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Euro Area Monetary Communications: Excess Sensitivity and Perception Shocks[*]

Valentin Jouvanceau[†]

Ieva Mikaliūnaitė[‡]

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[†] Lietuvos Bankas, VJouvanceau@lb.lt.

[‡] Lietuvos Bankas, IMikaliunaite@lb.lt.

Gedimino pr. 6, LT-01103 Vilnius

www.lb.lt

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ABSTRACT

We explore new dimensions of the ECB's monetary communications using the Euro Area Monetary Policy Event-Study Database (EA-MPD) built by Altavilla et al. (2019). We find that three new factors are needed to capture an excess sensitivity of long-term sovereign yields around monetary announcements. "Duration" surprises cause variations in real long-term rates and are mainly transmitted by term premiums. The "Sovereign spread" and "Save the Euro" surprises greatly influence the long-term yields of the periphery countries. These effects are difficult to reconcile with classic monetary policy shocks. We therefore study their underlying nature and discover that they have the characteristics of "Information", or what we label "Perception" shocks.

Keywords: Monetary surprises, Event-study, Excess sensitivity, Perception shocks, High-frequency Identification.

JEL Classification: E43, E44, E52, E58, G12.

1 Introduction

In the Euro area, monetary policy decisions have the peculiarity of being revealed in two stages. On the day of an announcement, the ECB first issues a press release and then holds a press conference. These events are distinct and separated by 45 minutes. In a remarkable contribution, Altavilla et al. (2019) (ABGMR) collect intraday changes in asset prices around these two communication windows.[1] The authors identify a set of recurring monetary surprises that affect the risk-free yield curve. However, this database also contains a wide range of risky assets which are not analyzed. Our main objective is to identify new monetary surprises that may be related to risky rates.

The motivations behind this goal are broader than one might think. This analysis obviously aims to reveal the disparate impacts of the ECB's monetary communications on representative countries of the Euro area. But above all, it aims to highlight the overreaction of long-term rates around the communication windows. Such a phenomenon is barely perceptible, as we shall see, if one focuses on the risk-free yield curve. Ultimately, this kind of observation is extremely interesting, since it cannot be justified by classical financial and macroeconomic theories. Our study therefore paves the way to discussing major theoretical issues.

Indeed, changes in long-term interest rates are at the heart of the transmission of monetary policy to the real economy. In macroeconomics, a monetary policy shock is associated with a temporary innovation in the short-term interest rates. As such, their effects cannot extend beyond a near-term horizon (Woodford (2011); Galí (2015)). In finance, if the expectations hypothesis of the term structure of interest rates is true, surprising changes in short-term rates should have a modest impact on long-term rates (Shiller (1979)).

However, sound evidence has accumulated to indicate an excess sensitivity of long-term rates around various central bank communications (Cochrane and Piazzesi (2002); Gürkaynak et al. (2005b); Hanson and Stein (2015); Hanson et al. (2018)). This empirical challenge implies, in our opinion, two alternatives. Either the classical theories on monetary shocks are incomplete and need to be revised, or many monetary surprises are the product of other types of shocks that are still poorly understood. We shall see throughout this paper that the second option is quite appealing. Before going any further, allow us to begin with some raw observations. The following three cases are of great interest.

On December 4, 2008 *(i)*, the ECB released a 75 basis points (b.p.) cut in the main refinancing rate (MRO). This decision resulted in a immediate increase in 10-year bond yields in Germany, France, Italy and Spain, by an average of

[1] The database is named Euro Area Monetary Policy Event-Study (EA-MPD). It is freely downloadable at: https://www.ecb.europa.eu/pub/pdf/annex/Dataset_EA-MPD.xlsx

5 b.p. On March 16, 2016 *(ii)*, the release of a 5 b.p. reduction in the MRO led symbolically to the zero lower bound (ZLB). This time, however, the 10-year yields on German and French bonds fell by 3 and 7 b.p., while the equivalent Italian and Spanish yields dropped by 9 and 10 b.p. Around the press conference of August 2, 2012 *(iii)*, yields on 10-year German bonds fell by 9 b.p. In the meantime, Italian and Spanish 10-year yields skyrocketed by 38 and 31 b.p. respectively.[2]

We find that ECB's monetary communications frequently produce variations in long-term yields that can be either homogeneous or heterogeneous among Euro area countries.[3] We therefore test the hypothesis of the existence of new monetary surprises around the press release and press conference windows. Several rank tests (à la Cragg and Donald (1997)) confirm that this hypothesis cannot be rejected. We identify the missing surprises using factor models (Gürkaynak et al. (2005a); Swanson (2017)).

Our first discovery concerns the homogeneous reactions of long-term yields in the release window. These are consecutive to what we call "Duration" surprises. In this window, a second factor corresponds to the heterogeneous responses of long-term yields. We name this factor "Sovereign spread". Finally, we identify a "Save the Euro" factor in the conference window, confirming the intuitions of Wright (2019). The latter has a maximum effect on the long-term yields of periphery countries.

In the literature, few studies analyze the intraday effects of the ECB's monetary communication by separating, as we do, the release and conference windows. Brand et al. (2010) are pioneers in identifying the "Target" and "Path" factors in the Euro area, but without dissociating the windows. Subsequently, ABGMR confirm the existence of a "Target" factor in the release window, and measure "Timing", "Forward Guidance" (FG) and "Quantitative Easing" (QE) factors in the conference window.[4] In addition, Leombroni et al. (2020) analyze the effects of ECB monetary surprises on different sovereign bond yields. By extracting a single factor in each window for each country, they find singularities between the "Target" and "Path" factors in the core and periphery countries. We distinguish ourselves from all these studies by jointly examining

[2] At that precise conference, a journalist asked the former President M. Draghi: "*Was it necessary to make that speech at that time in London?*" to which M. Draghi responded: "*Have you read the speech? Had you read it, you would have seen that there is no reference whatsoever to a bond buying programme.*" This journalist is evidently referring to the famous speech in London of July 26, 2012, where M. Draghi declared that the ECB would do "whatever it takes" to preserve the Euro.

[3] In our paper, the term "homogeneous" refers to uniform changes in long-term yields between core (Germany and France) and periphery (Italy and Spain) countries. The term "heterogeneous" refers to variations in yield differentials between core and periphery countries.

[4] Following ABGMR, the term "QE" is generic and refers to the various long-term asset purchase programmes of ECB (CSPP, PSPP, ABSPP, CBPP3). More information at https://www.ecb.europa.eu/mopo/implement/omt/html/index.en.html

high-frequency variations in the prices of risk-free assets (overnight indexed swaps (OIS)) and risky assets (sovereign bonds). To do so, we estimate a single factor model for each of the two communication windows. This leads to some important findings.

Overall, our research is the first to extensively measure both long-term homogeneous and heterogeneous effects of ECB's monetary communications. It is therefore also the first to obtain a market-based identification of excessive changes in long-term yields in response to Euro area monetary surprises. It is comforting to note that our results do not contradict what is already identified in ABGMR. Indeed, we identify a "Target" factor in the release window, and "Timing", "FG" and "QE" surprises in the conference window. We are thus pioneers in extending the identification of Euro area monetary surprises in new directions, in an unbiased manner and guided by statistical significance, i.e. not assumed beforehand.

On this basis, we can measure the effects of monetary surprises on the daily term structure of nominal and real risk-free interest rates. In addition, we decompose these rates to study whether monetary surprises are transmitted by the expectations in the future short-term rates or term premiums. Our results suggest that "Duration" surprises have a significant real impact through variations in term premiums. On the other hand, "Save the Euro" and "Sovereign spread" surprises are transmitted by long-term risky rates.

As mentioned above, classic "Monetary" shocks are unlikely to have such persistent effects. We therefore shed additional light on the underlying nature of each of these surprises. In this regard, recent research indicates that some communications can convey macroeconomic rather than monetary news (Nakamura and Steinsson (2018); Pflueger and Rinaldi (2020)). In other words, these shocks may inform investors about the future state of the economy. This implies that investors adhere to the central bank's projections, which they consider to be more consistent than their own. Nevertheless, we note that market commentaries and price changes often contradict this assumption. We document, for example, that this is the case if a (surprising) lack of monetary intervention creates disappointment in the markets. For an "Information" shock, such an absence sends a signal that the economy is doing better than investors thought. As a result, inflation and stock prices are expected to rise. Contrariwise, however, we observe that they are diminishing. We therefore argue that these reactions are the result of what we call "Perception" shocks. In the absence of theory on this point, we simply propose that "Perception" shocks can be identified if a monetary surprise causes a strong fluctuation in long-term risky rates and a joint movement of inflation and stock prices.

We delve deeper to determine whether our three new monetary surprises are, on average, related to "Information" or "Perception" shocks. In daily VAR models, we find that "Duration" surprises are associated with "Information" shocks during the crisis period (2008-2013). On the other hand, we identify

that "Save the Euro" and "Sovereign spread" have all the characteristics to be the result of "Perception" shocks since the onset of the crisis period.

Our paper is organized as follows: Section 2 proposes the identifying method and the narrative analysis. Section 3 sheds light on the excess sensitivity in long-term rates. Section 4 examines the underlying nature of our new monetary surprises. Section 5 draws conclusions.

2 Identification of the Euro area monetary surprises

2.1 Dataset

Throughout this document, the intraday data are taken from the EA-MPD database developed by ABGMR. This dataset presents high-frequency changes in asset prices during two separate ECB communication windows, namely the press release and the press conference.[5] In press releases, the ECB provides short documents on monetary decisions, which mainly contain information on the stance of short-term interest rates. These actions are published without being accompanied by a rationale. It is of note that after December 2014, additional information relating to "pending" decisions and/or details on asset purchase programmes can be found in press releases.

At press conferences, the president of the Governing Council justifies monetary decisions with a speech followed by questions and answers to the media. In our analysis, we treat the two windows independently. In this way, we can evaluate the importance of the rationales presented at press conferences. This assumes, however, that the information contained in the press releases has already been digested by market participants by the time the conferences begin.

The data sample begins in January 2002 and ends in September 2018. It includes changes in asset prices within the day of 180 monetary communications. Price changes corresponding to the release window are obtained by calculating the difference between median prices before the release, between 13:25-13:35, and median prices after the release, between 14:00-14:10. Price movements in the conference window are obtained by measuring the difference between the median quotations in the intervals 14:15-14:25 and 15:40-15:50. Figure 1 shows a diagram of the timeline of the ECB's monetary announcements.

We analyze intraday changes in the price of the following assets: 1, 3, 6 month and 1 year OIS rates, as well as yields on 2, 5 and 10 year German, French, Italian and Spanish bonds respectively (16 assets in total).[6] By directing our analysis not only to risk-free assets (OIS) but also to risky assets (sovereign bonds), we are able to capture a wide range of effects of monetary surprises, some of which are currently undocumented.

To assess the robustness of our results to changes in the macroeconomic and monetary environment, we also conduct our analysis in sub-samples. We consider a pre-crisis sub-sample from January 2002 to August 2008 (i.e. the period before the global financial crisis); a crisis sub-sample from September 2008 to December 2013 (i.e. the global financial crisis and the Euro area debt

[5] ABGRM's online appendix contains specific details on the chronology, structure, sources, etc. of the dataset and monetary events.

[6] All sources and descriptions of the data used in this paper are available in Appendix B.

crisis); and a QE sub-sample from January 2014 to September 2018 (i.e. the period when the ECB started its long-term asset purchase programme).[7]

2.2 Factor models and identification method

Let us assume that the intraday changes in assets prices are stacked into w $T \times n$ matrices X^w, with T rows representing the timing of the events, and n columns indicating the type of assets. Let $w = \{release, conference\}$ stand for the choice of the monetary window. The elements x_{ij}^w are the asset price changes of the j'th assets during the i'th monetary event. Therefore, suppose that the data have a factor structure:

$$X^w = F^w \Lambda^w + \varepsilon^w, \tag{1}$$

where, for each w, F^w is a $T \times k$ matrix of unobserved factors, Λ^w a $k \times n$ matrix of loadings and ε^w a $T \times n$ is a matrix of residuals. We are interested in estimating and identifying the factors in F^w. Before identification, we determine the number of factors (k) to be extracted using matrix rank tests. Accordingly, we proceed to Cragg and Donald (1997) test which is adapted to the case where the cross-section of the data is rather small. More precisely, we evaluate the significance of the number of factors on the three sub-samples defined above while keeping the press release and press conference windows separate.

The results of the rank tests are reported in Table 1.[8] In contrast with ABGMR, we find that the communications of ECB press releases have more than one dimension. In addition to the standard "Target" factor, we observe that two other factors are necessary to account for the variations in asset prices ($X^{release}$). Specifically, the test indicates two statistically significant factors in the pre-crisis period and three in the full sample period. In other words, the significance of the third factor occurs at the onset of the crisis period.

In the conference window ($X^{conference}$) and in line with ABGMR, the results suggest two significant factors in the pre-crisis period and an additional factor in the QE period. However, our test favors the presence of a new factor since the global financial crisis, bringing the number of significant factors to four in total.[9]

However, as such, the factors are only a eigendecomposition of the data. Thus, we rotate them so that they have a structural interpretation. Let $\widetilde{F}$ be the rotated factors such that $\widetilde{F} = FU$, where U is $k \times k$ orthogonal matrix, F are the

[7] The start of the QE period we choose is debatable but is consistent with the ABGMR study. Thus, the comparison is simpler. Note that robustness analyses are performed and do not reveal significant differences in the results we present.

[8] Appendix C contains more details about our testing procedure.

[9] We extract the factors from the principal components (PC) of X^w. As dictated by our rank tests, we choose 3 PC in the press release window and 4 PC in the conference window.

PC obtained through singular value decomposition. The structural interpretation is based on the identification restrictions imposed on the rotation matrix U.[10,11]

In the press release window, three restrictions are necessary for the factors to be identified. We identify a "Target" factor by requiring that the second and third factors have no effect on the 1-month OIS (2 zero restrictions).[12] It is therefore the only factor that captures market participants' expectations of changes in target rates over the coming month. Due to the orthogonality conditions imposed by the method, the second factor is in fact identified as well. We will see that this second factor captures most of the movements at the long end of the risk-free yield curve. The third restriction is to minimize the variance of the third factor over the pre-crisis period, i.e. from January 2002 to September 2008. The underlying idea is, as our ranking test indicates, to capture the effects of this new dimension of monetary surprises only after the beginning of the global financial crisis. This factor will reflect the variations in sovereign spreads resulting from monetary release surprises.[13]

In the conference window, six restrictions are required for identification. We follow the restrictions proposed by ABGMR to capture the "Timing", "FG" and "QE" factors. First of all, we impose that the "Timing" factor is the only one that can be correlated to the changes in 1-month OIS (3 zero restrictions). The second factor "FG" is therefore identified by the orthogonal conditions. Then, our ranking test suggests that only two factors are sufficient to capture asset price changes prior to the global financial crisis. We therefore minimize the variance of our third factor in the pre-crisis period (4th restriction). Finally, we require that the "QE" factor is orthogonal to the reactions in 3-month OIS and that its variance is minimized in the period preceding QE (5th and 6th restrictions). This zero restriction will allow the "QE" factor to influence the long end of the yield curve.

Table 2 gives the analysis of variance for each of the communication windows. In the release window, the "Target" factor explains the majority of the changes in short-term risk-free assets. By contrast, the "Duration" factor captures an increasing share of variations as the maturity of the assets lengthens. Then, the "Sovereign spread" factor proves to be crucial in capturing the volatility of the spreads between long-term sovereign yields in the core and the periphery. In the conference window, the "Timing" factor captures the variation of the shortest maturities. The "FG" is important for the medium

[10] The data are ordered as: OIS rates at 1, 3, 6 months and 1 year, followed by German, French, Italian and Spanish bond yields at 2, 5 and 10 years respectively.

[11] Appendix C details the estimation procedure and the identification strategy.

[12] This restriction is common to a large range of studies in the literature (see Gürkaynak et al. (2005b); Brand et al. (2010); Swanson (2017) among others.)

[13] We call "sovereign spread" the difference in yield between bonds with different credit qualities but similar maturities.

maturities. "Save the Euro" surprises explain most of the deviations in periphery sovereign yields. Finally, the "QE" factor mainly accounts for the long and risk-free maturities represented by German yields.

In summary, a single factor is insufficient to explain the variation in asset prices of the release window. We find that two other dimensions are statistically significant. We call the two new factors in the release window as follows: "Duration" and "Sovereign spread". Then, we identify a new factor as statistically relevant in the conference window. The latter is labeled "Save the Euro".

