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# Heterogeneous effects of unconventional monetary policy on the bond yields across the euro area <sup>\*</sup>

İshak Demir<sup>†</sup>, Burak A. Eroğlu<sup>‡</sup>, Seçil Yıldırım-Karaman<sup>§</sup>

## Abstract

This paper investigates the impact of the European Central Bank's unconventional monetary policies (UMP) between 2008-2019 on the European government bond yields. It adopts a novel econometric approach that combines a data-rich factor analysis and VAR with heteroskedasticity 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 the separate yield components, we find that the 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 the risk-mutualization in the European Monetary Union.

*Keywords:* Unconventional monetary policy, risk-mutualization, cross-country difference, sovereign bond yields, ECB, EMU

*JEL Classification:* C38, E43, E52, E58, F42, G12

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# 1 Introduction

The unconventional policies introduced during the Great Recession have redefined the tool-box 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 endeavour 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 impact of the 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.<sup>1</sup>

This study contributes to the literature by offering a comprehensive account of the impact of the European Central Bank’s (ECB) unconventional monetary policies 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 unconventional monetary policy shocks for eight different countries and up to eleven different maturities using high frequency data. For each country and maturity, the model also allows decomposing the total effect of the unconventional policy shocks into the separate effects on the market, risk-mutualization, troika and slope components of the bond yields 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 the unconventional policies. In particular, for the market component of the bond yields, we find that the unconventional policies reduced them for all countries and all maturities. As for the risk-mutualization component, the unconventional policies 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

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<sup>1</sup>For example Fratzscher et al. (2016), Chen et al. (2012) and IMF (2013) argue that the size of the effects depends on the specific characteristics of the UMP program implemented.

core economies through the ECB’s unconventional policy decisions. We also show that the 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 unconventional monetary policies investigated in this study are the extensive liquidity provision, the expanded asset purchase program which started in 2015 and rescue programs such as the Securities Market Program (SMP) and the Outright Monetary Transactions (OMT).<sup>2</sup> These policies were introduced when the short-term nominal interest rates in the developed economies hit the zero lower bound, leaving little room for the conventional monetary policy. Finding themselves in an uncharted territory, the central banks in the developed countries experimented with the new monetary policy instruments, with little past experience to rely on.

We investigate the impact of the unconventional monetary policies based on the experience of the European Monetary Union (EMU) countries. This choice is motivated by the unique structure of the EMU, where the decisions of a single central bank affect the 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 3 January 2008 and 31 December 2019. The model estimates the impact of the 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 to 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.<sup>3</sup> Reducing the 80 yield series into four common factors allows estimating a single model for the EMU

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<sup>2</sup>See Haldane et al. (2016), Joyce et al. (2012), Cecioni et al. (2011).

<sup>3</sup>These three factors are different from the level, slope and curvature factors in the affine term structure literature.

while preserving the variation across countries and maturities.

In the second step, we estimate the impact of the unconventional monetary policy shocks on each of the market, risk-mutualization, troika and slope factors. In these estimations, we rely on a VAR model with heteroskedasticity based identification which relies on the assumption that the volatility of the policy shocks are relatively higher on the announcement days.<sup>4</sup> The heteroskedasticity based identification allows addressing the measurement issue<sup>5</sup> and the time window selection problem<sup>6</sup> for the unconventional policy shocks. The VAR model, in turn, allows estimating the impulse response functions, and hence measuring the persistence of the shock rather than 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 the unconventional monetary policy shocks, we include controls for the conventional policy shocks.<sup>7</sup>

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

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<sup>4</sup>See Rigobon and Sack (2003) and Wright (2012) for a detailed account of the heteroskedasticity based identification.

<sup>5</sup>For the unconventional 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 the monetary policy shocks at high-frequency in the literature, does not address this problem for the unconventional monetary policy shocks. On the other hand, the heteroskedasticity based identification sidesteps this problem, because identification comes from the increase in the volatility on the policy announcement days.

<sup>6</sup>Because the 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 the 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 (Martin and Milas (2012) and Gagnon et al. (2011)). In the heteroskedasticity based identification, on the other hand, the window is identified by the model, based on the changes in the volatility.

<sup>7</sup>For the conventional monetary policy shocks, we rely on the Euro Area Monetary Policy Event Study Database constructed by Altavilla et al. (2019).

The results provide strong support for the effectiveness of the unconventional monetary policy. We find that the unconventional policy shocks decrease the bond yields for all countries and all maturities. In other words, the unconventional policies were successful in easing the 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 unconventional policies into their impacts on the market, risk-mutualization, troika and slope components, we find that the impact mainly works through the first two. For the market component, we find that the 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 the risk sharing in the EMU through the unconventional policy decisions by the ECB.

Finally, we investigate the link between the different unconventional policy programs and the estimated factors. To do so, we categorize the announcements into three categories: the liquidity providing operations, the sovereign bond purchase programs and the 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 the bond yields mainly through the market factor and decrease the 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 the dynamic factor analysis, the heteroscedasticity based identification and the VAR methodologies in the same model to investigate the impact of the unconventional policies. In the existing literature, one vein investigates the impact of unconventional monetary policies through the event study method. In this vein, Glick and Leduc (2012), Krishnamurthy and Vissing-Jorgensen (2011), Gagnon et al. (2011) investigate the impact of these policies for the US and Falagiarda and Reitz (2015), Eser and Schwaab (2016), Fratzscher et al. (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 heteroscedasticity based identification we adopt avoids some of the pitfalls associated with measuring the unconventional policy shocks. Wright (2012) and Rogers et al. (2014), on the other hand, employs the heteroscedasticity 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 the bond yields into the different 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 parameterisation. 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 the different unconventional policy programs and the estimated factors. Section 6 explores the policy implications and concludes.

## 2 Model and identification scheme

This section discusses the methodology for obtaining the EA sovereign bond yields' impulse response functions to the unconventional policy shocks by the ECB. For this purpose, we rely on a dynamic factor model and a VAR model together with the heteroscedasticity-based identification. The heteroscedasticity-based identification was introduced by Wright (2012) to uncover the monetary policy shocks' impact. This identification method requires two separate residual sequences from a VAR model of the yields for the policy announcement days and the non-policy days. However, this framework is only suitable for the low-dimensional VAR models since the number of announcement days is limited.

