Central Bank Communication and the Yield Curve*

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Abstract

Using the institutional features of ECB monetary policy announcements, we provide direct evidence for the risk premium channel of central bank communication. We show that on days when the ECB announces its monetary policy almost all of the variation of bond yields is driven by communication. Moreover, while the effect of monetary policy is homogeneous across countries before the European debt crisis, we document dramatic differences post crisis and show that communication shocks drive a wedge between peripheral and core yields. We empirically link the periphery-core wedge to break-up and credit risk premia, and study this channel theoretically through the lens of an equilibrium model in which central bank communication reveals information about the state of the economy.

Keywords: interest rates, monetary policy, central bank communication, risk premia, Eurozone.

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A central challenge in macroeconomics and asset pricing is to understand what impact monetary policy has on long-term real and nominal interest rates and through which channels policy operates.[1] The effectiveness of monetary policy, however, does not solely depend on the control of short-term interest rates but also on central banks' ability to shape market participants' beliefs, and central bank communication has emerged as a key tool for controlling those beliefs.[2]

This paper provides direct evidence that monetary policy affects long-term rates by influencing the risk premium investors require to hold long-term bonds, and that this is mainly induced by central bank communication. To this end, we exploit an institutional feature of the European Central Bank (ECB), which allows us to decompose monetary policy surprises into target and communication shocks. We identify the risk premium channel by focusing on cross-sectional differences in sovereign bond yields within the Eurozone. Indeed, simple accounting says that long-term interest rates are equal to expected future short rates plus a risk premium. Since the target rate is the same across Euro-area countries, changes in yield spreads around monetary policy decisions must be informative about potential risk premium channels. With our observation in hand, we document that communications by the ECB drove a wedge between peripheral and core countries' bond yields at a time when unconventional policies were being designed to reduce the spread. Empirically, we relate this wedge to a Euro-area break-up premium, and rationalize this finding within a multi-country single-currency equilibrium model in which central bank communication reveals information about the state of the Eurozone.

While most central banks inform the public about their monetary policy decisions, on the day of Governing Council meetings the ECB releases a press statement with the current policy decision, and 45 minutes later holds a separate press conference.[3] Hence, the institutional details of the ECB allow a decomposition of intraday changes in the Euro-area money market rates into news related to the level of the ECB policy interest rate (target rate shocks) and news related to the future path of monetary policy or the economy more generally (communication shocks). Moreover, the ECB has conducted some form of 'forward guidance' since inception, so it is a policy tool that extends well before the zero lower bound period.[4]

With the two shocks in hand, we document a number of novel results. First, target rate shocks affect bond yields almost one-for-one at the short end of the yield curve but

[1]A large literature argues that monetary policy shocks, as measured by high-frequency movements in short-term interest rates, have surprisingly large effects on long-term interest rates. However, while Gilchrist, López-Salido, and Zakrajšek (2015), Gertler and Karadi (2015), and Hanson and Stein (2015) argue that monetary policy primarily works by affecting term premia, Nakamura and Steinsson (2017), among others, suggest that the response to policy surprises reflects the fact that nominal rigidities are far stronger than assumed.

[2]For example, Svensson (2004) argues that "monetary policy is to a large extent the management of expectations," while according to Woodford (2003), "not only do expectations about policy matter, but ... very little else matters."

[3]The U.S. Federal Reserve introduced press conferences on a quarterly frequency in April 2011.

[4]For example, former ECB president Jean-Claude Trichet was active in steering rates both with his 'traffic light' system of varying degrees of 'vigilance' to signal upcoming rate hikes and with his comments on the appropriateness of the prevailing yield curve.

have little impact on long-term yields. Overall, the magnitude is in line with an earlier literature studying the effect of U.S. monetary surprises on bond yields. Communication shocks, however, have large effects on bond yields, being most pronounced for intermediate maturities but also having significant impact at long term maturities. For example, we find that during the 2001 to 2014 period, in response to a hypothetical 100bp change in the communication shock, two-year German bond yields move 150bps, while ten-year German yields move 60bps. Comparing their joint impact, we show that while target shocks can have a significant impact on bond yields in the statistical sense, almost all explained variability in bond yields on ECB days is due to communication.