2.3 Factor loadings

Once the factors have been identified, the effects of the different dimensions of monetary surprises can be gauged using simple OLS (Kuttner (2001); Gürkaynak et al. (2005b)). Thus, each factor loading is obtained by a linear regression of the form:

$$\Delta x^w = \alpha^w + \beta^w \widetilde{F}^w + \epsilon^w \tag{2}$$

where Δx^w is the intraday variation in the price of an asset and α^w is an intercept vector. The matrices $\widetilde{F}^w$ stand for our identified factors and ϵ^w are regression errors.[14,15] The resulting loadings are presented in Figure 2; the confidence intervals are obtained via robust standard errors.[16] The effects of "Target" surprises are illustrated in the first line of panel (a) (press release window). Its greatest impact is on 1-month OIS yields and then monotonically diminishes as the maturity increases. This pattern is standard in the literature (Gürkaynak et al. (2005a); Swanson (2017)). Moreover, we note that the effect of this factor is homogeneous in the countries of the Euro area. These results are thus opposed to those of Leombroni et al. (2020) which reveal heterogeneous reactions between core and periphery countries.[17] It should be reiterated that these surprises capture the variations of the expectations on short-term rates. In our opinion, it is difficult to imagine that these rates may

[14] After Brand et al. (2010), we also control for the surprise associated with the release of U.S. jobless claims data in the press conference window. This data is released at 14:30, coinciding with the beginning of the ECB press conference.

[15] Our factors are only identified up to scale. We adjust them to make the comparison as simple as possible in the different countries. This normalization ensures that the "Target, "Duration" and "Sovereign spread" factors have unit effects on the 1-month OIS rate, on 5-year German bond yields and on 10-year Italian bond yields, respectively. In the press conference window, "Timing" surprises have a unit impact on the 6-month OIS rate while the effects of the "FG" factor are unitary on the yields of 2-year German bond yields. "Save the Euro" surprise have a unit effect on 10-year Italian bond yields. Finally, "QE" has a one-to-one effect on 10-year German bonds. This normalization reflects the largest impact that each factor has on changes in asset prices.

[16] The regressions that led to Figure 2 are displayed in Table 3.

[17] Specifically, they find that "Target" shocks cause heterogeneous effects on core and periphery countries after 2009. Before this time, the responses are homogeneous.

differ between countries sharing a common monetary policy. Heterogeneity is explained, as we shall see, by other dimensions related to long-term yields.

The effects of the "Duration" factor, presented in the second row, are negligible on short maturities. By contrast, their impacts are significantly greater at the long end of the yield curve. It is crucial to stress that these long maturity effects are homogeneous from one country to another. In other words, we deduce that these surprises have a predominant impact on the risk-free yield curve. This is the reason why we refer to this factor as "Duration".[18]

On the other hand, "Sovereign spread" surprises have heterogeneous impacts on the long end of the yield curve. In particular, those are very strong on the long maturities of bonds of periphery countries. It is worth recalling that the rank test indicates that this factor only appears from the crisis period onwards. This suggests that certain monetary releases strengthened/reduced sovereign default risk premiums when the crisis topped out. These results are reminiscent of the ideas of a self-fulfilling sovereign debt crisis, which are further discussed below. It is important to keep in mind that while we require that the "Duration" and "Sovereign spread" factors do not affect the 1-month OIS rate, we do not restrict them to affect only the long end of the risky and risk-free yield curves. In other words, these results are the consequence of our estimates, not of assumptions.

In the conference window (panel (b)), the loadings of the "Timing" and "FG" factors, presented in the first and second rows respectively, show patterns similar to those of ABGMR. However, they reach their maximum at different maturities. "Timing" has its greatest effect on 1-year OIS and "FG" at 2 years in all countries. These factors are remarkably similar from one country to another. This is important because these surprises are supposed to be mainly transmitted by expectations of future short-term rates (Gürkaynak et al. (2005a); Woodford (2012)). Again, these new elements support our view that there is little reason why these expectations should differ among countries sharing a common monetary policy.

The "Save the Euro" surprises, shown in the third row, shift yields of the core and the periphery in opposite directions. They have a strong positive effect on Italian and Spanish bond yields (peaking at the 10-year maturity), and a small negative effect (or no effect at all) on German and French bond long-term yields. In addition, our rank test indicates that this factor arises during the crisis period. Such behavior suggests that some monetary conferences have been perceived in the markets as being aimed at *saving the Euro*. In this respect, Wright (2019) stresses the importance of factoring in these effects

[18]The term "Duration" refers to the risk associated with the sensitivity of the price of a bond to a 1% change in interest rates. In our results, this elasticity increases only slightly with the maturity of the bond. Indeed, the largest impact is on 5-year maturities, not 10-year maturities. Although this phenomenon of non-monotony remains puzzling, the effects are nonetheless quite significant at the end of the yield curve.

for a consistent identification of monetary surprises in the Euro area.

Unsurprisingly, the "QE" effects, presented in the fourth row, affect the long end of the yield curve. It should be noted that the impacts are rather similar in each country, with a peak at 10 years. These homogeneous effects are quite understandable insofar as the "Save the Euro" factor captures the share of monetary surprises that cause disparities in effects between countries.

Altogether, our identification procedure is globally consistent. We therefore check whether it remains in the three sub-samples (pre-crisis, crisis and QE periods). Table 4 presents the results for the press release window and Table 5 for the conference window. The estimated coefficients are broadly similar to those of the regressions for the full sample. The responses are also highly statistically significant. The only notable difference is in the last sub-sample, when the ZLB is reached. We observe that the effect of the "Target" factor is significantly smaller on the one-month OIS (Table 5, panel c).[19]

Last, we study the effects of the surprises on sovereign spreads. We construct these sovereign spreads by calculating the difference between the responses of German yields against those of France, Italy and Spain. Table 6 presents the results for the press release window and Table 7 for the conference window. As expected, in the release window, the effects on sovereign spreads are mainly captured by "Sovereign spread" surprises, regardless of the sub-sample.[20] In the conference window, the responses confirm what we have witnessed, namely, that "Save the Euro" surprises cause the majority of the spread changes. Conversely, the effects of "QE" are negligible.

Overall, the large values of R^2 over the regressions indicate that our factors capture a very large fraction of the intraday variation in OIS rates and sovereign bond yields around the ECB's monetary policy announcements. In the full sample, the R^2 varies from 70% to 92% for the press release window and from 90% to 98% for the conference window. In the regressions specified at sovereign spreads, they confirm that monetary communications have fairly heterogeneous impacts on yields in core and periphery countries. Thus, the high level of significance of the coefficients combined with these high values of R^2 show that our identification strategy is relevant for measuring the majority of the effects of Euro area surprises. In particular, the identification of significant changes in long-term yields in the two communication windows is unprecedented in the literature.

[19] It is on the 6-month OIS that the effect becomes strongest. This result is not displayed in order to avoid overloading the reader with information; it is available upon request.

[20] Note that as the French spreads are very low over the entire sample, it is not surprising that the responses are insignificant. In addition, the negative effects of "Duration" surprises on Spanish spreads do not require serious consideration. In fact, they are highly volatile in the whole sample, leading to a significant reaction from time to time.

2.4 Interpretation by the narratives

We propose a narrative analysis in order to better understand the causes of the homogeneous and heterogeneous effects of ECB communication surprises. To this end, we draw on ECB press release documents and transcripts of press conferences. In addition, we collect news as well as commentaries from market participants in the Financial Times (FT). We focus this analysis only on the new identified factors, namely "Duration", "Sovereign spread" and "Save the Euro".[21] Their series are presented in Figure 3. Panel (a) reports those from the press release window, and panel (b) those from the press conference window.

Before the narrative analysis, a few general observations on the series are worth mentioning. First of all, our identifying restrictions are working well; "Sovereign spread" and "Save the Euro" surprises are almost nil before September 2008, and similarly, for the "QE" factor, no noticeable peak is observed before January 2014. Second, the factors in the conference window, with the exception of the "QE" surprises, show less variation since January 2015. Contrariwise, those in the release window continue to show large swings. We recall that since January 2015, the ECB has introduced additional information in its press release documents. This information consists of simple phrases such as "Further monetary policy measures will be communicated by the president of the ECB" or details of asset purchase programmes, and such information seems to have had a significant impact.

Now to the narratives. All sources and urls for ECB press release documents and press conference transcripts, as well as online and printed FT articles, are listed in Appendix D. In addition, Table 8 details the yield changes for each of the events listed below.

The greatest realizations (positive and negative) of the "Duration" are always related to the release of changes in the target rates. The two largest positive peaks took place during the global financial crisis on December 4, 2008, and April 2, 2009, when the ECB reduced its MRO by 75 and 25 b.p. respectively. Surprisingly, both events were followed by consistent increases in all long-term bond yields. The most plausible explanation for these movements can be found in the market commentaries of the time. The latter indicated that the ECB had cut its key rates less than investors had originally expected.[22] Thus, we believe that market participants did not correct their inaccurate expectations in short-term rates because they expected further re-

[21] A similar analysis on the other factors is available in the study of ABGMR.

[22] An FT article published online on April 2, 2009, reported that: "The ECB cut its main lending rate by 25 b.p. to 1.25 per cent, confounding expectations for a 50 b.p. move". Moreover, on December 4, 2008, the ECB suffered from a comparison with two other large policy rate cuts. Earlier in the day, the Bank of England and the Swedish Riskbank had cut their policy rates by 100 and 200 b.p. respectively. The latter can explain why investors expected a larger cut that day.

ductions in target rates in the future. If expectations in short-term rates remain unchanged while long-term rates rise, then changes in term premiums may be involved. This is discussed below.

On the other hand, the largest negative episodes of the "Duration" factor occurred when the ECB acted more "dovish" than expected in the financial markets. For example, the factor reached a negative peak on November 7, 2013, when the ECB surprised the investors by reducing its MRO from 50 to 25 b.p.[23] In addition, "Duration" surprises plunged on June 14, 2018, when the ECB released a gradual reduction of the QE, while deciding to keep interest rates unchanged at historically low levels.[24] These decisions have led to a uniform decline in long-term yields.

With regard to the "Sovereign spread" factor, its lowest realization occurred on March 10, 2016, when the ECB surprised the markets with the publication of a larger than expected stimulus package. In this press release, the ECB announced the extension of the QE program and a reduction of two of its main target rates. In particular, the MRO was lowered to 0, symbolically reaching the zero lower bound for the first time.[25] Investors have welcomed this initiative. This had the effect of sharply lowering long-term bond yields in the periphery, while the effects on core yields were milder. The "Sovereign spread" factor reached a positive peak on August 4, 2011, when the ECB decided to keep key rates unchanged, despite increasing calls for interest rate cuts to relieve the heavily indebted periphery.[26] In response, yields in the periphery countries increased, while yields in the core rose slightly.

Finally, the highest "Save the Euro" values were achieved during the Euro area sovereign debt crisis on December 8, 2011; July 5, 2012; and August 2, 2012. At the time, the ECB was under pressure from investors to launch QE. However, the president of the ECB repeated several times at these press conferences that the central bank was not prepared to buy government debt directly.[27] These announcements were a major disappointment to the markets,

[23] An FT article published online on November 7, 2013, wrote that: "The European Central Bank still managed to shock almost everyone on Thursday by cutting rates in response to fears that the currency bloc could succumb to deflation."

[24] The next day, June 15, 2018, a printed article in the FT reported that: "[The] dovishness on interest rates calmed market nerves that had been jolted by recent political turbulence in Italy".

[25] The next day, March 11, 2016, a printed article in the FT confirmed that: "The ECB raised the amount of bonds the eurozone's central bankers buy each month under QE from a 60bn to a 80bn a greater amount than many analysts had expected."

[26] On August 4, 2011, a printed article in the FT reported what Jose Manuel Barroso (then head of the European Commission) had declared the previous day: "The tensions in bond markets reflect a growing concern among investors about the systemic capacity of the Euro area to respond to the evolving crisis."

[27] On August 3, 2012, FT published a printed article entitled "Draghi disappoints the markets".

which were expecting aggressive ECB intervention to support the periphery countries. The lack of ECB action led to a sharp rise in medium- and long-term yields in Italy and Spain, while German bond yields moved slightly in the opposite direction. However, the most significant negative realization of the factor occurred on September 6, 2012, when President Draghi announced that the ECB would purchase government bonds in the secondary market.[28] This long-awaited decision resulted in a sharp decline in long-term yields in the periphery.

3 Excess sensitivity of long-term rates

3.1 Interest rate estimations and decompositions

Our previous results show that long-term yields are highly sensitive to monetary surprises. Classical theories of finance and macroeconomics hardly corroborate this phenomenon. Nevertheless, we support their consistency by providing more evidence as well as theoretical arguments.

In standard macroeconomic theory, monetary shocks are considered to be short-lived, i.e. having no real impact beyond the horizon of price rigidity, a horizon that cannot reasonably exceed two years (Woodford (2011); Galí (2015)). In classic finance, if the expectations hypothesis of the term structure of interest rates holds, monetary shocks should have modest impacts on long-term rates (Shiller (1979)). Moreover, this hypothesis states that term premiums are a constant fraction of long-term rates. Therefore, they should not change in response to these shocks. From this perspective, the excess sensitivity of long-term yields is undoubtedly a puzzling feature of the data (Shiller et al. (1983); Cochrane and Piazzesi (2002); Hanson et al. (2018)). In addressing this anomaly, Gürkaynak et al. (2005b) suggests this phenomenon can occur if long-term inflation expectations are not properly anchored.

Does this also apply to our newly identified monetary surprises? To address this question, we proceed as follows. We decompose the nominal rates of risky and risk-free bonds into their components, namely short-term interest rate expectations and term premiums. Next, we distinguish between what arises from the real and inflation dimensions. Term premiums are not observable and must be estimated. We do not have access to intraday data, either for nominal yields or inflation rates. Therefore, we estimate nominal rates using daily ECB spot rates.[29] For consistency with ECB techniques, we decompose these spot rates using dynamic-factor Nelson-Siegel-Svensson models (DNSS, Diebold and Li (2006); Christensen et al. (2009)).

[28] The following day, September 7, 2012, an article entitled "ECB signals resolve to save euro" was published in the FT.

[29] Zero-coupon rates that are derived from a Svensson-type model (Svensson (1994))

The ECB spot rates are produced using two different samples: AAA-rated Euro area central government bonds, and all Euro area central government bonds (including AAA-rated). This differentiation allows us to track the dynamic of sovereign spreads in Euro area government bonds.[30] Then, we use daily zero-coupon Euro area ILS data to distinguish between the real and inflation dimensions. ILS offer two main advantages: *(i)* they exclude the exchange of notional amounts and are therefore less exposed to liquidity premiums. *(ii)* their inflation legs are linked to annual changes in the HICP, thereby smoothing out monthly seasonal variations. However, ILS are exposed to counterparty and credit risks. We purge these risks by regressing them on BBB-AAA corporate bond spreads. Further details on the DNSS models and *raw* data are provided in Appendices B and C.

Figure 4 shows the results of our decompositions. Panel (a) presents, in order, the components of expectations for the AAA-rated nominal and real rates, as well as inflation rates. Panel (b) provides the term premiums for these same variables. Figure 5 displays our estimates of the daily sovereign spreads. Overall, the important features of these decompositions are as follows. First, they reflect the very sharp decline in nominal and real expectations in 2009. Second, they show a surge in sovereign spreads at the height of the sovereign debt crisis. Finally, they indicate a steady decline in term premiums since 2009, with a negative slide in 2014.[31]

3.2 Daily evidence on nominal rates

To estimate the effects of monetary surprises on nominal rates, we run daily regressions that are similar to the equation 2.[32] Tables 9 and 10 show the coefficients with robust standard errors. We present the responses for two

[30] The sovereign spreads are given by the differences between our resulting estimates of the daily constant maturity rates of AAA-rated bonds and bonds of all ratings. Since AAA-rated bonds are included in both samples, our sovereign spreads are lower bound estimates. We find that they are two to three times smaller than the spreads that could be calculated with observed yields (Italian/Spanish - German yields). However, their dynamics are extremely similar. Hence, all the following results are robust and available upon request.

[31] Although each decomposition method is likely to produce different estimates for the expectations and term premiums, our results are broadly consistent with trends and dynamics observed elsewhere in the literature. In particular, our estimates are in line with the application of Adrian et al. (2013)'s model to German government zero-coupon bond yields in Cohen et al. (2018).

[32] We rescale the factors to account for the change in frequency (from intradaily to daily). The normalization ensures that the "Target", "Duration" and "Sovereign spread" factors have unit effects on the 3-month AAA nominal rates, on 10-year AAA nominal rates and on 10-year sovereign spreads, respectively. In the press conference window, the "Timing" surprise has a unit impact on the 1-year AAA nominal rates while the effects of the "FG" factor are unitary on the 2-year AAA nominal rates. The "Save the Euro" factor has a unit effect on 10-year sovereign spreads. Finally, "QE" has a one-to-one effect on 10-year AAA nominal rates.

maturities (5 and 10 years) for which monetary surprises are assumed to be theoretically neutral (or very small).