This study evaluates the impact of the unconventional monetary shocks on eighty sovereign government bond yields for eight EMU countries. Such a large number of yield series makes it infeasible to rely on the heteroscedasticity-based identification due to the degrees of freedom issue discussed above. To overcome this problem, we 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. The second stage employs the heteroscedasticity-based identification on these factors to derive the impulse response functions (IRF). In the last step, we back out the IRFs for the yield series from the IRFs of the dynamic factors.

### 2.1 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  $t = 1, 2, \dots, T$ . Each variable in  $Y_t$  can be defined as  $Y_{i,t}$  for  $i = 1, 2, \dots, N_Y$ . Consequently, the model that relates the observable variables  $Y_t$ ,  $Z_t$ ,  $X_t$  and the latent factors



$F_t$  is as follows:

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

$$\Phi(L)E_t = X_t\beta + \epsilon_t \quad (2)$$

where  $E_t = [F_t \ Z_t]^\top$  is the vector of endogenous variables,  $\lambda_i$  is a  $1 \times r$  vector of the factor loadings for each variable  $i = 1, 2, \dots, N_Y$ ,  $\beta$  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  $i = 1, 2, \dots, N_Y$  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.<sup>8</sup>

Equation (2) assumes a VAR structure for the factors  $E_t$  where  $\Phi(L)$  is the lag polynomial that governs the VAR model, and  $\epsilon_t$  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<sup>9</sup> 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.<sup>10</sup> However, we can

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<sup>8</sup>Because some of the the policy announcement days in our sample also include the conventional monetary policy decisions, we control for their impact by including exogenous measures of the conventional policy surprises in the model. When we estimate the model without the controls for the conventional policy shocks we find no significant change in our results.

<sup>9</sup>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).

<sup>10</sup>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 non-stationary in our model, we prefer to estimate the factors after taking the difference of the yield

recover  $F_t$  by integrating the estimated factors from the differenced model.<sup>11</sup> We denote the estimated  $r$  principal components as  $\Delta\hat{F}_t$ . Integrating these principal components, we get the  $r$  estimated factors, namely  $\hat{F}_t$ .

## 2.2 Heteroscedasticity based identification

This subsection uses the estimated factors and the heteroscedasticity based identification that exploits the volatility difference between the announcement and the non-announcement days to identify the unconventional monetary policy shocks, following Wright's (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 the 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 heteroscedasticity based identification builds the identification procedure on the volatility difference of the specific shocks at different regimes. The basic structure is given as follows:

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

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  $\sigma_{\eta_{1,1}}^2$  on the announcement and  $\sigma_{\eta_{1,0}}^2$  on the non-announcement days. For the other structural shocks  $j = 2, \dots, k$ , we

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series. This operation does not render the estimation inconsistent under the stationary or nonstationary idiosyncratic errors (Bai and Ng, 2004).

<sup>11</sup>The details of the PC method can be found in Stock and Watson (2002).

assume  $\sigma_{\eta_j,1}^2 = \sigma_{\eta_j,0}^2$ . In words, the policy announcements only influence the monetary policy shock volatility while the variances of the other shocks remain constant.

Let  $\Sigma_1$  be the  $(r+1) \times (r+1)$  dimensional variance-covariance matrix of  $\epsilon_t$  on the announcement days and  $\Sigma_0$  be the  $(r+1) \times (r+1)$  dimensional variance-covariance matrix on the non-announcement days. The difference between the variance-covariance matrices on the announcement and the non-announcement days can be represented as:

$$\Sigma_1 - \Sigma_0 = (\sigma_{\eta_1,1}^2 - \sigma_{\eta_1,2}^2) R_1 R_1'$$

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

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

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 non-announcement days,  $\hat{V}_1$  is the estimated variance-covariance matrix of  $\operatorname{vech}(\hat{\Sigma}_1)$  and  $\hat{V}_0$  is the estimated variance-covariance matrix of  $\operatorname{vech}(\hat{\Sigma}_0)$ . 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.

## 2.3 The impulse response functions

This subsection describes how we obtain the impulse response functions (IRF) 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:

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

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:

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

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

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

where for  $i \in \{1, \dots, r+1\}$   $IRF_{h,i}$  is the impulse response of the  $i^{\text{th}}$  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 impulse response functions for the yield series  $Y_t$ . We can reconstruct the impulse responses by simply multiplying the first  $r$  components of  $IRF_h$  ( $IRF_h^F = [IRF_{h,1} \dots IRF_{h,r}]$ ) with  $\Lambda$ , that is  $\widetilde{IRF}_h^F = \Lambda' IRF_h^F$ . Note that  $IRF_h^F$  is a  $r \times 1$  vector and  $\widetilde{IRF}_h^F$  is a  $N_Y \times 1$  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 non-announcement 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  $H_0 : \Sigma_0 = \Sigma_1$  vs  $H_1 : \Sigma_0 \neq \Sigma_1$ . The methodology of this test is discussed in more detail in the online appendix.

### 3 Data and summary statistics

Our data consists of 80 daily bond yield series and runs from 3 January 2008 to 31 December 2019.<sup>12</sup> It covers from one to thirty year maturity fixed zero-coupon bond yields for 8 EMU countries: Austria, Belgium, France, Germany, Italy, Netherlands, Portugal and Spain.<sup>13</sup> Bond yield data is taken from the Thomson Reuters Database. We also include EA aggregate 5-year and 10-year bond yields data from the ECB as the average yields for the euro area. We use the implied stock market volatility index (VIX) 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 the unconventional policy 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 the unconventional announcements relies on the press releases on monetary policy from the ECB’s website.<sup>14</sup> Some of the announcement days coincide with the scheduled policy meeting days. To control for the impact of the conventional policy announcements, in the VAR analysis, we control for the one month OIS rate change in the press release window relying on the data from the Euro Area Monetary Policy Event Study Database.<sup>15</sup>

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<sup>12</sup>The weekends and holidays are removed from the sample.

<sup>13</sup>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.

<sup>14</sup>The ECB’s policy announcement days are listed in the Table A.1 of Appendix.

<sup>15</sup>The data is based on Altavilla et al. (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.

-Figure 1 around here-

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 (Ángel García and Gimeno (2014)). The yields for these countries began to decrease following the ECB's announcement of the SMP and the OMT programs.<sup>16</sup> The trajectory of the yields suggests that the ECB intervention successfully led to a decline in the risk premium in the distressed sovereign markets.