Second, we split our sample into the pre- and post-crisis periods. We find that before 2009, monetary policy shocks affected bond yields of all Euro-area countries uniformly. After 2009, however, a differential effect of communication shocks arose between core and peripheral yields, which increased yield spreads at a time when unconventional measures were implemented to reduce them.[5] Specifically, we show that post crisis, peripheral yields' response to communication shocks became muted, whereas core country reactions were unchanged. Using rolling regressions, we find that the effect of central bank communication on peripheral bond yields began to decline in early 2011, becoming insignificant by 2013. Combining this observation with the fact that communication shocks were mostly negative post 2009—meaning that the market had expected higher future short rates than what the ECB then signalled—we show that yields went down in core countries considerably whereas peripheral countries' yields did not react. As a result, communication is responsible for a significant wedge that, at its peak around the end of 2011, represented 20% of the total two-year yield spread.

We attribute the heterogeneous effect of communication shocks on core and peripheral countries to an emergence of a risk premium that affects peripheral bond yields but not core countries' yields, and consider different channels.[6] In particular, by promising to keep interest rates low for an extended period, central banks can signal bad news to the market and this influences peripheral countries more than core countries. We find that monetary policy significantly affected neither break-even inflation, nor market risk (as captured by stock returns), nor illiquidity in bond markets. One natural candidate to explain this wedge is the fear of a Euro-area breakup and sovereign default risk. Indeed, this is alluded to in ECB President Draghi's famous "whatever it takes" speech in which he relates peripheral countries' high borrowing costs to the emergence of liquidity, redenomination, and credit risk. To test this hypothesis, we explore the effect of monetary policy shocks on credit default swaps (CDS) and CDS quanto spreads. The latter are the difference between two otherwise identical CDSs denominated in different currencies; in case of the Euro-area, these are CDS

[5] We define the core as Germany and France, and the periphery and Italy and Spain. These countries account for about 76% of the total GDP of the Eurozone.

[6] A large literature studies whether monetary policy affects risk premia. For example, most of the unconventional monetary policy measures undertaken during the financial crisis by the U.S. Fed have compressed term premia and directly targeted other risky assets. However, it is well-known that monetary policy also affects risk premia in "normal times"; see, e.g., Yellen (2011).

in U.S. dollars and Euros. A potential default of a Eurozone country would immediately trigger a devaluation of the Euro vis-à-vis the dollar and hence Euro-area CDS denominated in dollars trade at a higher spread (and are in general also more liquid). Therefore, CDS quanto spreads do not capture just credit risk of a country per se, but rather the expected devaluation of the Euro as well as the correlation between default risk and currency risk. We find that communication shocks have a significant effect on CDS spreads of all countries and the effect is much larger for peripheral countries. Moreover, while communication shocks have no effect on quanto spreads of core countries, peripheral quanto spreads significantly increase on ECB announcement days as a reaction to shocks in communication.

Finally, when we control for CDS or CDS quanto spreads in a regression from peripheral and core bond yields on monetary policy shocks, we find the estimated coefficients on the communication shocks to be aligned between core and peripheral countries. In other words, CDS and quanto spreads represent a large part of the "missing risk premium" when studying the effect of communication shocks on sovereign bond yields.

To shed light on the question of why central bank communication commands a risk premium, we develop an equilibrium term structure model in which monetary policy, via a signalling channel, induces demand shocks in the fixed-income market. We consider a currency union of two countries that we refer to as Eurozone and study the impact of monetary policy shocks that change the perceived probability of the breakup of this union, and hence, impact the demand of risk-averse banks for sovereign bonds.

Within the model, when the central bank announces changes to the intended path of monetary policy, bond yields can be affected in two ways. The direct impact of monetary policy operates through the expectation channel: a positive current target rate shock increases all future expected target rates. Thus, as a reaction, all yields go up. In addition, central bank communication provides information about intended future (medium-term) target rates, so a positive communication shock also increases bond yields.

The second, indirect, effect works through the risk premium channel: by providing information about the probability of breakup and thus of suffering losses on risky bond holdings, monetary policy shocks also influence the demand of risk-averse banks. In our model, a negative target rate or communication shock is interpreted as bad news; it makes banks less willing to hold risky bonds, so in equilibrium, they demand higher risk premia on all debt. Since negative monetary policy shocks also lower rates via the expectation channel, the risk premium channel dampens the overall effect of monetary policy. However, as banks suffer larger losses on peripheral bonds conditional on breakup, peripheral bond returns and yields are more exposed to breakup risk. Because the expectation channel is identical for bonds of the two countries, core country bond yields are overall more responsive to monetary policy shocks than peripheral bonds. Hence, our model provides an understanding of how target and communication shocks can affect bond prices in equilibrium across countries.