In the full sample, changes in long-term expected short-term rates are mainly due to the "Target", "Timing", and "FG" surprises (Table 9). In particular, the "Timing" and "FG" shocks have important effects during the crisis. Conversely, "Target" surprises dominate the QE period. It should be emphasized that the "Duration", "Save the Euro" and "Sovereign spread" factors do not have a significant effect on these components of expectations. By contrast, "Duration" shocks dictate the daily variations in nominal term premiums, especially in times of crisis (Table 10).

Allow us to focus on these changes in term premiums. Although these movements may be unusual after a standard monetary shock, Campbell et al. (2020) illustrate that they occur frequently over business cycles. To explain this phenomenon, the authors emphasize the importance of revisions to the risk properties of nominal long-term bonds. By varying over time, this risk is a source of changes in investor attitudes.[33] Empirically, the correlation between stock and bond returns is particularly relevant to highlight the typical behavior of investors. If this correlation is negative, then nominal long-term bonds are likely to be considered safe assets. Figure 6 shows this evidence in the Euro area. Adjusting for a 5-year window, the correlation is permanently negative, which implies that bond prices are likely to rise during recessions. In other words, nominal term premiums should be low during those periods of trough. Moreover, the 6-month window reveals that another mechanism is at stake. Indeed, the large swings suggest that not only the quantity but also the price of risk may vary over time.[34] In Campbell et al. (2020), this has to be tied to preferences in consumption habits.[35] The closer consumption is to habits, the more risk-averse agents are and therefore more attracted to safe assets. As a result, term premiums come under additional downward pressure and can even be negative during recessions.

By influencing the phases of economic cycles, monetary surprises may thus alter investor behavior. Excessive changes in term premiums would therefore only reflect compensation for changes in the risk associated with long-term

[33]The authors show a qualitative and quantitative evolution of the risks associated with 5-year US Treasury bonds since the early 2000s. These changes simply imply that these bonds have moved from risky to safe assets (Campbell et al. (2009)). At low frequencies (monthly, quarterly), this change appears to be caused by a change in the correlation between inflation and the output gap. If this correlation is positive, the nominal yields of long-term bonds increase in periods of low marginal utility. Consequently, these assets are hedging portfolios during periods of recession.

[34]In this regard, Campbell et al. (2020) point to the existence of a "dual-frequency story" in stock-bond correlation.

[35]The reader may refer to Campbell and Cochrane (1999) for more details on external consumption habits.

bonds.[36] In this respect, Pflueger and Rinaldi (2020) constructs a small-scale New-Keynesian model around the habit-formation preferences in Campbell et al. (2020). The authors find that a monetary policy tightening shock can create an increase in risk aversion and thus amplify the fall in stock prices (through the risk premium components). In turn, demand for long-term bonds becomes acute, putting pressure on nominal term premiums.

Beyond that, there is another dimension to our results that is unusual in the classical theory: the heterogeneous reactions of long-term yields between core and periphery countries (see sub-section 2.3). Table 11 displays the outcomes of daily regressions on sovereign spreads. The "Save the Euro" surprises significantly affect the spreads, particularly in times of crisis. Conversely, the "Sovereign spread" shocks have little effect overall, although there is an exception in the period of QE.[37] How can these results be rationalized? De Grauwe (2011); Jeanne (2012); De Grauwe and Ji (2013) raise the specter of a self-fulfilling sovereign debt crisis in the Euro area. Hence, the cocktail of liquidity shortages and excessive borrowing costs can lead to pessimistic expectations in financial markets and thus create multiple equilibriums within the area.[38,39] Along these lines, Wright (2019) argues that monetary communications can reduce/amplify these imbalances and thus have heterogeneous impacts. These ideas imply that investors' perception of the current or future state of the economy is of great importance in the pricing of bonds.[40]

[36] These reactions usually are referred to as "flight to quality"/"flight to safety" episodes. They are the subject of much attention in the literature (see Caballero and Krishnamurthy (2008), Beber et al. (2009) among others).

[37] The "Target" surprises influence sovereign spreads but only during the QE period. We suspect that this factor therefore captures some of the information that has been added to press releases since January 2015.

[38] Sovereign debts are issued in a currency over which countries have no direct control. Mechanically, countries are therefore more exposed to liquidity shortages. In depressed times, financial markets may be concerned about the solvency of some countries in the area. As a result, default premiums on sovereign bonds may rise sharply, while others may maintain their financial strength.

[39] In September 6, 2012, President Draghi recognized the existence of multiple equilibriums: "The assessment of the Governing Council is that we are in a situation now where you have large parts of the Euro area in what we call a "bad equilibrium", namely an equilibrium where you may have self-fulfilling expectations that feed upon themselves and generate very adverse scenarios. So, there is a case for intervening, in a sense, to "break" these expectations, which, by the way, do not concern only the specific countries, but the Euro area as a whole."

[40] In addition, this volatility in sovereign spreads could also be influenced by the risk of "redenomination" (De Santis (2019)). At the time of the Euro area sovereign debt crisis on July 26, 2012, President Draghi also stated that the ECB faces a "risk of convertibility". In other words, the ECB recognized the high expectations of a possible dislocation of the area. If this had happened, countries with large fiscal imbalances would have been likely to have a new currency that would have depreciated sharply against the value of the current euro. Disappointing monetary surprises therefore have had the potential to create a rise in sovereign spreads through this risk of "redenomination" (and vice versa).

3.3 Daily evidence on real rates

Going further, it is interesting to examine whether our new monetary surprises are having any real effects. We thus perform daily regressions on the decomposition of our real rates. We find that the impacts on real expectations are roughly similar to their nominal counterparts (Table 12 against Table 9). These effects could be considered as quite disconcerting if we consider a classic monetary policy shock. However, Nakamura and Steinsson (2018); Pflueger and Rinaldi (2020) develop theoretical arguments and find evidence that U.S. monetary surprises can convey news about the state of the economy. These two studies reveal that "Information" shocks can induce significant changes in real interest rate expectations within two years at most. Beyond this horizon, breakeven inflation rates are the main drivers. Our evidence suggest that these effects may be more persistent in the Euro area.

On the other hand, the responses of real term premiums to "Duration" surprises are also close to their nominal equivalents (Table 13 against Table 10). Again, these variations may reflect, as explained in the previous sub-section (3.2), a protection against macroeconomic fluctuations. Otherwise, Hanson and Stein (2015) and Hanson et al. (2018), find similar evidence in a large number of countries. To support their findings, they suggest that some investors are much more concerned about current yields than those they could expect in the future. These "reach for yield" behaviors lead investors to prefer longer maturities when a monetary shock reduces the expected short-term rates. This surge in demand compresses term premiums as if, according to the authors, they were "recruited" by the initial decline in short-term rates.

It must be recognized that our daily regressions are by construction less accurate than intraday regressions. In particular, we lose significance in some sub-period, especially for the "Sovereign spread" surprises (see sub-section 2.3). However, the results, which remain globally significant, reinforce the evidence that the ECB's monetary communications have a substantial impact on long-term rates.[41]

4 Information and Perception shocks

4.1 The role of the investors' perception

At this point, many elements point to the possibility that our new surprises may not be standard monetary shocks. Indeed, an academic would define a monetary policy shock as the orthogonal residual of the systematic response of a central bank based on its assessment of the macroeconomic outlook. However, this definition overlooks that the central bank can convey macroeconomic

[41] We intend to refine this exercise in the future if the data permit.

news (unintentionally or not) beyond the future stance of monetary policy. In other words, monetary communications could be informative enough for market participants to reshape their expectations. Curiously, there are market reactions that neither "Monetary" nor "Information" shocks can reasonably predict. These episodes are generally characterized, as we have seen (sub-section 2.4 and Table 8), by excessive variations in long-term rates, but also, as we shall see, by unexpected responses of inflation and stock prices. The following scenario illustrates this phenomenon.

Consider that investors have anticipated a quarter-point decrease in the main target rate and the central bank subsequently reveals the rate is to be maintained. This situation can be seen as an unexpected increase in the short-term nominal rate. Indeed, the difference between the rate expected by investors and the actual rate is positive. If this were the result of a "Monetary" shock, then nominal yields should rise and inflation and stock prices should fall. Under an "Information" shock, this unexpected increase in the target rate would be a signal to investors that the economy is not deteriorating as much as they thought. As a result, nominal yields, inflation, and stock prices should rise simultaneously.

Nevertheless, we affirm that investors can also be confident in their forecasts about the future state of the economy and therefore be *disappointed* by the central bank's decision. Because they have anticipated a decline in the target rate, investors may think that a decision to maintain it at the current level is inadequate. In the end, instead, they will expect the economy to deteriorate further. We argue that what we call a "Perception" shock may, in this situation, lead to a joint decline in both inflation and stock prices.[42]

We assume that the "Monetary", "Information" and "Perception" shocks are nested in the data. Researchers generally rely on nominal yields, inflation and stock prices to distinguish between "Monetary" and "Information" shocks. In these two types of shocks, the response of nominal yields is in fact equivalent, but the responses of inflation and stock prices are opposite (Jarociński and Karadi (2020); Andrade and Ferroni (2020)). In our case, the presence of "Perception" shocks invalidates this strategy. Indeed, there are many situations in which at least two of these shocks provoke market reactions that are observationally equivalent.

Fortunately, the peculiarities we have observed in the market reactions help us to solve this problem. In particular, several market commentaries highlight a strong disappointment after the absence of QE. If this had been the consequence of an "Information" shock, this surprising absence would indicate that

[42] In the face of this shock, the response of the expected short-term rates (hence part of the nominal yields) is, in our opinion, difficult to predict. On the one hand, it could increase, thereby reducing the gap with the actual rate. On the other hand, it could remain unchanged if investors believe that the central bank will have to reduce it afterwards. Finally, it could fall if investors feel that this lack of intervention will further strengthen the imbalances.

the economy was not in need of such a measure. However, market reactions indicate otherwise. In the data, these episodes are characterized by a strong increase in peripheral yields coupled with a decrease in core yields. There is therefore a contradiction between the interpretation by an "Information" shock and the investors' reactions. Rather than rejecting the existence of "Information" shocks, we therefore argue that there is a gap to be filled.[43] To address it, we assume that risky rates are a way of isolating "Perception" shocks.

Thus, we use the daily changes in our estimates of Euro area risk-free rates (AAA-rated), risky rates (AAA-rated and others), inflation rates (all at 2-year maturity) and Euro area stock prices to dissociate the three types of shocks.[44] We begin by estimating the daily responses of these four variables to intraday monetary surprises. Next, we assume that there is a unique sign combination in the fitted values associated with each of the three shocks. Table 14 details these combinations.[45]

The outline of the procedure is as follows. First, we separate the three shocks into two categories: one in which the reaction of the risky rate is stronger than that of the risk-free rate, and the other in which the opposite occurs. Thus a "Perception" shock will always be characterized by a stronger response of the risky rate. Contrariwise, an "Information" or "Monetary" shock requires a large response of the risk-free rate. Second, a "Perception" shock is identified if the response of the risky rate is the negative of the reactions of inflation and stock prices. Third, an "Information" shock is found if the response of the risk-free rate is the same as the reactions of inflation and stock prices. Finally, a "Monetary" shock is identified if the response of the 2-year risk-free rate is the opposite of the reactions of inflation and stock prices.

As risk-free and risky rates are at the very heart of the identification strategy, we shall therefore examine whether there is a glaring contrast in their reactions to monetary surprises. In addition, we shall highlight which of the risk-free rates or risky rates reacted most strongly to each event. The first and second panels of Figure 7 show the fitted responses of the risk-free and risky rates respectively. These are large and quite distinct. Moreover, the frequency of occurrence of these two types of events is rather balanced. These results reinforce the coherence of our approach.

Let us then proceed with the identified shocks. The distinction between the

[43] This identification is therefore totally based on our knowledge of the data (and the narratives) and shall not be considered as having a general scope.

[44] We choose to identify the different types of shocks via 2-year rates since it is maturity on which all surprises have an effect (see figure 2). Moreover, this maturity escapes the problems associated with the ZLB. Finally, note that it is common to proceed in this way (see Altavilla et al. (2019); Andrade and Ferroni (2020); Jarociński and Karadi (2020)).

[45] An identification based solely on market comments could be an elegant extension to our approach. However, such a procedure, in our view, would be very cumbersome and could be inaccurate if a representative set of market comments is not captured. We leave open the possibility of refining our identification strategy for future research.

shocks is illustrated in figure 8. The first and the second panels show the fitted reaction in 2-year risk-free and risky rates respectively.[46] At first glance, our results are consistent with those of ABGMR. Indeed, during the crisis period, we observe a majority of "Information" type shocks. Conversely, from the QE period onwards, many shocks are identified as "Monetary". However, 2012 seems to be a pivotal year where the shocks of "Perception" arise. Understanding the fundamental reasons for these changes in perception would be very interesting but falls outside the scope of this paper. It should be nonetheless mentioned that 2012 was the year when President Draghi declared in July that the ECB would do "Whatever it takes" to save the Euro. The monetary conference that followed was characterized by an unprecedented disappointment by investors and an explosion of yields in periphery countries. This event gives an entry point, in our opinion, to a more detailed analysis.

4.2 Daily VAR

In the previous sub-section (4.1), the strategy for identifying the different types of shocks is based on the linear combination of the effects of all monetary surprises. Our objective is now to determine the underlying nature of the "Duration", "Sovereign spread" and "Save the Euro" surprises only.

However, we are not starting at the very beginning. Up to this point, our findings are as follows. "Duration" surprises have homogeneous impacts on long-term rates, mainly through term premiums. It is unlikely that such persistent effects are the result of "Monetary" shocks. However, these could arise under the heading of "Information" shocks (Pflueger and Rinaldi (2020)). On the other hand, the "Sovereign spread" and "Save the Euro" surprises have heterogeneous impacts on long-term rates. More precisely, they have strong repercussions on periphery yields (risky rates). These are effects that the shocks of "Perception" may generate.

We therefore assert that these three surprises could be strong instruments to identify either "Information" or "Perception" shocks. To prove this claim, we perform instrumentations in daily VAR models. The form of a model is as follows:[47]

$$Y_t = \alpha + \sum_{j=1}^{p} B_j Y_{t-j} + A_0 \varepsilon_t \tag{3}$$

where Y_t is the vector of endogenous variables (10-year nominal AAA rates (risk-free) or 10-year nominal AAA and other rates (risky), 10-year inflation

[46] Our results display a significant number of "unclassified" shocks. These shocks occur when the reactions of inflation and stock prices have opposite signs. These shocks are therefore inconsistent with any theoretical arguments, hence left "unclassified.

[47] More details on VAR with external instruments can be found in Stock and Watson (2012); Mertens and Ravn (2013)

rates, and log of the Euro Stoxx 600 index).[48] The vector α stands for intercepts, B_j are VAR coefficients, p the lag length and ε_t errors.

The objective of the instrumentation is to identify the coefficients in the matrix A_0 that are associated with the structural shocks of "Perception" or "Information". To serve this purpose, the external instruments Z_t (the monetary surprises) must satisfy two conditions:

$$\mathbb{E}\left(\varepsilon_{1,t} Z_t'\right) \neq 0 \tag{4}$$

$$\mathbb{E}\left(\varepsilon_{i,t} Z_t'\right) = 0, \quad i = 2, \ldots, m \tag{5}$$

The first condition ensures that the instrument is correlated with the structural shock of interest $\varepsilon_{1,t}$. The second is an exogeneity condition which implies that each of the instruments is not correlated with the remaining shocks $\varepsilon_{i,t}$.

Previous results lead us to instrument the residuals of long-term risk-free rates by "Duration" surprises. It is also reasonable to instrument the residuals of risky long-term rates by either "Sovereign spread" or "Save the Euro" surprises. In addition, as shown in figure 8, the nature of the shocks may change over time. We therefore test the relevance of these instruments in the two sub-periods of crisis and QE. This relevance is given by the F-statistics in Table 15. The rule of thumb recommends keeping instruments with an F-statistic of 10, so in times of crisis the "Duration" and "Save the Euro" surprises are kept. In the period of QE, it is relevant to use the factors of "Sovereign spread" and "Save the Euro".[49]

Figure 9 shows the impulse response functions of the identified shocks. Column (a) contains the responses to "Duration" shocks, column (b) those to "Sovereign spread" shocks and column (c) those to "Save the Euro" shocks.

First, let us interpret the impulse responses surrounded by red confidence intervals that correspond to the crisis period. The shock of "Duration" (panel (a)) is sized to cause a 10 b.p. increase in long-term nominal risk-free rates. The result is a simultaneous increase in inflation and stock prices. Thus, these

[48] We estimate 3 different VARs in order to identify as precisely as possible each of the two types of shocks. In one case, the instrumentation by the "Duration" surprises is done in a model comprising the 10-year risk-free rates, the 10-year inflation rate and the log of stock prices (10-year risky rates are omitted because it is not important in the identification of the "Information" shocks). In the two other cases, the instrumentation by the "Sovereign spread" and "Save the Euro" shocks are realized independently in two similar models with 10-year risky rates, 10-year inflation rate and the log of stock prices (10-year risk-free rates are not added because they are not relevant in the identification of the "Perception" shocks). Note that for robustness reasons, we have instrumented each of the surprises in models with all 4 variables, and the results are identical.

[49] The F-statistic of "Save the Euro" is less than 10 during the crisis period. However, we are aware that our estimates of risky rates are limited by the presence of risk-free rates (see Appendix 5). For this reason, we have resorted to the instrumentation of the Italian and Spanish 10-year yields. The F-statistics are huge in both cases and the IRFs are qualitatively similar to our benchmark VAR. In view of these results, we decided to keep this instrumentation.

surprises have, on average, all the characteristics of "Information" shocks. On the other hand, a positive shock instrumented by the surprises of "Save the Euro" (panel (b)) leads to different reactions. The shock is scaled to shift risky long-term rates by 10 b.p. In response, inflation, and stock prices all fall persistently. These are the markers of "Perception" shocks. Finally, the QE period is symbolized by responses with blue confidence intervals. The shocks instrumented by "Sovereign spread" and "Save the Euro" (panels (b) and (c)) are both scaled to cause a 10 b.p. increase in risky rates. These two shocks cause, again, reactions characteristic of "Perception" shocks.

5 Conclusion

Returning to the motivations of this paper, the task of uncovering and explaining the new dimensions of the ECB's monetary communication proves to be much more difficult than we might have imagined. Indeed, one of the aspects that surprised us is the incredible complexity of investors' perception of monetary communications.

To sum up, the Euro Area Monetary Policy event-study Database (EA-MPD) allows us to shed light on the new dimensions of the ECB's communications. Two of them belong to the press release window, namely "Duration" and "Sovereign spread" factors. In addition, we find that surprises from "Save the Euro" occur in the press conference window, confirming the recommendations of Wright (2019). It is important to reiterate that we have not assumed the presence of these new dimensions. We estimated them by following the guidelines of statistical rank tests.

We find that the three new types of surprises can cause large fluctuations in long-term yields. On the one hand, these overreactions are homogeneous to a representative sample of the countries of the Euro area; they are what we call "Duration" surprises. This is a type of excessive variation that, if we stick strictly to the expectations hypothesis of the term structure, cannot occur. We therefore propose an in-depth investigation to grasp the theoretical issues involved. We show that these variations are mainly explained by changes in term premiums. Surprises of "Duration" are on average greater during the crisis period (2008-2013) and are probably the product of "Information" shocks.

On the other hand, we identify heterogeneous reactions in the long-term yields of core and periphery countries. We refer to them as "Sovereign spread" and "Save the Euro" surprises. We demonstrate that these surprises may reflect what we call "Perception" shocks. The latter are characterized by investors' disappointment or approval of a surprising monetary decision. They explain, for example, the reactions of asset prices at the time of the mid-2012 announcements when investors were surprised by the lack of QE. These episodes were, on average, characterized by a sharp increase in periphery yields and a decline in inflation and stock prices. We find strong evidence that "Perception" shocks began to appear in 2012 and became widespread thereafter.

All of these elements add substantially to the overall understanding of the impacts of monetary communications in the Euro area. But despite all our contributions, many questions remain unanswered. Two of them are of particular interest to us: Are these excessive changes in long-term yields observable at lower frequencies? If so, what would be the macroeconomic impacts of "Perception" surprises?

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Appendix

Appendix A: Tables and Figures

Table 1: Rank tests: number of factors to be extracted in monetary surprises

	Press release window			Press conference window		
	Pre-crisis	Pre-QE	Full sample	Pre-crisis	Pre-QE	Full sample
$H_0 : k = 0$	146.39	96.37	79.12	196.83	165.63	166.97
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
$H_0 : k = 1$	70.18	59.46	51.47	63.48	79.21	81.72
	(0.0000)	(0.0003)	(0.0030)	(0.0000)	(0.0000)	(0.0000)
$H_0 : k = 2$	25.49	35.58	31.40	30.08	37.82	42.85
	(0.1450)	(0.0118)	(0.0364)	(0.0507)	(0.0062)	(0.0014)
$H_0 : k = 3$	-	16.57	18.81	-	20.99	22.35
	-	(0.1666)	(0.0933)	-	(0.0505)	(0.0337)
$H_0 : k = 4$	-	-	-	-	-	12.59
	-	-	-	-	-	(0.1989)

Note: The results show Wald's statistics and the p-value in parentheses from Cragg and Donald's (1997) rank test. The test confronts the null hypothesis $k = k_0$ with the alternative $k > k_0$. The test is performed on the two windows separately (release and conference) and for three sub-samples. The pre-crisis sample gathers monetary surprises between January 2002 and August 2008. The pre-QE sample collects monetary surprises between January 2002 and December 2013. The full sample contains monetary surprises between January 2002 and September 2018. More details on the rank tests are provided in Appendix C.

Table 2: Analysis of variance (ANOVA), proportion of variance among the asset price changes (in %)

	1M	3M	6M	1Y	D2Y	D5Y	D10Y	F2Y	F5Y	F10Y	I2Y	I5Y	I10Y	E2Y	E5Y	E10Y	Tot.
Release																	
Target	88.5	88.6	88.4	74.2	28.5	7.4	0.0	30.0	12.8	0.0	17.8	10.0	1.5	22.2	8.7	3.9	30.2
Duration	0.0	1.4	3.8	16.7	59.7	85.3	82.3	52.2	78.6	65.6	28.7	41.3	37.5	25.7	33.5	35.6	40.5
Sov. spread	0.0	0.0	0.1	0.0	0.0	2.3	4.9	0.0	3.8	11.7	33.4	38.2	52.5	21.8	40.8	47.5	16.0
Residuals	11.5	9.9	7.7	9.1	11.8	5.0	12.7	17.7	4.9	22.7	20.0	10.5	8.4	30.2	17.1	13.1	13.3
Conference																	
Timing	90.5	61.5	46.2	31.0	12.2	6.9	3.0	13.6	7.4	3.0	6.2	2.8	2.5	7.1	3.8	2.1	18.7
FG	0.0	23.0	41.8	57.1	70.1	54.0	21.1	66.8	54.8	22.8	67.8	48.0	19.9	72.0	57.0	25.4	43.9
Save the Euro	0.0	4.2	5.9	6.9	7.6	8.9	8.3	9.1	3.3	0.1	17.0	36.0	49.1	8.0	24.2	46.3	14.7
QE	0.0	0.0	0.4	1.5	7.8	23.5	63.5	6.4	28.6	72.0	2.3	9.8	23.6	3.2	9.4	23.3	17.1
Residuals	9.5	11.3	5.9	3.4	2.3	6.7	4.2	4.1	5.8	2.1	6.6	3.5	4.9	9.7	5.7	2.9	5.6

Note: The table shows the shares of variance for each asset price change (in percent) on each factor in each window (after rotation). In the title columns, D represents German assets, F French assets, I Italian assets and E Spanish assets. The "Residuals" row gives the variance that is not explained by any factor in the analysis. The last column shows the total variance explained by each factor.

Table 3: Estimated effects of monetary policy surprises on OIS rates and sovereign bond yields, January 2002 – September 2018 (Full sample)

(a) Press release window

	Dependent Variable									
	OIS1M	OIS1Y	DE2Y	DE10Y	FR2Y	FR10Y	IT2Y	IT10Y	ES2Y	ES10Y
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Target	1.00***	0.59***	0.39***	−0.01	0.41***	0.01	0.47***	0.12**	0.45***	0.18***
	(0.05)	(0.03)	(0.04)	(0.03)	(0.04)	(0.06)	(0.08)	(0.05)	(0.08)	(0.04)
Duration	0.0000	0.40***	0.81***	0.80***	0.78***	0.89***	0.86***	0.84***	0.68***	0.78***
	(0.07)	(0.04)	(0.05)	(0.05)	(0.07)	(0.06)	(0.16)	(0.04)	(0.11)	(0.09)
Sovereign spread	−0.0001	0.02	−0.001	0.20***	0.01	0.38***	0.94***	1.00***	0.64***	0.91***
	(0.09)	(0.03)	(0.06)	(0.06)	(0.05)	(0.11)	(0.16)	(0.07)	(0.12)	(0.11)
Observations	180	180	180	180	180	180	180	180	180	180
R^2	0.88	0.91	0.88	0.87	0.82	0.77	0.80	0.92	0.70	0.87

(b) Conference window

	Dependent Variable									
	OIS1M	OIS1Y	DE2Y	DE10Y	FR2Y	FR10Y	IT2Y	IT10Y	ES2Y	ES10Y
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Timing	0.53***	1.13***	0.85***	0.28***	0.86***	0.28***	0.73***	0.41***	0.66***	0.34***
	(0.03)	(0.05)	(0.03)	(0.04)	(0.04)	(0.02)	(0.09)	(0.08)	(0.09)	(0.06)
FG	0.001	0.76***	1.00***	0.36***	0.94***	0.39***	1.19***	0.58***	1.04***	0.58***
	(0.02)	(0.03)	(0.03)	(0.02)	(0.04)	(0.02)	(0.04)	(0.04)	(0.05)	(0.04)
Save the Euro	−0.0002	−0.29***	−0.36***	−0.25***	−0.38***	−0.03	0.65***	1.00***	0.38***	0.87***
	(0.02)	(0.05)	(0.03)	(0.06)	(0.06)	(0.02)	(0.13)	(0.15)	(0.11)	(0.07)
QE	0.001	0.19***	0.52***	1.00***	0.46***	1.08***	0.35***	1.00***	0.35***	0.89***
	(0.01)	(0.03)	(0.02)	(0.03)	(0.03)	(0.03)	(0.06)	(0.06)	(0.06)	(0.03)
USjc	0.02	−0.03	−0.09	0.03	0.0001	0.01	0.12	−0.02	0.15	−0.10*
	(0.03)	(0.05)	(0.06)	(0.04)	(0.07)	(0.03)	(0.11)	(0.08)	(0.12)	(0.06)
Observations	180	180	180	180	180	180	180	180	180	180
R^2	0.91	0.97	0.98	0.96	0.96	0.98	0.93	0.95	0.90	0.97

Note: The tables report the effect of monetary policy surprises on intraday changes in OIS rates with 1-month and 1-year maturity, and country-specific sovereign yields with 2- and 10-year maturities (DE – Germany, FR – France, IT – Italy, SP – Spain). The coefficients are obtained using high-frequency regressions around the release and conference windows (see eq. 2). The responses are scaled to have unit effects on specific assets (see sub-section 2.3). We control for the surprise associated with the release of the U.S. jobless claims data in the press conference window (*USjc*). Robust standard errors are presented in the parentheses. ***, **, * denote statistical significance at 1%, 5% and 10% levels, respectively.

Table 4: Estimated effects of monetary policy surprises on OIS rates and sovereign bond yields, sub-sample analysis for press release window

(a) Pre-crisis period: January 2002 – August 2008

	Dependent Variable									
	OIS1M	OIS1Y	DE2Y	DE10Y	FR2Y	FR10Y	IT2Y	IT10Y	ES2Y	ES10Y
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Target	1.24***	0.54***	0.32***	0.10	0.31***	0.09	0.45***	0.09	0.42***	0.09
	(0.09)	(0.05)	(0.07)	(0.08)	(0.11)	(0.07)	(0.07)	(0.08)	(0.07)	(0.07)
Duration	−0.21*	0.52***	0.92***	0.68***	0.99***	0.69***	0.82***	0.65***	0.80***	0.66***
	(0.11)	(0.05)	(0.09)	(0.11)	(0.15)	(0.10)	(0.07)	(0.11)	(0.09)	(0.10)
Observations	75	75	75	75	75	75	75	75	75	75
R^2	0.90	0.74	0.87	0.82	0.84	0.80	0.84	0.78	0.59	0.83

(b) Crisis period: September 2008 – December 2013

	Dependent Variable									
	OIS1M	OIS1Y	DE2Y	DE10Y	FR2Y	FR10Y	IT2Y	IT10Y	ES2Y	ES10Y
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Target	1.01***	0.60***	0.40***	−0.003	0.42***	0.02	0.46***	0.13**	0.40***	0.21***
	(0.03)	(0.03)	(0.06)	(0.05)	(0.06)	(0.06)	(0.12)	(0.06)	(0.08)	(0.06)
Duration	0.09	0.36***	0.81***	0.82***	0.70***	0.90***	0.77***	0.75***	0.86***	0.77***
	(0.05)	(0.07)	(0.11)	(0.07)	(0.10)	(0.10)	(0.12)	(0.10)	(0.21)	(0.08)
Sovereign spread	−0.08**	0.01	0.07	0.11*	0.05	0.22***	1.00***	0.89***	0.85***	0.81***
	(0.03)	(0.05)	(0.06)	(0.06)	(0.05)	(0.06)	(0.10)	(0.10)	(0.17)	(0.07)
Observations	63	63	63	63	63	63	63	63	63	63
R^2	0.97	0.95	0.89	0.91	0.82	0.74	0.86	0.88	0.76	0.88

(c) QE-period: January 2014 – September 2018

	Dependent Variable									
	OIS1M	OIS1Y	DE2Y	DE10Y	FR2Y	FR10Y	IT2Y	IT10Y	ES2Y	ES10Y
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Target	0.48*	0.67***	0.51***	−0.18	0.54***	−0.16	0.44	0.03	0.73***	0.19
	(0.26)	(0.07)	(0.09)	(0.12)	(0.10)	(0.18)	(0.43)	(0.14)	(0.19)	(0.26)
Duration	0.14*	0.30***	0.76***	0.84***	0.77***	0.87***	1.20	1.04***	0.29**	0.64
	(0.07)	(0.08)	(0.09)	(0.13)	(0.08)	(0.19)	(0.74)	(0.13)	(0.14)	(0.45)
Sovereign spread	−0.01	0.08**	−0.08	0.30***	−0.03	0.63***	0.65	1.07***	0.50***	1.16***
	(0.14)	(0.04)	(0.11)	(0.05)	(0.04)	(0.21)	(0.42)	(0.11)	(0.13)	(0.24)
Observations	42	42	42	42	42	42	42	42	42	42
R^2	0.67	0.95	0.94	0.93	0.94	0.91	0.74	0.98	0.89	0.88

Note: The tables report the effect of monetary policy surprises on intraday changes in OIS rates with 1-month and 1-year maturity, and country-specific sovereign yields with 2- and 10-year maturities (DE – Germany, FR – France, IT – Italy, SP – Spain). The coefficients are obtained using high-frequency regressions around the release and conference windows (see eq. 2), considering (1) the full sample period: January 2002 – September 2018; (2) the pre-crisis period: January 2002 – August 2008; (3) the crisis period: September 2008 – December 2013; and (4) the QE-period: September 2008 – September 2018. The responses are scaled to have unit effects on specific assets (see sub-section 2.3). Robust standard errors are presented in the parentheses. ***, **, * denote statistical significance at 1%, 5% and 10% levels, respectively.

