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İSHAK DEMİR
BURAK A. EROĞLU
SEÇİL YILDIRIM-KARAMAN

Heterogeneous Effects of Unconventional Monetary Policy on the Bond Yields across the Euro Area

This paper investigates the impact of the European Central Bank's unconventional monetary policies (UMP) between 2008 and 2019 on European government bond yields. It adopts a novel econometric approach that combines a data-rich factor analysis and Vector autoregression (VAR) with heteroskedastic-based identification. The results identify a significant and substantial impact for all countries and maturities, but stronger and persistent impact for the periphery. When we decompose the impact into separate components, we find that UMP decreases the market component for all countries. It decreases the risk-mutualization component for the periphery permanently at the cost of a small increase for the core countries, which provides evidence for risk-mutualization in the EMU.

JEL codes C38, E43, E52, E58, F42, G12
Keywords: cross-country difference, ECB, EMU, risk-mutualization, sovereign bond yields, unconventional monetary policya

The unconventional monetary policies (UMPs) introduced during the Great Recession have redefined the toolbox of monetary policy, and played a major role in the recovery that followed. Despite their importance, however, we are still far from a complete understanding of their impact. One challenge in this endeavor is their short history, and the limitations it imposes on the available data. A second issue is that the standard tools that macroeconomists have developed to identify the

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İSHAK DEMİR *is at Middlesex University London; University of Lincoln; and Ekonomi Araştırmaları Platformu* (*E-mail*: i.demir@mdx.ac.uk). BURAK A. EROĞLU *is at Istanbul Bilgi University* (*E-mail*: burak.eroglu@bilgi.edu.tr). SEÇİL YILDIRIM-KARAMAN *is at Marmara University* (*E-mail*: secil.yildirim@marmara.edu.tr).

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impact of conventional monetary policies are not well suited for the unconventional ones. Consequently, most existing studies provide a partial picture of their impacts, focusing on individual countries, specific channels, or specific time frames.[1]

This study contributes to the literature by offering a comprehensive account of the impact of the European Central Bank's (ECB) UMPs on the government bond yields between January 2008 and November 2019 and a discussion of the cross-country differences in responses. In particular, we estimate the impact of the ECB's UMP shocks for eight different countries and up to 11 different maturities using high-frequency data. In the model, bond yields are decomposed into four separate factors. These four factors are "medium-term market" factor, which captures the trajectory of average yields for the EMU,"risk-mutualization" factor, which captures the sharing of the risk of the periphery countries by the core, "troika" factor, which captures the increase in the risk for Portugal, and "slope" factor, which captures the change in the yields with maturity.[2] This factor decomposition allows investigating the impacts on different bond yield components separately for each country and maturity and tracking the persistence of these effects over time. This comprehensive treatment is made feasible by a novel econometric model that combines a dynamic factor model, heteroskedasticity-based identification, and a VAR model. The estimation results provide strong support for the effectiveness of UMP. In particular, for the market component of the bond yields, we find that UMP reduced them for all countries and all maturities. As for the risk-mutualization factor, UMP reduced them significantly for the periphery economies, while increasing them slightly for the core countries. This result implies that the sovereign risk in the periphery economies is partially shared by the core economies through the ECB's unconventional policy decisions. We also show that risk-mutualization between the two country groups is mainly driven by the rescue programs implemented in the early phase of the eurozone debt crisis.

The UMPs investigated in this study are the extensive liquidity provision, the expanded asset purchase program that started in 2015 and rescue programs such as the Securities Market Program (SMP) and the Outright Monetary Transactions (OMT).[3] These policies were introduced when the short-term nominal interest rates in the developed economies hit the zero lower bound, leaving little room for conventional monetary policy. Finding themselves in an unchartered territory, central banks in developed countries experimented with new monetary policy instruments, with little past experience to rely on.

We investigate the impact of UMP based on the experience of the European Monetary Union (EMU) countries. This choice is motivated by the unique structure of the

1. For example Fratzscher, Duca, and Straub (2016), Chen, Filardo, He, and Zhu (2012), and IMF (2013) argue that the size of the effects depends on the specific characteristics of the UMP program implemented.

2. Factors are discussed in detail in Section 4.1

3. See Haldane, Roberts-Sklar, Wieladek, and Young (2016), Joyce, Miles, Scott, and Vayanos (2012), and Cecioni, Ferrero, and Secchi (2011).

EMU, where the decisions of a single central bank affect bond yields across different countries and maturities. We adopt a novel econometric approach that captures this structure, and exploits the variation it offers. The event days in the sample are the ECB's unconventional policy announcement days between January 3, 2008 and December 31, 2019. The model estimates the impact of unconventional shocks on these days for 80 different government bond yield series, spanning Germany, France, Austria, Netherlands, Belgium, Italy, Portugal, and Spain and maturities ranging between 1 and 30 years.

The econometric model works in three steps. In the first step, relying on a dynamic factor model, we estimate four common factors for 80 bond yield series for different countries and maturities. These four common factors, respectively, capture the medium-term market, risk-mutualization, troika, and slope components of the bond yields in the euro area.[4] Reducing the 80 yield series into four common factors allows estimating a single model for the EMU while preserving the variation across countries and maturities.

In the second step, we identify the impact of the UMP shocks on each of the market, risk-mutualization, troika, and slope factors. In these estimations, we rely on heteroskedasticity-based identification in the VAR context. The heteroskedasticity-based identification exploits the heteroskedasticity in the innovation terms following Rigobon and Sack (2003). More explicitly, we assume that the volatility of the policy shocks is relatively higher on the announcement days. This feature of the heteroskedasticity-based identification allows addressing the measurement issue[5] and the time window selection problem[6] for UMP shocks. The VAR model, in turn, allows estimating the impulse response functions (IRFs), and hence measuring the persistence of the shock and not just the instantaneous effect. One concern with the estimation is that on some of the event days, there were both unconventional and conventional monetary policy shocks. Since we are interested in identifying the impact of UMP, we also include controls for conventional policy shocks.

Finally, in the third step, for each country and each maturity, we back out the responses of the market, risk-mutualization, troika, and slope components of the bond yields to UMP shocks. To do so, we multiply the impulse responses of each of the four components obtained in the second step with the factor loadings obtained in the

4. These three factors are different from the level, slope, and curvature factors in the affine term structure literature.

5. For UMP shocks, it is difficult to measure the market expectation before the policy announcement, and calculate the unexpected shock component. Consequently, the event study method, which is commonly used to identify the news and monetary policy shocks at high-frequency in the literature, does not address this problem for UMP shocks. On the other hand, heteroskedasticity-based identification sidesteps this problem, because identification comes from the increase in the volatility on the policy announcement days.

6. Because unconventional policies are difficult to interpret and analyze, it takes time for the market to price them. The event study method requires selecting a time window for pricing. A narrow time window may fail to capture the full effect of the policy, while a wide window may contaminate its effect with the other shocks (Gagnon, Raskin, Remache and Sack 2011, Martin and Milas 2012). In the heteroskedasticity-based identification, the window is identified by the model, based on the changes in the volatility.

first step. Consequently, we are able to derive a complete characterization of the impact of the common UMP shocks across countries, maturities, yield components, and over time.

The results provide strong support for the effectiveness of UMP in the euro area. We find that UMP shocks decrease the bond yields for all countries and all maturities. In other words, unconventional policies were successful in easing financial distress across the board. With respect to the cross-country variation, we find that the impact is stronger and more persistent in the periphery countries than that in the core countries. These patterns suggest that the policies were more effective where they were needed the most.

When we decompose the overall impact of the policy shocks into their impacts on the market, risk-mutualization, troika, and slope components of the bond yields, we find that the impact mainly works through the first two. For the market component, we find that unconventional policies decrease the yields for all countries, with a stronger effect on the core countries. As for the risk-mutualization component, the yields decrease significantly in the periphery countries and increase slightly in the core countries. This significant decrease in the yields of the periphery economies, which have relatively higher risk premia, and the increase in the yields of the core economies, which are financially stronger, provide evidence for risk sharing in the EMU through unconventional policy decisions by the ECB.

Finally, we investigate the link between different unconventional policy programs and estimated factors. To do so, we categorize the announcements into three categories: liquidity providing operations, sovereign bond purchase programs, and asset purchase programs. We then investigate the impacts of these three policy categories on the estimated factors relying on the event study methodology. The regression results suggest that the sovereign bond purchase programs and the asset purchase programs affect the bond yields mainly through the risk-mutualization factor with a more substantial impact for the former. This finding provides evidence that the sovereign bond purchase programs resulted in a greater risk-mutualization in the EMU. The liquidity providing operations, however, affect bond yields mainly through the market factor and decrease bond yields for all countries and maturities with a stronger impact on the core countries and longer maturities.

The contribution of the paper to the literature builds on the novel econometric approach. To the best of our knowledge, our study is the first to employ dynamic factor analysis, heteroskedasticity-based identification, and VAR methodologies in the same model to investigate the impact of UMP. In the existing literature, one vein investigates the impact of UMP through the event study method. In this vein, Glick and Leduc (2012), Krishnamurthy and Vissing-Jorgensen (2011), and Gagnon, Raskin, Remache and Sack (2011) investigate the impact of these policies for the United States and Falagiarda and Reitz (2015), Eser and Schwaab (2016), Fratzscher, Duca, and Straub (2016), and Chadha and Hantzsche (2018) for the euro area. While our findings on the effectiveness of the policies are consistent with these studies, the heteroskedasticity-based identification we adopt avoids some of the pitfalls associated with measuring UMP shocks. Wright (2012) and Rogers, Scotti, and Wright

(2014), on the other hand, employ the heteroskedasticity-based identification with VAR, but estimate separate models for each country and use the data for only some of the maturities. In our analysis, the dynamic factor model in the first step allows decomposing bond yields into separate components that capture the different dynamics of the yields and estimating the impact for all countries and all maturities in a single model without heavy parameterization. It also decreases the model uncertainty caused by the omitted variables, unobservable factors, and lagged endogeneity, and therefore, provides a reliable forecast for the persistence of the monetary policy impact. Consequently, we are able to exploit the unique structure of the EMU and engage in cross-country comparisons within the euro area.

The rest of the paper proceeds as follows. Section 2 introduces the econometric model and Section 3 the data set. Section 4 presents and discusses the results. Section 5 discusses the link between different unconventional policy programs and estimated factors. Section 6 explores the policy implications and concludes.

1. MODEL AND IDENTIFICATION SCHEME

This section discusses the methodology for obtaining the EA sovereign bond yields' IRFs to unconventional policy shocks by the ECB. The high dimension of our data set allows us to adopt a three-stage procedure. In the first stage, we apply a dynamic factor model for dimension reduction and obtain a smaller set of dynamic factors from the yield series. In the second stage, we employ the heteroskedasticity-based identification on these factors to derive the IRFs. In the last step, we back out the IRFs for the yield series from the IRFs of the dynamic factors. In the following subsections, we elaborate on these three stages.

1.1 Dynamic Factor Model

Let the N_Y vector Y_t stack all sovereign government bond yields, the N_Z vector Z_t denotes the other endogenous variable(s), and the N_X vector X_t include the other exogenous covariates at the time period $t = 1, 2, \ldots, T$. Each variable in Y_t can be defined as $Y_{i,t}$ for $i = 1, 2, \ldots, N_Y$. Consequently, the model that relates the observable variables Y_t, Z_t, X_t and the latent factors F_t is as follows:

$$Y_{i,t} = \lambda_i^\top F_t + e_{i,t} \quad \forall i = 1, 2, \ldots, N_Y, \tag{1}$$

$$\Phi(L)E_t = X_t\beta + \epsilon_t, \tag{2}$$

where $E_t = [F_t \; Z_t]^\top$ is the vector of endogenous variables, λ_i is a $1 \times r$ vector of the factor loadings for each variable $i = 1, 2, \ldots, N_Y$, β is the vector of the coefficients of the covariates X_t, F_t is an r vector of the static factors, and $e_{i,t}$ is the residuals for all $i = 1, 2, \ldots, N_Y$ in the factor model. The covariate Z_t, where $N_Z = 1$, contains the implied stock market volatility index (VIX), which is the observable factor that captures the global financial turmoil and the economic risk. This indicator allows disentangling the responses of the yields to the ECB's announcements from those to the global uncertainty. X_t is the vector of exogenous control variables, where $N_X = 2$. It includes a dummy variable for the Fed's policy announcement days and the ECB's conventional monetary policy surprise series to control for the impacts of the Fed policies and the ECB's conventional policy shocks on the bond yields.[7]

Equation (2) assumes a VAR structure for the factors E_t where $\Phi(L)$ is the lag polynomial that governs the VAR model, and ϵ_t is an r vector of innovations. Note that we impose $r < N_Y$ to achieve dimension reduction. We elaborate on the selection of r in the results section.

We employ the principal component (PC) method[8] for the extraction of the factors. Before applying this technique, following Bai and Ng (2004), we first generate the first differences of the observable variables since they are nonstationary.[9] However, we can recover F_t by integrating the estimated factors from the differenced model.[10] We denote the estimated r PCs as $\Delta\hat{F}_t$. Integrating these PCs, we get the r estimated factors, namely $\hat{F}_t$.

1.2 Heteroskedasticy-Based Identification

This subsection uses the estimated factors and the heteroskedasticity-based identification that exploits the volatility difference between the announcement and the nonannouncement days to identify UMP shocks, following Wright (2012).

Let $\hat{F}_t$ be the r factors estimated as described in the previous section, and the dynamic structure of E_t is governed by equation (2). VAR models' standard identification procedure relies on the factorization of the variance–covariance matrix of the reduced form error terms. In contrast, the heteroskedasticity-based identification builds the identification procedure on the volatility difference of the specific shocks at different regimes. The basic structure is given as follows:

$$\epsilon_t = \sum_{i=1}^{k} R_i \eta_{i,t}, \tag{3}$$

7. Because some of the policy announcement days in our sample also include conventional monetary policy decisions, we control for their impact by including exogenous measures of conventional policy surprises in the model. When we estimate the model without the controls for conventional policy shocks, we find no significant change in our results.

8. In the PC method, we utilize the "principal component normalization," which is required for the identification of the latent factors. Additionally, this normalization restricts the factors to be orthonormal. For further discussion, see Stock and Watson (2002).

9. Notice that the principle component model can be estimated in levels rather than differences if the idiosyncratic components are stationary (Bai 2004). However, since some of the idiosyncratic components are nonstationary in our model, we prefer to estimate the factors after taking the difference of the yield series. This operation does not render the estimation inconsistent under the stationary or nonstationary idiosyncratic errors (Bai and Ng 2004).

10. The details of the PC method can be found in Stock and Watson (2002).

where $\eta_{i,t}$s are k independent shocks and $(r+1) \times 1$ vector R_i is the constant weight of each shock. In this setup, each shock may correspond to an economic or financial event that affects the factor structure with different weights. For instance, we assume that the first shock, $\eta_{1,t}$, to be the monetary policy shock. R_1 quantifies the impact of this shock. The shocks' ordering does not matter since the shocks are not directly associated with the variables in E_t. Rather, they are associated with the other economic or financial events. Moreover, we assume that $\eta_{1,t}$ has zero mean with a variance of $\sigma^2_{\eta_1,1}$ on the announcement and $\sigma^2_{\eta_1,0}$ on the nonannouncement days. For the other structural shocks $j = 2, \ldots, k$, we assume $\sigma^2_{\eta_j,1} = \sigma^2_{\eta_j,0}$. In words, the policy announcements only influence the monetary policy shock volatility, while the variances of the other shocks remain constant.

Let Σ_1 be the $(r+1) \times (r+1)$ dimensional variance–covariance matrix of ϵ_t on the announcement days and Σ_0 be the $(r+1) \times (r+1)$-dimensional variance–covariance matrix on the nonannouncement days. The difference between the variance–covariance matrices on the announcement and the nonannouncement days can be represented as:

$$\Sigma_1 - \Sigma_0 = \left(\sigma^2_{\eta_1,1} - \sigma^2_{\eta_1,2}\right) R_1 R_1',$$

where we normalize $\sigma^2_{\eta_1,1} - \sigma^2_{\eta_1,2}$ to 1, since $R_1 R_1'$ and $\sigma^2_{\eta_1,1} - \sigma^2_{\eta_1,2}$ cannot be separately identified. To estimate the vector R_1, we will use the following optimization problem proposed by Wright (2012):

$$\hat{R}_1 = \underset{R_1}{\text{argmin}}[vech(\hat{\Sigma}_1 - \hat{\Sigma}_0) - vech(R_1 R_1')]'[\hat{V}_0 + \hat{V}_1]^{-1}[vech(\hat{\Sigma}_1 - \hat{\Sigma}_0) - vech(R_1 R_1')], \tag{4}$$

where $\hat{\Sigma}_1$ is the estimated variance–covariance matrix of the reduced-form error terms on the announcement days, $\hat{\Sigma}_0$ is the estimated variance–covariance matrix of the reduced-form VAR residuals on the nonannouncement days, $\hat{V}_1$ is the estimated variance–covariance matrix of $vech(\hat{\Sigma}_1)$, and $\hat{V}_0$ is the estimated variance–covariance matrix of $vech(\hat{\Sigma}_0)$. After we obtain an estimate for R_1, we can use it to compute the impulse response of each factor to the monetary policy shock.

1.3 The Impulse Response Functions

This subsection describes how we obtain the IRFs for the sovereign bond yields. For this purpose, we first generate the IRFs for the factor model and then compute the IRFs for the variables in Y_t. First, suppose that the estimated full sample VAR is given as:

$$E_t = \hat{\Phi}_0 + \hat{\Phi}_1 E_{t-1} + \hat{\Phi}_2 E_{t-2} + \cdots + \hat{\Phi}_p E_{t-p} + \hat{\epsilon}_t,$$

where p is the lag length selected based on the Bayesian information criterion. We can rewrite this estimated model in vector moving average representation as follows:

$$E_t = \hat{\epsilon}_t + \hat{\Theta}_1\hat{\epsilon}_{t-1} + \hat{\Theta}_2\hat{\epsilon}_{t-2}\ldots$$

with $\hat{\Theta}_i = \sum_{j=1}^{i} \hat{\Theta}_{i-j}\hat{\Phi}_j$ for all $i = 1, 2, \ldots$. The h period ahead impulse response of the ith variable to the monetary policy shock can be computed as follows:

$$\frac{\partial E_{i,t+h}}{\partial \eta_{1,t}} = IRF_{h,i} \quad for\ i = 1, 2, \ldots, r+1,$$

where for $i \in \{1, \ldots, r+1\}$ $IRF_{h,i}$ is the impulse response of the ith variable in E_t to the one-standard-deviation monetary policy shock. In matrix form, we have $IRF_h = \hat{\Theta}_h \times \hat{R}_1$. However, our goal is to derive the IRFs for the yield series Y_t. We can reconstruct the impulse responses by simply multiplying the first r components of IRF_h ($IRF_h^F = [IRF_{h,1} \ldots IRF_{h,r}]$) with Λ, that is, $\widetilde{IRF}_h^F = \Lambda' IRF_h^F$. Note that IRF_h^F is an $r \times 1$ vector and $\widetilde{IRF}_h^F$ is an $N_Y \times 1$ vector. Notice that these responses can be extracted from the impulse responses of the factors. Accordingly, we ignore the last impulse response, which belongs to the other endogenous variable VIX.

The next step is constructing the confidence intervals for the impulse responses. To derive these intervals, we rely on the stationary block bootstrap of Politis and Romano (1994) combined with the Kilian (1998) bias adjustment. The bootstrapping procedure is described in the online Appendix.

Notice that our identification scheme relies on the difference between the variance of the reduced-form residuals on the announcement and the nonannouncement days. We check this condition relying on the Box's M test (Box 1949). This test is based on the hypothesis that the two (or more) variance–covariance matrices are equal to each other, that is, $H_0 : \Sigma_0 = \Sigma_1$ versus $H_1 : \Sigma_0 \neq \Sigma_1$. The methodology of this test is discussed in more detail in the online Appendix.

2. DATA AND SUMMARY STATISTICS

Our data consist of 80 daily bond yield series and runs from January 3, 2008 to December 31, 2019.[11] It covers from 1- to 30-year maturity fixed zero-coupon bond yields for eight EMU countries: Austria, Belgium, France, Germany, Italy, Netherlands, Portugal, and Spain.[12] Bond yield data are taken from the Thomson Reuters Database. We also include EA aggregate 5- and 10-year bond yields data from the ECB as the average yields for the euro area. We use the implied stock market VIX

11. The weekends and holidays are removed from the sample.

12. Our sample starts from 2008, since it is possible to construct a balanced dataset only after this date. Greece and Ireland are dropped from the sample due to the lack of data.

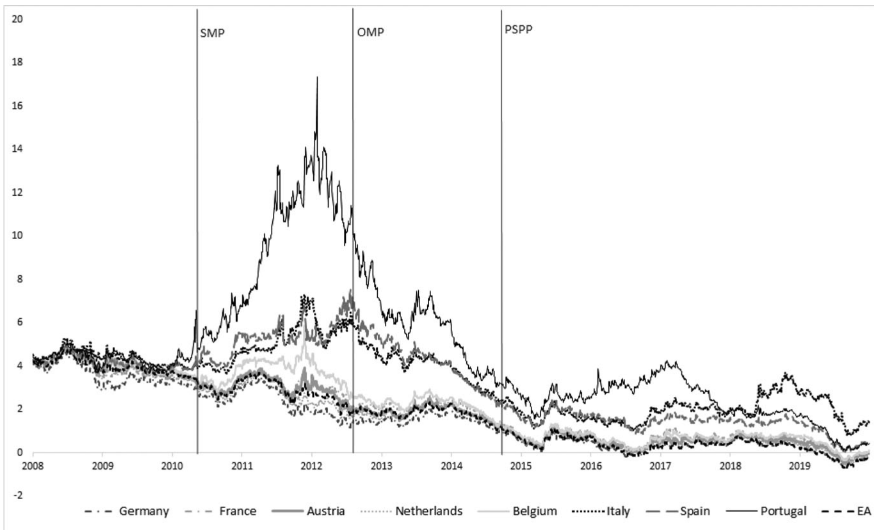


Fig 1. Ten-Year Bond Yields.

from the CBOE to control for the market fear and the global risk aversion and the FED policy dummy to control for the U.S. monetary policy.

We cover all UMP announcements by the ECB in the sample period including the extensive liquidity provision, the expanded asset purchase program introduced in 2015, and the rescue programs such as the SMP and the OMT implemented in the early phase of the eurozone crisis. The data for unconventional announcements rely on the press releases on monetary policy from the ECB's website.[13] Some of the announcement days coincide with the scheduled policy meeting days. To control for the impact of conventional policy announcements, in the VAR analysis, we control for the 1-month OIS rate change in the press release window relying on the data from the Euro Area Monetary Policy Event Study Database.[14]

Figure 1 shows the movements in the 10-year sovereign bond yields. Except for the sovereign debt crisis period, yields are highly correlated and move together. This pattern suggests a strong common market factor, arguably driven by the common exchange rate and the single monetary policy. After mid-2010, Italy, Portugal, and Spain diverged from the core countries as a result of the increase in the risk and the term premia (Garcia and Gimeno 2014). The yields for these countries began to

13. The ECB's policy announcement days are listed in the Table A1 of Appendix.

14. The data are based on Altavilla, Giannone, and Lenza (2019). We use the rate change in the press release window, since it provides information only about the policy decision itself and not the related discussion.

decrease following the ECB's announcement of the SMP and the OMT programs.[15] The trajectory of the yields suggests that the ECB intervention successfully led to a decline in the risk premium in the distressed sovereign markets.

3. EMPIRICAL RESULTS

In this section, we first present the estimated factors and their loadings and interpret them economically. Second, we present the evidence on the contribution of each factor to the overall impact of the monetary policy shocks. Third, we present the results for the overall impact on the maturities and the term structure of the interest rates.

3.1 Interpretation of the Estimated Factors

We derive the factors relying on the PCs methodology and interpret them based on the loadings of the factors, as in Litterman and Scheinkman (1991), Knez, Litterman, and Scheinkman (1994), and Piazzesi (2010). Our factor model, however, differs from these earlier studies in an important way. These studies rely predominantly on a single-country framework. Consequently, they interpret the first three PCs, respectively, as the level, slope, and curvature factors, because the loadings are, respectively, horizontal, downward sloping, and hump-shaped with respect to the maturity. In contrast, our model derives the factors in a multicountry framework. Consequently, the factors capture the different dynamics of the bond yields, and require different interpretations, as elaborated below.

We estimate that the four common factors[16] explain about 72% of the variation in the yields. Figure 2 plots the R^2s ordered by the countries and the maturities.

The relative importance of the four factors varies across the countries and maturities. They explain about 80% of the variation in the longer maturities and between 7% and 35% of the variation in the shorter maturities.[17] Interestingly, the idiosyncratic component explains the highest share of the variation at the short end of the yield curve (around 25% for the core and 10% for the periphery countries).

15. ECB President Mario Draghi made the "Whatever it takes." speech on July 26, 2012 followed by the official announcement of the OMT Program in the early August 2012.

16. We obtain the optimal number of factors by using the selection criteria in Onatski (2010).

17. While for the maturities longer than 5 years, our factor model explains more than 75% of the variation, for 1- and 2-year bond yields, it only explains about 45% of the variation. This worse model fit for the short-term yields might be associated with the effective zero lower bound in the sample period. More specifically, the estimated dynamic factor model is not constrained by the effective zero lower bound that creates misspecification issues. At the same time, the zero lower bound does not bias the main results of the paper. In particular, dynamic factor model allows us to extract the common components that explain most of the variation in the variables and drive the comovement between them without relying on tight assumptions when we are uncertain about the structure of the economy (Hübler and Frohn 2007).

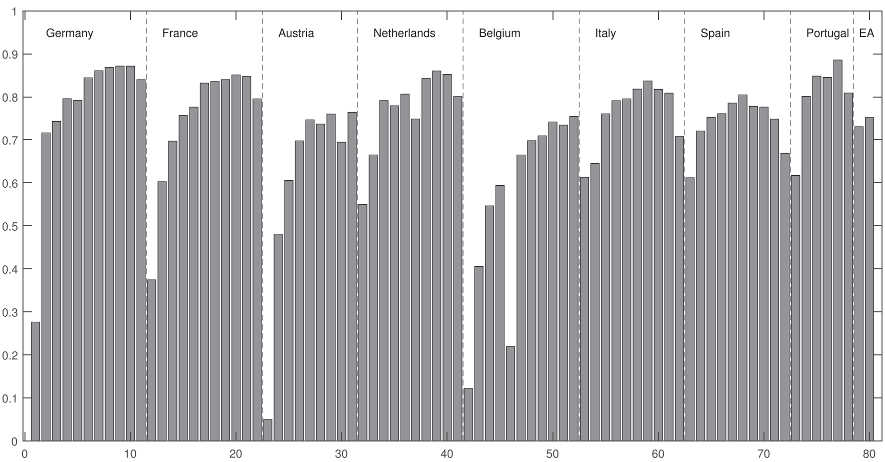


Fig 2. Model Fit and R^2.

TABLE 1

Factors Estimated: Total Variation Explained, 0.72

mR^2(f1)	0.44	mR^2(f2)	0.19	mR^2(f3)	0.05	mR^2(f4)	0.05
gb7y_Fra	0.81	gb5y_Ita	0.61	gb4y_Por	0.61	gb30y_Ger	0.18
gb6y_Fra	0.81	gb8y_Ita	0.60	gb5y_Por	0.58	gb30y_Net	0.17
gb8y_Fra	0.80	gb6y_Ita	0.60	gb6y_Por	0.57	gb2y_Fra	0.16
gb9y_Fra	0.79	gb4y_Ita	0.59	gb3y_Por	0.55	gb1y_Fra	0.15
gb10y_Fra	0.77	gb7y_Ita	0.59	gb10y_Por	0.47	gb2y_Aus	0.15
gb7y_Aus	0.74	gb9y_Ita	0.56	gb2y_Por	0.43	gb30y_Fra	0.14
gb5y_Fra	0.74	gb7y_Spa	0.55	gb30y_Ita	0.05	gb2y_Ger	0.14
gb6y_Net	0.73	gb6y_Spa	0.55	gb10y_Ita	0.04	gb2y_Net	0.13
gb8y_Net	0.72	gb10y_Ita	0.55	gb2y_Ger	0.04	gb3y_Fra	0.12
gb10y_Aus	0.72	gb5y_Spa	0.55	gb30y_Spa	0.04	gb30y_Bel	0.12
gb9y_Net	0.71	gb4y_Spa	0.54	*gb30y_Fra*	0.04	gb3y_Aus	0.12
gb4y_Net	0.71	gb8y_Spa	0.53	gb9y_Ita	0.03	gb2y_Bel	0.11
gb6y_Aus	0.70	*gb3y_Spa*	0.53	gb8y_Ita	0.03	gb10y_Por	0.11
gb5y_Net	0.70	gb9y_Spa	0.52	gb2y_Aus	0.03	gb1y_Ger	0.11
gb10y_Net	0.69	gb3y_Ita	0.50	gb3y_Ger	0.03	gb3y_Bel	0.10

Note: This table lists the 15 series that load most heavily on the first four factors along with R^2 in a regression of the series on the factor. For example, factor 1 explains 0.44 variation of 80 series. First factor explains 0.81 of the variation in 7-year French yields, and 0.74 of the variation of 7-year Australian yields.

Following McCracken and Ng (2016), we also calculate the marginal R^2s to see the corresponding series that load the most heavily on each factor. The results are presented in Table 1.

We interpret the first factor as the medium-term market factor, or in short, as the market factor. The term market factor reflects the observation that the first factor closely follows the average yields in the EMU, as evident in Figure 4(a). In terms of the factor loadings, they are negative for all countries and all maturities, and hence, a

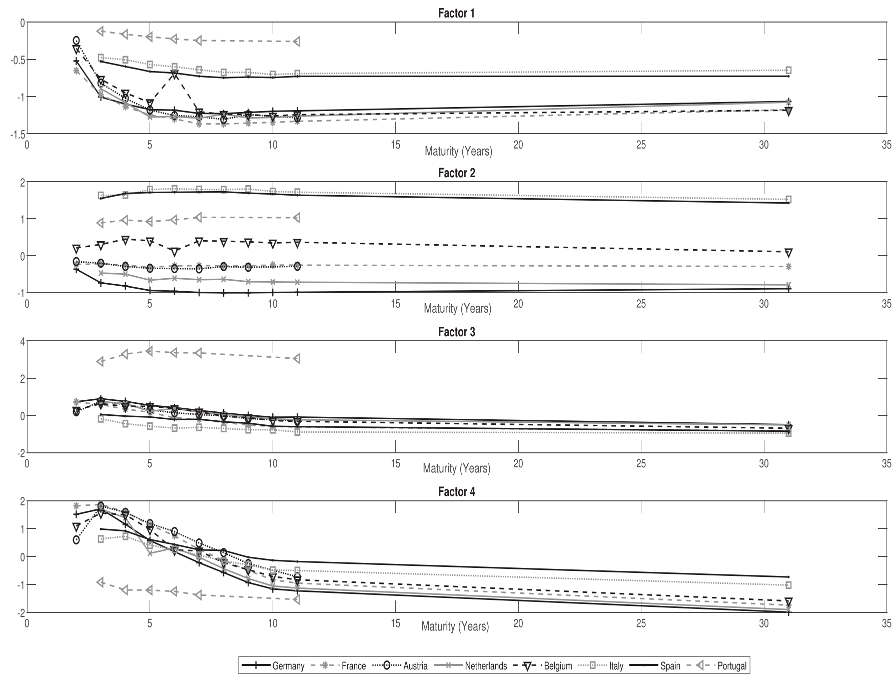
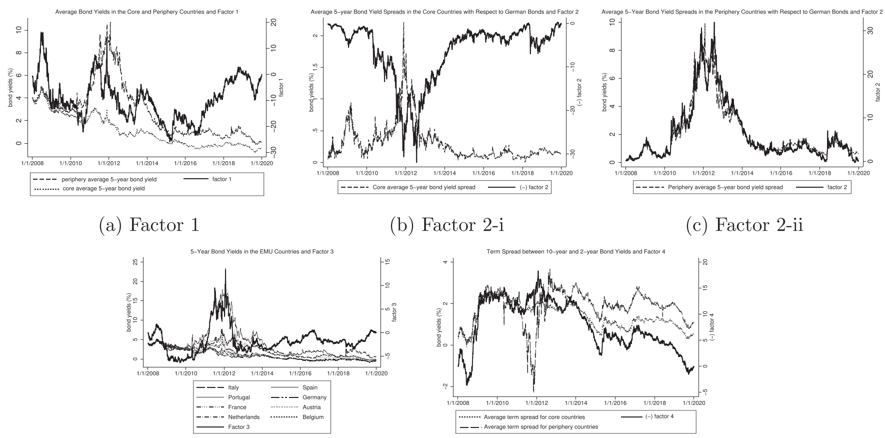


Fig 3. Factors Loadings.

change in factor 1 affects all bond yields in the same direction.[18] The term "medium-term" reflects the pattern that the explanatory power of the first factor peaks at the medium-term maturity yields. In particular, the absolute values of the loadings of the first factor increase until 6 years of maturity, as can be seen in Figure 3.

We interpret the second factor as the risk-mutualization factor. The interpretation is motivated by the larger and positive loadings for the periphery economies, and the smaller and negative loadings for the core, as evident in Figure 3. In other words, a change in factor 2 moves the yields in the opposite directions for the periphery and the core. Figures 4(b) and 4(c) show the average 5-year bond yield spreads for the core and periphery economies with respect to the 5-year German bonds and the second factor multiplied with the sign of the loadings. We observe that the second factor moves in the same direction with the spreads in the periphery countries and in the opposite direction with those in the core countries, given the minus sign of their loadings. This factor is arguably specific to the European Monetary Union, due to

18. The caveat for the first factor's loadings is that this principle component loads heavily on the core countries, moderately on Italy and Spain and weakly on Portugal. Overall, however, factor 1 is more volatile than the German yields, the commonly used proxy for the risk-free yields in the EA. This observation, together with factor 1's overlap with the behavior of the average medium-term yields across the continent, motivates the medium-term market factor interpretation.



(a) Factor 1 (b) Factor 2-i (c) Factor 2-ii

(d) Factor 3 (e) Factor 4

Fig 4. Factors and Related Economic Variables.

its unique structure with a single monetary policy but multiple sovereigns. The economic interpretation of the impact through this factor is that transferred some of the risk in the periphery to the core, hence the name risk-mutualization. Empirically documenting risk-mutualization is a novel contribution of this study, and we investigate this factor further in section 4.

We interpret the third factor as the troika factor. This interpretation is motivated by the observation that it has extremely positive loadings for Portugal and close to zero loadings for the other countries. What sets Portugal apart from the other EMU countries is that its bond yields diverged in the early phase of the financial crisis due to the concerns about the sustainability of the government debt, as evident in Figure 4(d). This pattern suggests that this factor captures the impact of the rescue programs, such as the SMP, on Portugal in the early phase of the euro area debt crisis before the rise in the Spanish and Italian yields.[19] We investigate this conjecture by examining whether the loadings on the third factor change significantly if we drop SMP and pre-SMP periods, and find that they do.[20]

Finally, the fourth factor is interpreted as the "slope" factor. This interpretation reflects the observation that the loading values on the fourth factor decrease with the maturity for all countries, as evident in Figure 3. This pattern suggests that the factor captures the difference between the short end and the long end of the yield curve, hence the name the slope factor following the earlier literature. The impact of

19. We do not include Greece and Ireland in the analysis due to the data quality issues. If Greece and Ireland were included in the analysis, factor 3 would probably capture also those countries.

20. The results are presented in the online Appendix.

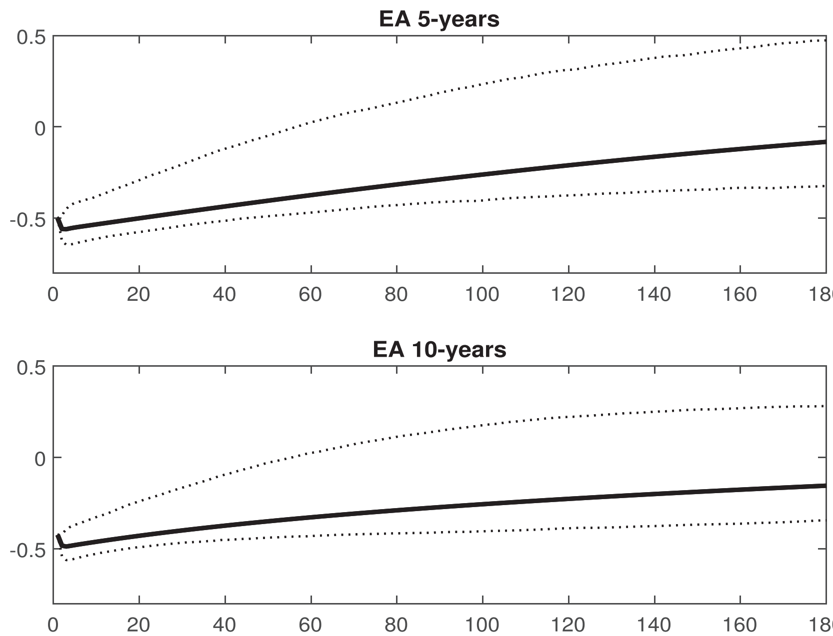


Fig 5. Impulse Responses of the EA Bond Yields.

unconventional policy measures through this factor shows how these policies affected the slope of the yield curve.

3.2 *Impulse Response Analysis*

In this subsection, we first verify the identification condition of the monetary policy shocks in the model by testing whether the variance–covariance matrices of the two regimes are different from each other. As we discussed in Section 1.3, we employ the Box's M test to verify this condition. We find that the Box's M statistic (BM statistic) is 2,604.5 with a bootstrap critical value of 787.7 and bootstrap *p*-value of 0. Hence, there is strong evidence that the variance–covariance matrices are different for the policy and the nonpolicy days.

We next investigate the impact of UMP shocks on the EA 5- and 10-year bond yields to normalize the monetary policy shock. Figure 5 plots the estimated responses of the EA bond yields to an expansionary monetary policy shock with a 95% bootstrap confidence interval. The identified monetary policy shock is normalized to lower the EA 5-year yields by 50 basis points.[21] The shock also lowers the EA 10-year bond

21. We normalize the shock for the 5-year yield as it is at the midpoint of the yield curve. The ECB mainly targets the bonds with 2–10 years maturity when implementing UMP.

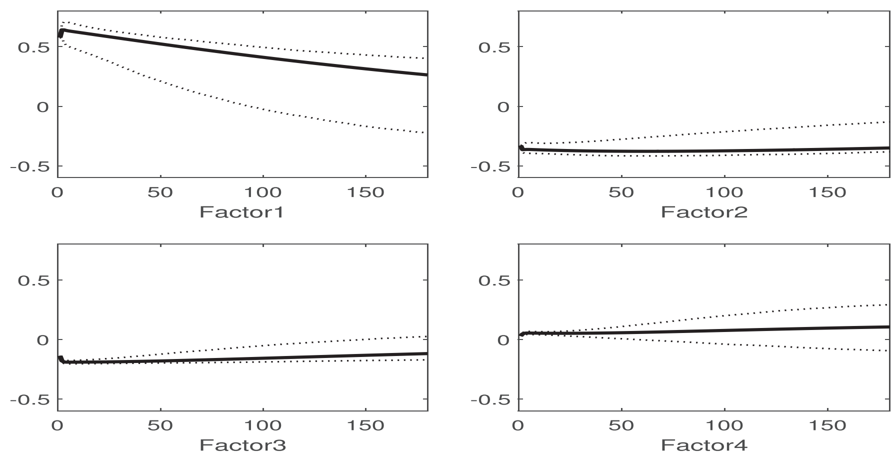


Fig 6. Impulse Responses of the Estimated Factors.

yield, but the magnitude of the impact is slightly smaller. The half-life of the estimated impulse responses for the EA yields is about 2 months.

In the next subsection, we first discuss the impact of this normalized policy shock on the estimated factors. Second, we discuss the impacts on the market, risk-mutualization, troika, and slope components of the yields. Third, we show the composite effect of the normalized policy shock on the bond yields and the persistence of the responses. Finally, we present the initial and time-lagged responses of the yield curves for each country.

The impact on different components of the bond yields. In this subsection, we present the results for the impact of unconventional policy measures on the market, risk-mutualization, troika, and slope components of the bond yields. We then discuss the role that each individual factor played in the overall impact of the shock.

Figure 6 shows the responses of the four factors to a normalized UMP shock. The market and risk-mutualization factors respond strongly and significantly. The responses of the troika and slope factors are also significant but weaker than the responses of the first two factors.

We obtain the impulse responses for the market component of the bond yields by multiplying the IRF of the market factor with its loadings. The market factor increases in response to a normalized UMP shock. The loadings for the market factor are negative for all countries and maturities. This pattern implies that applied unconventional policy shocks reduce the yields for all countries and maturities and shift the yield curve downward through its impact on the market factor, as evident in Figure 7. The impact through the market factor is relatively stronger at the long end of the yield curve, which causes a decline in the liquidity premium and makes the yield curve flatter.

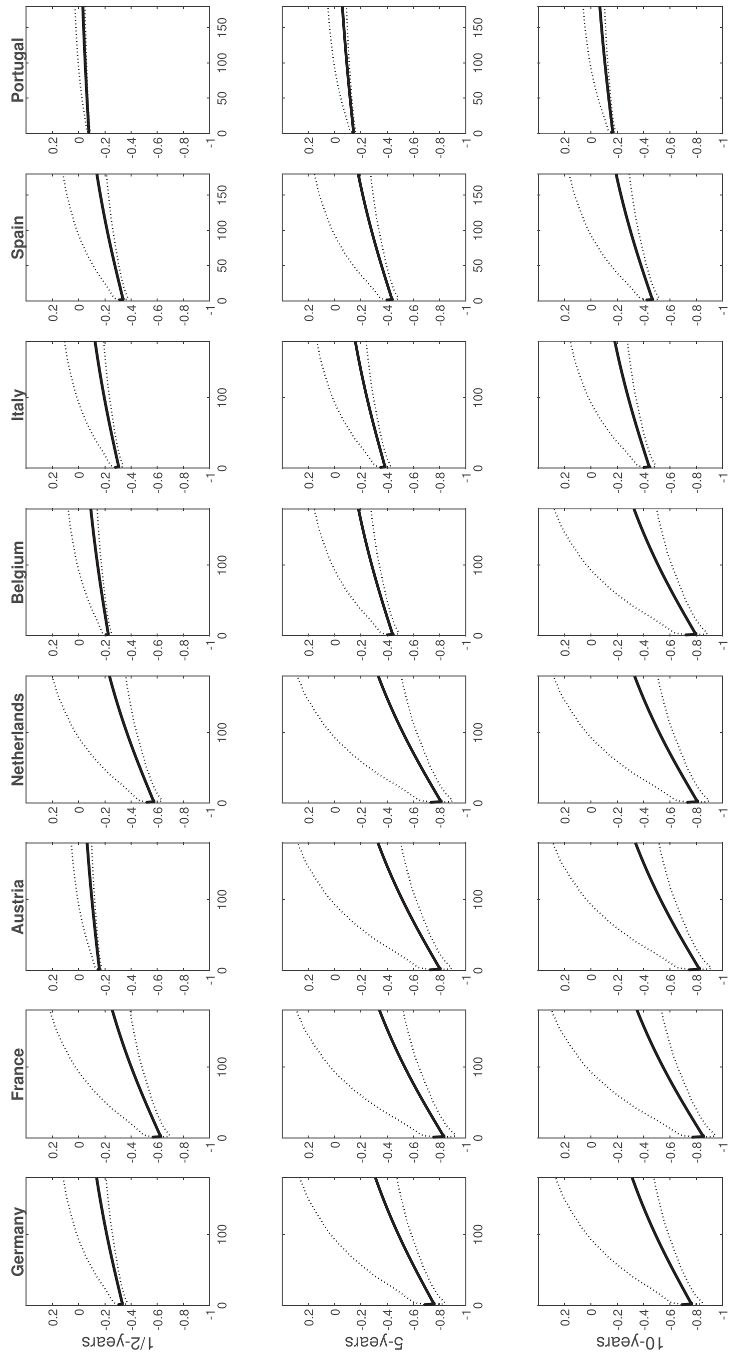


Fig 7. Impulse Responses of the Selected Maturities through Factors.

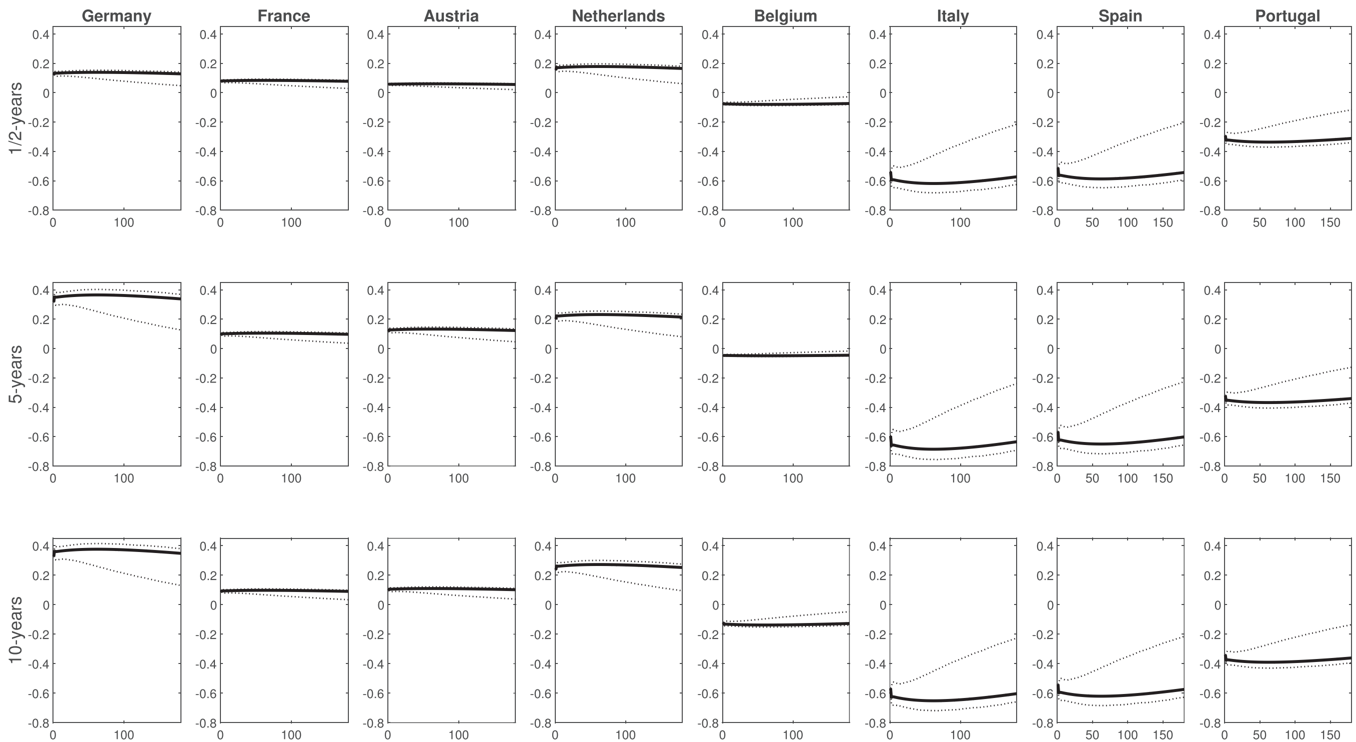


Fig 7. *Continued*

Our findings suggest that UMPs were effective in decreasing the market component of the government bond yields. However, the absolute values of the loadings for the market factor are higher for the core countries, which imply that the impact of the policy shocks on the bond yields through the market factor is stronger for the core countries. This heterogeneous response might be due to the structural differences between the two country groups. In Section 5, we observe that the liquidity providing operations affect the bond yields mainly through the market factor and the impact of the liquidity provision depends on how deep and solvent the banking sector is.[22] Consequently, the countries with more developed banking systems benefit more from the extensive liquidity provision. This pattern is consistent with Jäger and Grigoriadis (2017), which shows that the impact of the long-term liquidity financing operations and lowering the deposit rate to 0% is negative and significant for the noncrisis EMU countries, while they are insignificant for the crisis EMU countries.

We also investigate whether the stronger impact of unconventional policies through the market factor for the core economies is caused by a local supply effect. The local supply effect argument posits that limited local supply of the riskier long-term government bonds might reduce the risk premiums required to hold them.[23] Since such assets are relatively scarce in the core countries, large-scale asset purchase programs might have caused greater declines in their yields, and this stronger impact might have been captured by the market factor. To investigate this idea, we reestimate the model for a subsample that ends before the ECB started to purchase the safe country assets in 2015. The results show that both the loadings and the impulse responses for the market factor are similar for this subsample and the whole sample, suggesting that the results for the impact through the first factor are not driven by the local supply effect.

We obtain the impulse responses for the risk-mutualization component of the bond yields by multiplying the IRF of factor 2 with its loadings. The risk-mutualization factor decreases significantly in response to a normalized UMP shock. The loadings on the risk-mutualization factor are positive and substantial for the periphery countries, negative and smaller in absolute value for the core countries. Consequently, as shown in Figure 7(b), unconventional policy shocks decrease the risk-mutualization component of the bond yields substantially for the periphery countries and increase it slightly for the core countries. Our results also suggest that the impact is persistent for the periphery countries. This pattern provides evidence for risk-mutualization in the EMU through the UMP decisions by the ECB.

22. Gerlach, Schulz, and Wolff (2010) and Fratzscher and Rieth (2019) show that the bank-related factors play an important role in explaining the EA sovereign spreads. Due to the bank based structure of the EA, unconventional policy measures include extensive liquidity provision to the banking system. Darracq-Paries and De Santis (2015) show that the main transmission channels of the liquidity providing operations are the increase in the credit provision by the banking sector and the improvement in the agents' expectations for the future stance of the economy.

23. D'Amico and King (2013) and Gagnon, Raskin, Remache and Sack (2010).

The impact through the risk-mutualization factor is specific to the EMU, due to its unique structure with multiple economies and a single monetary authority, and needs further investigation. In Section 5, we investigate which policies resulted in greater risk-mutualization and find that the impact of the sovereign bond purchase programs such as the SMP and the OMT on the risk-mutualization factor is stronger compared to that of the other unconventional policies. This finding implies that risk-mutualization in the EMU is mainly driven by the sovereign bond purchase programs in the sample period. One possible explanation for this pattern is that the risk on the ECB's balance sheet increases due to the purchases of the risky country bonds, which, in turn, affects the risk assessment of the core countries negatively and increases their bond yields. In other words, the risk in the periphery economies is partially shared by the core economies through the ECB's asset purchases from the periphery economies. This finding is consistent with Falagiarda and Reitz (2015), Eser and Schwaab (2016), and Chadha and Hantzsche (2018), which show that the SMP reduced the risk in the euro area by decreasing the sovereign spreads in the stressed EMU countries.

To obtain the impulse responses for the troika and slope components of the bond yields, we multiply the IRFs of the troika and slope factors with their loadings. The troika factor responds negatively to UMP shocks. Loadings for the troika factor are positive and substantial for Portugal and close to zero for the other EMU countries. It implies that unconventional policy decisions decreased the troika component of the bond yields significantly for Portugal and the impact is negligible for the other countries. This finding reflects the observation that the third factor captures the impact of the rescue programs such as the SMP on Portugal in the early phase of the euro area crisis before the yields increased in Spain and Italy. The response of the slope factor to UMP shock is very weak. Unconventional policy decisions increase the short-term yields and decrease the long-term yields weakly through its impact on the slope factor. On the whole, the troika and slope factors contribute relatively little to the overall impact, and the results for the impacts through these factors are relegated to the online Appendix.

The overall impact on the EMU countries. This subsection investigates the overall responses of the bond yields to UMP shocks. A nonstandard monetary policy shock that is equivalent to a 50 bps drop in the EA 5-year yields induces significant drops in the yields for all maturities and countries. Expectedly, accommodative monetary shocks are priced rapidly in the bond market.

Figure 8 shows the aggregate responses of the selected bond yields to the ECB's UMP announcements.[24] The figure suggests that the identified unconventional policy announcements have been effective in easing financial conditions in both the core and periphery EMU countries, as they helped prevent sovereign defaults, financial collapse, and the breakup of the EMU. The impact is substantial and persistent for the periphery while it is weaker and temporary for the core countries.

24. The impulse responses for the individual maturities are reported in the online Appendix B.

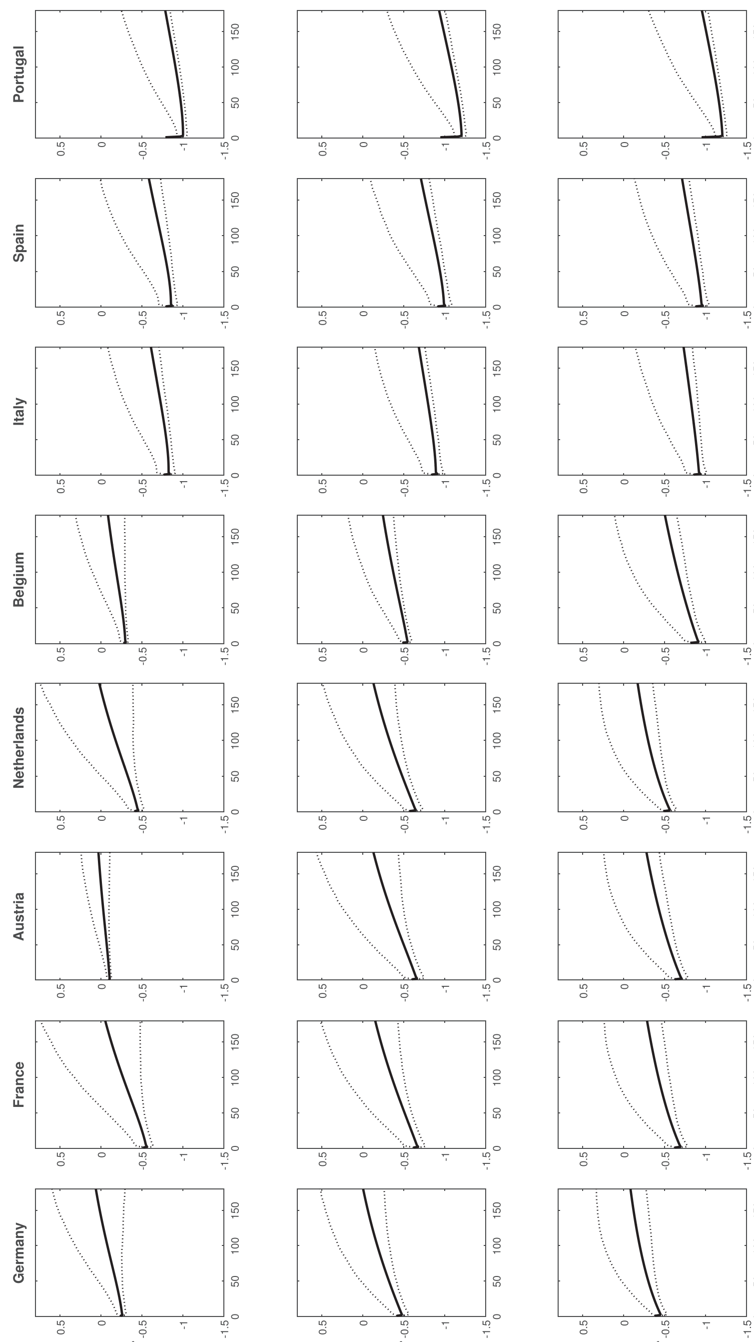


Fig 8. Aggregate Impulse Responses of the Bond Yields for Selected Maturities.

NOTES: There is no 1-year yield data available for Netherlands, Italy, Spain, and Portugal. Two-years maturity yields are used as the shortest maturity for these countries.

The results also show that a normalized UMP shock decreases the medium-term and the long-term bond yields by around 100 basis points for Italy and Spain and 120 basis points for Portugal. The responses of the bond yields are persistent for all maturities. This pattern suggests that unconventional policy measures shift the yield curve downward permanently in the periphery countries.

The results for Germany, France, Austria, Netherlands, and Belgium differ from those for the periphery countries. The previous section provided evidence that the policy shocks affect the bond yields in these countries negatively through the market factor and positively through the risk-mutualization factor. The cumulative responses show that the impact through the market factor is stronger and the overall impact is negative. A normalized UMP shock reduces the medium-term bond yields by around 50 basis points in Germany, France, Austria, Netherlands, and Belgium. The responses are weaker and transitory in these countries compared to those in the periphery countries.

The results provide evidence that the periphery countries benefited from the nonstandard policies by the ECB more than the core countries did. The heterogeneity in the responses of the periphery and the core countries can be explained by the shifts in the sovereign risk as captured by the risk-mutualization factor. The sovereign bond spreads in Italy, Spain, and Portugal increased relative to Germany due to the deterioration in the fiscal positions and the macroeconomic fundamentals and concerns about the sustainability of the government debt.[25] We find that unconventional policy measures, especially the SMP and the OMT announcements, were effective in addressing these concerns and led to the convergence of the bond yields in the EA.

We find that the impact of UMP is persistent, lasting longer than a year, for the European periphery. This finding contrasts with the earlier studies that find that the impact dies within 6 months for the United States, United Kingdom, and EA (Wright 2012, Rogers, Scotti, and Wright 2014). Neely (2014) argue that this transitory impact result in the earlier studies was driven by the instability of the structural VAR models caused by the model misspecification. Arguably, what allows our model to sidestep this problem and identify the persistent impact is the dimension reduction in the first step, which decreases the model uncertainty caused by the omitted variables, unobservable factors, and lagged endogeneity. Hence, when we test for the structural stability by using Bai and Perron (2003) test based on the global information criterion, the procedure[26] finds no breaks in the model, and suggests that the model is stable and provides reliable forecasts for the overall impact and the persistence.

25. Gerlach, Schulz, and Wolff (2010), Arghyrou and Kontonikas (2012), De Grauwe and Ji (2013), De Santis (2012), and Giordano, Pericoli, and Tommasino (2013).

26. In this procedure, we utilize the Schwarz information criterion and heteroskedasticity- and autocorrelation-corrected standard errors. Considering the sample size of the announcement day VAR, we utilize 10% trimming for arranging the search region for the structural breaks. Furthermore, we allow all coefficients of each equation in the VAR to change simultaneously. This allows us to analyze equation by equation stability of the system.

One concern for the results of the impulse response analysis is their robustness to the selection of the number of factors. We conduct the analysis with four factors, based on the selection criteria in Onatski (2010). Nevertheless, for further robustness, we repeat the analysis for three and five factors. The results, discussed in the online Appendix, highlight that changing the number of factors leads to minor changes in the results.

The overall impact on the term structure of interest rates. This subsection investigates the responses of the term structure of interest rates to UMP shocks. The initial responses of the bond yields to the policy announcements increase with the maturity approximately until 6–7 years, and then stay constant. This pattern is in line with the aim of unconventional policy measures. The ECB, like other major central banks, mostly targets the longer term interest rates directly with unconventional policy announcements. The findings are also consistent with the recent literature that studies the impact of unconventional policy announcements on the bond yields. Bernhard and Ebner (2017) find that the impact of the expansionary policy shocks is larger for the Swiss long-term government bond yields, in particular for the bond yields with maturities of 7–10 years. Rogers, Scotti, and Wright (2014) find that the impact of the monetary policy shocks at the ZLB is larger at the long end of the yield curve for the United States, United Kingdom, and Japan.[27]

In explaining why the impact of the ECB's unconventional policies peaked at the medium maturities, one plausible reason is that these policies mainly involved the purchase of medium-term maturity assets. More specifically, for the ECB's asset purchase programs, Eser, Lemke, Nyholm, Radde, and Vladu (2019) show that the average maturities were concentrated around 7–8 years. This increased demand for the medium maturity assets helps explain why our model captures a higher impact on the mid-maturities.

Figure 9 shows the responses of the yield curves to a normalized monetary policy shock for each country. The solid black lines are the yield curves of the countries drawn using the average bond yields over the period 2008–2019 for the maturities up to 10 years. The dashed lines are the estimated initial responses of the yields and the responses after 1 week, 1 month, 3 months, 6 months, and 1 year from the policy shock. The figure clearly shows that the accommodative policy shocks diminish all yields considerably on the announcement day and shifts the yield curve downward for all countries. However, the impact is more persistent for the periphery countries, where it takes more than a year for the yields to return to the initial levels, compared to 6 months for the core economies. The unconventional policy announcements have a strong flattening effect on the yield curve for Portugal and a weak flattening effect for the other countries. They also decrease the curvature of the yield curve for Portugal.

27. In contrast, Altavilla, Giannone, and Lenza (2016) and Eser and Schwaab (2016) show that the SMP and OMT announcements cause a higher drop at the short end of the yield curve. However, these studies cover the period in which OMP and SMP programs were announced and implemented. In this study, we are interested in the overall impact of the policy announcements regardless of the specific programs.

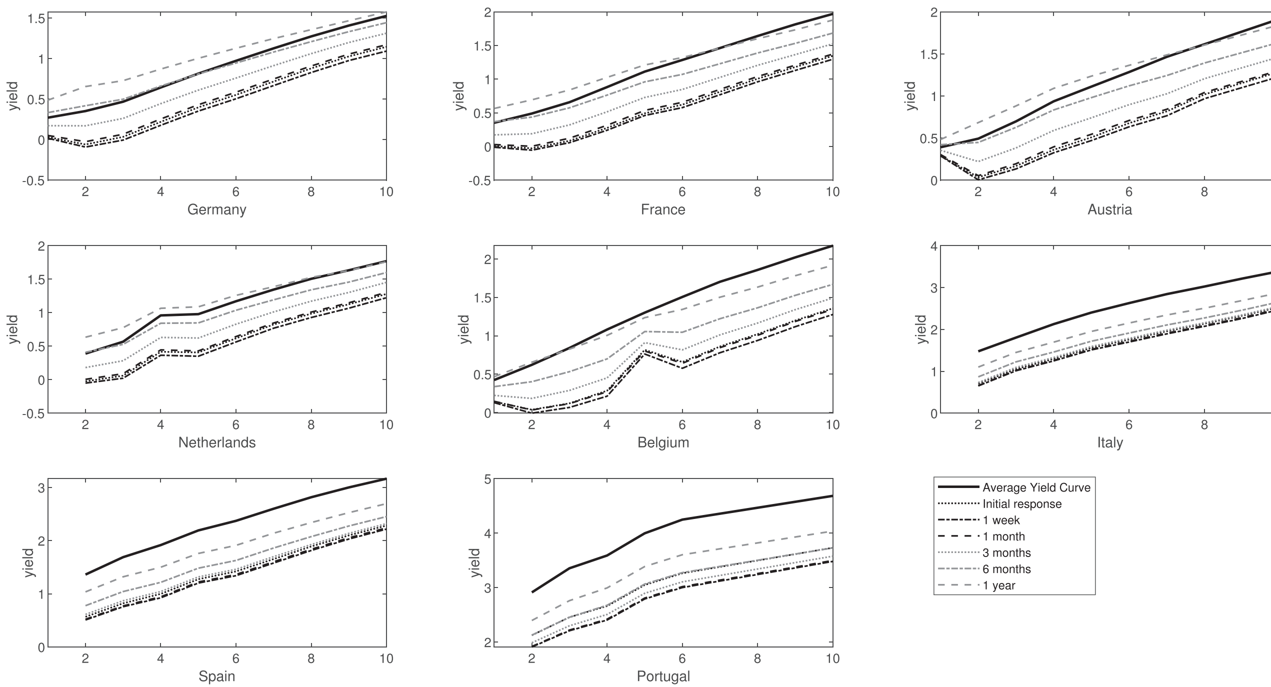


Fig 9. Impact of the UMP on the Yield Curves.

TABLE 2

Responses of the Factors to the Different Policy Dummies

	$\Delta f1$	$\Delta f2$	$\Delta f3$	$\Delta f4$
Constant	−0.005	0.007	0.001	0.001
	(0.013)	(0.008)	(0.004)	(0.004)
Sovereign bond purchase programs	0.752***	−1.605****	−0.269***	0.054
	(0.249)	(0.160)	(0.085)	(0.082)
Liquidity provision	0.163**	−0.084*	−0.051*	−0.049*
	(0.078)	(0.050)	(0.027)	(0.026)
Asset purchase programs	−0.11	−0.154**	0.051	0.032
	(0.119)	(0.076)	(0.041)	(0.039)

Standard deviations in parenthesis. Levels of statistical significance: * 0.1, ** 0.05, *** 0.01, **** 0.001.

4. THE RELATIONSHIP BETWEEN DIFFERENT POLICY PROGRAMS AND ESTIMATED FACTORS

In this section, we investigate the link between different unconventional policy programs and estimated factors. The unconventional announcements used in the analysis are presented in Table A1. We categorize the announcements into three categories. The first category, liquidity providing operations, includes the long-term refinancing operations, targeted long-term refinancing operations, fixed-rate full allotment policies, collateral policies, and U.S. dollar liquidity providing operations that aimed to provide liquidity to the banking system. The second category, sovereign bond purchase programs, includes the SMP and OMT announcements that aimed to reduce the sovereign risk in the financially stressed EMU countries in the early phase of the euro area crisis. The third category, asset purchase programs, includes the corporate sector purchase program, public sector purchase program, asset-backed securities purchase program, and covered bond purchase program that aimed to mitigate the risks of the euro area and revive the economic activity.

To formally investigate the impacts of the three policy programs on the different factors, we assign dummy variables to each policy category, and run event study regressions for each factor. The results are presented in Table 2, which shows the impact for different unconventional program and factor combinations.

The sovereign bond purchase programs have significant impacts on the market, risk-mutualization, and troika factors. The signs of the impacts are positive for the first factor, and negative for the second and the third. Based on the loading values on these factors, this finding implies that the sovereign bond purchase programs decreased the market component of the yields for all countries and maturities, decreased the risk-mutualization component for the periphery countries substantially at the cost of increasing it for the core countries, and decreased the troika component for Portugal. In terms of the magnitudes, the impact is the strongest for the risk-mutualization factor. In words, the sovereign bond purchase programs appear to work mainly by transferring the risk of the financially stressed countries to the core and resulted in greater risk-mutualization than the other programs in the EMU.[28]

As for the liquidity providing operations, the impacts are significant on all four of the market, risk-mutualization, troika, and slope factors. However, for the latter three, the impacts are only significant at 10% level and the estimated magnitudes for the impacts are small. For some of the liquidity programs, if the expectation is greater than the realization, these events might have contractionary impacts. This might be the reason that we find a weaker impact for the liquidity providing programs. Nevertheless, the findings suggest that the liquidity-providing operations affected the bond yields mainly through the market factor. In particular, the negative loading values imply that liquidity operations reduced the average bond yields in the EMU.

Finally, for the asset purchase programs, the impact is significant only for the risk-mutualization factor, with a negative coefficient. Because the loadings on this factor are substantially positive for the periphery and slightly negative for the core, the results imply that the asset purchase programs decreased the bond yields in the periphery at the cost of a small increase in the core. This result suggests that the asset purchase programs contributed to risk-mutualization in the EMU.

5. CONCLUSION

During the Great Recession, central banks in developed economies were forced to bring the interest rates down to zero, leaving no room for conventional policy. Consequently, central banks experimented with several UMP, with little guidance from the past experience. In the light of the recovery that followed, the common wisdom about these unconventional policies is that they were successful. There is, however, little consensus over the magnitude of their causal impact, and how the impact varied across countries, assets, and horizons.

This paper provides a comprehensive picture of the impact of UMP on the government bond yields in the EMU. What allows this in-depth treatment is a novel methodology that combines a dynamic factor model, the identification through heteroskedasticity, and a VAR model. This methodology allows exploiting the unique structure of the EMU with a single central bank and multiple economies, and estimating the impact of the common unconventional policy shocks on 80 different bond yields. It also allows us to decompose the overall impact into the impacts on the different components of the yields and to investigate risk-mutualization in the EMU. Consequently, we are able to describe the impact of unconventional policies across different countries, maturities, yield components, and time horizons.

The results corroborate that unconventional policies had a strong overall effect, but with significant variation across the countries. Broadly speaking, the policies decreased the risk-mutualization component of the bond yields substantially for the

28. Our finding for the effectiveness of the sovereign bond purchase programs is consistent with Falagiarda and Reitz (2015), Eser and Schwaab (2016), and Chadha and Hantzsche (2018).

periphery and increased them slightly for the core countries. This differential impact provides evidence that unconventional policy announcements by the ECB resulted in a risk sharing in the EMU and drove the convergence in the bond yields between the periphery and core economies. The impact in the periphery is also more persistent than that in the core. As for the maturities, we find that the impact worked on all, with a stronger impact for the medium-term and the long-term maturities.

The heterogeneity in the impact of UMPs that we document motivates further research into its drivers. From a theoretical perspective, the heterogeneity is of interest, as it provides insights about the relative importance of the different transmission channels discussed in the literature. From a policy perspective, understanding the heterogeneity matters, as it allows the monetary authorities to design more effective interventions. While unconventional policies were introduced somewhat haphazardly during the crisis, they are now an important part of the monetary policy toolbox, and understanding how they interact with the local economic structures is essential for using them effectively.

APPENDIX: DATA

TABLE A1

ECB Unconventional Policy Announcements

Announcement date	Announcement description
7-Feb-08	The ECB decided to renew two outstanding supplementary longer term refinancing operations.
28-Mar-08	The ECB decided to conduct supplementary longer term refinancing operations.
31-Jul-08	The ECB decided to renew two outstanding supplementary longer term refinancing operations.
4-Sep-08	The ECB decided to renew three outstanding supplementary longer term refinancing operations.
7-Oct-08	The ECB decided to enhance longer term refinancing operations and expand U.S. dollar providing liquidity operations.
8-Oct-08	The ECB decided to adopt a fixed-rate tender with full allotment.
15-Oct-08	The ECB decided to expand the list of assets eligible as collateral, enhance the provision of longer term refinancing operations, and provide U.S. dollar liquidity through foreign exchange swaps.
18-Dec-08	The ECB decided that the main refinancing operations will continue to be carried out through a fixed-rate tender procedure with full allotment as long as needed.
5-Mar-09	The ECB decided to continue the fixed-rate tender procedure with full allotment for all main refinancing operations, special term refinancing operations, and supplementary and regular longer term refinancing operations for as long as needed.
7-May-09	The ECB decided to purchase euro-denominated covered bonds issued in the euro area and to conduct liquidity providing longer term refinancing operations.

(*Continued*)

TABLE A1
(Continued)

Announcement date	Announcement description
4-Jun-09	The ECB decided upon technical modalities of CBPP1.
2-Jul-09	The ECB started with the purchases of covered bonds.
20-Nov-09	The ECB amends rating requirements for asset-backed securities in Eurosystem credit operations.
3-Dec-09	The ECB decided to continue conducting its main refinancing operations as fixed-rate tender procedures with full allotment for as long as needed, and to enhance the provision of longer term refinancing operations.
4-Mar-10	The ECB decided to continue conducting its main refinancing operations as fixed-rate tender procedures with full allotment for as long as needed, and to variable rate tender procedures in the regular 3-month longer term refinancing operations.
10-May-10	The ECB decided to proceed with the SMP, to reactivate the liquidity swap lines with the FED, to adopt a fixed-rate tender procedure with full allotment in the regular 3-month longer term refinancing operations and to conduct new special longer term refinancing operations.
10-Jun-10	The ECB decided to adopt a fixed-rate tender procedure with full allotment in the regular 3-month longer term refinancing operations.
28-Jul-10	The ECB reviews risk control measures in its collateral framework.
2-Sep-10	The ECB decided to continue to conduct its main refinancing operations as fixed-rate tender procedures with full allotment for as long as necessary and to conduct the 3-month longer term refinancing operations.
2-Dec-10	The ECB decided to continue conducting its main refinancing operations as fixed-rate tender and to procedures with full allotment for as long as necessary and to conduct the 3-month longer term refinancing operations.
16-Dec-10	The ECB decided to establish loan-by-loan information requirements for asset-backed securities in the Eurosystem collateral framework.
21-Dec-10	The ECB decided to continue to conduct U.S. dollar liquidity-providing operations with a maturity of 7 days. These Eurosystem operations will continue to take the form of repurchase operations against eligible collateral and will be carried out as fixed-rate tenders with full allotment.
3-Mar-11	The ECB decided to continue conducting its main refinancing operations as fixed-rate tender procedures with full allotment for as long as necessary and to conduct the 3-month longer term refinancing operations.
9-Jun-11	The ECB decided to continue conducting its main refinancing operations as fixed-rate tender procedures with full allotment for as long as necessary and to conduct the 3-month longer term refinancing operations.
4-Aug-11	The ECB decided to conduct a liquidity-providing supplementary longer term refinancing operation with a maturity of approximately 6 months. The operation will be conducted as a fixed-rate tender procedure with full allotment. ECB also decided to continue conducting its MROs as fixed-rate tender procedures with full allotment for as long as necessary.
8-Aug-11	The ECB decided to relaunch the Securities Market Program for Italy and Spain after a period of inactivity.
6-Oct-11	The ECB decided to launch a new covered bond purchase program and decided to conduct two longer term refinancing operations, one with a maturity of approximately 12 months and the other with a maturity of approximately 13 months. The operations will be conducted as fixed-rate tender procedures with full allotment.
3-Nov-11	The ECB decided upon the technical modalities of the second Covered Bond Purchase Programme.
8-Dec-11	The ECB announced 2 three-year longer term refinancing operations and decided on additional enhanced credit support measures to support bank lending and liquidity in the euro area money market.
16-Dec-11	The ECB decided to conduct two 1-day liquidity-providing fine-tuning operations.

(*Continued*)

TABLE A1

(Continued)

Announcement date	Announcement description
6-Jun-12	The ECB decided to continue conducting its main refinancing operations as fixed-rate tender procedures with full allotment for as long as necessary and to conduct the 3-month longer term refinancing operations.
22-Jun-12	The ECB decided to take further measures to increase collateral availability for counterparties.
26-Jul-12	The ECB announced that it is ready to do whatever it takes to preserve Euro.
02-Aug-12	The ECB announced that it would undertake outright transactions in secondary, sovereign bond markets.
6-Sep-12	The ECB started Outright Monetary Transactions Programme and decided on additional measures on collateral availability.
6-Dec-12	The ECB decided to continue conducting its main refinancing operations as fixed-rate tender procedures with full allotment for as long as necessary and to conduct the 3-month longer term refinancing operations.
21-Feb-13	The ECB announced the details on securities holdings acquired under the Securities Markets Programme.
22-Mar-13	The ECB announced changes to the use as collateral of certain uncovered government-guaranteed bank bonds.
2-May-13	The ECB decided to continue conducting its main refinancing operations (MROs) as fixed-rate tender procedures with full allotment for as long as necessary and to conduct the 3-month longer-term refinancing operations.
18-Jul-13	The ECB reviewed its risk control framework allowing for a new treatment of asset-backed securities.
27-Sep-13	The ECB adopted decisions to follow up on the review of its risk control framework.
22-Nov-13	The ECB suspended early repayments of the 3-year longer term refinancing operations during the year-end period.
5-Jun-14	The ECB decided to continue conducting its main refinancing operations as fixed-rate tender procedures with full allotment for as long as necessary, to suspend the weekly fine-tuning operation sterilizing the liquidity injected under the Securities Markets Programme, to conduct a series of targeted longer term refinancing operations and announced for the first time that the deposit facility rate would be below zero.
3-Jul-14	The ECB announced further details of the targeted longer term refinancing operations.
4-Sep-14	The ECB decided to set deposit facility rate even more negative (–0.20), to modify the loan-level reporting requirements for asset-backed securities (ABSs) and to take additional measures on collateral availability.
16-Sep-14	The ECB announced the first targeted longer term refinancing operations (TLTRO).
18-Sep-14	The ECB allotted 82.6 billion EUR in the first TLTRO.
2-Oct-14	The ECB announced operational details of asset-backed securities and covered bond purchase programs.
30-Oct-14	The ECB appoints executing asset managers for the ABS Purchase Programme.
7-Nov-14	The ECB suspended early repayments of the 3-year longer term refinancing operations during the year-end period.
9-Dec-14	The ECB Announced the second TLTRO.
11-Dec-14	The ECB allotted 129.8 billion in the second TLTRO.
22-Jan-15	The ECB announced an expanded asset purchase program and announces a modification to the interest rate applicable to future targeted longer term refinancing operations.
17-Mar-15	The ECB announced the third TLTRO.
19-Mar-15	The ECB allotted 97.8 billion in the third TLTRO.
16-Jun-15	The ECB announced the fourth TLTRO.
18-Jun-15	The ECB allotted 73.7 billion in fourth TLTRO.
22-Sep-15	The ECB announced the fifth TLTRO.

(*Continued*)

TABLE A1
(Continued)

Announcement date	Announcement description
23-Sep-15	The ECB decided to increase the proportion of purchases by national central banks rather than external managers in the Asset-Backed Securities Purchase Programme.
24-Sep-15	The ECB allotted 15.5 billion in the fifth TLTRO.
9-Nov-15	The ECB increased the Public Sector Purchase Program issue share limit from 25% to 33% per international securities identification number.
3-Dec-15	The ECB set deposit facility rate even more negative (−0.30).
9-Dec-15	The ECB announced the sixth TLTRO and started applying the −0.30 deposit facility rate.
11-Dec-15	The ECB allotted 18.3 billion in the sixth TLTRO.
10-Mar-16	The ECB announced a new series of TLTROs, added the corporate sector purchase program to the asset purchase program, set deposit facility rate even more negative (–0.40).
16-Mar-16	The ECB started applying the −0.40 deposit facility rate.
22-Mar-16	The ECB announced the seventh TLTRO.
24-Mar-16	The ECB allotted 7.3 billion in the seventh TLTRO.
21-Apr-16	The ECB announced the details of the corporate sector purchase program.
2-Jun-16	The ECB announced the remaining details of the corporate sector purchase program.
8-Jun-16	The ECB started corporate sector purchase program.
5-Oct-16	The ECB made changes to collateral eligibility criteria and risk control measures for unsecured bank bonds.
3-Nov-16	The ECB reviewed its risk control framework for collateral assets.
8-Dec-16	The ECB adjusted parameters of its asset purchase program and introduced cash collateral for private sector purchase program securities lending facilities.
15-Dec-16	The ECB adjusted the purchase process in Asset-Backed Securities Purchase Programme.
19-Jan-17	The ECB confirmed that it will continue to make purchases under the asset purchase program at the current monthly pace of 80 billion EUR until the end of March 2017.
9-Mar-17	The ECB confirmed that it will continue to make purchases under the asset purchase program at the current monthly pace of 80 billion EUR until the end of March 2017.
27-Apr-17	The ECB confirmed that the net asset purchases, at the new monthly pace of 60 billion EUR, are intended to run until the end of December 2017, or beyond, if necessary.
8-Jun-17	The ECB confirmed that the net asset purchases, at the current monthly pace of 60 billion EUR, are intended to run until the end of December 2017,or beyond, if necessary.
20-Jul-17	The ECB confirmed that the net asset purchases, at the current monthly pace of 60 billion EUR, are intended to run until the end of December 2017, or beyond, if necessary.
7-Sep-17	The ECB confirmed that the net asset purchases, at the current monthly pace of 60 billion EUR, are intended to run until the end of December 2017, or beyond, if necessary.
26-Oct-17	The ECB confirmed that the net asset purchases, at the current monthly pace of 60 billion EUR, are intended to run until the end of December 2017, or beyond, if necessary.
26-Oct-17	The ECB provided additional data on redemptions as well as information about reinvestments and role of private sector purchase programs.
14-Dec-17	The ECB confirmed that from January 2018 it intended to continue to make net asset purchases under the asset purchase program at a monthly pace of 30 billion EUR, until the end of September 2018, or beyond, if necessary.
25-Jan-18	The ECB confirmed that the net asset purchases, at the new monthly pace of 30 billion EUR, are intended to run until the end of September 2018, or beyond, if necessary.
8-Mar-18	The ECB confirmed that the net asset purchases, at the current monthly pace of 30 billion EUR, are intended to run until the end of September 2018, or beyond, if necessary.

(*Continued*)

TABLE A1
(Continued)

Announcement date	Announcement description
26-Apr-18	The ECB confirmed that the net asset purchases, at the current monthly pace of 30 billion EUR, are intended to run until the end of September 2018, or beyond, if necessary.
14-Jun-18	The ECB decided to continue to make net purchases under the asset purchase program at the current monthly pace of 30 billion EUR until the end of September 2018 and decrease the monthly pace of the net asset purchases to 15 billion EUR until the end of December 2018 and that net purchases will then end.
11-July-18	The ECB published indicative calendars for the Eurosystem's regular tender operations and reserve maintenance periods in 2019.
26-July-18	The ECB confirmed that it will continue to make net purchases under the asset purchase program at the current monthly pace of 30 billion EUR until the end of September 2018 and decrease the monthly pace of the net asset purchases to 15 billion EUR until the end of December 2018 and that net purchases will then end.
13-Sep-18	The ECB confirmed that it will continue to make net purchases under the asset purchase program at the current monthly pace of 30 billion EUR until the end of this month and decrease the monthly pace of the net asset purchases to 15 billion EUR until the end of December 2018 and that net purchases will then end.
25-Oct-18	The ECB confirmed that it will continue to make net purchases under the asset purchase program at the new monthly pace of 15 billion EUR until the end of December 2018 and subject to incoming data confirming the medium-term inflation outlook, net purchases will then end.
13-Dec-18	The ECB confirmed that the net purchases under the asset purchase program will end in December 2018 and announced its intention to continue reinvesting, in full, the principal payments from maturing securities purchased under the APP for an extended period of time.
24-Jan-19	The ECB announced its intention to continue reinvesting, in full, the principal payments from maturing securities purchased under the APP for an extended period of time.
7-Mar-19	The ECB announced its intention to continue reinvesting, in full, the principal payments from maturing securities purchased under the APP for an extended period of time and also announced that a new series of quarterly targeted longer term refinancing operations (TLTRO-III) will be launched.
22-Mar-19	The ECB announced that transparency requirements of EU Securitisation Regulation to be incorporated into Eurosystem collateral framework.
10-Apr-19	The ECB announced its intention to continue reinvesting, in full, the principal payments from maturing securities purchased under the APP for an extended period of time.
6-Jun-19	The ECB announced its intention to continue reinvesting, in full, the principal payments from maturing securities purchased under the APP for an extended period of time and also announced the details of new targeted longer term refinancing operations.
25-Jul-19	The ECB announced its intention to continue reinvesting, in full, the principal payments from maturing securities purchased under the APP for an extended period of time.
29-Jul-19	The ECB published a legal act adopted on July 22, 2019 relating to the third series of targeted longer term refinancing operation.
12-Sep-19	The ECB announced that net purchases will be restarted under the Governing Council's asset purchase program at a monthly pace of 20 billion EUR as from November 1. It also announced the modalities of the new series of quarterly targeted longer term refinancing operations will be changed to preserve favorable bank lending conditions.
24-Oct-19	The ECB confirmed that net purchases will be restarted under the Governing Council's asset purchase program at a monthly pace of 20 billion EUR as from November 1.
12-Dec-19	The ECB announced that it expects to run the asset purchase program for as long as necessary to reinforce the accommodative impact of its policy rates.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

Data S1