The rest of the paper is organized as follows. After the literature review, Section 1 describes the institutional settings of ECB monetary policy days and Section 2 outlines the estimation and identification of the monetary policy shocks. We present our main empirical findings in Sections 3 and 4, and provide a theoretical model in Section 5. Section 6 concludes. An Online Appendix gathers additional results omitted from the main paper.

Related literature: This paper contributes to several strands of the literature. First, a handful of papers have studied how central bank communication can affect asset prices. Ehrmann and Fratzscher (2005) compare the communication strategies of the Federal Reserve, the Bank of England, and the ECB by measuring the tone in speeches and statements. Their findings suggest that central bank communication is a key determinant of the market's ability to anticipate monetary policy decisions and the future path of interest rates. Rosa and Verga (2008) examine the effect of ECB communication on the price discovery process in the Euribor futures market using a tick-by-tick dataset. Brand, Buncic, and Turunen (2010) study the effect of monetary policy shocks on Eurozone money market rates. A number of studies have constructed wording indicators to classify the content of the statements of the ECB's or Fed's press conferences. Lucca and Trebbi (2011) construct a hawkish/dovish indicator from statements of Federal Open Committee Members and find longer-dated yields react to changes in communication around announcements. Schmeling and Wagner (2016) explore the effect of central bank tone on asset prices, where the tone measures the number of "negative" words in the press statement following the target rate announcement. Different from these papers, we can separately identify target rate versus communication shocks from asset prices and show that communication about monetary policy is not only the dominant factor driving interest rate changes on announcement days but also has significantly differential effects in the cross-section of Euro-area bond yields.

Second, a large literature studies the effect of monetary policy shocks on long-term interest rates. Cochrane and Piazzesi (2002) find that a 100bps increase in the one-month Eurodollar rate around FOMC announcements leads to a 52bps increase in ten-year Treasury yields. Hanson and Stein (2015) use changes in two-year nominal yields as monetary policy shocks and find large responses of both nominal and real long-term interest rates. The authors argue that monetary policy affects term premia due to shifts in the demand of "yield-oriented" investors. Hanson, Lucca, and Wright (2018) provide international evidence for the "excess sensitivity" of long-term interest rates in response to monetary policy shocks and link it to slow-moving arbitrage capital. While most papers focus on one-day changes, Brooks, Katz, and Lustig (2017) document significant government and corporate bond yield reactions at longer horizons in response to changes in the Federal funds rate. Similar to these papers, we find highly significant and economically relevant reactions in Euro-area bond yields, however, we attribute the majority of the variation of bond yield changes explicitly to communication. Moreover, in our paper, monetary policy signals news about the state of the economy which induces demand shifts in risk-averse investors' bond holdings.

Third, our paper is related to the literature that explores the signaling channel of monetary policy. A large literature argues that monetary policy actions communicate information about the state of the economy to an imperfectly informed public: the policymaker has more information about economic fundamentals, hence the central bank's action taken in response to these fundamentals provide information to private agents. In the words of Campbell, Fisher, Justiniano, and Melosi (2016), monetary policy surprises "have a Delphic component." In support of this, Nakamura and Steinsson (2017) find that FOMC forward guidance conveys the FOMC's private information to market participants and that this information transfer has large macroeconomic effects. Gürkaynak, Sack, and Swanson (2005b) show that one way to explain the large effects of monetary policy on long-term forward rates is to assume that the private agents' views of long-term inflation are not well-anchored. Tang (2015) documents that surprises in the Federal funds rate are empirically linked to inflation expectations. Different from these papers, we are primarily interested in the effect of communication on risk premia in sovereign bond markets.

Finally, our paper also contributes to the theoretical literature that explores the effect of monetary policy and bond supply on the term structure of interest rates. We build on the framework developed by Vayanos and Vila (2009), in which risk-averse arbitrageurs demand higher risk premia on bonds if their exposure to interest-rate risk increases due to shifts in the net supply of bonds. Greenwood and Vayanos (2014) use this theoretical framework to study the implications of a change in the maturity structure of government debt supply, and Hanson (2014) and Malkhozov, Mueller, Vedolin, and Venter (2016) extend the model to include mortgage backed securities, and Greenwood, Hanson, and Vayanos (2016) study forward guidance in rates and bond supply to evaluate the impact of QE announcements in the U.S.[7] In these papers, which only consider a single country, risk premia are driven solely by shocks to supply and its future path. Thus, the impact of conventional monetary policy tools on bond yields, via the expectation channel only, concentrates at the very short end of the yield curve and becomes negligible for longer maturities. In contrast, our framework incorporates forward guidance into the risk premium channel that works via demand shocks of investors; communication can have a significant impact on long-maturity bond yields, too. Further, our multi-country setting allows us to study cross-sectional differences in yield reactions between core and peripheral countries.

1 ECB Governing Council Meetings

1.1 Announcement Dates

Our sample period runs from February 1, 2001, to December 31, 2014. During this period there is one ECB meeting per month, except for the years 2001 and 2008, when there were 20 and 13 meetings, respectively. From the 177 announcement days we exclude 16 that were either not followed by a press conference or were unscheduled. We also ignore other

[7] Greenwood, Hanson, and Liao (2017) model asset price dynamics in segmented markets to assess the impact of recent large-scale asset purchases by central banks.

speeches done by the ECB President or Vice-President for identification issues, as our focus is purely on disentangling target rate and communication shocks arising from official and pre-scheduled announcements, and studying their effects on asset prices.[8] Our final sample thus consists of 161 announcement days: there are 19 days when the main refinancing rate was raised, 10 days when the interest rate was lowered, and 132 meetings with no change.

There are two noteworthy points regarding our sample. First, since 2010, the ECB also announces so-called unconventional monetary policy such as the securities market program (SMP), long-term refinancing operations (LTROs), outright market transactions (OMT), or asset purchase programs (APP). These announcements have been the focus of a recent literature. In our sample of 161 announcements, we identify six dates on which an unconventional measure was announced during the press conference, and we verify in the Online Appendix that these six announcements do not significantly affect our results. Second, since January 2015, the press release refers to current and future unconventional policy measures, too. Our period of interest thus ends in December 2014 to keep our identification clean.[9]

1.2 Market Reaction around Announcements

The ECB publishes a brief press release announcing its policy rate decision at 13:45 CET. In our sample, the press release only contains information about the ECB's policy rates. From 14:30 CET, the ECB President and Vice-President hold a press conference which starts with an introductory statement, whose structure has remained the same since the very beginning: it contains (i) a summary of the ECB's monetary policy decision and balance of risks to price stability, and, since July 2013, an open-ended forward guidance; (ii) a discussion of both real and monetary developments in the Euro area; and (iii) a conclusion with some considerations on fiscal policy and structural reforms. The press conference then continues with a Question-and-Answer session.

To get a first impression of how the target rate announcement and the press conference affect interest rates, we illustrate the market reaction in high frequency at three specific announcements. Figure 1 plots the two-year Euribor swap rate throughout the day from 09:00 to 17:30 CET for April 6, 2006 (upper panel), June 5, 2008 (middle panel), and November 3, 2011 (lower panel).

April 6, 2006: The ECB decided to keep interest rates unchanged, following a 25bps increase at the previous meeting in March. Indeed, while we find no reaction in the swap rate at the target rate announcement, there is a sharp decrease right after the start of the press conference at 14:30, when the swap rate fell from 3.54% to 3.47% within 30 minutes. Market participants did not expect any change in interest rates at the April meeting but expected an interest rate hike later in the year. However, when at the press conference ECB President Jean-

[8] The exclusion dates are summarized in the Online Appendix.

[9] The ECB also started to publish its monetary policy deliberations in January 2015.

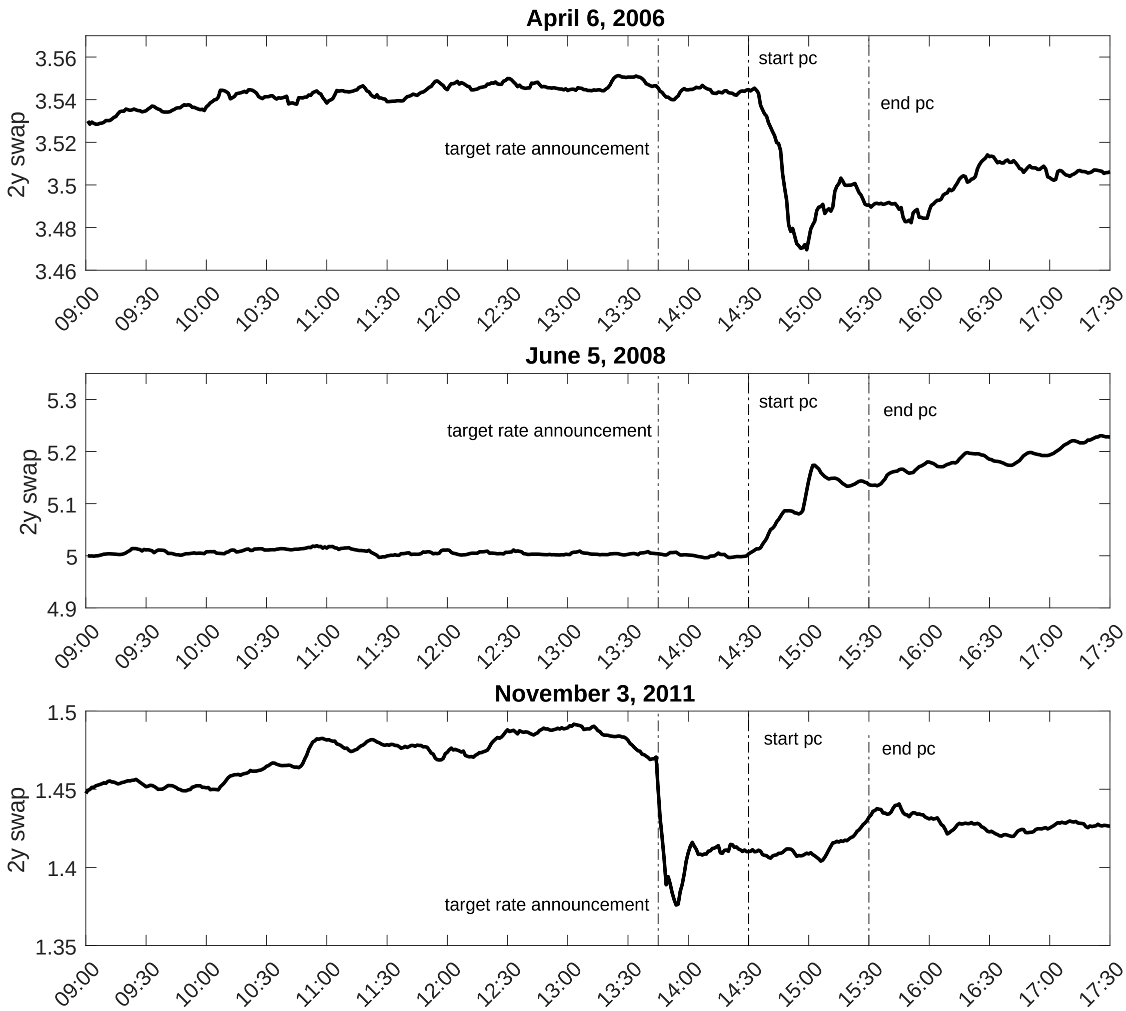


Figure 1. The two-year swap rate on three ECB announcement days

The figure plots the two-year swap rate on April 6, 2006 (upper panel), June 5, 2008 (middle panel) and November 3, 2011 between 09:00 and 17:30. Vertical lines represent the target rate announcement (13:45), the start of the press conference (14:30), and the end of the press conference (15:30). All times are in CET.

Claude Trichet told the press that "the current suggestions regarding the high probability of an increase of rates in our next meeting do not correspond to the present sentiment of the Governing Council," money market rates started to fall rapidly as the market revised its expectations about future interest rates downward.

June 5, 2008: The ECB decided to keep interest rates unchanged; President Trichet, however, indicated that risks to price stability had increased, and that inflation had risen significantly. The introductiory statement also included that the Governing Council was in a "state of heightened alertness." During the Q&A, he also said that "we could decide to move our rates by a small amount in our next meeting." As a result, the swap rate increased from 5% to 5.15%

within the first 30 minutes of the press conference. Indeed, a rate hike was then decided by the Governing Council at their next meeting, on July 3, 2008.

November 3, 2011: At President Mario Draghi's first meeting as new chairman, the ECB unexpectedly cut interest rates by 25bps, for the first time in two years. