationship between sovereign yields and the stock of

(2017) publicly owned, bailed-out and poorly capitalized banks responded to sovereign stress by scaling up their holdings of domestic sovereign debt by more relative to other banks. This pattern turns out to be especially pronounced for public owned banks at the time of large liquidity injections by the ECB in December 2011 and March 2012. These results show support for both a carry-trade and moral suasion behavior. Evidence provided by Drechsler et al. (2016) suggests that weakly capitalized banks in particular reacted to the ECB's liquidity injections during the euro area sovereign debt crisis by investing a substantially higher fraction of the additional liquidity in domestic government bonds.[7] Peydro et al. (2017) look at Italian banks and find a positive relationship between the ECB's liquidity injections and the accumulation of domestic sovereign bonds, which is mostly driven by less well capitalized banks. However, the latter tend to increase their holdings of relatively safe bonds instead of riskier assets, which suggests that the reach for liquidity and safety are much more important drivers than risk-shifting or regulatory arbitrage. Unlike our study, these studies do not explore how the *aggregate* banking sector's sovereign bond portfolio changes in response to unconventional monetary policy surprises.

Finally, Colangelo et al. (2017) and Battistini et al. (2014) also built empirical macroeconomic models to study the sovereign-bank nexus in the euro area. Colangelo et al. (2017) employ the VAR methodology and report that after 2011 banks tended to increase the home bias in their government bond portfolios. Battistini et al. (2014) resort to a vector error correction model (VECM) and explore how banks' domestic sovereign debt portfolios in euro area countries are related to changes in the *common risk* and the *country-specific risk* components of sovereign yields.[8] Nevertheless, unlike us, Colangelo et al. (2017) and Battistini et al. (2014) do not discuss the response of banks' sovereign debt portfolios to shocks triggered by non-standard monetary policy.

3 Panel VAR with sign restrictions

3.1 Benchmark specification

Consider a panel VAR model in reduced form:

$$y_{k,t} = \sum_{j=1}^{p} B_j y_{k,t-j} + \tilde{c}_k + \varepsilon_{k,t}, \tag{3.1}$$

domestic government bonds held by banks.

[7] Crosignani et al. (2017) and Jasova et al. (2018) report that Portuguese banks also used the funds obtained via the ECB's LTROs conducted between 2011 and 2012 to buy domestic government debt which was then offered as collateral to obtain short-run liquidity. Carpinelli and Crosignani (2017) derive similar evidence for Italian banks.

[8] Battistini et al. (2014) observe that in most countries an increase in the common-risk component is associated with a rise in banks' domestic exposures. In periphery countries, this positive relationship is also present in the case of the country-specific risk component.

where $y_{k,t}$ is a vector of endogenous variables for country k, B_j is a matrix of autoregressive coefficients for lag j, p is the number of lags, $\tilde{c}_k$ is a vector of country-specific intercepts, which accounts for possible heterogeneity across the units. Furthermore, $\varepsilon_{k,t}$ is a vector of reduced form residuals. In our benchmark model, the vector $y_{k,t}$ consists of industrial production as a measure for real activity, the Core Harmonized Consumer Price Index[9] (Core HCPI), the Eurosystem's amount of total assets, the policy rate on the main refinancing operations, the level of financial stress, which is approximated by the Country-level Index of Financial Stress (CLIFS), the spread between EONIA and the policy rate, and the monetary financial institutes' (MFI) domestic government bond holdings relative to total assets. The Eurosystem's amount of total assets, the policy rate and the interest spread are aggregate variables, i.e. identical for all countries, while the remaining variables are country-specific. Each variable is linearly de-trended at the country level over the sample period. For each element of $y_{k,t}$ we use a pooled set of $M \cdot T$ observations, where M denotes the number of countries and T denotes the number of observations corrected for the number of lags p. The reduced form residuals $\varepsilon_{k,t}$ are stacked into a vector $\varepsilon_t = [\varepsilon'_{1,t} \dots \varepsilon'_{M,t}]'$, which is normally distributed with mean zero and variance-covariance matrix Σ.

Since our sample is short, we follow Ciccarelli et al. (2015) by using a panel of euro area countries that comprises Austria (AT), Belgium (BE), Germany (DE), Spain (ES), Finland (FI), France (FR), Italy (IT), the Netherlands (NL) and Portugal (PT).[10] The panel approach allows us to pool the diverse information from the countries, while controlling for heterogeneity in the constant term. A main advantage of the approach is that it increases the efficiency of the statistical inference. However, this comes at the cost of disregarding cross-country differences by imposing the same underlying structure for each cross-section unit. Subsequently, we also consider sub-panels by distinguishing between euro area crisis countries and core countries to take account of this shortcoming. Additionally, we adopt the hierarchical prior approach of Jarocinski (2010), which allows us to explore the reaction of individual euro area economies to innovations related to unconventional monetary policy.

3.2 Data

The data is taken from the ECB and collected on a monthly basis covering the period from 2007M1 to 2014M12.[11] The beginning of the sample period is determined by the launch of the ECB's unconventional monetary policy measures that started during 2007 before the financial crisis intensified. In particular, the central bank conducted supplementary long-

[9]The Core Harmonized Consumer Price Index covers all items (consumer goods) excluding energy and unprocessed food.

[10]Note that we exclude Ireland from our analysis, because compared to the other countries the Irish series on industrial production is characterized by a marked volatility. Nevertheless, including Ireland in our panel of countries has virtually no effect on the adjustment of the MFIs' domestic government bond holdings ratio to shocks related to unconventional monetary policy, but on the response of industrial production.

[11]See the Appendix for a description of the data.

term refinancing operations (LTRO) in August 2007 in response to the financial turmoil. The switch to main refinancing operations (MRO) with fixed rates and full allotment occurred in October 2008 and was accompanied by the implementation of LTROs with a maturity of 6 and 12 months, respectively, which were also offered at fixed rates with full allotment (ECB, 2011). At the same time, government guaranteed own-use bonds were accepted as collateral and the collateral rating for central bank refinancing was reduced. The SMP was launched in May 2010 in response to the sovereign debt crisis and supported the effects of two covered bond purchasing programs (CBPP). The announcement of the OMT in September 2012 contributed to a lowering of sovereign bond yields, although the program itself was not activated (Altavilla et al., 2016).[12] Meanwhile LTROs were offered with a maturity of up to 36 months, which were followed by a series of Targeted Long Term Refinancing Operations (TLTROs) with a maturity of 45 and 48 months, respectively. Additionally, the interest rate on the deposit facility was cut to become negative. Finally, the ECB modified its communication policy by intensifying its *forward guidance*. The end of the sample period is related to the ECB's launch of the Extended Asset Purchase Program (APP) that was announced in January 2015 (Breckenfelder et al., 2016). The reason for excluding the APP from our analysis is that the path of the corresponding asset purchases was to a large degree anticipated by economic agents. In fact, the central bank published precisely the monthly volumes of its asset purchases, the structure of the purchases as well as the duration of the program. Later information on the extension of the program as well as on the modalities of the end of the net purchases were released. Thus, the APP generated much of its effects through announcement by signalling that the future path of interest rates will be low, which is akin to forward guidance, i.e. the announcement that policy interest rates will remain at the lower bound over a longer period (Breckenfelder et al., 2016).[13] Accordingly, if anything, the 2015-2018 episode is likely characterized by, at most, negligible monetary shocks. Thus, simply extending our sample beyond 2014 could bias our estimates and inference. Although the launch of the APP came with the implementation of a second series of TLTROs, it seems that the program reflects a structural break in the conduct of unconventional monetary policy due to its differences compared to earlier non-standard measures.

The main variable of interest is the ratio of MFIs' holdings of domestic government bonds to total assets of a country's MFIs.[14] Besides this ratio, the selection of variables refers to Gambacorta et al. (2014) and Boeckx et al. (2017) and aims to capture the main economic interactions after the financial crisis. Industrial production and the dynamics of prices are supposed to reflect the macroeconomic development. The Eurosystem's volume

[12] See also Dell'Ariccia et al. (2018b) or Hristov et al. (2019), among others, for a discussion.

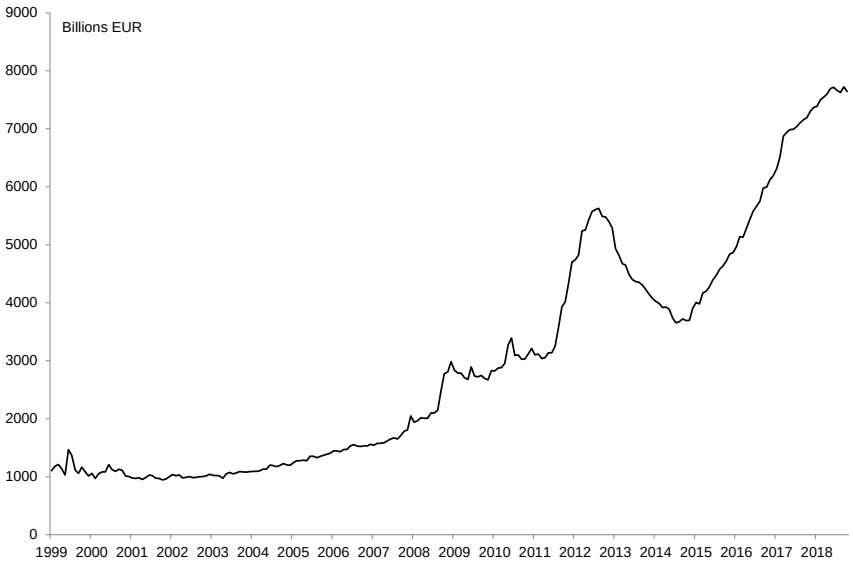
[13] A large quantity of asset purchases by the central bank under a program like the APP can be seen as a credible commitment by monetary policy to keep interest low in the future. Following Krishnamurthy and Vissing-Jorgensen (2011), this transmission channel of monetary policy is denoted as the signalling channel. Note that the OMT, in contrast to the APP, was only announced but not activated.

[14] In this paper we only consider those (aggregate) exposures of banks to sovereign debt which are directly observable as explicit balance sheet positions. Beyond that, banks are also exposed to sovereign risk through positions in various derivatives or potentially through offshore institutions. However, we abstract from such exposure due to the very limited availability of suitable data (Koijen et al., 2017).

of total assets serves as a measure of unconventional monetary policy (ECB, 2015). As shown in Figure 2, total assets increased markedly after the onset of the financial crisis.

Other studies like Weale and Wieladek (2016), Hesse et al. (2018) or Gambetti and Musso (2017) use the central bank's asset purchases as a measure of non-standard monetary policy. However, in the case of the ECB's unconventional monetary policy conducted over the period 2007-2014, focusing only on asset purchases might be too narrow because it neglects the monetary policy effects that arose in the wake of open market operations with full allotment or the relaxing of collateral requirements. Alternatively, the effects of unconventional monetary policy may be measured by an expanding monetary base (Schenkelberg and Watzka, 2013). However, monetary policy measures like the SMP would then not be considered, since the asset purchases conducted under this program were sterilized (Boeckx et al., 2017). The MRO rate is included to facilitate the distinction between conventional and unconventional monetary policy shocks. The interest spread is included as an additional indicator of non-standard monetary policy. Figure 3 displays that the spread was relatively close to zero in normal times, indicating that EONIA was sticking closely to the policy rate.[15] Essentially, the provision of open market operations with full allotment widened the interest rate spread.

Figure 2: Eurosystem's total assets



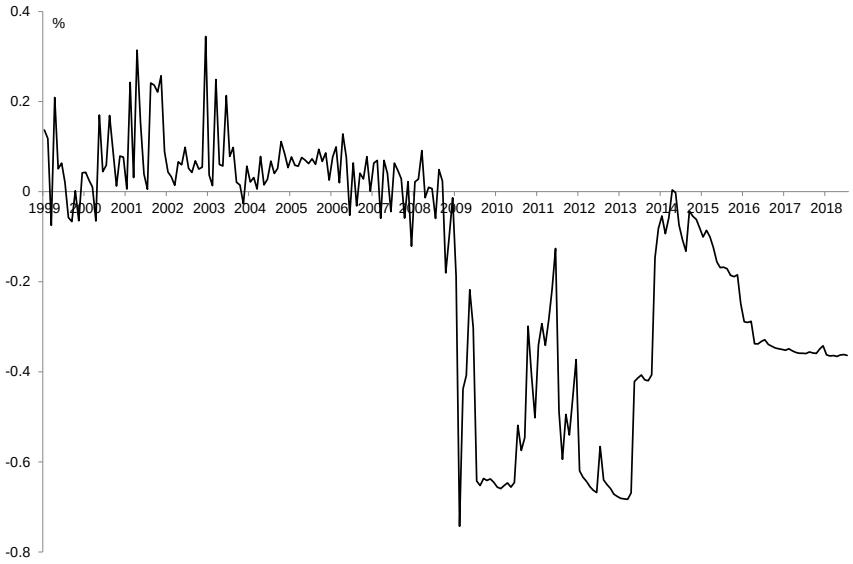
Notes: Data taken from the ECB.

Finally, the CLIFS indicator is a measure of financial stress. By conditioning on it, we control for possible endogenous reactions of the Eurosystem's balance sheet to financial turbulence. More precisely, given the ECB's full allotment policy, changes in the Eurosystem's balance sheet might be demand-induced in the case of elevated financial stress (Boeckx et al., 2017). Industrial production, the price level, the Eurosystem's volume of total assets and the CLIFS are in logs, while the MFIs' domestic government

[15]The banks' usage of the marginal lending facility at the end of a minimum reserve maintenance period mainly caused the shifts of the spread between 1999 and 2003.

bond holdings ratio, the policy rate and the interest rate spread are expressed in percent.

Figure 3: Interest rate spread



Notes: Data taken from the ECB. Own calculations. Spread is the difference between EONIA and policy rate on main refinancing operations.

3.3 Identification of unconventional monetary policy shock

The VAR model (3.1) is estimated with Bayesian methods using a Normal Wishart prior, 10,000 draws and a lag order of $p = 2$. The results proved relatively robust against alternative lag lengths of 3 and 4 lags. Based on the outcome of the estimated model, we generate impulse responses of the variables to structural shocks η_t. We identify the structural shocks through sign restrictions using the algorithm of Arias et al. (2014), which allows for imposing sign restrictions as well as zero restrictions on the impulse responses to a structural shock.

The structural representation of the VAR model (3.1) can be expressed as:

$$A_0 y_{k,t} = \sum_{j=1}^{p} A_j y_{k,t-j} + c_k + \eta_{k,t}, \tag{3.2}$$

with $\eta_{k,t} \sim N(0, I)$, where I is the identity matrix. The reduced form representation of the SVAR is derived by multiplying both sides of (3.2) with A_0^{-1}. The structural shocks $\eta_{k,t}$ relate to the reduced form residuals $\epsilon_{k,t}$ according to $\epsilon_{k,t} = A_0^{-1}\eta_{k,t}$, where $\epsilon_{k,t} \sim N(0, \Sigma)$. The identification of the structural parameters of the model is equivalent to finding the appropriate matrix $\tilde{A} = A_0^{-1}$, which is done by means of sign and zero restrictions. The algorithm of Arias et al. (2014) uses the fact that the Cholesky decomposition of the covariance matrix of the reduced form residuals $\Sigma = PP'$, where P' is lower triangular, can be extended by any orthogonal matrix Q as follows: $\Sigma = PP' = P'Q'QP$, where $QQ' = I$. As the algorithm further requires that Q has a uniform distribution with respect to the Haar measure, Q can be generated by means of a QR-factorization of a

random matrix W of proper dimensions, where each element of W follows an independent standard normal distribution. A particular Q is considered a solution to the identification problem if the impulse responses implied by $\tilde{A} = P'Q'$ satisfy a set of sign restrictions. To estimate the posterior of the structural model, we follow the steps suggested by Arias et al. (2014): *(i)* we draw from the posterior of the reduced form model, *(ii)* then we draw an orthogonal matrix Q, *(iii)* we keep the draw if the combination of reduced form parameters and Q satisfies the sign and zero restrictions, and discard it otherwise, *(iv)* we return to *(i)* until the required number of draws satisfying the restrictions is obtained. Our results are based on 10,000 draws consistent with the imposed sign restrictions. The latter are discussed subsequently.[16]

3.3.1 Identification of unconventional monetary policy shocks in the literature

Following Curdia and Woodford (2011), a number of studies have extended dynamic stochastic general equilibrium (DSGE) models by incorporating unconventional monetary policy (Chen et al., 2012; Falagiarda, 2014; Le et al., 2016; Quint and Rabanal, 2017; Hohberger et al., 2018). Although these studies differ in their conclusion regarding the effectiveness of disturbances related to non-standard measures of monetary policy, they all show that output is stimulated in response to an unconventional monetary policy shock, which is conducted in terms of a quantitative easing, i.e. through the purchase of sovereign bonds that induces the level of base money to rise. Simultaneously, they report that inflation rises after the shock, whereas the government bond yield, the spread between the bond rate and the short-term rate or the risk premium on credit, decline. Table 1 summarizes the findings.

Table 1: Theoretical effects of an unconventional monetary policy shock

	Real output	Inflation rate	Government bond purchases	Government bond yield	Risk premium	Interest rate spread
Falagiarda (2014)	↑	↑	↑	↓		
Chen et al. (2012)	↑	↑			↓	
Le et al. (2016)	↑	↑	↑		↓	
Quint and Rabanal (2017)	↑	↑	↑			↓
Hohberger et al. (2018)	↑	↑	↑	↓		

Notes: Chen et al. (2012) report impulse responses to a simulated shock to market value of long-term debt. Regarding Quint and Rabanal (2017) we report the case when the stock of assets held by the central bank follows an AR(2) process and the unconventional monetary policy shock is conducted by purchasing government bonds. The interest rate spread denotes the difference between the government bond rate and the short-term rate.

In addition, Gertler and Karadi (2011) analyze the effects of non-standard monetary

[16]It has to be noted that sign restriction relying on the Haar measure regarding the rotation matrix Q could lead to implicit priors on the impact impulse responses (Baumeister and Hamilton, 2015, 2018).

policy conducted by the central bank in terms of a credit injection in reaction to a capital quality shock. Unconventional monetary policy significantly moderates the recession induced by an adverse shock, because it dampens the rise in the interest spread, which in turn dampens the investment decline. The central bank's balance sheet rises, but decreases slowly thereafter over time. Inflation remains largely benign.