## 4 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.

### 4.1 Interpretation of the estimated factors

We derive the factors relying on the principal components methodology and interpret them based on the loadings of the factors, as in Litterman and Scheinkman (1991), Knez et al. (1994), 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 principal components 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

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<sup>16</sup>ECB President Mario Draghi made the “Whatever it takes.” speech on 26 July 2012 followed by the official announcement of the OMT Program in the early August 2012.

in a multi-country 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<sup>17</sup> explain about 72% of the variation in the yields. Figure 2 plots the  $R^2$ s ordered by the countries and the maturities.

-Figure 2 around here-

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 7-35% of the variation in the shorter maturities.<sup>18</sup> 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).

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

-Table 1 around here

-Figure 3 around here-

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 European Monetary Union, as evident in Figure 4a. In terms of the factor loadings, they are negative for all countries and all maturities, and hence a change in factor 1 affects all bond yields in the same direction.<sup>19</sup> The term “medium-term”

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<sup>17</sup>We obtain the optimal number of factors by using the selection criteria in Onatski (2010).

<sup>18</sup>While for the maturities longer than five years our factor model explains more than 75% of the variation, for one and two-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 which 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 which explain most of the variation in the variables and drive the co-movement between them without relying on tight assumptions when we are uncertain about the structure of the economy (Hübler and Frohn, 2007).

<sup>19</sup>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.

reflects the pattern that the absolute values of the loadings increase with the maturity up to six years and level off afterwards, as depicted in Figure 3.

-Figure 4 around here-

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 4b and 4c 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 its unique structure with a single monetary policy but multiple sovereigns. The economic interpretation of the impact through this factor is that the unconventional monetary policies transferred some of the risk in the periphery to the core, hence the name risk-mutualization. Empirically documenting the risk-mutualization is a novel contribution of this study, and we investigate this factor further in section 5.

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 4d. 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.<sup>20</sup> We investigate this conjecture by examining whether the loadings on the third factor change

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<sup>20</sup>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.



significantly if we drop SMP and pre-SMP periods, and find that they do.<sup>21</sup>

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

## 4.2 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 2.3, we employ the Box’s M test to verify this condition. We find that the Box’s M statistic (BM statistic) is 2604.5 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 non-policy days.

We next investigate the impact of the unconventional monetary policy 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.<sup>22</sup> The shock also lowers the EA 10-year bond yield, but the magnitude of the impact is slightly smaller. The half-life of the estimated impulse responses for the EA yields are 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

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<sup>21</sup>The results are presented in the online appendix.

<sup>22</sup>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 the unconventional monetary policies.

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.

-Figure 5 around here-

#### **4.2.1 The impact on the different components of the bond yields**

In this subsection, we present the results for the impact of the 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 unconventional monetary policy 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.

-Figure 6 around here-

We obtain the impulse responses for the market component of the bond yields by multiplying the impulse response function of the market factor with its loadings. The market factor increases in response to a normalized unconventional monetary policy shock. The loadings for the market factor are negative for all countries and maturities. This pattern implies that the unconventional monetary 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.

Our findings suggest that the unconventional policies 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 implies 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.<sup>23</sup> Consequently, the countries with more developed financial 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 zero percent is negative and significant for the non-crisis EMU countries while they are insignificant for the crisis EMU countries.

We also investigate whether the stronger impact of the unconventional policies through the market factor for the core economies is caused by a local supply effect.<sup>24</sup> According to this argument, the ECB announcements might have had a stronger impact on the core countries, because they had lower debt to GDP ratios, and the scarcity of their bonds might have amplified the impact of the announcements. To investigate this idea, we re-estimate 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.<sup>25</sup>

-Figure 7 around here-

We obtain the impulse responses for the risk-mutualization component of the bond yields by multiplying the impulse response function of factor 2 with its loadings. The risk-mutualization factor decreases significantly in response to a normalized unconventional monetary policy 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.

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<sup>23</sup>Gerlach et al. (2010) and Fratzscher and Rieth (2015) 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) shows 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.

<sup>24</sup>D'Amico and King (2013), Vissing Jorgensen and Krishnamurthy (2011), McLaren et al. (2014).

<sup>25</sup>The results are presented in the online appendix.

Consequently, as shown in Figure 7b, the 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 the risk-mutualization in the European Monetary Union through the unconventional policy decisions by the ECB.

The impact through the risk-mutualization factor is specific to the European Monetary Union, 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 the risk-mutualization in the European Monetary Union 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 impulse response functions of the troika and slope factors with their loadings. The troika factor responds negatively to the unconventional policy shocks. Loadings for the troika factor are positive and substantial for Portugal and close to zero for the other EMU countries. It implies that the 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 the unconventional monetary policy shock is very weak. The 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.

#### 4.2.2 The overall impact on the EMU countries

This subsection investigates the overall responses of the bond yields to the unconventional monetary policy shocks. A non-standard monetary policy shock which 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 around here-

Figure 8 shows the aggregate responses of the selected bond yields to the ECB's unconventional monetary policy announcements.<sup>26</sup> The figure suggests that the identified unconventional policy announcements have been effective in easing financial conditions in both the core and periphery EMU countries. The impact is substantial and persistent for the periphery while it is weaker and temporary for the core countries.

The results also show that a normalized unconventional monetary policy 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 the 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

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<sup>26</sup>The impulse responses for the individual maturities are reported in the online appendix B.

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 unconventional monetary policy 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 non-standard 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.<sup>27</sup> We find that the 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 the unconventional monetary policies is persistent, lasting longer than a year, for the European periphery. This finding contrasts with the earlier studies which find that the impact dies within six months for the US, UK and EA (Wright (2012) and Rogers et al. (2014) ). Neely et al. (2014) argues that this transitory impact result in the earlier studies was driven by the instability of the structural VAR models caused by the model mis-specification. 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's

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<sup>27</sup>Gerlach et al. (2010), Arghyrou and Krontonikas (2012), De Grauwe and Ji (2013), De Santis (2012) and Giordano et al. (2013).

(2003) test based on the global information criterion, the procedure<sup>28</sup> finds no breaks in the model, and suggests that the model is stable and provides reliable forecasts for the overall impact and the persistence.

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 3 and 5 factors. The results, discussed in the online appendix, highlight that changing the number of factors leads to minor changes in the results.

### **4.2.3 The overall impact on the term structure of interest rates**

This subsection investigates the responses of the term-structure of the interest rates to the unconventional monetary policy 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 the unconventional policy measures. The ECB, like other major central banks, mostly targets the longer-term interest rates directly with the unconventional policy announcements. The findings are also consistent with the recent literature which studies the impact of the unconventional policy announcements on the bond yields. Bernhard and Ebner (2017) finds 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 to 10 years. Rogers et al. (2014) finds that the impact of the monetary policy shocks at the ZLB is larger at the long end of the yield curve for the US, UK and Japan.<sup>29</sup>

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<sup>28</sup>In this procedure, we utilize the Schwarz information criterion and heteroscedasticity 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.