Table 5: Estimated effects of monetary policy surprises on OIS rates and sovereign bond yields, sub-sample analysis for press conference window

(a) Pre-crisis period: January 2002 – August 2008

	Dependent Variable									
	OIS1M	OIS1Y	DE2Y	DE10Y	FR2Y	FR10Y	IT2Y	IT10Y	ES2Y	ES10Y
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Timing	0.45***	1.21***	0.67***	0.23	0.50***	0.24	0.77***	0.21	0.60***	0.23
	(0.07)	(0.10)	(0.14)	(0.17)	(0.17)	(0.19)	(0.15)	(0.18)	(0.20)	(0.18)
FG	0.01	0.80***	1.08***	0.40***	1.05***	0.38***	1.03***	0.37***	0.97***	0.38***
	(0.04)	(0.06)	(0.03)	(0.08)	(0.04)	(0.09)	(0.05)	(0.08)	(0.08)	(0.08)
USjc	−0.03	−0.06	−0.21**	−0.24*	−0.14	−0.27**	−0.20**	−0.26**	−0.15	−0.27**
	(0.03)	(0.06)	(0.09)	(0.13)	(0.15)	(0.13)	(0.08)	(0.13)	(0.10)	(0.13)
Observations	75	75	75	75	75	75	75	75	75	75
R^2	0.74	0.98	0.97	0.66	0.96	0.63	0.97	0.62	0.95	0.64

(b) Crisis period: September 2008 – December 2013

	Dependent Variable									
	OIS1M	OIS1Y	DE2Y	DE10Y	FR2Y	FR10Y	IT2Y	IT10Y	ES2Y	ES10Y
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Timing	0.53***	1.15***	0.83***	0.18*	0.87***	0.16*	0.65***	0.40***	0.58***	0.30***
	(0.03)	(0.07)	(0.06)	(0.10)	(0.06)	(0.09)	(0.17)	(0.12)	(0.18)	(0.12)
FG	−0.01	0.77***	0.99***	0.43***	0.89***	0.41***	1.31***	0.58***	1.10***	0.62***
	(0.02)	(0.03)	(0.08)	(0.08)	(0.05)	(0.10)	(0.13)	(0.09)	(0.08)	(0.08)
Save the Euro	0.0004	−0.30***	−0.40***	−0.34***	−0.41***	−0.12**	0.61***	0.93***	0.33***	0.81***
	(0.02)	(0.05)	(0.05)	(0.08)	(0.07)	(0.06)	(0.14)	(0.17)	(0.12)	(0.08)
USjc	0.10**	−0.15	−0.24	−0.24	−0.05	−0.37	0.39	−0.51	0.35	−0.61**
	(0.04)	(0.12)	(0.27)	(0.28)	(0.15)	(0.33)	(0.25)	(0.36)	(0.31)	(0.28)
Observations	63	63	63	63	63	63	63	63	63	63
R^2	0.95	0.97	0.91	0.55	0.92	0.39	0.90	0.88	0.84	0.90

(c) QE-period: January 2014 – September 2018

	Dependent Variable									
	OIS1M	OIS1Y	DE2Y	DE10Y	FR2Y	FR10Y	IT2Y	IT10Y	ES2Y	ES10Y
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Timing	0.61***	0.84***	0.92***	0.13	0.90***	0.23**	0.67***	0.20	0.73***	0.14
	(0.05)	(0.13)	(0.08)	(0.12)	(0.09)	(0.10)	(0.14)	(0.13)	(0.20)	(0.14)
FG	−0.004	0.66***	1.02***	0.15	0.87***	0.32***	0.86***	0.71***	0.80***	0.58***
	(0.04)	(0.08)	(0.08)	(0.10)	(0.07)	(0.08)	(0.10)	(0.07)	(0.13)	(0.15)
Save the Euro	−0.01	−0.29***	−0.35***	−0.28***	−0.31***	−0.02	0.48***	1.07***	0.35***	0.88***
	(0.03)	(0.09)	(0.06)	(0.07)	(0.06)	(0.06)	(0.10)	(0.10)	(0.12)	(0.09)
QE	−0.03*	0.26***	0.49***	1.05***	0.47***	1.12***	0.39***	1.12***	0.40***	0.93***
	(0.02)	(0.04)	(0.03)	(0.03)	(0.04)	(0.04)	(0.03)	(0.04)	(0.06)	(0.05)
USjc	−0.004	0.07	−0.03	0.05	0.08	0.02	−0.14	0.04	0.17	−0.01
	(0.07)	(0.09)	(0.17)	(0.11)	(0.13)	(0.10)	(0.14)	(0.12)	(0.11)	(0.16)
Observations	42	42	42	42	42	42	42	42	42	42
R^2	0.95	0.86	0.94	0.99	0.93	0.99	0.93	0.98	0.94	0.98

Note: The tables report the effect of monetary policy surprises on intraday changes in OIS rates with 1-month and 1-year maturity, and country-specific sovereign yields with 2- and 10-year maturities (DE – Germany, FR – France, IT – Italy, SP – Spain). The coefficients are obtained using high-frequency regressions around the release and conference windows (see eq. 2), considering (1) the full sample period: January 2002 – September 2018; (2) the pre-crisis period: January 2002 – August 2008; (3) the crisis period: September 2008 – December 2013; and (4) the QE-period: September 2008 – September 2018. The responses are scaled to have unit effects on specific assets (see sub-section 2.3). We control for the surprise associated with the release of the U.S. jobless claims data in the press conference window ($USjc$). Robust standard errors are presented in the parentheses. ***, **, * denote statistical significance at 1%, 5% and 10% levels, respectively.

Table 6: Estimated effects of monetary policy surprises on sovereign bond yield spreads, press release window

(a) Full sample period: January 2002 – September 2018

	Dependent Variable								
	IT2Y	IT5Y	IT10Y	SP2Y	SP5Y	SP10Y	FR2Y	FR5Y	FR10Y
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Target	0.08	0.14	0.12**	0.05	0.05**	0.19***	0.02	0.07	0.01
	(0.05)	(0.10)	(0.06)	(0.07)	(0.02)	(0.03)	(0.04)	(0.06)	(0.05)
Duration	0.05	0.01	0.04	−0.13	−0.28***	−0.02	−0.04	−0.01	0.09**
	(0.16)	(0.09)	(0.05)	(0.09)	(0.07)	(0.08)	(0.09)	(0.04)	(0.04)
Sovereign spread	0.94***	0.82***	0.80***	0.64***	0.64***	0.71***	0.01	0.05	0.18**
	(0.14)	(0.08)	(0.06)	(0.10)	(0.08)	(0.08)	(0.05)	(0.05)	(0.08)
Observations	180	180	180	180	180	180	180	180	180
R^2	0.65	0.69	0.79	0.49	0.62	0.73	0.01	0.11	0.18

(b) Crisis period: September 2008 – December 2013

	Dependent Variable								
	IT2Y	IT5Y	IT10Y	SP2Y	SP5Y	SP10Y	FR2Y	FR5Y	FR10Y
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Target	0.06	0.19	0.13	0.001	0.05*	0.22***	0.03	0.10	0.03
	(0.08)	(0.15)	(0.09)	(0.07)	(0.03)	(0.03)	(0.05)	(0.09)	(0.07)
Duration	−0.03	−0.03	−0.07	0.05	−0.31***	−0.04	−0.11	−0.03	0.08
	(0.17)	(0.10)	(0.15)	(0.14)	(0.08)	(0.05)	(0.16)	(0.06)	(0.09)
Sovereign spread	0.93***	0.83***	0.78***	0.78***	0.69***	0.70***	−0.02	0.06	0.11
	(0.11)	(0.11)	(0.15)	(0.14)	(0.11)	(0.05)	(0.06)	(0.07)	(0.08)
Observations	63	63	63	63	63	63	63	63	63
R^2	0.73	0.70	0.77	0.60	0.66	0.80	0.04	0.20	0.07

(c) QE-period: January 2014 – September 2018

	Dependent Variable								
	IT2Y	IT5Y	IT10Y	SP2Y	SP5Y	SP10Y	FR2Y	FR5Y	FR10Y
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Target	−0.07	0.002	0.22*	0.22	0.21*	0.37*	0.03	0.01	0.02
	(0.36)	(0.21)	(0.13)	(0.22)	(0.11)	(0.21)	(0.10)	(0.06)	(0.12)
Duration	0.44	0.10	0.21**	−0.47**	−0.50***	−0.20	0.01	0.004	0.03
	(0.66)	(0.35)	(0.09)	(0.20)	(0.17)	(0.36)	(0.08)	(0.11)	(0.11)
Sovereign spread	0.73**	0.73***	0.77***	0.58***	0.69***	0.86***	0.05	0.01	0.33
	(0.33)	(0.24)	(0.15)	(0.21)	(0.07)	(0.27)	(0.11)	(0.13)	(0.24)
Observations	42	42	42	42	42	42	42	42	42
R^2	0.58	0.75	0.92	0.67	0.80	0.73	0.04	0.004	0.59

Note: The tables report the effect of monetary policy surprises on intraday changes in sovereign spreads for Italian (IT), Spanish (ES) and French (FR) bond yields. The sovereign spreads are first obtained by the difference between the responses of German yields against those of Italy, Spain and France. The coefficients are obtained using high-frequency regressions around the release and conference windows (see eq. 2), considering (1) the full sample period: January 2002 – September 2018; (2) the pre-crisis period: January 2002 – August 2008; (3) the crisis period: September 2008 – December 2013; and (4) the QE-period: January 2014 – September 2018. The responses are scaled to have unit effects on specific assets (see sub-section 2.3). Robust standard errors are presented in the parentheses. ***, **, * denote statistical significance at 1%, 5% and 10% levels, respectively.

Table 7: Estimated effects of monetary policy surprises on sovereign bond yield spreads, press conference window

(a) Full sample period: January 2002 – September 2018

	Dependent Variable								
	IT2Y	IT5Y	IT10Y	SP2Y	SP5Y	SP10Y	FR2Y	FR5Y	FR10Y
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Timing	−0.12	−0.08	0.14*	−0.19**	−0.10**	0.06	0.01	−0.01	0.005
	(0.10)	(0.06)	(0.08)	(0.09)	(0.04)	(0.07)	(0.04)	(0.06)	(0.03)
FG	0.19***	0.22***	0.21***	0.04	0.13***	0.22***	−0.06***	−0.02	0.02
	(0.05)	(0.05)	(0.05)	(0.05)	(0.04)	(0.04)	(0.02)	(0.05)	(0.02)
Save the Euro	1.01***	1.35***	1.25***	0.74***	1.04***	1.12***	−0.02	0.15**	0.22***
	(0.15)	(0.08)	(0.21)	(0.14)	(0.06)	(0.13)	(0.05)	(0.06)	(0.06)
QE	−0.18**	−0.11**	−0.003	−0.17**	−0.24**	−0.11***	−0.06*	0.05	0.08***
	(0.07)	(0.04)	(0.06)	(0.07)	(0.10)	(0.04)	(0.03)	(0.06)	(0.02)
USjc	0.21*	0.07	−0.05	0.24	0.03	−0.14*	0.09	0.20**	−0.02
	(0.12)	(0.07)	(0.10)	(0.15)	(0.08)	(0.08)	(0.09)	(0.09)	(0.05)
Observations	180	180	180	180	180	180	180	180	180
R^2	0.82	0.93	0.91	0.71	0.86	0.94	0.12	0.17	0.52

(b) Crisis period: September 2008 – December 2013

	Dependent Variable								
	IT2Y	IT5Y	IT10Y	SP2Y	SP5Y	SP10Y	FR2Y	FR5Y	FR10Y
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Timing	−0.19	−0.11*	0.22	−0.25	−0.12	0.13	0.04	−0.04	−0.01
	(0.18)	(0.06)	(0.16)	(0.17)	(0.09)	(0.12)	(0.06)	(0.11)	(0.05)
FG	0.32***	0.17***	0.15	0.11	0.06	0.19***	−0.10	−0.09	−0.02
	(0.11)	(0.06)	(0.10)	(0.13)	(0.07)	(0.07)	(0.06)	(0.11)	(0.05)
Save the Euro	1.01***	1.36***	1.27***	0.73***	1.06***	1.14***	−0.004	0.15**	0.22***
	(0.17)	(0.08)	(0.24)	(0.15)	(0.06)	(0.14)	(0.06)	(0.08)	(0.07)
USjc	0.63**	0.002	−0.27	0.58	0.04	−0.37**	0.18	0.18	−0.13
	(0.32)	(0.19)	(0.30)	(0.46)	(0.21)	(0.17)	(0.20)	(0.23)	(0.17)
Observations	63	63	63	63	63	63	63	63	63
R^2	0.86	0.96	0.92	0.74	0.91	0.95	0.14	0.29	0.52

(c) QE-period: January 2014 – September 2018

	Dependent Variable								
	IT2Y	IT5Y	IT10Y	SP2Y	SP5Y	SP10Y	FR2Y	FR5Y	FR10Y
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Timing	−0.26	−0.20*	0.08	−0.19	−0.21	0.01	−0.03	−0.02	0.10
	(0.18)	(0.12)	(0.14)	(0.21)	(0.28)	(0.19)	(0.08)	(0.16)	(0.20)
FG	−0.15	−0.01	0.56***	−0.21	−0.07	0.43**	−0.15**	−0.14	0.17
	(0.14)	(0.13)	(0.13)	(0.17)	(0.44)	(0.22)	(0.07)	(0.24)	(0.12)
Save the Euro	0.83***	1.37***	1.35***	0.70***	1.15***	1.16***	0.03	0.17**	0.26**
	(0.13)	(0.09)	(0.13)	(0.14)	(0.17)	(0.13)	(0.05)	(0.07)	(0.12)
QE	−0.10**	−0.11***	0.07*	−0.09	−0.24	−0.12**	−0.02	0.07	0.07*
	(0.05)	(0.04)	(0.04)	(0.07)	(0.19)	(0.06)	(0.03)	(0.11)	(0.04)
USjc	−0.11	0.21	−0.01	0.19	0.06	−0.06	0.10	0.09	−0.03
	(0.24)	(0.17)	(0.17)	(0.19)	(0.26)	(0.22)	(0.10)	(0.13)	(0.18)
Observations	42	42	42	42	42	42	42	42	42
R^2	0.58	0.91	0.90	0.60	0.62	0.84	0.25	0.37	0.56

Note: The tables report the effect of monetary policy surprises on intraday changes in sovereign spreads for Italian (IT), Spanish (ES) and French (FR) bond yields. The sovereign spreads are first obtained by the difference between the responses of German yields against those of Italy, Spain and France. The coefficients are obtained using high-frequency regressions around the release and conference windows (see eq. 2), considering (1) the full sample period: January 2002 – September 2018; (2) the pre-crisis period: January 2002 – August 2008; (3) the crisis period: September 2008 – December 2013; and (4) the QE-period: January 2014 – September 2018. The responses are scaled to have unit effects on specific assets (see sub-section 2.3). We control for the surprise associated with the release of the U.S. jobless claims data in the press conference window (*USjc*). Robust standard errors are presented in the parentheses. ***, **, * denote statistical significance at 1%, 5% and 10% levels, respectively.

Table 8: Intraday changes on asset prices: narrative events

Date	1M	1Y	DE2Y	DE10	FR2Y	FR10	IT2Y	IT10	ES2Y	ES10	Factor
Press release window											
2008-12-04	0.03	0.02	0.02	0.05	0.01	0.07	0.02	0.04	0.00	0.06	Duration
2009-04-02	0.05	0.04	0.09	0.05	0.05	0.05	0.05	0.05	0.08	0.05	Duration
2011-08-04	0.01	0.00	0.01	0.00	0.01	0.00	0.06	0.05	0.07	0.04	Sovereign spread
2013-11-07	0.00	-0.03	-0.05	-0.05	-0.05	-0.07	-0.12	-0.11	-0.09	-0.09	Duration
2016-03-10	0.02	0.03	0.03	-0.03	0.03	-0.07	-0.02	-0.09	-0.01	-0.10	Sovereign spread
2018-06-14	0.00	-0.01	-0.04	-0.05	-0.04	-0.06	-0.17	-0.09	-0.02	-0.04	Duration
Press conference window											
2011-12-08	0.00	-0.02	0.00	-0.02	-0.05	0.04	0.09	0.15	0.11	0.16	Save the Euro
2012-07-05	0.01	-0.01	-0.01	-0.02	-0.04	-0.01	0.22	0.17	0.11	0.16	Save the Euro
2012-08-02	0.00	0.02	-0.01	-0.09	-0.01	0.00	0.22	0.38	0.13	0.31	Save the Euro
2012-09-06	0.00	-0.01	0.00	-0.01	0.01	0.01	-0.19	-0.09	-0.13	-0.10	Save the Euro

Note: This table shows the changes in yields around the communications on the dates mentioned in the first column. Acronyms: DE – Germany, FR – France, IT – Italy, SP – Spain.

Table 9: Estimated effects of monetary policy surprises on daily expected nominal rates (AAA-rated bonds)

	Dependent Variable					
	Y5	Y10	Y5	Y10	Y5	Y10
	(1)	(2)	(3)	(4)	(5)	(6)
Target	0.99*	0.81*	1.04	0.86	1.34***	1.11***
	(0.54)	(0.47)	(0.80)	(0.70)	(0.26)	(0.27)
Duration	−0.32	−0.43	−0.56	−0.68	0.14	0.03
	(0.54)	(0.49)	(1.01)	(0.91)	(0.20)	(0.16)
Sovereign spread	0.23	0.08	−0.15	−0.25	0.23	0.03
	(0.58)	(0.52)	(1.47)	(1.32)	(0.61)	(0.47)
Timing	1.01***	0.75***	1.01**	0.77**	0.43	0.23
	(0.24)	(0.20)	(0.44)	(0.38)	(0.39)	(0.34)
FG	0.77***	0.55***	0.93**	0.68*	0.08	−0.13
	(0.14)	(0.12)	(0.41)	(0.36)	(0.64)	(0.59)
Save the Euro	−0.35	−0.23	−0.36	−0.20	−0.65	−0.55
	(0.26)	(0.23)	(0.32)	(0.29)	(0.54)	(0.49)
QE	0.18	0.07			0.03	−0.07
	(0.38)	(0.34)			(0.28)	(0.25)
USjc	0.39	0.39	0.56	0.59	0.23	0.24
	(0.55)	(0.50)	(0.82)	(0.74)	(0.36)	(0.34)
Observations	150	150	63	63	42	42
R^2	0.39	0.31	0.33	0.28	0.41	0.33

Note: These estimates are obtained by daily regressions (see equation 2) of the variables mentioned in each column on intraday monetary surprises. Models (1) and (2) deal with the full sample (January 2002 – September 2018). Models (3) and (4) take into account the crisis period (September 2008 – December 2013). Models (5) and (6) focus on the QE period (January 2014 – September 2018). The abbreviations "Y5" and "Y10" refer to maturities of 5 years and 10 years respectively. Finally, the monetary surprises are rescaled as described in sub-section 3.2. Robust standard errors are presented in the parentheses. ***, **, * denote statistical significance at 1%, 5% and 10% levels, respectively.

Table 10: Estimated effects of monetary policy surprises on daily term premiums of nominal rates (AAA-rated bonds)

	Dependent Variable					
	Y5	Y10	Y5	Y10	Y5	Y10
	(1)	(2)	(3)	(4)	(5)	(6)
Target	−0.99*	−1.00	−1.02	−1.02	−1.50	−1.76*
	(0.59)	(0.93)	(0.85)	(1.29)	(1.07)	(0.99)
Duration	1.37***	1.43**	1.82**	1.91*	0.53	0.52
	(0.52)	(0.69)	(0.76)	(1.07)	(0.32)	(0.48)
Sovereign spread	0.59	0.18	0.71	0.15	1.24	1.13
	(0.79)	(1.06)	(1.32)	(1.85)	(1.58)	(2.31)
Timing	−0.24	−0.38	−0.42	−0.57	0.60	0.43
	(0.23)	(0.29)	(0.40)	(0.52)	(0.77)	(1.29)
FG	0.17	−0.13	0.16	−0.17	1.54	1.44
	(0.13)	(0.16)	(0.43)	(0.52)	(1.38)	(2.45)
Save the Euro	−0.34	−0.32	−0.56	−0.57	0.58	0.79
	(0.37)	(0.45)	(0.45)	(0.56)	(1.11)	(1.69)
QE	0.95**	0.93			0.93*	1.00
	(0.43)	(0.62)			(0.56)	(0.98)
USjc	−0.72	−0.74	−1.43*	−1.44	−0.58	−0.89
	(0.57)	(0.72)	(0.86)	(1.08)	(0.75)	(0.94)
Observations	150	150	63	63	42	42
R^2	0.26	0.18	0.31	0.24	0.52	0.37

Note: These estimates are obtained by daily regressions (see equation 2) of the variables mentioned in each column on intraday monetary surprises. Models (1) and (2) deal with the full sample (January 2002 – September 2018). Models (3) and (4) take into account the crisis period (September 2008 – December 2013). Models (5) and (6) focus on the QE period (January 2014 – September 2018). The abbreviations "Y5" and "Y10" refer to maturities of 5 years and 10 years respectively. Finally, the monetary surprises are rescaled as described in sub-section 3.2. Robust standard errors are presented in the parentheses. ***, **, * denote statistical significance at 1%, 5% and 10% levels, respectively.

Table 11: Estimated effects of monetary policy surprises on daily sovereign spreads

	Dependent Variable					
	Y5	Y10	Y5	Y10	Y5	Y10
	(1)	(2)	(3)	(4)	(5)	(6)
Target	−0.19	−0.36	−0.33	−0.47	0.80***	0.59
	(0.39)	(0.44)	(0.48)	(0.50)	(0.28)	(0.49)
Duration	−0.15	−0.37	−0.35	−0.73	−0.04	0.11
	(0.28)	(0.32)	(0.41)	(0.45)	(0.17)	(0.23)
Sovereign spread	0.76	1.00	0.52	0.73	0.87	1.40**
	(0.85)	(0.92)	(1.22)	(1.35)	(0.54)	(0.65)
Timing	−0.14	−0.04	−0.19	−0.01	−0.12	−0.34
	(0.13)	(0.13)	(0.25)	(0.24)	(0.30)	(0.34)
FG	−0.10	0.06	−0.39	−0.09	−0.29	−0.24
	(0.12)	(0.12)	(0.30)	(0.32)	(0.44)	(0.64)
Save the Euro	0.77	1.00***	0.90*	1.13***	0.79*	0.38
	(0.51)	(0.37)	(0.54)	(0.39)	(0.43)	(0.46)
QE	−0.30*	−0.11			−0.30**	−0.07
	(0.17)	(0.18)			(0.14)	(0.25)
USjc	−0.40	−0.26	−0.64	−0.40	−0.42	−0.44
	(0.30)	(0.25)	(0.59)	(0.48)	(0.36)	(0.36)
Observations	150	150	63	63	42	42
R^2	0.22	0.33	0.25	0.41	0.38	0.32

Note: These estimates are obtained by daily regressions (see equation 2) of the variables mentioned in each column on intraday monetary surprises. Models (1) and (2) deal with the full sample (January 2002 – September 2018). Models (3) and (4) take into account the crisis period (September 2008 – December 2013). Models (5) and (6) focus on the QE period (January 2014 – September 2018). The abbreviations "Y5" and "Y10" refer to maturities of 5 years and 10 years respectively. Finally, the monetary surprises are rescaled as described in sub-section 3.2. Robust standard errors are presented in the parentheses. ***, **, * denote statistical significance at 1%, 5% and 10% levels, respectively.

Table 12: Estimated effects of monetary policy surprises on daily expected real rates (AAA-rated bonds)

	Dependent Variable					
	Y5	Y10	Y5	Y10	Y5	Y10
	(1)	(2)	(3)	(4)	(5)	(6)
Target	1.04*	0.84*	1.11	0.89	1.34***	1.11***
	(0.57)	(0.49)	(0.83)	(0.71)	(0.32)	(0.23)
Duration	−0.38	−0.46	−0.68	−0.74	0.10	0.01
	(0.64)	(0.54)	(1.18)	(1.00)	(0.21)	(0.17)
Sovereign spread	0.19	0.06	−0.34	−0.35	0.22	0.02
	(0.62)	(0.53)	(1.66)	(1.41)	(0.68)	(0.49)
Timing	0.96***	0.73***	0.94**	0.73*	0.55	0.30
	(0.23)	(0.20)	(0.46)	(0.39)	(0.56)	(0.42)
FG	0.64***	0.49***	0.78**	0.60*	0.20	−0.07
	(0.14)	(0.11)	(0.39)	(0.35)	(0.87)	(0.70)
Save the Euro	−0.24	−0.17	−0.25	−0.15	−0.42	−0.44
	(0.25)	(0.23)	(0.33)	(0.29)	(0.73)	(0.57)
QE	0.28	0.12			0.02	−0.07
	(0.45)	(0.38)			(0.36)	(0.29)
USjc	0.61	0.50	0.84	0.73	0.18	0.21
	(0.64)	(0.55)	(0.98)	(0.82)	(0.41)	(0.34)
Observations	150	150	63	63	42	42
R^2	0.29	0.25	0.25	0.24	0.33	0.28

Note: These estimates are obtained by daily regressions (see equation 2) of the variables mentioned in each column on intraday monetary surprises. Models (1) and (2) deal with the full sample (January 2002 – September 2018). Models (3) and (4) take into account the crisis period (September 2008 – December 2013). Models (5) and (6) focus on the QE period (January 2014 – September 2018). The abbreviations "Y5" and "Y10" refer to maturities of 5 years and 10 years respectively. Finally, the monetary surprises are rescaled as described in sub-section 3.2. Robust standard errors are presented in the parentheses. ***, **, * denote statistical significance at 1%, 5% and 10% levels, respectively.

Table 13: Estimated effects of monetary policy surprises on daily term premiums of real rates (AAA-rated bonds)

	Dependent Variable					
	Y5	Y10	Y5	Y10	Y5	Y10
	(1)	(2)	(3)	(4)	(5)	(6)
Target	-0.75^{*}	-0.92	-0.81	-0.99	-0.97	-1.13
	(0.45)	(0.73)	(0.65)	(1.02)	(1.46)	(1.37)
Duration	1.09^{**}	1.10^{*}	1.35^{**}	1.38	0.45	0.50
	(0.44)	(0.65)	(0.60)	(0.97)	(0.42)	(0.61)
Sovereign spread	0.94	0.43	0.55	-0.33	1.36	1.52
	(0.85)	(1.13)	(1.23)	(1.70)	(2.22)	(2.98)
Timing	-0.38	-0.45	-0.70^{*}	-0.77	0.33	-0.01
	(0.24)	(0.30)	(0.40)	(0.52)	(0.69)	(1.18)
FG	0.01	-0.28	-0.12	-0.48	1.16	0.90
	(0.13)	(0.17)	(0.43)	(0.49)	(1.08)	(2.08)
Save the Euro	-0.03	-0.003	-0.28	-0.27	1.46	1.73
	(0.46)	(0.58)	(0.52)	(0.67)	(0.99)	(1.56)
QE	1.23^{***}	1.13^{**}			1.11^{**}	1.21
	(0.34)	(0.53)			(0.43)	(0.81)
USjc	-0.33	-0.64	-0.84	-1.08	-1.09^{*}	-1.24
	(0.50)	(0.70)	(0.69)	(0.97)	(0.65)	(0.89)
Observations	150	150	63	63	42	42
R^2	0.29	0.20	0.24	0.20	0.67	0.54

Note: These estimates are obtained by daily regressions (see equation 2) of the variables mentioned in each column on intraday monetary surprises. Models (1) and (2) deal with the full sample (January 2002 – September 2018). Models (3) and (4) take into account the crisis period (September 2008 – December 2013). Models (5) and (6) focus on the QE period (January 2014 – September 2018). The abbreviations "Y5" and "Y10" refer to maturities of 5 years and 10 years respectively. Finally, the monetary surprises are rescaled as described in sub-section 3.2. Robust standard errors are presented in the parentheses. ***, **, * denote statistical significance at 1%, 5% and 10% levels, respectively.

Table 14: Identifications strategy: combination of signs

	↑ in target rate			↓ in target rate		
	Mon.	**Inf.**	**Per.**	**Mon.**	**Inf.**	**Per.**
Inflation	↓	↑	↓	↑	↓	↑
Stock prices	↓	↑	↓	↑	↓	↑
Risk-free rate (Rf)	↑	↑	?	↓	↓	?
Risky rate	?	?	↑	?	?	↓
Risky>Rf	No	No	Yes	No	No	Yes

Note: "Mon." stands for "Monetary, "Inf." for "Information" and "Per." for "Perception". Changes in the target rate are supposed to be unanticipated. The up (↑) and down (↓) arrows indicate the sign of response to the type of shock mentioned. A question mark (?) underlines that we leave the response of this variable open. "Risky>Rf" indicates that for this type of shock, the response of the risky rate is wider than that of the risk-free rate.

Table 15: Relevance of the instruments, (F-statistics)

	Duration		Sovereign spread		Save the Euro	
	Crisis	QE	Crisis	QE	Crisis	QE
10y risk-free rate	13.14***	5.16**	-	-	-	-
10y risky rate	-	-	0.26	13.07***	6.06**	18.25***
Robustness						
10y Italian yields	13.14***	5.16**	1.09	6.92***	55.68***	38.08***
10y Spanish yields	13.14***	5.16**	0.62	9.35***	64.53***	38.93***

Note: This table presents the F-statistics for the regression of each surprise on the reduced-form residuals of each of the daily VAR models to which they belong. The endogenous variables of each model are the 10-year AAA nominal rate (risk-free, for "Duration" surprises), the 10-year AAA rate and other (risky, for "Sovereign spread" and "Save the Euro" surprises) rates, 10-year inflation rate and logarithm of the Euro Stoxx 600 index (stock market index). We instrument the residuals of the 10-year AAA nominal (risk-free) rates with the surprises of the "Duration". Residuals of AAA nominal 10-year rates and other (risky) rates are instrumented by the "Sovereign spread" and "Save the Euro" factors. Our estimated risky rates are based on AAA-rated and other rates, which means that a portion of the estimates is "risk-free" (see Appendix C for further details). As such, they can only be a lower bound estimate of risky rates. Therefore, we check whether the instrumentation is performed on the observed Italian and Spanish yields. In view of the high significance, we decided to keep the instrumentation by "Save the Euro" factors in the crisis sub-period. Note that the impulse response functions are qualitatively similar in all three cases (risky rates (benchmark), 10y Italian yields and 10y Spanish yields). The outcome is the same for the QE sub-period and the instrumentation by the "Sovereign spread" surprises. ***, **, * denote statistical significance at 1%, 5% and 10% levels, respectively.

Figure 1: Sequence of events: ECB monetary communications

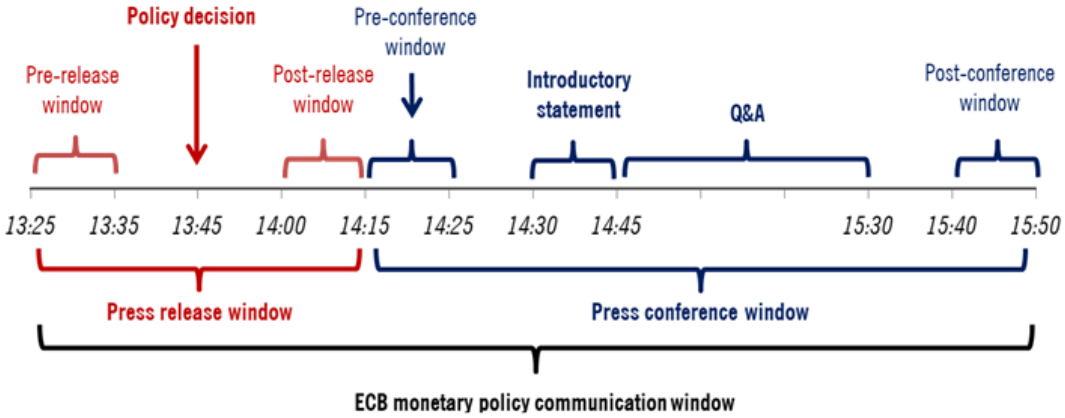
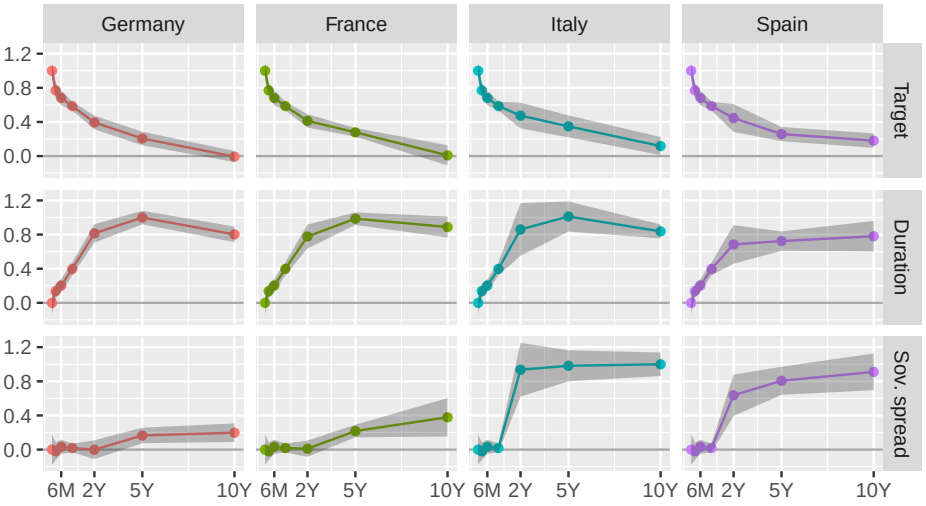
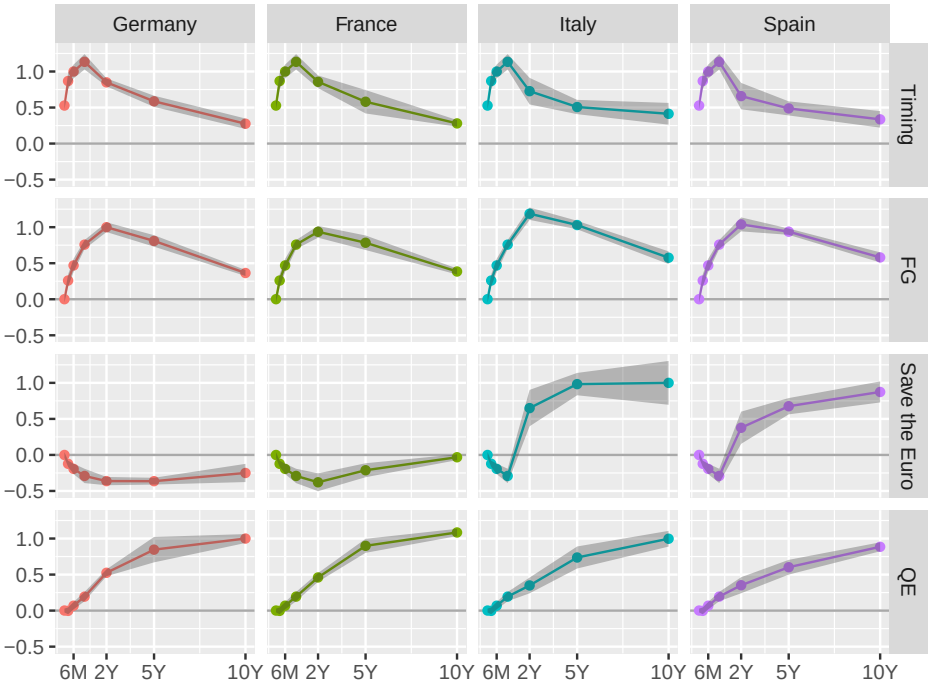