Using VAR models, Baumeister and Benati (2013), Schenkelberg and Watzka (2013), Gambacorta et al. (2014), Weale and Wieladek (2016), Boeckx et al. (2017), Hesse et al. (2018) and Burriel and Galesi (2018) explore empirically the macroeconomic effects across countries of an innovation related to non-standard monetary policy. The latter is identified by imposing sign restrictions.[17] Table 2 summarizes the different identification schemes which comprise a shock to a central bank's total assets (Gambacorta et al., 2014; Boeckx et al., 2017), a QE shock related to the central bank's asset purchases (Weale and Wieladek, 2016; Hesse et al., 2018)) or an increase in reserves (Schenkelberg and Watzka, 2013) as well as an interest spread shock induced by non-standard interventions of monetary policy (Baumeister and Benati, 2013).[18]

In general, the results of these studies indicate that the estimated response of output to a non-standard monetary policy shock is positive and similar to the one found in the literature on the effects of *conventional* monetary policy. Simultaneously, the price level rises in response to a disturbance to unconventional monetary policy, whereas the bond yield, the spread between the government bond rate and the short-term rate, as well as financial stress decline.[19]

3.3.2 Sign restrictions

In our benchmark specification, we follow Boeckx et al. (2017) regarding the identification of a shock to unconventional monetary policy. Table 3 summarizes our set of restrictions, which comprises both zero restrictions and sign restrictions.[20]

[17] Weale and Wieladek (2016) also identify an unconventional monetary policy shock by adopting a Cholesky ordering.

[18] Kapetanios et al. (2012) and Hristov et al. (2019) adopt the identification scheme of Baumeister and Benati (2013) to identify unconventional monetary policy shocks in the U.K. and the euro area.

[19] Alternatively, a number of studies seek to identify the effects of unconventional monetary policy by using an *event study* approach that is based on high-frequency data and focuses on a narrow window around the policy announcement. See Dell'Ariccia et al. (2018b) for an overview and discussion.

[20] Recently, a controversy has surrounded the identification strategy adopted by Boeckx et al. (2017). In particular, Elbourne and Ji (2019) have argued that this strategy does not identify shocks to unconventional monetary policy. They argue that one basically obtains very similar impulse responses even without the main identifying restriction - that imposed upon the ECB's total assets. However, Boeckx et al. (2019) demonstrate through a number of empirical exercises that the approach by Boeckx et al. (2017) indeed successfully identifies unconventional monetary policy shocks.

Table 2: Identification of an unconventional monetary policy shock in the empirical literature

Study	Model	Restrictions imposed
Gambacorta et al. (2014)	Panel VAR for nine advanced economies. 2008M1-2011M6	Output: 0 on impact; price level: 0 on impact; financial stress: ≤ 0; central bank total assets: ≥ 0
Boeckx et al. (2017)	VAR model for the euro area. 2007M1 - 2014M12	Output: 0 on impact; price level: 0 on impact; central bank total assets: ≥ 0; financial stress: ≤ 0; spread between EONIA and policy rate: ≤ 0; policy rate: 0 on impact
Burriel and Galesi (2018)	GVAR for euro area countries. 2007M1 - 2015M9	Output: 0 on impact; price level: 0 on impact; central bank total assets: ≥ 0; CISS: ≤ 0; spread between EONIA and policy rate: ≤ 0; policy rate: 0 on impact; new credit growth: 0 on impact
Hesse et al. (2018)	VAR models for the U.S. and the U.K. 2008M11 - 2014M10	Output: 0 on impact; price level: 0 on impact; bond yield: ≤ 0; stock prices ≥ 0; asset purchase announcements: ≥ 0
Weale and Wieladek (2016)	VAR model for the U.S. 2009M3 - 2014M5	Output: unrestricted; price level: unrestricted; central bank asset purchases: ≥ 0, bond yield: ≤ 0, and real equity prices: ≥ 0
Schenkelberg and Watzka (2013)	VAR model for Japan. 1995M1 - 2010M9	Output: 0 on impact; price level: 0 on impact and ≥ 0 thereafter; central bank reserves: > 0
Baumeister and Benati (2013)	TVP-VAR models for the U.S. and U.K. 1965Q4 - 2011Q4 and 1975Q2 - 2011Q4	Output: ≥ 0; price level: ≥ 0; short-term rate: 0 on impact; interest rate spread: ≤ 0

Table 3: Identification of an unconventional monetary policy shock

	Benchmark model
Output	0
Price level	0
Eurosystem's total assets	≥ 0
Policy rate	0
Money market spread	≤ 0
CLIFS	≤ 0
MFIs' bond holdings ratio	?

Notes: Restrictions are set in accordance with Boeckx et al. (2017). Money market spread denotes the spread between EONIA and the policy rate. Zero restrictions are denoted by 0. Sign restrictions are imposed as ≥ 0 or ≤ 0 and are binding over a period of four months. Unrestricted responses are denoted by '?'.

Industrial production, prices and the policy rate are restricted to a zero response on impact after the shock. Furthermore, the Eurosystem's total assets are assumed to increase, whereas the interest rate spread, i.e. the spread between EONIA and the policy rate, as well as financial stress are supposed not to rise. Finally, the reaction of the MFIs' domestic government bond holdings ratio to an unconventional monetary policy shock is unrestricted. The sign restrictions are imposed as $\leq$ or $\geq$ and are binding over a period of four months.[21]

According to Boeckx et al. (2017), the set of restrictions is rich enough to ensure that the unconventional monetary policy shock is orthogonal to real economy disturbances, shocks in financial markets and conventional innovations to monetary policy. Typically, output and prices move in opposite directions after an aggregate supply shock. An aggregate demand shock is characterized by an immediate reaction of monetary policy, whereby the spread between EONIA and the policy rate normally does not widen.[22] A shock to standard monetary policy also causes an immediate response of the policy rate, which exerts direct influence on output and the price level. Ultimately, adverse disturbances in financial markets increase financial stress, thereby causing a recession that is followed by an immediate expansionary response of monetary policy.

[21] Note that the choice of the period over which the sign restrictions are binding is arbitrary. Thus, we also considered a period of two months over which the restrictions are binding. The results are very similar to those reported below.

[22] Indeed, VAR models estimated in normal times to investigate the macroeconomic effects of a monetary policy shock frequently use the EONIA as a proxy for conventional monetary policy. See Ciccarelli et al. (2015) as an example.

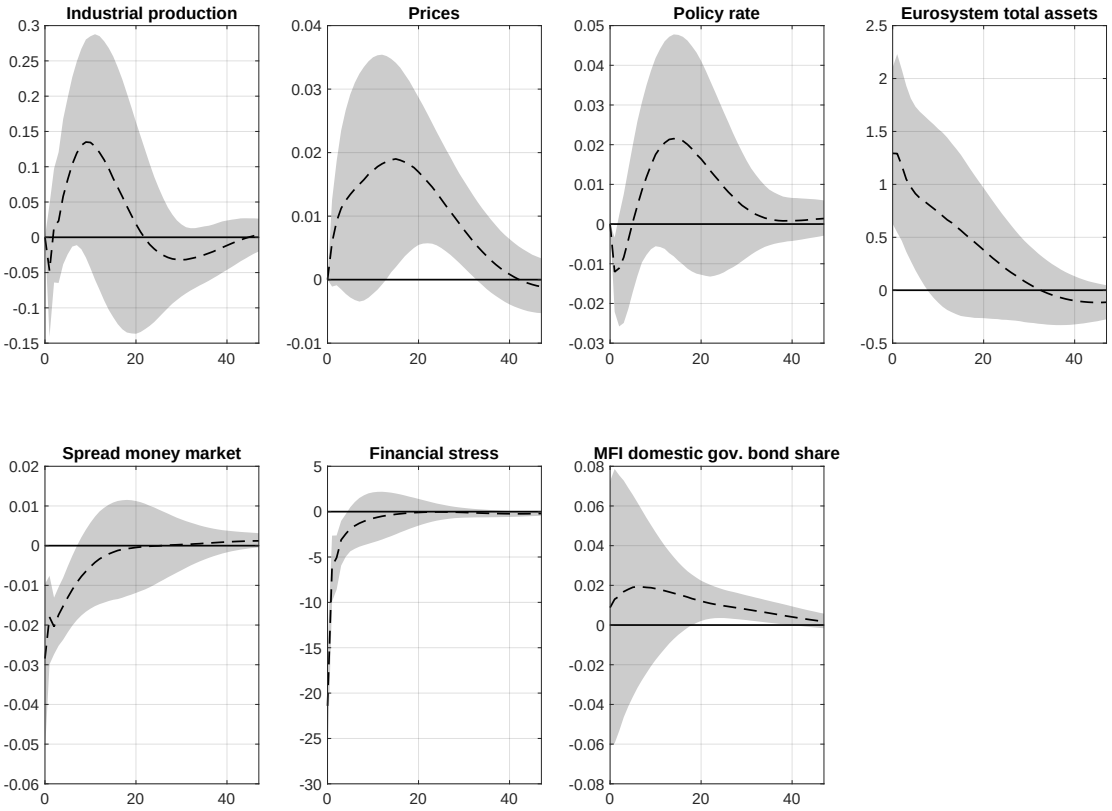
4 Results

4.1 Benchmark model

4.1.1 Impulse response analysis: Pooling across core and crisis countries

Figure 4 shows the average reaction of a euro area member country in the benchmark model to an expansionary unconventional monetary policy shock. The dotted lines are the median impulse responses of the posterior distribution. The shaded areas correspond to the 68% posterior credibility bounds. The simulation horizon covers 30 months. For simplicity, we refer to an impulse response as being significant if the zero line lies outside the corresponding credibility bound.

Figure 4: Benchmark model impulse responses to a UMP shock
All countries



Notes: UMP shock denotes an unconventional monetary policy shock. Industrial production, prices, the Eurosystem's volume of total assets and the CLIFS are in logs, while the remaining variables are in percent. The dotted black lines are the median impulse responses. The shaded areas reflect the 68% credible set. The unconventional monetary policy shock is identified as in Boeckx et al. (2017) by using the same set of zero and sign restrictions. Time is in months.

The results indicate that output increases after the sudden unconventional monetary policy loosening. Prices also rise, which induces monetary policy to tighten the policy rate with a certain delay. The peak effect arises after around eight to 12 months after the shock has hit the economy. These results are in line with the findings of Boeckx et al. (2017), who also report a boom of the economy after a positive central bank balance

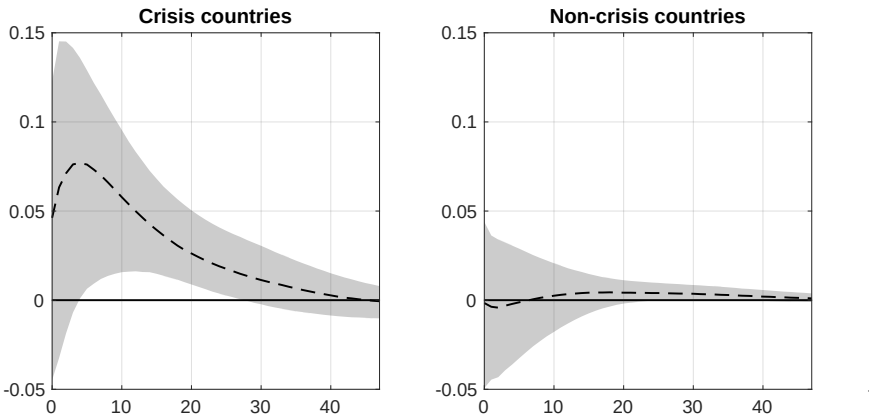
sheet innovation that is followed by a tightening of standard monetary policy. The spread between the EONIA and the policy rate remains negative for about five months, and the CLIFS financial stress indicator declines. Banks appear to respond to the favorable unconventional monetary policy shock by increasing their domestic sovereign debt portfolios. However, the adjustment occurs with a substantial delay of around 20 months after the unexpected disturbance until it becomes significant.

4.1.2 Impulse response analysis: Splitting the cross-section into core and crisis countries

The impulse responses presented in the previous section are based on the assumption that, in the period 2007 - 2014, the dynamic transmission of monetary as well as other kinds of shocks was the same across the nine countries in our panel. However, such an assumption might be too restrictive and mask important heterogeneities between certain country groups. In particular, the period 2010 - 2013 was dominated by the developments associated with and stemming from the European debt crisis. This event affected unequally the individual member states of the EMU. In particular, Italy, Spain and Portugal suffered severe capital outflows and their sovereigns faced massive difficulties in tapping international capital markets, leading to extraordinary fiscal distress. As explained in the introduction, the unfavorable situation was likely exaggerated by the emergence of *doom loops* due to the sovereign-bank nexus. All these culminated in outright financial and banking crises. As a consequence, Italy, Spain and Portugal found themselves forced to initiate substantial recapitalizations and restructurings of their banking sectors, adopt massive cyclical and structural adjustments in fiscal policy and start launching far-reaching structural reforms in labor and good markets. In contrast, apart from undergoing mild or moderate recessions over the years 2011 - 2013, the remaining countries did not face crisis-like eruptions, were not forced to undertake substantial structural adjustments, and even benefited from being accepted as *safe havens* by international investors.

Given these quite distinct historical experiences across the two groups of countries, we split our cross-section into crisis countries, i.e. Italy, Spain and Portugal, and non-crisis countries, i.e. Germany, France, the Netherlands, Belgium, Austria and Finland. This allows for heterogeneity in the transmission of unconventional monetary policy shocks across the two country groups. Figure 5 depicts the corresponding reaction of the MFIs' domestic government bond holdings ratio to a disturbance caused by unanticipated unconventional monetary policy measures.

Figure 5: Reaction of the MFIs' domestic government bond holdings ratio to a UMP shock



Notes: See Figure 4. Crisis countries include Italy, Spain and Portugal. Core countries comprise Austria, Belgium, Germany, Finland, the Netherlands and France.

The results indeed indicate that, on average, the banking sector in the crisis countries responded very differently from that in the average core economy. In particular, the share of domestic government bonds in MFIs' balance sheets exhibits a sizable and significant increase only in the crisis economies. The adjustment of the domestic sovereign debt portfolios occurs swiftly, i.e. within five months. By contrast, in the non-crisis countries the reaction of the bond holdings ratio turns out to be hardly significant.

4.2 Forecast error variance decomposition for the crisis countries

In order to understand the quantitative importance of the unconventional monetary policy shock for the euro area crisis countries, we compute the forecast error variance decomposition (FEVD), which in contrast to the impulse response analysis takes into account the estimated magnitude of the shock. Table 4 reports the forecast error variance decomposition of each variable at different forecast horizons.

Table 4: Crisis countries forecast error variance decomposition

Month	Output	Price level	Eurosystem's total assets	Policy rate	Interest rate spread	CLIFS	MFIs bond holdings ratio
1st	–	–	14.04	–	11.80	27.19	12.87
2nd	0.07	0.07	13.25	0.06	12.70	23.91	13.17
3rd	0.19	0.17	12.57	0.29	13.85	21.86	13.66
6th	0.57	0.64	10.68	1.42	14.16	18.40	15.30
12th	1.42	1.95	8.45	3.49	11.25	16.37	17.79
24th	2.57	3.20	8.11	5.47	10.91	15.94	20.24
36th	2.39	3.55	8.42	6.29	11.12	15.89	19.80
48th	3.14	3.73	8.49	6.55	11.33	15.81	19.55

Notes: Quantitative importance of unconventional monetary policy shock measured in percent. Crisis countries include Italy, Spain and Portugal. Zero restrictions set on output, prices and the policy rate are imposed over one month. In this respect,'–' signals impact of zero restriction. Sign restrictions set on remaining variables are imposed over the first four months. The reaction of the MFIs' domestic government bond holdings ratio to an unconventional monetary policy shock is unrestricted.

We find that fluctuations in output in the euro area crisis countries are hardly explained by the unconventional monetary policy shock. The same holds true for the evolution of prices with a maximum share of only about 4%. In contrast, the variation of the MFIs' domestic government bond holdings ratio triggered by a shock to non-standard policy is considerably larger. On average, the shock explains around 19% of the fluctuation. Moreover, the contribution of the fluctuation of the CLIFS indicator of financial stress caused by disturbances related to non-standard monetary policy is also notable, fluctuating on average also around 17%.

4.3 Alternative identification schemes

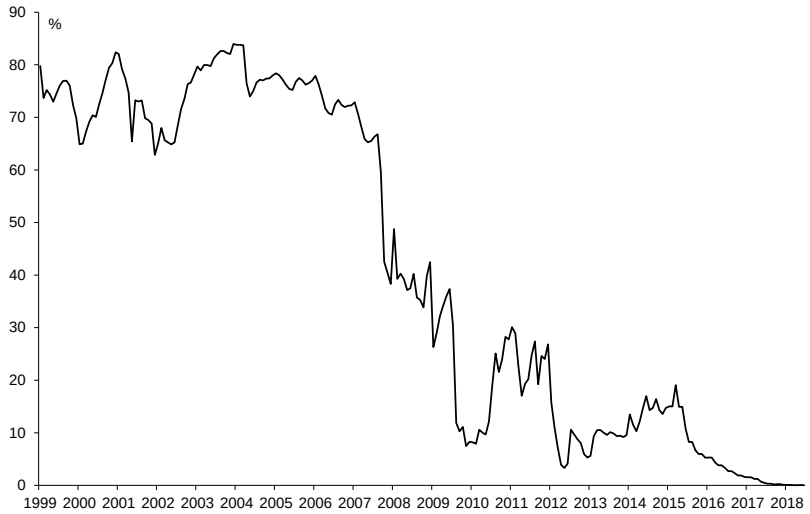
We consider three alternative identification schemes to assess the robustness of our results. In each of the three cases we perform the estimation for the sub-panel comprising the crisis country and the sub-panel covering the non-crisis economies separately.

4.3.1 Alternative (a)

In the first alternative specification we exclude the policy rate on the main refinancing operations from the model, and include another variable instead: the volume of liquidity provided via the MROs relative to total assets. The ECB's main refinancing operations were in normal times the most important open market operations through which the bulk of liquidity was provided. They played a pivotal role in signaling the stance of monetary policy and managing the liquidity situation in the money market. Figure 6 shows that the share of liquidity provided via the MROs relative to all liquidity-providing open market operations amounted to about 75% on average between 1999 and 2007, i.e. before the onset of the financial crisis. However, the share of the MROs dropped markedly after the intensification of the financial crisis in 2008 as longer-term refinancing operations,

targeted longer-term refinancing operations as well as outright purchases became more and more important. Hence, the ECB's unconventional monetary policy measures are characterized not only by causing an extension in the central bank balance sheet, but also by causing a change in its composition. Accordingly, to identify an unconventional monetary policy shock, we assume that it is associated with non-positive response of the ratio of MRO-volume to the Eurosystem's total assets. Column 2 in Table 5 displays the set of restrictions imposed to identify the unconventional monetary policy shock. The restrictions regarding the Eurosystems's total assets, industrial production, the price level, the money market spread and the CLIFS indicator are the same as in our benchmark specification.

Figure 6: Share of main refinancing operations relative to all liquidity-providing open market operations



Notes: Data taken from the ECB. Own calculations. Liquidity-providing open market operations include the main refinancing operations, longer-term refinancing operations and other liquidity-providing operations such as outright purchases, structural operations and fine tuning operations.

4.3.2 Alternative (b)

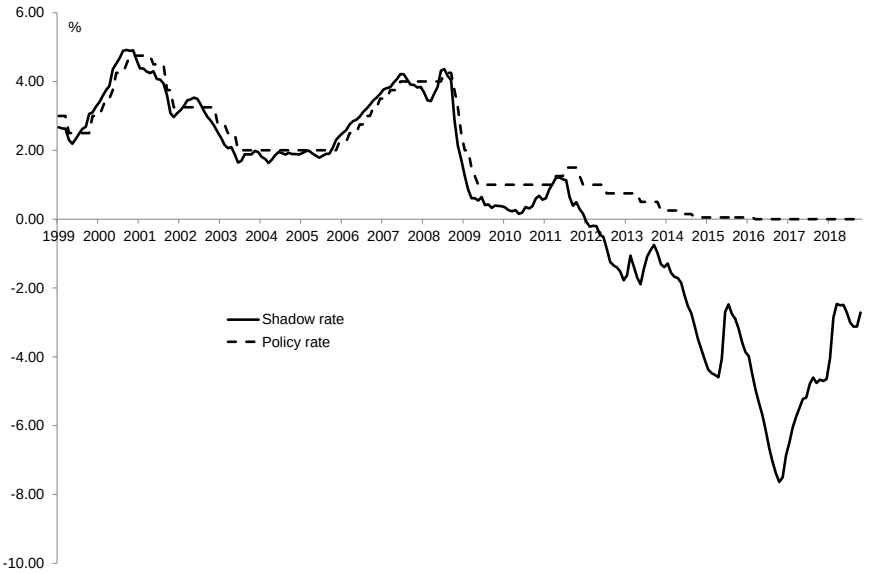
In our second alternative identification scheme we replace the Eurosystems's total assets by the volume of liquidity provided by the LTROs. The latter were used by banks to fund their assets.[23] To identify an unconventional monetary policy shock, we assume that it induces an increase in the volume of LTROs. The remaining variables are subject to the same sign and zero restrictions as in our baseline specification. The third column of Table 5 summarizes restrictions imposed.

[23]The provision of the LTROs is frequently associated with the term "Sarko trade". Former French president Nicolas Sarkozy suggested that each government in the euro area may borrow from their own commercial banks, which in turn could use the LTROs to gain access to central bank refinancing.

4.3.3 Alternative (c)

Finally, in our third alternative specification we replace the Eurosystem's total assets by a shadow rate. In particular, we resort to the shadow rate constructed by Krippner (2013), which is derived from a term structure model and attempts to proxy the true stance of monetary policy in times when conventional monetary policy is constrained by the zero lower bound and non-standard measures of monetary policy are adopted.[24] Figure 7 displays the shadow rate for the euro area together with the policy rate.

Figure 7: Euro area shadow rate



Notes: Data taken from the ECB and Krippner.

The shadow rate stuck closely to the policy rate before the onset of the financial crisis. Deviations emerged when the ECB conducted its first non-standard measures in 2007, and intensified thereafter when the policy rate moved towards the zero lower bound.

We identify the shock related to an expansionary unconventional monetary policy by restricting the shadow rate to decrease while the remaining variables are again subject to the same sign and zero restrictions as in the benchmark specification (see column 4 in Table 5).[25]

[24] Leo Krippner's shadow rate series for the euro area is available under `https://www.rbnz.govt.nz/research-and-publications/research-programme/additional-research/measures-of-the-stance-of-united-states-monetary-policy/comparison-of-international-monetary-policy-measures`.

[25] In addition, we performed several further experiments with models including a shadow rate. First, replacing Krippner's shadow rate by the one proposed by Wu and Xia (2016) leaves the results unchanged. Second, irrespective of the shadow rate used, replacing the zero restrictions on industrial production and prices by "$\geq$" sign restrictions or excluding the CLIFS and the money market spread from the model delivers qualitatively similar impulse responses. The results obtained in these robustness checks are available upon request.

Table 5: Alternative identification schemes

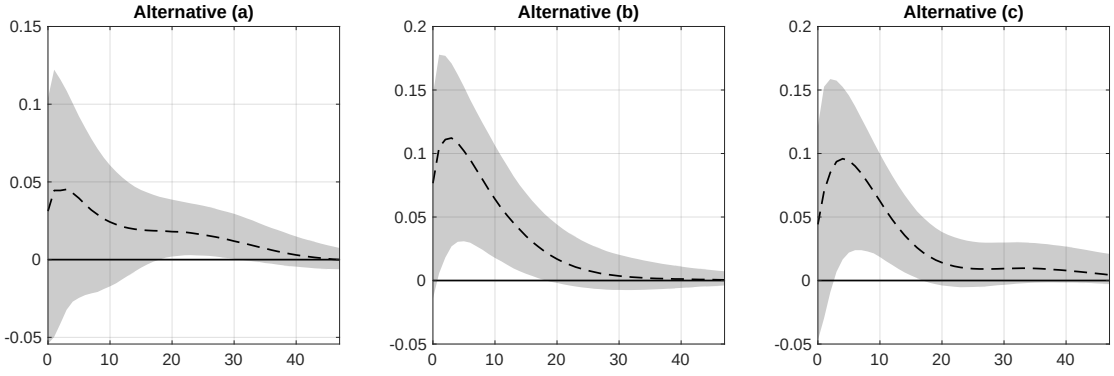
	Alternative (a)	Alternative (b)	Alternative (c)
Output	0	0	0
Price level	0	0	0
Policy rate	•	0	0
Eurosystem's total assets	≥ 0	•	•
Volume LTROs	•	≥ 0	•
Shadow rate	•	•	≤ 0
Volume MROs to total assets	≤ 0	•	•
Money market spread	≤ 0	≤ 0	≤ 0
CLIFS	≤ 0	≤ 0	≤ 0
MFIs' bond holdings ratio	?	?	?

Notes: Money market spread denotes the spread between EONIA and the policy rate. Zero restrictions on impact are denoted by 0. Sign restrictions are imposed as ≥ 0 or ≤ 0 and are binding over a period of six months. Unrestricted responses are denoted by '?'. Finally, '•' denotes that the variable is not included in the respective model.

4.3.4 Impulse responses based on the alternative specifications

For each of the three alternative specifications, Figure 8 summarizes the effect of a favourable unconventional monetary policy shock on banks' aggregate holdings of domestic government bonds (as a share in total assets) for the sub-panel comprising the three crisis countries (Italy, Spain, Portugal). As can be seen, the impulse responses confirm those implied by our benchmark specification. In particular, those countries' banks react by significantly increasing the fraction of sovereign bonds in their balance sheets.[26] Regarding the non-crisis economies of the euro area, each of the three alternative specifications suggest an insignificant reaction of banks' balance-sheet share of domestic government bonds to unconventional monetary policy shocks, thus again confirming our benchmark results.[27]

Figure 8: Reaction of the MFIs' domestic government bond holdings ratio to a UMP shock



Notes: See Figure 4. The MFI ratio impulse responses are calculated on the basis of the alternative model specifications (a)-(c).

[26]The responses of the remaining model variables are also qualitatively and quantitatively similar to those derived from the benchmark specification and shown in Figure 4. They are not shown here but are available upon request.

[27]The corresponding impulse responses are available upon request.

4.4 Cross-country heterogeneity

Next, we assess possible heterogeneity across the euro area economies.

4.4.1 Impulse response analysis

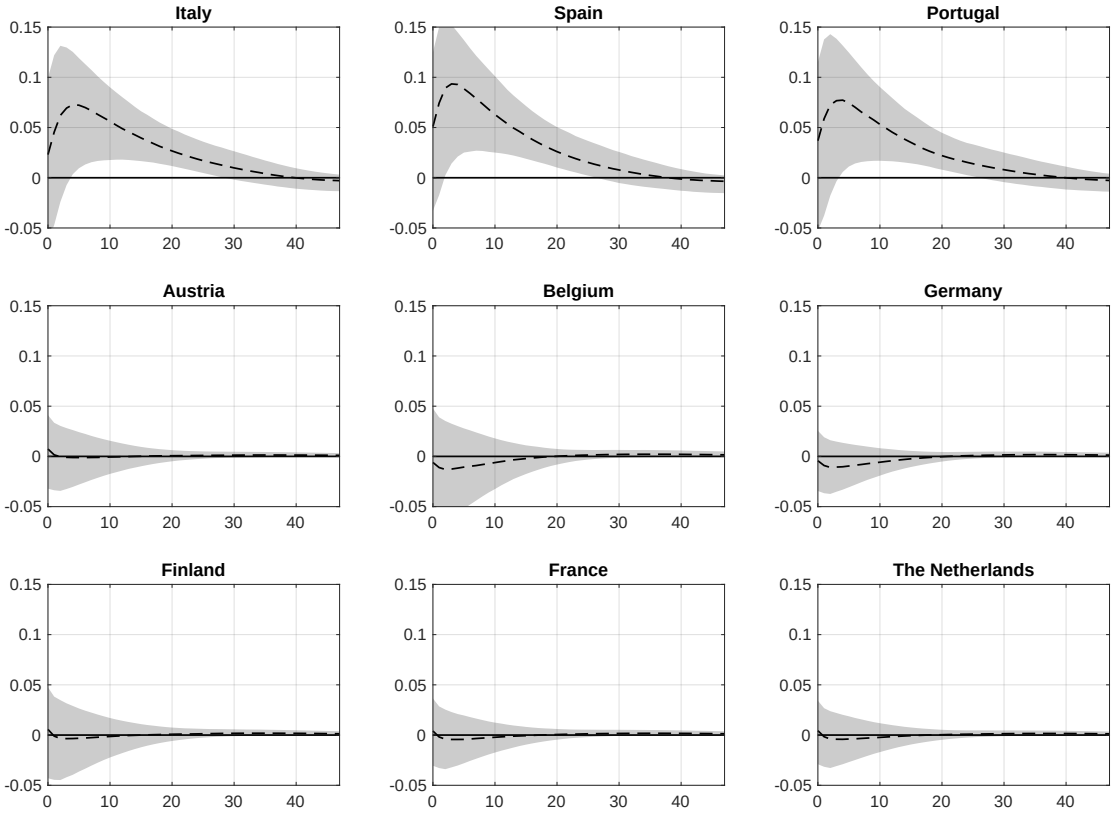
Following Jarocinski (2010), we estimate a panel of VAR models for both groups of euro area countries, i.e. the crisis economies and the core economies, by using a hierarchical Bayesian panel model estimator. The VAR model for country k reads as follows:

$$y_{k,t} = \sum_{j=1}^{p} B_{k,j} y_{k,t-j} + \tilde{c}_k + \varepsilon_{k,t}, \tag{4.1}$$

where the matrices of autoregressive coefficients $B_{k,j}$ are now country-specific. The Bayesian estimation is conducted with the prior that the countries in every sub-panel do not differ in terms of their macroeconomic dynamics. Hence, the countries are assumed to be special cases of the same underlying economic model, which implies that the matrices B_j tend to be similar across the economies. This prior results in the posterior which pools information across countries (Jarocinski, 2010). Every model is estimated with a lag length of two. We identify the unconventional monetary policy shock as in the benchmark model, i.e. by imposing the same zero restrictions and sign restrictions.[28]

[28] We resort to the BEAR toolbox of Dieppe et al. (2016) for estimation. The estimation requires Gibbs sampling. We perform the algorithm 10,000 times, discarding the first 5,000 samples as burn-in. The standard priors are set according to: For the overall tightness – a parameter strongly affecting the degree of cross-sectional heterogeneity – we set the starting value to $\lambda_1 = 0.1$, and assume the following inverse-gamma prior $\lambda_1 \sim IG(s_0/2, v_0/2)$ with $s_0 = 0.001$ and $v_0 = 0.001$. For the country-specific vector of slope coefficients we have a Normal prior, i.e. $\beta_i \sim \mathcal{N}(b, \Sigma_b)$ with a diffuse prior for the overall mean b, and a Minnesota-type prior for the covariance matrix Σ_b, i.e. $\Sigma_b = (\lambda_1 \otimes I_q)\Omega_b$, where the matrix Ω_b is defined in standard Minnesota-style manner while λ_1 is the overall-tightness parameter. Furthermore, a diffuse prior is used for the covariance matrix Σ_i of the reduced form, residuals of cross-sectional unit i. Finally, we set the prior for exogenous variable tightness to 100.

Figure 9: Impulse responses of MFIs' ratios across euro area countries to a UMP shock



Notes: Impulse responses are derived from a panel of VAR models using a hierarchical Bayesian panel model estimator. The dotted black lines display the median impulse responses. The shaded areas are the 68% credible set.

Figure 9 summarizes the responses of the MFIs' domestic government bond holdings ratios across the countries in both sub-panels to an expansionary shock related to non-standard monetary policy. In the crisis countries, the ratios increase significantly. The adjustment across the countries appears to be qualitatively and quantitatively quite similar. By contrast, in the core countries the reaction of the ratios turns out to be insignificant.

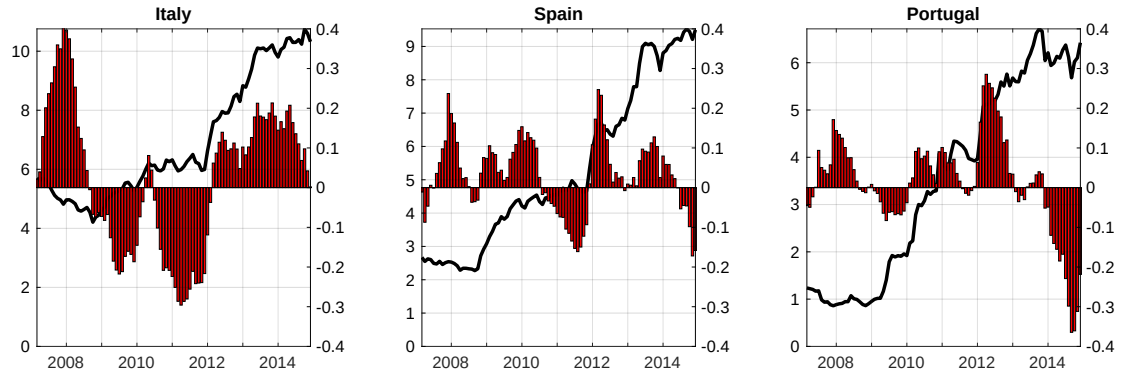
4.4.2 Historical decomposition

On the basis of the VAR models (4.1) estimated for the crisis countries we compute a historical decomposition. While the FEVD sheds some light on the quantitative importance of the structural shocks over the entire sample period, the historical decomposition allows to figure out the relevance of a shock for each month within the sample period. We base our calculation of the historical decomposition on the models estimated in the spirit of Jarocinski (2010) because the approach allows for differences across countries by imposing only the restriction that the mean of the slope coefficients are identical for each unit.

For every crisis country, Figure 10 displays the MFIs' domestic government bond holdings ratio and the historical contributions to its variation by shocks to unconventional

monetary policy. A positive value signals a stimulating effect on the MFIs domestic sovereign bond portfolios, whereas a negative value reflects a contracting impact.

Figure 10: Historical decomposition



Notes: The left axis shows MFIs domestic government bond holdings ratio measured in percent. The right axis displays the historical decomposition derived from Bayesian estimation measured in percentage points.

Our findings suggest that in the crisis countries the variation of banks' domestic government bond holdings ratios was affected by unconventional monetary policy shocks. The ECB's non-standard measures conducted between 2008 and 2009 contributed positively to the development of the MFIs' ratios in the crisis countries although the latter declined. Since the aim of these policy measures was to support the banking sector by serving as a lender of last resort, the drop in the ratios may be explained by the rise in total assets associated with the increasing use of the deposit facility that served as a store of liquidity. Moreover, the ECB's SMP seemed to generate a remarkable effect on the share of domestic government debt in banks' balance sheets between 2010 and 2012, which can be decomposed into two parts. In Portugal the asset purchases stimulated the share in May 2010, while in Italy and Spain they initially had a contracting effect, which, however, possibly arose because both countries were not included in the first wave of purchases. The asset purchases conducted between August 2011 and February 2012 also comprised Italian and Spanish sovereign bonds. The shares in Italy and Spain started to rise after these purchases were conducted. The ECB's announcement of the OMT program in September 2012 also appeared to stimulate the accumulation of domestic sovereign debt, possibly by removing distortions in government bond markets that were reflected by a severe rise in sovereign risk premia. Finally, the ECB conducted LTROs with extended maturities between 2013 and 2014, started to implement forward guidance and set a negative interest rate on the deposit facility.[29] In response, especially in Italy and Spain, the variation of the domestic government debt shares appeared to be stimulated by these measures.

[29]The ECB introduced its forward guidance on July 4, 2013 when President Mario Draghi stated: "The Governing Council expects key ECB interest rates to remain at present or lower levels for an extended period of time". See also Dell'Ariccia et al. (2018b) for a discussion.

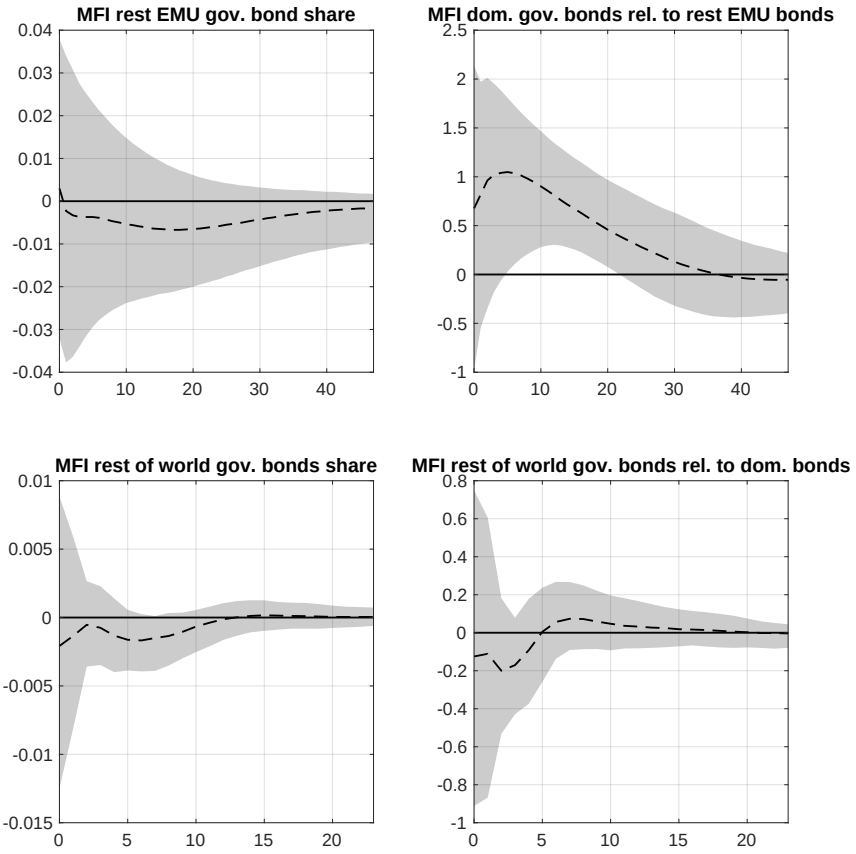
4.5 Sovereign debt portfolio adjustment

So far, our results suggest that euro area crisis countries' banks increase their holdings of domestic government bonds relative to total assets after unconventional monetary policy shocks. However, this finding does not allow us to infer whether banks indeed increased the home bias of their sovereign bond portfolios. The reason is that the decline in the share of domestic government debt in total assets might purely mechanically reflect a reduction in the stock of outstanding loans and, thus, in total assets, without any active adjustments of the bond portfolio. In this case, the share in total assets of sovereign bonds issued by other euro area countries and by countries outside the currency union should exhibit a similar increase in response to the monetary shock.

Therefore, we seek to shed some light on the MFIs' decisions in managing their sovereign debt portfolio. To this purpose, we estimate additional models for both sub-panels, i.e. the crisis countries and the core countries, which differ from our benchmark specification in that the MFIs' domestic government bond holdings ratio is replaced by alternative ratios. In particular, we investigate the response to unconventional monetary policy shocks of *(i)* the holdings of government bonds issued in the rest of EMU relative to total assets, *(ii)* the ratio of domestic government bonds to those from the rest of EMU, *(iii)* the holdings of government bonds issued outside the EMU relative to total assets, and *(iv)* the ratio of domestic government bonds to those issued outside the EMU. Note that due to data availability, when working with banks' holdings of bonds from issuers outside the currency union, we have to switch from a monthly to a quarterly frequency.

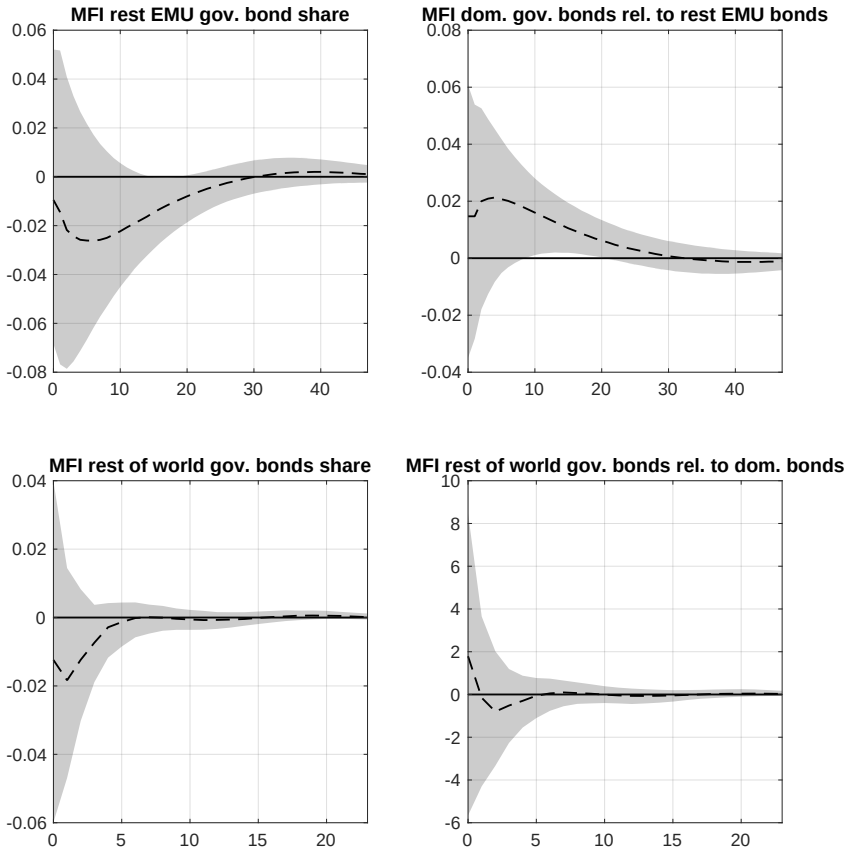
Figure 11 summarizes the impulse responses of the alternative MFIs' ratios to an innovation related to unconventional monetary policy. In the crisis countries, banks hardly reduce their holdings of rest of EMU government bonds relative to total assets. However, the management of the sovereign debt portfolios appears to be home biased, as the ratio of domestic to rest of EMU government bond holdings rises. Thus, the adjustment of both ratios suggests that the home bias is triggered by a notable increase in domestic government bonds rather than a notable reduction in the holdings of rest EMU government bonds. By contrast, the share of banks' holdings of sovereign bonds issued by countries outside the EMU does not change in response to the unconventional monetary policy shock.

Figure 11: Impulse responses of alternative MFIs' ratios to a UMP shock
Crisis countries



Notes: See Figure 4. MFIs' rest of EMU government bond share reflects the banks' holdings of rest EMU government bonds relative to total assets. Monthly data.

Figure 12: Impulse responses of alternative MFIs' ratios to an UMP shock
Core countries



Notes: See Figure 4. MFIs' rest of EMU government bond share reflects the banks' holdings of rest EMU government bonds relative to total assets. Monthly data.

Interestingly, in the core countries, banks also seem to adjust their sovereign debt portfolios after the non-standard monetary policy disturbances, but in a different manner (see Figure 5). Banks' holdings of rest of EMU bonds relative to total assets decline. Additionally, the ratio of home issued sovereign bonds to rest EMU bonds rises. Hence, the rise in the ratio appears to be triggered by a decline in the holdings of rest of EMU bonds sovereign bonds rather than a rise in the holdings of domestic government bonds. By contrast, the holdings of sovereign bonds issued by countries outside the EMU seem not to be affected by disturbances related to unconventional monetary policy.

4.6 Extended period: 2007-2018

Note that we have excluded the ECB's APP from our sample because the program that started in 2015 was expected (Boeckx et al., 2017). The conditions of APP were reported in the press, following the various announcements by the ECB Executive Board members, which summarized the details regarding the conduct of the program (Gambetti and Musso, 2017). In particular, the ECB announced the precise volume of the monthly asset purchases, the composition of these purchases regarding the securities issued by euro area

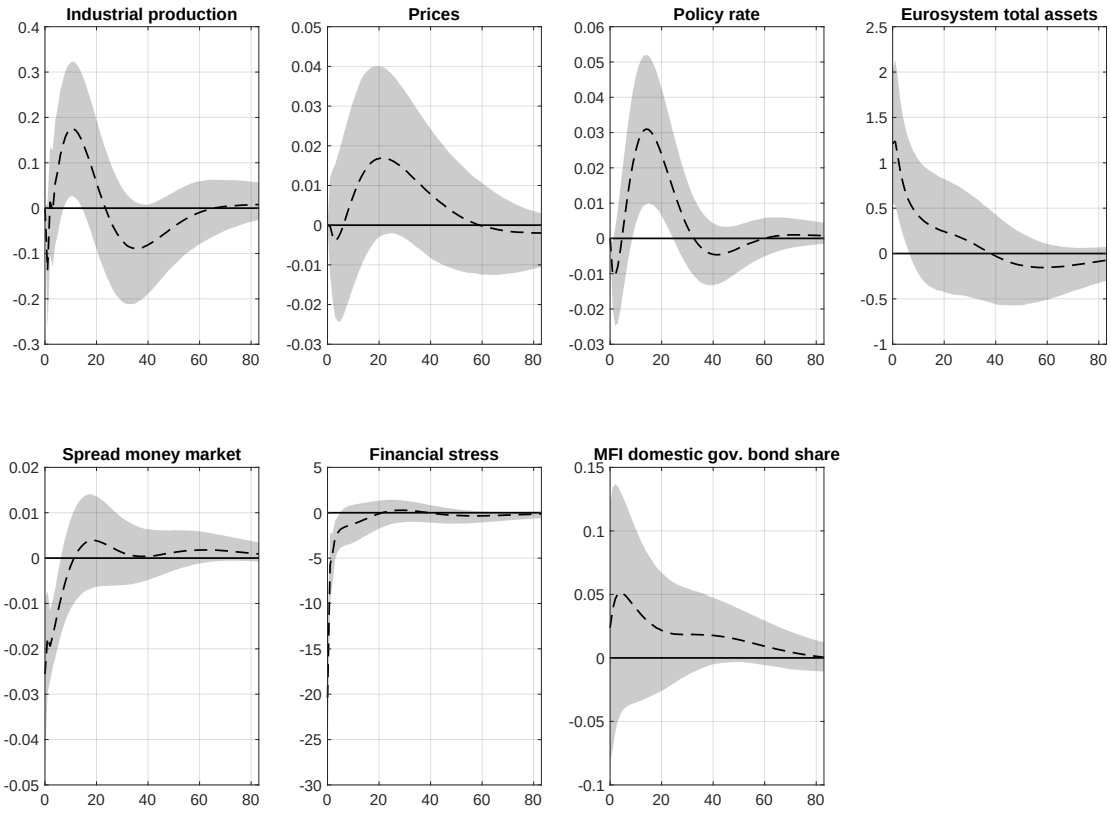
governments as well as the maturity of the program. Latter changes to the program were communicated.[30] Overall, the use of impulse response analysis might not be appropriate under these conditions because due to a lack of surprises, the effects of an unexpected shock can hardly be identified.

Despite the exception to embedding the episode of the ECB's APP in an impulse response analysis, we proceed by estimating our benchmark model (3.1) over the period 2007-2018 to gain additional insights into the reaction of the MFIs' domestic government bond holdings ratio to an unconventional monetary policy shock. Referring to Table 1, we identify the shock by imposing zero and sign restrictions.

For the crisis countries, Figure 13 shows the impulse responses of the model variables to a favorable unconventional monetary policy shock. The results are quite similar to those reported for the period 2007-2014. Output initially rises after the shock. The boom of the economy is accompanied by an increase in prices. Banks seem to adjust their domestic sovereign debt portfolios. The MFIs' domestic government bond ratio rises, hardly significantly, however, and with a substantial delay.

[30]Initially, the ECB announced with the start of the APP a monthly amount of securities purchases of €60 billion in January 2015, which were intended to be carried out until September 2016. However, the ECB decided to expand the monthly amount of securities purchases to €80 billion in March 2016, while in April 2017 the pace of monthly purchases was reduced to €60 billion. Furthermore, the APP was expanded to run until December 2018. Finally, the ECB decided in 2018 to reduce the monthly purchases further to €30 billion and €15 billion, respectively. Overall, the ECB's accumulated purchases of sovereign securities amounted to €2,102,048 billion at the end of 2018.

Figure 13: Impulse responses to an UMP shock
Crisis countries



Notes: Crisis countries comprise Italy, Spain, Portugal and Belgium. Impulse responses calculated from benchmark model that is estimated over the period 2007-2018. See notes of Figure 4 for further explanations.

The delayed reaction of banks' domestic government bond holdings to innovations triggered by unconventional monetary policy might be explained by the characteristics of the ECB's APP program, whose introduction marked a break in the conduct of unconventional monetary policy measures. In particular, the size of the monthly securities purchases under the APP exceeded all existing purchases programs that had been implemented before. Thus, banks might have taken more time to adjust their domestic sovereign debt portfolio in response to unconventional monetary policy disturbances over the period 2007-2018 compared to 2007-2014.

5 Conclusion

We estimate panel VAR models for euro area member countries to explore whether the ECB's unconventional monetary policy conducted between 2007 and 2014 induced banks to increase their domestic government bond holdings, thereby possibly promoting the sovereign-bank nexus. We impose sign restrictions on impulse responses to identify innovations related to non-standard monetary policy. Our findings can be summarized as follows. Euro area crisis countries' banks shifted their asset portfolios towards domes-

tic sovereign bond holdings in response to expansionary unconventional monetary policy shocks, thus making their balance sheets more sensitive to fluctuations in sovereign risk. Non-standard monetary policy disturbances explain around 19% on average of the variation in the national banking sectors' share of domestic government bonds. Moreover, banks seemed to manage their sovereign debt portfolios actively. While banks' domestic government bond holdings increased relative to total assets in response to an unanticipated unconventional monetary policy loosening, the share of their holdings of sovereign bonds issued in the rest of EMU declined. Thus, the reaction of banks' sovereign debt portfolios can be characterized by a home bias. In contrast, euro area core countries' banks did not increase their domestic government bond holdings relative to total assets in response to disturbances related to unconventional monetary policy. However, banks rather restructured their sovereign bond portfolios by lowering their holdings of rest EMU government bonds. Furthermore, estimations using the approach by Jarocinski (2010) confirmed that crisis countries' banks responded in a qualitatively different way to unconventional monetary policy shocks as compared to banks in the core countries. While in Italy, Spain, and Portugal, the change in the domestic government bond holdings ratio occurred swiftly, in none of the core economies can a significant response of the domestic government bond holdings ratio be found. Finally, our results suggest that the ECB's SMP contributed to an increase in banks' sovereign debt portfolios. In Portugal, the effect was immediately observable after May 2010, while in Italy and Spain it became apparent after February 2012. Moreover, the announcement of the OMT program in September 2012 appears to have contributed to a higher domestic government bond holdings ratio. Overall, we conclude that euro area crisis countries' banks enlarged their exposure to domestic sovereign debt in response to expansionary innovations stemming from unconventional monetary policy. While banks' liquidity position improves by such monetary policy measures, they might also contribute to the undesirable side effect of making the banking sector more vulnerable to sovereign distress.

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Data

The aggregate balance sheet items for a country's monetary financial institutions (MFIs) or the Eurosystem as a whole as well as the series for the main refinancing operations rate (MRO), industrial production and the financial stress index (CLIFS) are taken from the Statistical Data Warehouse (SDW) of the European Central Bank. In what follows we report the series' codes, where ** is a placeholder for the country acronym:[31]

- Total assets of a country's MFIs, outstanding amount (stock) in millions of Euro, monthly frequency,
  Code: `BSI.M.**.N.A.T00.A.1.Z5.0000.Z01.E`

- MFIs' holdings of domestic government bonds, outstanding amount (stock) in millions of Euro, monthly frequency,
  Code: `BSI.M.**.N.A.A30.A.1.U6.2100.EUR.E`

- MFIs' holdings of government bonds issued by other EMU countries, outstanding amount (stock) in millions of Euro, monthly frequency,
  Code: `BSI.M.**.N.A.A30.A.1.U5.2100.EUR.E`

- MFIs' holdings of government bonds issued by countries outside the EMU, outstanding amount (stock) in millions of Euro, quarterly frequency,
  Code: `BSI.Q.**.N.A.A30.A.1.U4.2100.Z01.E`

- Total assets of the Eurosystem, outstanding amounts (stock), in millions of Euro, monthly frequency,
  Code: `BSI.M.U2.N.C.T00.A.1.Z5.0000.Z01.E`

- ECB main refinancing operations rate – fixed rate tenders, in percent per annum, monthly frequency,
  Code: `FM.D.U2.EUR.4F.KR.MRR_FR.LEV`

- Volume of main refinancing operations, outstanding amount (stock) in millions of Euro, monthly frequency,
  Code: `ILM.M.U2.C.A050100.U2.EUR`

- Country-Level Index of Financial Stress (CLIFS), monthly frequency,
  Code: `CLIFS.M.**._Z.4F.EC.CLIFS_CI.IDX`

- Index of industrial production, Total industry - NACE Rev2, monthly frequency,
  Code: `STS.M.**.Y.PROD.NS0010.4.000`

[31] The country acronyms are: Austria (AT), Belgium (BE), Germany (DE), Spain (ES), Finland (FI), France (FR), Italy (IT), the Netherlands (NL) and Portugal (PT).

Each country's consumer price index corresponds to the overall harmonized index of consumer prices *excluding energy and unprocessed food* (Core HICP). The series are taken from Eurostat and have a monthly frequency and a code: `TOT_**_NRG_FOOD_NP`. The Euro Overnight Index Average Rate (EONIA) is provided by Tomson Reuters Datastream, in percent per annum, with a monthly frequency and a code: `EMIBORON`. Finally, the shadow rate is constructed and provided by Krippner (2013).