<sup>29</sup>In contrast, Altavilla et al. (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 programmes were announced and implemented. In this study, we are interested in the overall impact of the policy announcements regardless of the specific programmes.

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 et al. (2019) shows 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 around here-

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 one week, one month, three months, six months and one 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.

## **5 The relationship between the different policy programs and the estimated factors**

In this section, we investigate the link between the different unconventional policy programs and the estimated factors. The unconventional announcements used in the analysis are presented in Table A.1. We categorize the announcements into three categories. The first category, the liquidity providing operations, include the long-term refinancing operations,



the targeted long-term refinancing operations, the fixed rate full allotment policies, the collateral policies and the US Dollar liquidity providing operations that aimed to provide liquidity to the banking system. The second category, the sovereign bond purchase programs, include the SMP and the 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, the asset purchase programs, include the corporate sector purchase program, the public sector purchase program, the asset-backed securities purchase program and the 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 the different unconventional program and factor combinations.

- Table 2 around here-

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.<sup>30</sup>

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

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<sup>30</sup>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 Hantzsch (2018).

impacts are only significant at the 10% level and the estimated magnitudes for the impacts are small. These 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 the risk-mutualization in the EMU.

## 6 Conclusion

During the Great Recession, the central banks in the developed economies were forced to bring the interest rates down to zero, leaving no room for the conventional policy. Consequently, the central banks experimented with several unconventional monetary policies, 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 the unconventional monetary policies on the government bond yields in the European Monetary Union. 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 the risk-mutualization in the EMU. Consequently, we are able to describe the impact of the unconventional policies across different countries, maturities, yield components and time horizons.

The results corroborate that the 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 periphery and increased them slightly for the core countries. This differential impact provides evidence that the 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 the unconventional monetary policies 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 the 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.

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## Tables and Figures

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	<i>gb30y_Fra</i>	0.04	gb3y_Aus	0.12
gb4y_Net	0.71	gb8y_Spa	0.53	gb9y_Ita	0.03	gb2y_Bel	0.11
<i>gb6y_Aus</i>	0.70	<i>gb3y_Spa</i>	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

Notes: This table lists the 15 series that load most heavily on the first 4 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, 0.74 of the variation of 7-year Australian yields.

Table 2: Responses of the Factors to the Different Policy Dummies

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

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

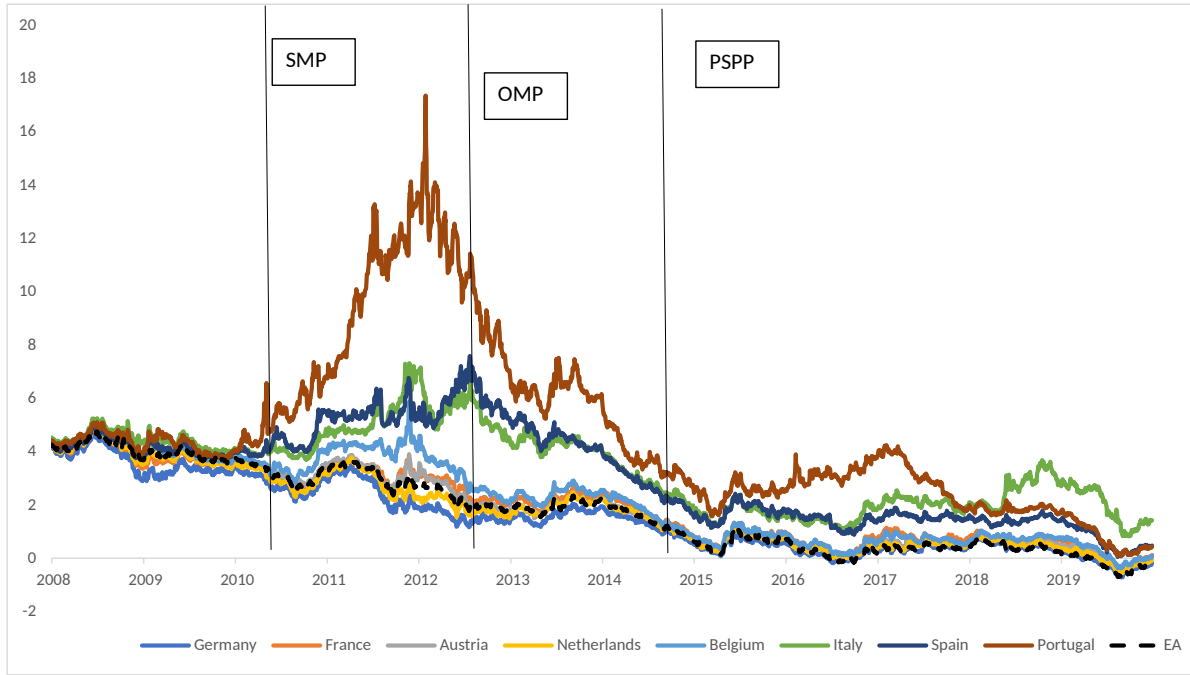


Figure 1: 10-year Bond Yields