Figure 2: Factor loadings

(a) Press release window



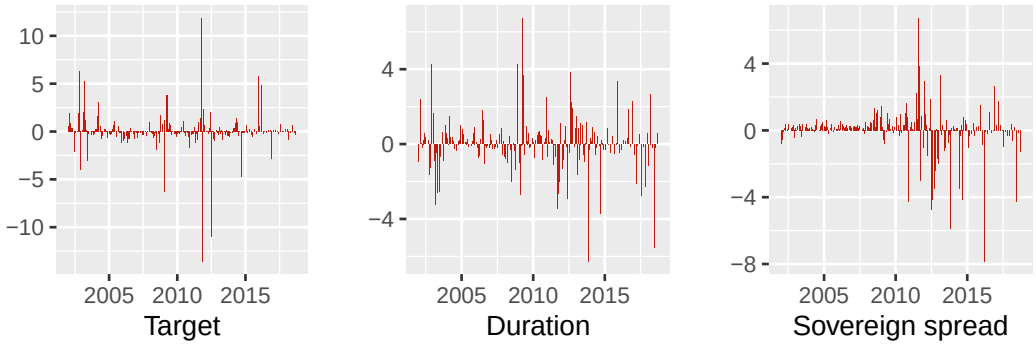
(b) Press conference window



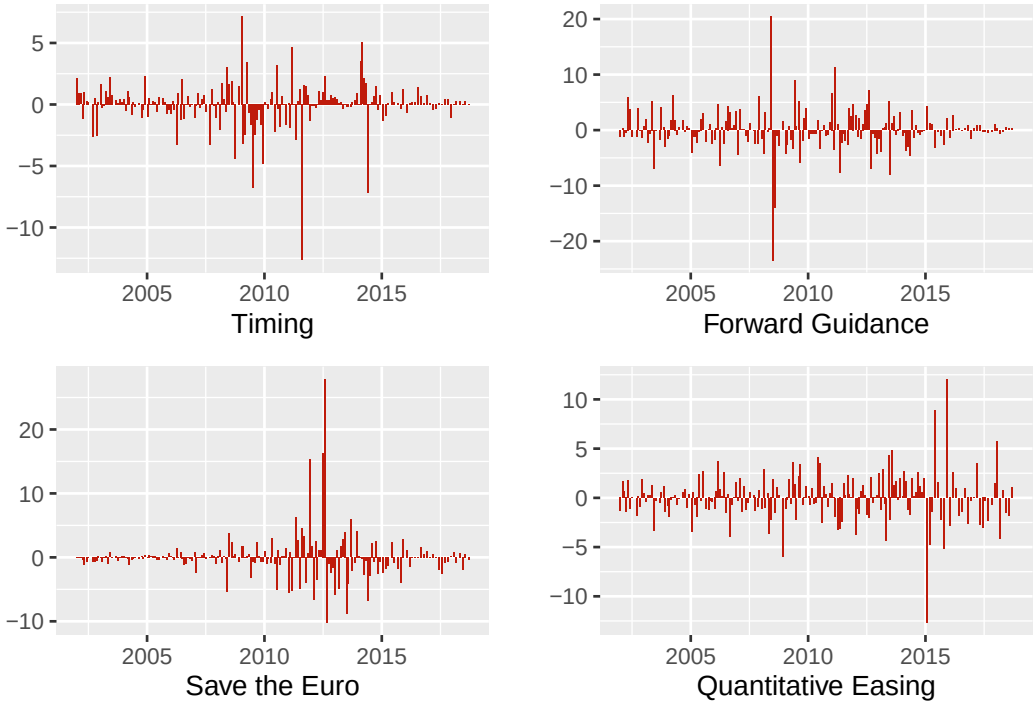
Note: OIS rates with maturities of 1, 3, 6 months and 1 year are common to each country. The 2, 5 and 10-year maturities are specific to each country. Panel (a) shows the loadings for the press release window and panel (b) for the conference window. For each maturity, the loadings are obtained by regressing the variable of interest on factors, also taking into account the surprise associated with the release of U.S. jobless claims data in the press conference window. The shaded areas represent the 95% confidence intervals around the point estimates.

Figure 3: Structural monetary surprises in the Euro area

(a) Press release window



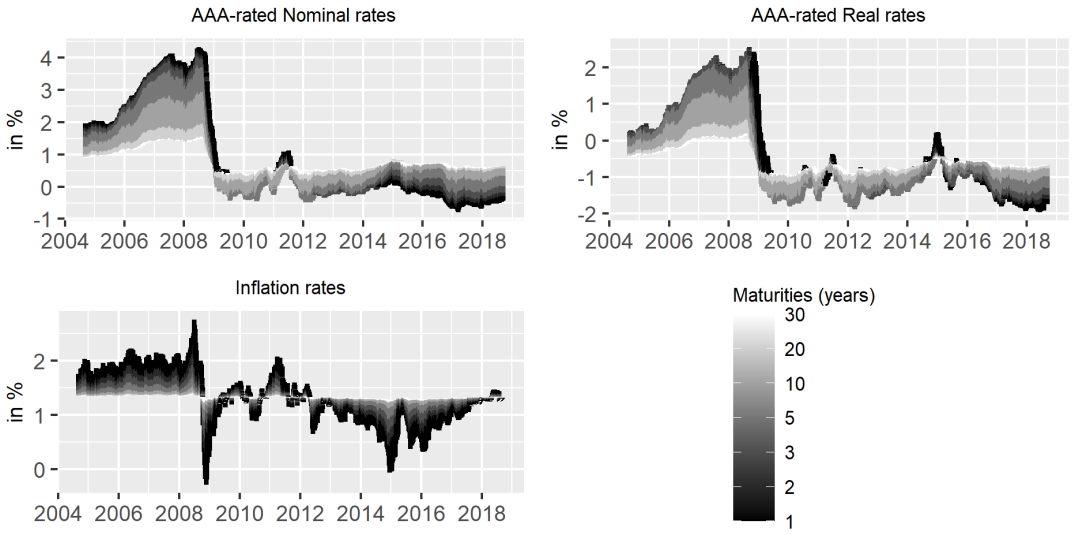
(b) Press conference window



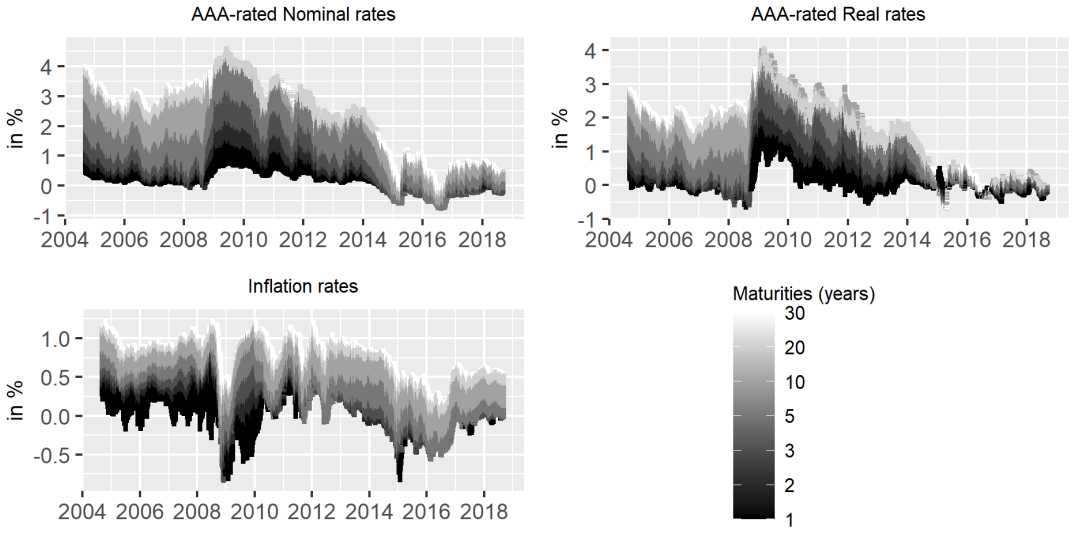
Note: The figures display series of identified factors for the period from January 2002 to September 2018. The series are obtained by extracting the principal components through SVD (3 in the press release window and 4 in the press conference window). Then, the factors are rotated following the identification strategy detailed in Appendix C.

Figure 4: Daily estimates of nominal, real and inflation rates from the DNSS models

(a) Expectations of short-term rates

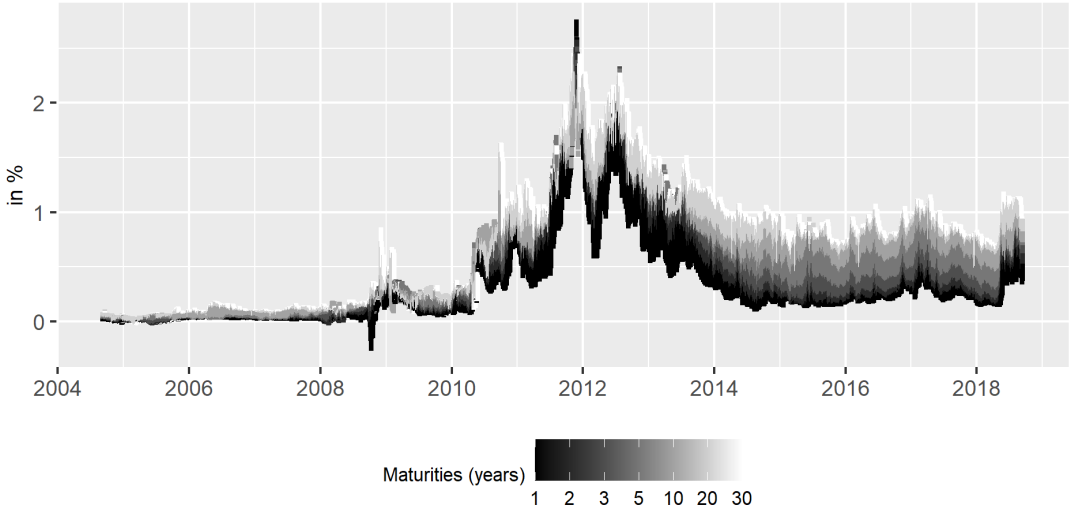


(b) Term premiums



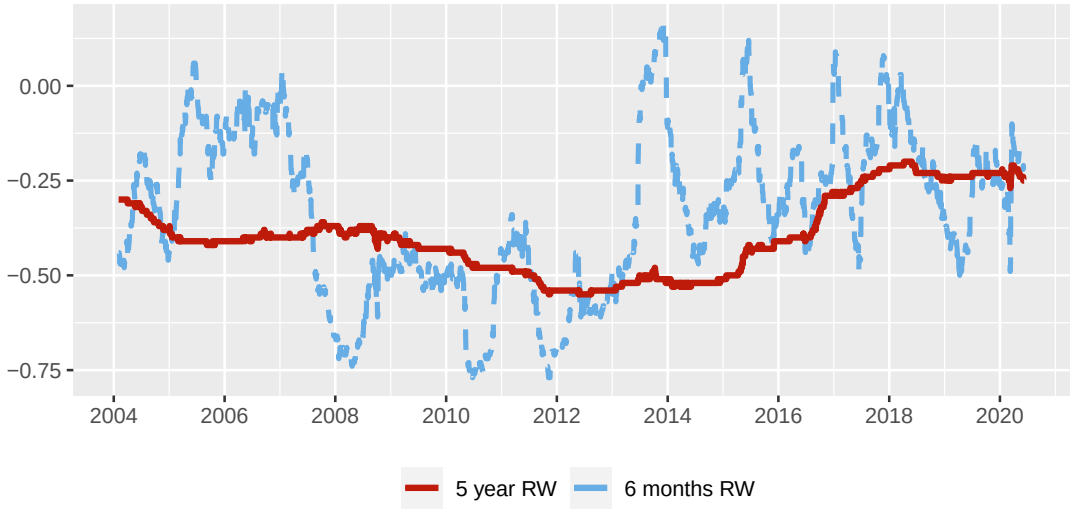
Note: Panel (a) shows the expectation components of AAA nominal and real rates and inflation rates. Panel (b) displays the term premiums for AAA nominal and real rates and inflation rates. The series are estimated using two independent DNSS models (see methodology in Appendix C) on daily spot rates for AAA-rated Euro area government bonds and inflation-linked swaps (data sources are given in Appendix B). The maturities represented are: 1 year, 2 years, 3 years, 5 years, 10 years, 20 years and 30 years (these maturities are based on the availability of daily ILS).

Figure 5: Daily estimates of sovereign spreads from DNSS models



Note: The series are estimated using the constant-maturity differences between two independent DNSS models (see methodology in Appendix C) on daily spot rates for AAA-rated Euro area government bonds and all Euro area central government bonds (including AAA-rated) (data sources are given in Appendix B). The maturities represented are: 1 year, 2 years, 3 years, 5 years, 10 years, 20 years and 30 years (these maturities are based on the availability of daily ILS).

Figure 6: Daily rolling correlations between stock and bond returns in the Euro area



Note: This figure shows the daily correlations between the log difference in the European stock and bond returns on 5 years and 6 months rolling windows. The data are obtained from Thomson Reuters Datastream. The stock prices index is extracted from "Stoxx Europe 600 E - price index". The bond prices index is given by the "EMU Benchmark 10 yr. DS Govnt. Index".

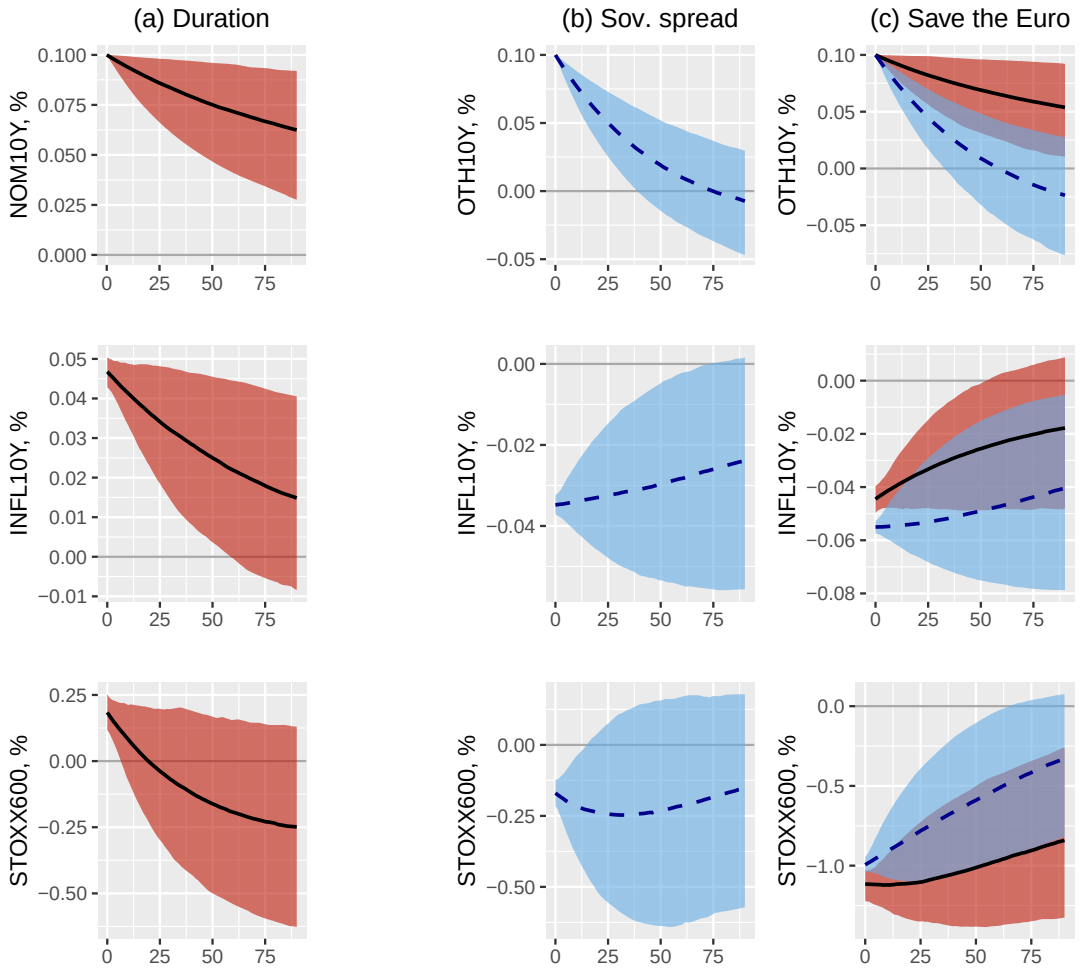
Figure 7: Fitted daily changes in risk-free and risky rates after monetary surprises

Note: The first and second panels shows the daily reaction of 2-year AAA-rated nominal yields and 2-year AAA-rated and others in response to the combination of monetary surprises for each communication (release+conference). The abbreviation "AAA. shock" means that at the time of this communication the risk-free rates (AAA-rated only) reacted more than risky rates (AAA-rated and others). The abbreviation "Oth. shock" means that at the time of this communication risky rates reacted more than risk-free rates.

Figure 8: Classification: Monetary, Information and Perception shocks

Note: The first panel shows the daily reaction of 2-year AAA-rated nominal rates (risk-free) in response to the combination of monetary surprises for each communication (release+conference). The second panel displays the daily reaction of 2-year AAA-rated and other nominal rates (risky) in response to the combination of monetary surprises for each communication (release+conference). Each color then represents the type of shock that has been identified during this event (see the legend). For more details on the procedure for identifying combined monetary surprises, refer to sub-section 4.1 and Table 14.

Figure 9: Daily VAR, impulse responses to "Information" and "Perception" shocks instrumented by "Duration", "Sovereign spread" and "Save the Euro" surprises



Note: Impulse responses surrounded by red confidence intervals relate to the crisis period (September 2008 – December 2013). Responses with blue intervals relate to the QE period (January 2014 – September 2018). 95% confidence interval bands are obtained with 1000 bootstrap replications. Each panel shows the impulse responses linked to the shocks instrumented by the surprises of "Duration" (a), "Sovereign spread" (b) and "Save the Euro" (c), respectively. "INFL10Y" shows the responses (in %) of the 10-year inflation-linked swaps. "NOM10Y" reports the responses (in %) of the nominal 10-year AAA-rated rates (risk-free). "OTH10Y" gives the responses (in %) of the 10-year AAA-rated and others rates (risky). "STOXX600" returns the variation (in %) of the logarithm in Euro area stock prices. Further details can be found in the sub-section 4.2

Appendix B: Data

Intraday data for factor identification:

Variables: changes in the prices of (around the release and conference windows separately): 1-month OIS, 3-month OIS, 6-month OIS, 1-year OIS, 2-year German bond yields, 5-year German bond yields, 10-year German bond yields, 2-year French bond yields, 5-year French bond yields, 10-year French bond yields, 2-year Italian bond yields, 5-year Italian bond yields, 10-year Italian bond yields, 2-year Spanish bond yields, 5-year Spanish bond yields, 10-year Spanish bond yields.

Source: Euro Area Monetary Policy Event-Study Database (EA-MPD), url: https://www.ecb.europa.eu/pub/pdf/annex/Dataset_EA-MPD.xlsx. More details are available in the online appendix of ABGMR.

Intraday data for high-frequency regressions:

Variables: Euro area stock price index: Euro Stoxx 50

Source: Euro Area Monetary Policy Event-Study Database (EA-MPD), url: https://www.ecb.europa.eu/pub/pdf/annex/Dataset_EA-MPD.xlsx.

Daily data for DNSS models:
Variables: spot rates of the AAA-rated Euro area central government bonds and all Euro area central government bonds (including AAA-rated). Maturities: 3-month, 6-month, 9-month and all years from 1-year to 30-year.

Source: Euro area government bond yield curves, Statistical Data Warehouse European Central Bank, url: https://sdw.ecb.europa.eu/browse.do?node=9691417

Variables: zero-coupon inflation-linked swaps (ticker: EUSWIx in Bloomberg, x stands for the maturity). Maturities: 1-year, 2-year, 3-year, 5-year, 10-year, 20-year, 30-year.

Source: Bloomberg

Variable: BBB-AAA corporate bond spread.

Source: Altavilla et al. (2019) (ABGMR), file named: `05daily_data_var`, url: http://www.bilkent.edu.tr/~refet/ABGMR_replication_files.zip

Appendix C: Methods

Testing procedures

We select nine (1M OIS, 3M OIS, 6M OIS, 1Y OIS, 2Y Germany, 5Y Germany, 10Y Germany, 5Y Italy, 10Y Italy) of the 16 assets that compose our full sample to perform our tests in each window separately. These variables are sufficient to represent the maturity spectrum of the risk and risk-free yield curves. Note that the number of factors obtained is robust to changes in the selected assets (if the full spectrum is maintained). We do this for several reasons. First, Cragg and Donald (1997) is a type of minimum discrepancy type test being chi-squared distributed. In other words, to infer the rank of an unknown matrix W_0, the test considers a statistic $\hat{W}$, under H_0, that converges to a weighted chi-square distribution. However, as shown by Portier and Delyon (2014), the actual distribution of the statistic may differ from the asymptotic distribution. The main reason is that the test involves the inversion of a large matrix. We therefore limit our sample to be parsimonious and avoid potential singularity problems (that we observe when the matrix of data is fatter in the sub-periods if we use 16 variables: T smaller, N larger). Second, the test tends to favor too many factors as the sample size increases. If these other factors are not related to noise, it is nevertheless difficult to make economic interpretations of additional monetary dimensions (as these factors are related to variations specific to each country, not really general).

All of these do not call into question the validity of this test, which, to our knowledge, is one of the few that can statistically determine the number of factors in a small sample. In our analysis, alternative tests like Bai and Ng (2002) favor greater numbers of factors in all cases.

Factor Identification

Our identification procedure follows Swanson (2017) and Altavilla et al. (2019).[50] Let us recall that our factor models are of the form of:

$$X^w = F^w \Lambda^w + \varepsilon^w, \tag{6}$$

where for each w, X^w contains $(n = 16)$ standardized intraday asset price responses. We extract 3 and 4 principal components in the release and conference windows respectively (using singular value decomposition). Like this, the factors are not identified. We therefore rotate them to obtain structural interpretations (identified up to scale). Let U^w be an orthogonal matrix. The equation is (6) is equivalent to:

$$X^w = F^w U^w (U^w)' \Lambda^w + \varepsilon^w, \tag{7}$$

Define $\widetilde{F^w} \equiv F^w U^w$, $\widetilde{\Lambda^w} \equiv (U^w)' \Lambda^w$. From all possible models, we seek to find a unique rotation matrix U^w that maps the principal components F^w into factors $\widetilde{F^w}$ that have our structural interpretations.

In the press the release window, the (3×3) orthogonal matrix U requires 3 restrictions. As discussed in the sub-section 2.2, the first two identifying restrictions impose that second and third factors have no effect on 1-month OIS rate. The latter can be written as:

$$U' \Lambda_1 = \begin{array}{c} \\ Target: \\ Duration: \\ Sovereign\ spread: \end{array} \begin{array}{c} 1\text{M} \\ \begin{bmatrix} * \\ 0 \\ 0 \end{bmatrix} \end{array} \tag{8}$$

where Λ_1 denotes the first column of Λ, i.e. the loadings of the 1-month OIS rate on the three factors. Let U_i denote the i'th column of U. Then, $\Lambda_1' U_2 = 0$ and $\Lambda_1' U_3 = 0$.

Our third restriction minimizes the variance of the "Sovereign spread" factor in the pre-crisis period (i.e. from January 2002 to August 2008). Hence, we solve for $U_3' (F^{preC})' F^{preC} U_3$, where F^{preC} denotes the "Sovereign spread" factor in the pre-crisis period.

In the press conference window, the unique (4×4) orthogonal matrix U requires 6 restrictions. As explained in more detail in the sub-section 2.2, the first three identifying restrictions impose that the "Forward Guidance", "Save the Euro" and "QE" factors have no effect on 1-month OIS. The fourth restriction dictate that the "QE" factor does not load on 3-month OIS changes:

[50] We would like to thank Eric T. Swanson for sharing his Matlab codes to replicate his identification procedure in Swanson (2017).

$$U'\Lambda_{1:2} = \begin{array}{c} \\ Timing: \\ FG: \\ Save.: \\ QE: \end{array} \begin{array}{c} \text{1M, 3M} \\ \begin{bmatrix} * & * \\ 0 & * \\ 0 & * \\ 0 & 0 \end{bmatrix} \end{array} \tag{9}$$

where $\Lambda_{1:2}$ denotes the first and the second columns of Λ, i.e. the loadings of the 1-month and 3-month OIS rate on the four factors. Let U_i denote the i'th column of U. In summary, $\Lambda_1' U_2 = 0$, $\Lambda_1' U_3 = 0$, $\Lambda_1' U_4 = 0$, and $\Lambda_2' U_4 = 0$.

Moreover, the fifth restriction minimizes the variance of the "Save the Euro" factor in the pre-crisis period (i.e. from January 2002 – August 2008): $U_3'(F^{preC})'F^{preC}U_3$, and the sixth restriction minimizes the variance of the "QE" factor in the pre-QE period (i.e. from January 2002 – December 2013): $U_4'(F^{pre-QE})'F^{pre-QE}U_4$, where F^{pre-QE} represents the value of the "QE" factor in the pre-QE period.

Overall, these restrictions allow to uniquely identify $\widetilde{F}$ only up to scale. We rescale the factors as indicated in sub-section 2.2.

DNSS procedures

We use three different and independent dynamic Nelson-Siegel-Svensson DNSS (Christensen et al. (2009)) models to estimate (and their decompositions) nominal and real daily rates, as well as inflation and sovereign credit spreads.

The *raw* data for this dynamic decomposition are extracted from: Euro area government bond yield curves, Statistical Data Warehouse European Central Bank (nominal rates) and Bloomberg (inflation-linked swaps) (see Appendix B for further details).

One DNSS model is applied to the AAA spot rates (33 maturities), another to the AAA and other spot rates (33 maturities), and the last to the inflation-linked swaps (7 maturities).

The dynamic model representation of a DNSS yield curve is given by:

$$y_t(\tau) = L_t + S_t\left(\frac{1-e^{-\lambda_1\tau}}{\lambda_1\tau}\right) + C_t^1\left(\frac{1-e^{-\lambda_1\tau}}{\lambda_1\tau} - e^{-\lambda_1\tau}\right) + C_t^2\left(\frac{1-e^{-\lambda_2\tau}}{\lambda_2\tau} - e^{-\lambda_2\tau}\right) \tag{10}$$

where $y_t(\tau)$ is the zero-coupon yield, with τ the time to maturity and λ_1 and λ_2 model parameters. Christensen et al. (2009) show that L_t, S_t, C_t^1 and C_t^2 can be interpreted as level, slope, and two curvature factors. Our DNSS models are estimated using Ken Nyholm's term structure modeling class programmed in Matlab. Url: https://ken-nyholm.com/matlab.html. This website also contains a detailed explanation of how the decomposition between expectations and term premiums is carried out.

The synthetic real rates are obtained by the difference between our resulting estimates of the daily constant maturity rates of AAA-rated bonds and inflation rates. Finally, the sovereign spreads are the differences between our resulting estimates of the daily constant maturity rates of AAA-rated bonds and AAA-rated and others bonds.

Appendix D: Miscellaneous

This list provides the sources and market commentaries that were used in our narrative analysis of sub-section 2.4.

Duration factor:
1. ECB announcement on April 2, 2009:

- "The interest rate on the main refinancing operations of the Eurosystem will be decreased by 25 basis points to 1.25%".
  Source: ECB press release document, available on: https://www.ecb.europa.eu/press/pr/date/2009/html/pr090402.en.html

- "The ECB cut its main lending rate by 25 basis points to 1.25 per cent, confounding expectations for a 50 basis point move".
  Source: Financial Times online article *"Euro jumps after ECB rate decision"*, published on April 2, 2009, available on: https://on.ft.com/2ScBihM.

2. ECB announcement on November 7, 2013:

- "The interest rate on the main refinancing operations of the Eurosystem will be decreased by 25 basis points to 0.25%".
  Source: ECB press release document, available on: https://www.ecb.europa.eu/press/pr/date/2013/html/pr131107.en.html

- "The European Central Bank still managed to shock almost everyone on Thursday by cutting rates in response to fears that the currency bloc could succumb to deflation".
  Source: Financial Times online article *"Q and A: what caused the ECB to act"*, published on November 7, 2013, available on: https://on.ft.com/35cbUhl.

3. ECB announcement on June 14, 2018:

- "The Governing Council anticipates that, after September 2018, [...] the monthly pace of the net asset purchases will be reduced to €15 billion until the end of December 2018 and that net purchases will then end".
  "The Governing Council expects the key ECB interest rates to remain at their present levels at least through the summer of 2019".
  Source: ECB press release document, available on: https://www.ecb.europa.eu/press/pr/date/2018/html/ecb.mp180614.en.html

- "[The] dovishness on interest rates calmed market nerves that had been jolted by recent political turbulence in Italy".
  Source: Financial Times (Europe) ePaper article *"ECB moves to pull plug on*

€2.4tn stimulus scheme by end of year", Friday, June 15, 2018. Section: Front Page, Page: 1.

Sovereign spread factor:
1. ECB announcement on August 4, 2011:

- "The interest rate on the main refinancing operations and the interest rates on the marginal lending facility and the deposit facility will remain unchanged".
  Source: ECB press release document, available on: https://www.ecb.europa.eu/press/pr/date/2011/html/pr110804.en.html

- Jose Manuel Barroso (then head of the European Commission) had declared on August 3, 2011: "The tensions in bond markets reflect a growing concern among investors about the systemic capacity of the Euro area to respond to the evolving crisis."
  Source: Financial Times (Europe) ePaper article *"Europe sparks global sell-off"*, Thursday, August 04, 2011. Section: Front Page, Page: 1.

2. ECB announcement on March 10, 2016:

- "The monthly purchases under the asset purchase programme will be expanded to €80 billion starting in April".
  "The interest rate on the main refinancing operations of the Eurosystem will be decreased by 5 basis points to 0.00%".
  Source: ECB press release document, available on: https://www.ecb.europa.eu/press/pr/date/2016/html/pr160310.en.html

- "The ECB raised the amount of bonds the eurozone's central bankers buy each month under QE from a 60bn to a 80bn a greater amount than many analysts had expected".
  Source: Financial Times (Europe) ePaper article *"ECB cuts rates and boosts QE to ratchet up eurozone stimulus"*, Friday, March 11, 2016. Section: Front Page, Page: 1.

Save the Euro factor:
1. ECB announcement on December 8, 2011:

- In the Question and Answer session, Mr. Draghi said that the ECB will not boost ECB sovereign bond purchasing: "The answer to the first question is no".
  Source: The ECB introductory statement to the press conference (with Q&A), available on: https://www.ecb.europa.eu/press/pressconf/2011/html/is111208.en.html

- "The market reaction compounded earlier investor disappointment with remarks from Mario Draghi, European Central Bank president, who played down the prospect of boosting ECB sovereign bond purchasing". *Source:* Financial Times (Europe) ePaper article *"Banks' shortfall at €115bn"*, Friday, December 09, 2011. Section: Front Page, Page: 1.

3. ECB announcement on July 5, 2012:

- In the Question and Answer session, Mr. Draghi gave no details about bond-buying by the ECB: "I do not think I want to elaborate on further non-standard measures at this point in time".
  Source: The ECB introductory statement to the press conference (with Q&A), available on: https://www.ecb.europa.eu/press/pressconf/2012/html/is120705.en.html.

- "The action by the ECB did little to lift sentiment on European assets".
  Source: Financial Times (Europe) ePaper article "Central banks take action", Friday, July 06, 2012. Section: Front Page, Page: 1.

2. ECB announcement on August 2, 2012:

- "The adherence of governments to their commitments, namely fiscal reforms, structural reforms and so on, and the fulfilment by the EFSF/ESM of their role are necessary conditions for some actions on the ECB's side. So, the first thing is that governments have to go to the EFSF, because, as I said several times, the ECB cannot replace governments".
  Source: The ECB introductory statement to the press conference (with Q&A), available on: https://www.ecb.europa.eu/press/pressconf/2012/html/is120802.en.html.

- "Draghi disappoints markets".
  Source: Financial Times (Europe) ePaper article *"Draghi disappoints markets"*, Friday, August 03, 2012. Section: Front Page, Page: 1.

4. ECB announcement on September 6, 2012:

- "[...] the Governing Council today decided on the modalities for undertaking Outright Monetary Transactions (OMTs) in secondary markets for sovereign bonds in the Euro area."
  Source: The ECB introductory statement to the press conference (with Q&A), available on: https://www.ecb.europa.eu/press/pressconf/2012/html/is120906.en.html.

- "ECB signals resolve to save euro".
  Source: Financial Times (Europe) ePaper article *"ECB signals resolve to save euro"*, Friday, September 07, 2012. Section: Front Page, Page: 1.