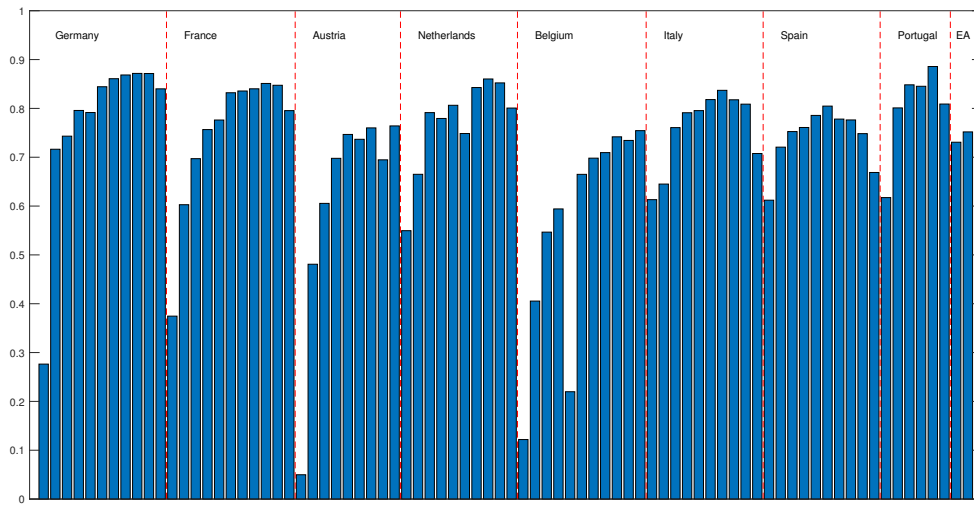


Figure 2: Model Fit and  $R^2$

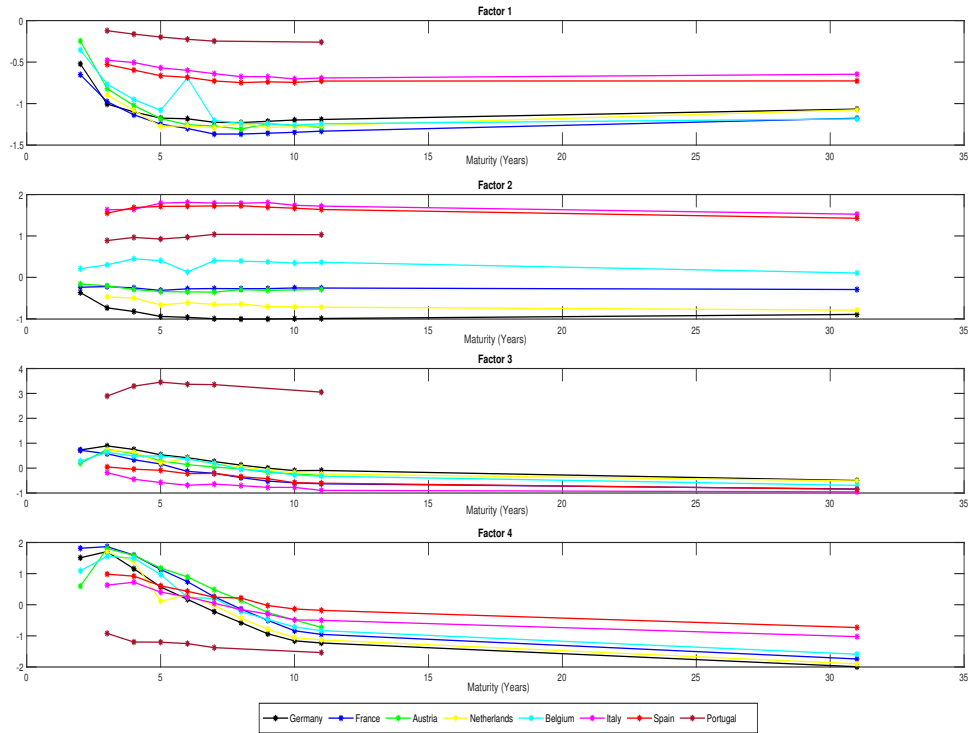


Figure 3: Factors Loadings

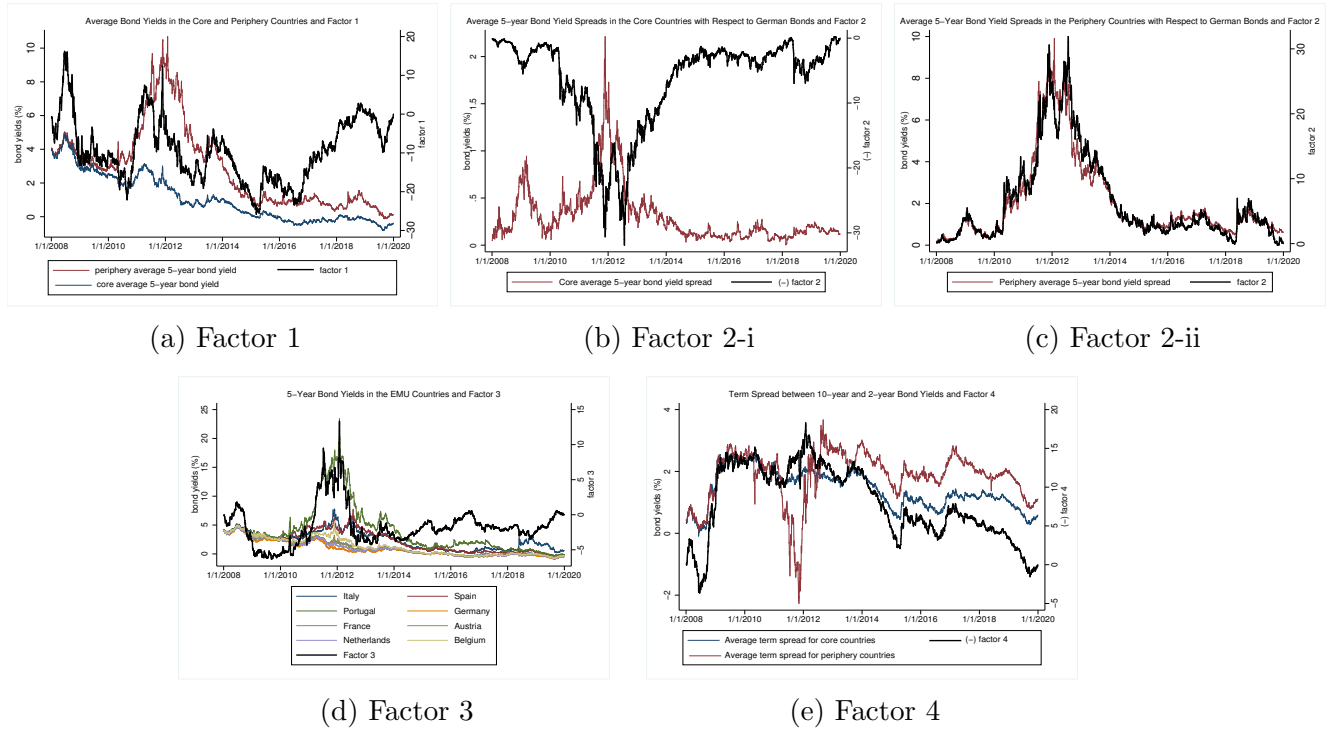


Figure 4: Factors and Related Economic Variables

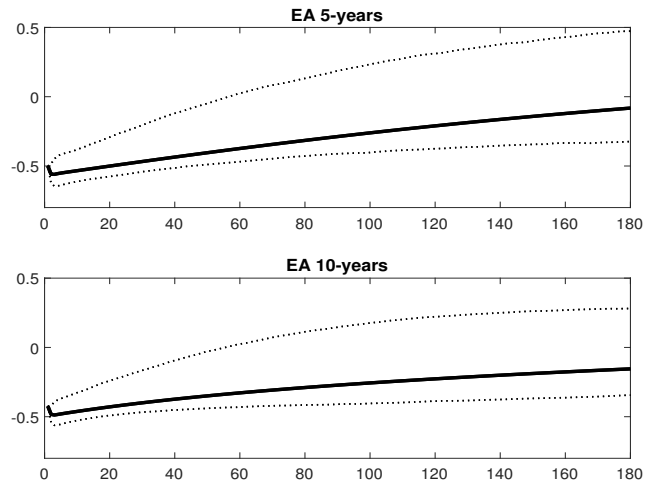


Figure 5: Impulse Responses of the EA Bond Yields

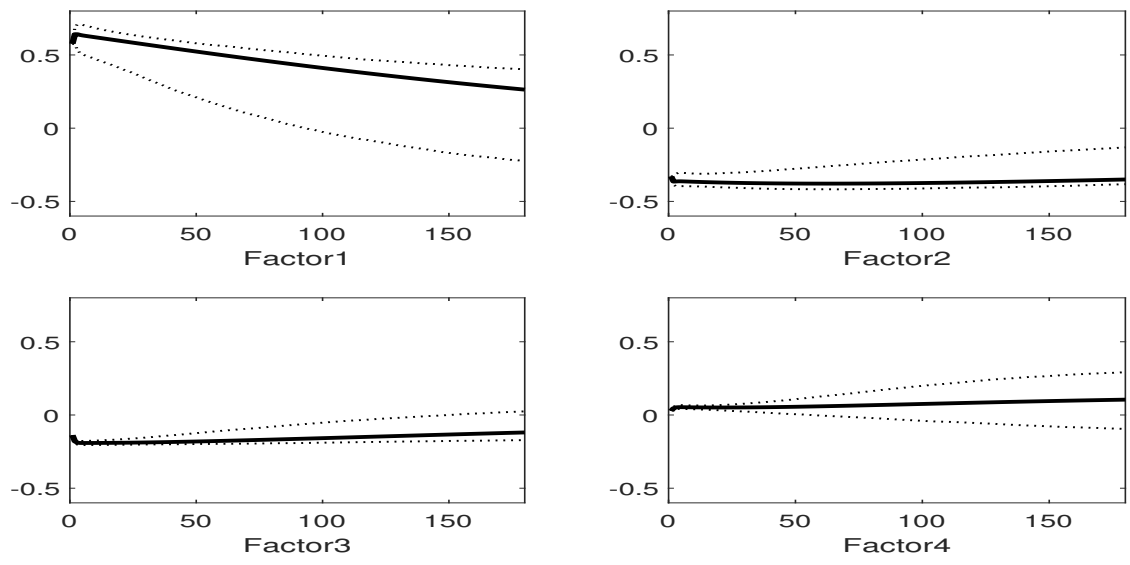
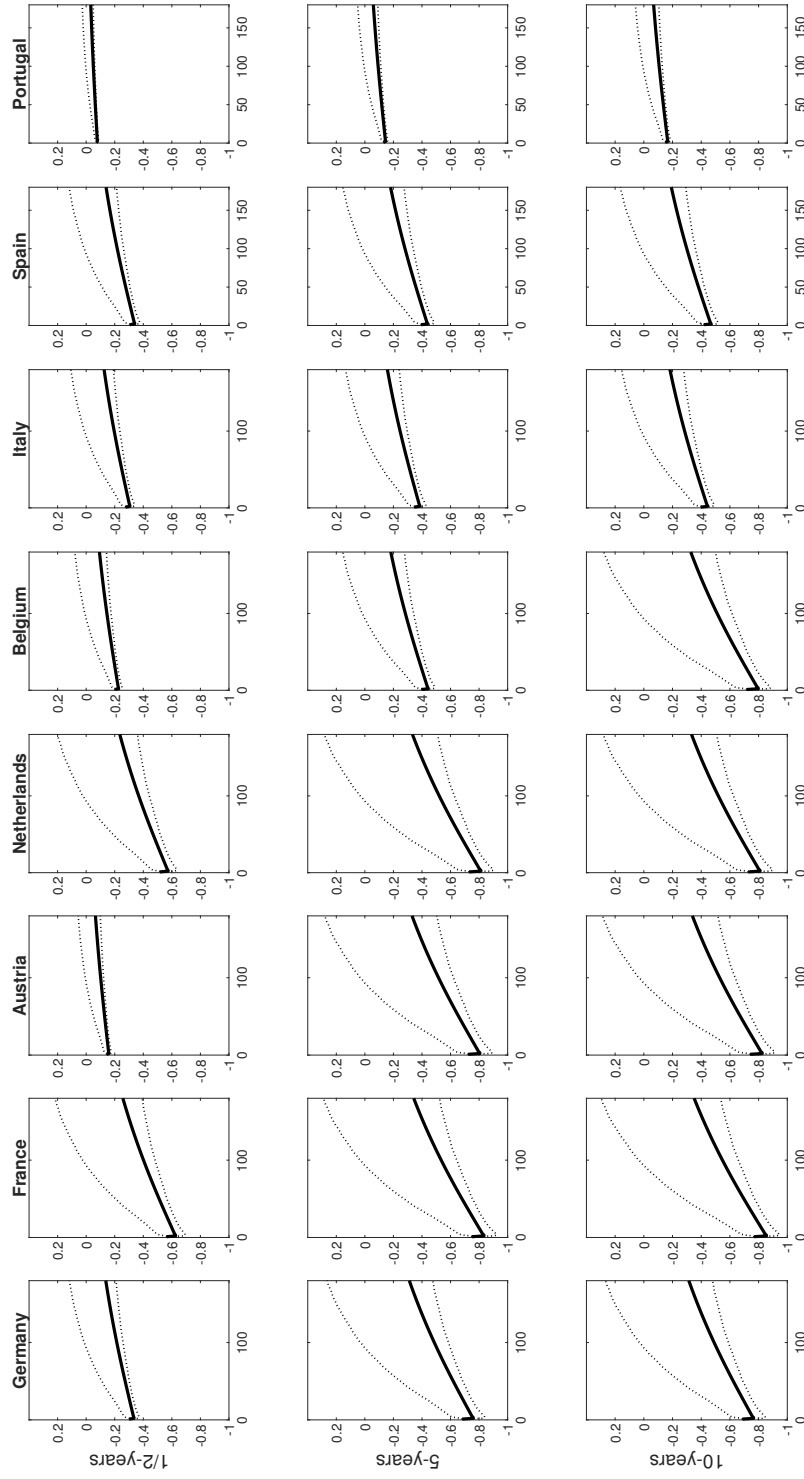
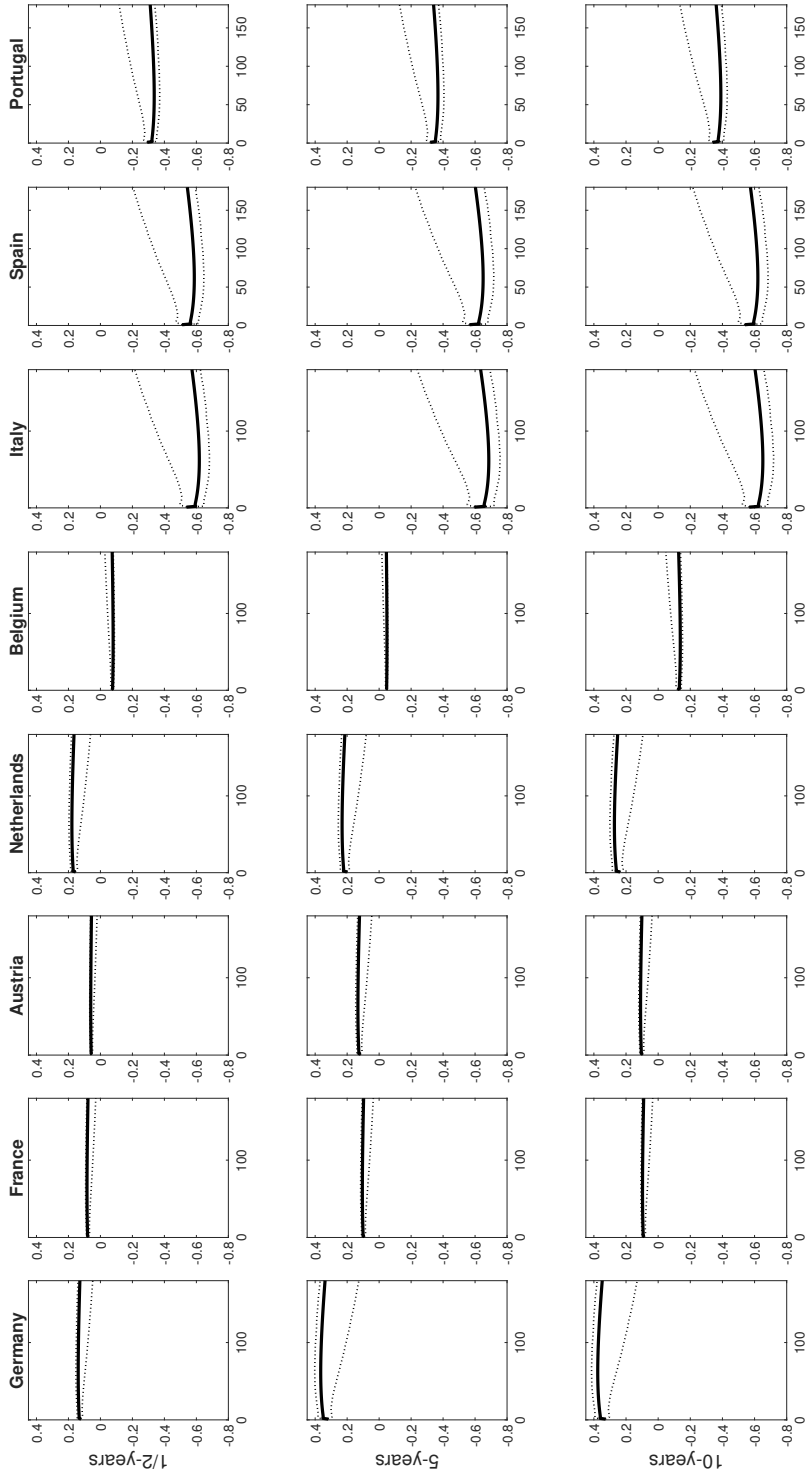


Figure 6: Impulse Responses of the Estimated Factors



(a) Factor 1

Figure 7: Impulse Responses of the Selected Maturities Through Factors



(b) Factor 2

Figure 7: Impulse Responses through Factors for Selected Maturities

Notes: There is no 1-year yield data available for Netherlands, Italy, Spain and Portugal. 2-years maturity yields are used as shortest maturity for these countries.

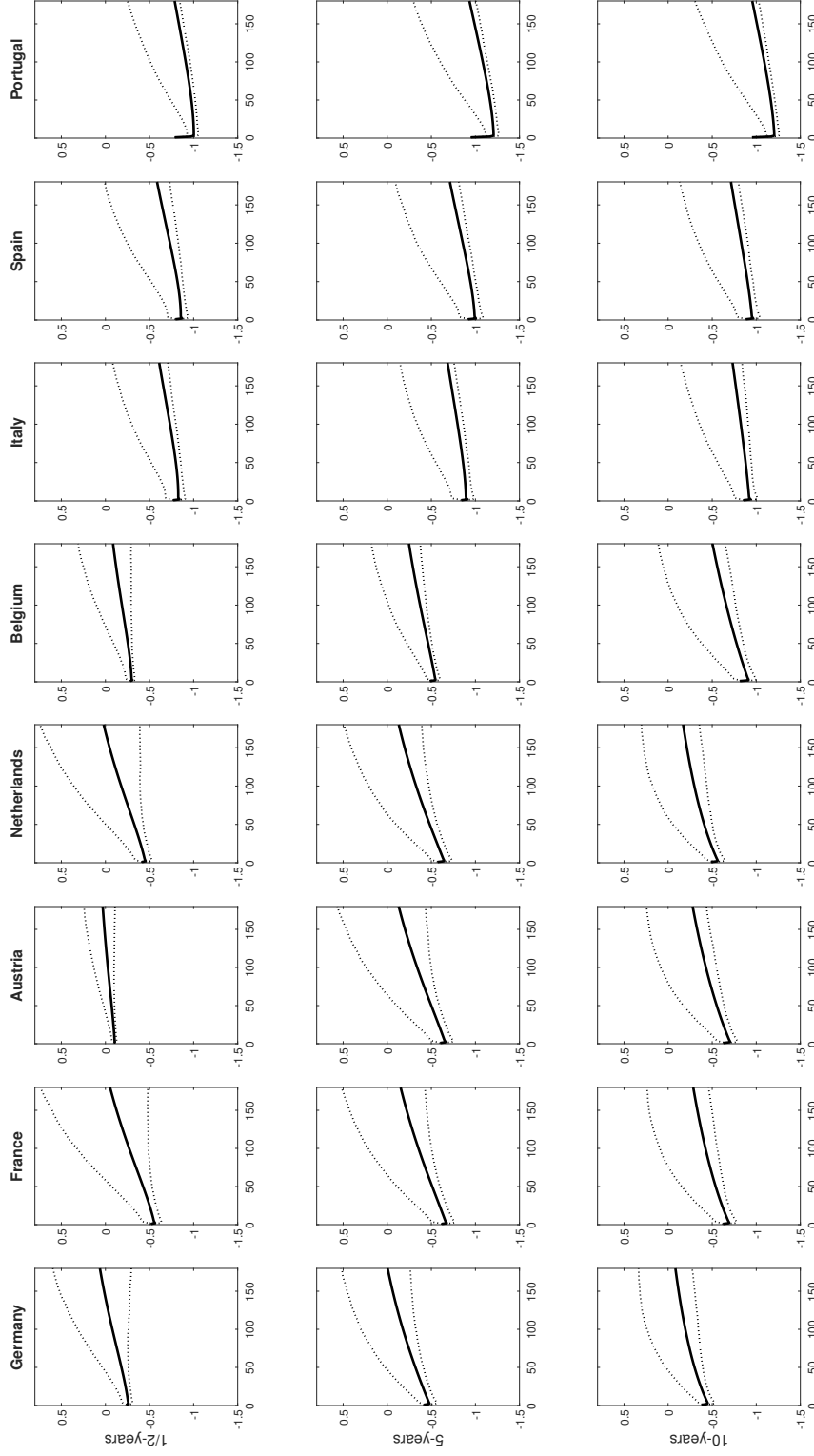


Figure 8: Aggregate Impulse Responses of the Bond Yields for Selected Maturities

Notes: There is no 1-year yield data available for Netherlands, Italy, Spain and Portugal. 2-years maturity yields are used as shortest maturity for these countries.

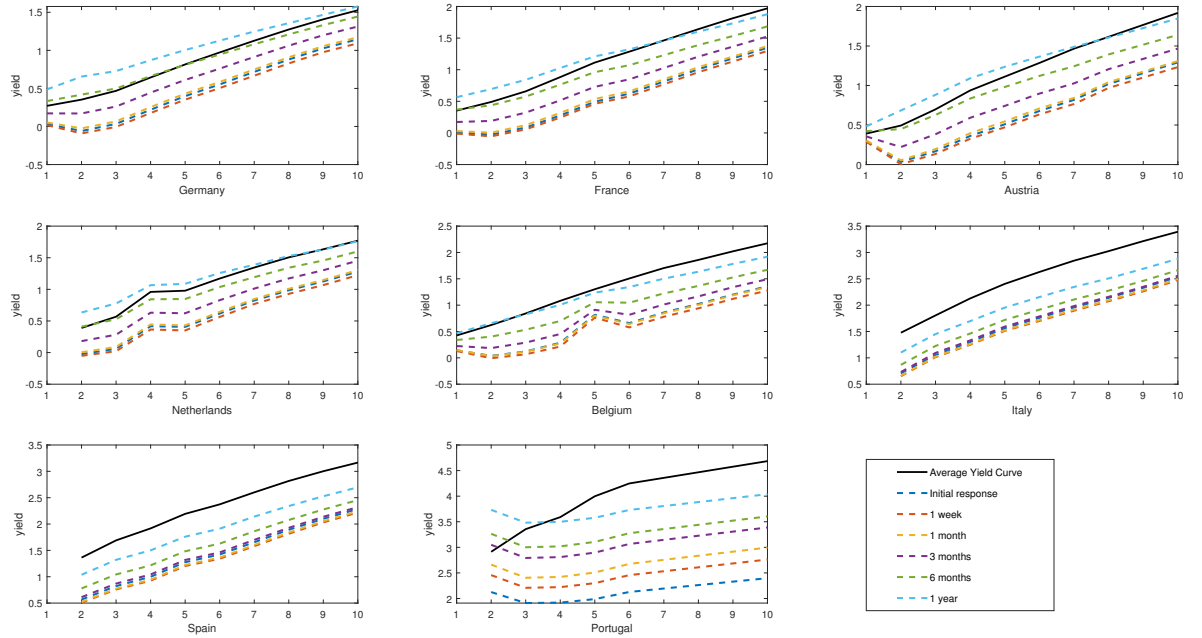


Figure 9: Impact of the UMP on the Yield Curves

## A Appendix: Data Appendix

Table A.1: ECB Unconventional Policy Announcements

<u>Announcement date</u>	<u>Announcement description</u>
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 US 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 US 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.
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.

Continuation of Table A.1

<i>Announcement date</i>	<i>Announcement description</i>
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 three-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 three-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 US dollar liquidity-providing operations with a maturity of seven 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 three-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 three-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 six 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 programme and to 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 one-day liquidity-providing fine-tuning operations.
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 three-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 three-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 three-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 three-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 sterilising 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 programmes.
30-Oct-14	The ECB appoints executing asset managers for the ABS Purchase Programme.
7-Nov-14	The ECB suspended early repayments of the three-year longer term refinancing operations during the year-end period.
9-Dec-14	The ECB Announced the second TLTRO.



Continuation of Table A.1

<i>Announcement date</i>	<i>Announcement description</i>
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.
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 programme.
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 programme 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 programme 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 programme 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 programmes.
14-Dec-17	The ECB confirmed that from January 2018 it intended to continue to make net asset purchases under the asset purchase programme 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.
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 programme 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 programme 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 programme 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.

Continuation of Table A.1

<i>Announcement date</i>	<i>Announcement description</i>
25-Oct-18	The ECB confirmed that it will continue to make net purchases under the asset purchase programme 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 programme 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 22 July 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 programme at a monthly pace of 20 billion EUR as from 1 November. It also announced the modalities of the new series of quarterly targeted longer-term refinancing operations will be changed to preserve favourable bank lending conditions.
24-Oct-19	The ECB confirmed that net purchases will be restarted under the Governing Council's asset purchase programme at a monthly pace of 20 billion EUR as from 1 November.
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.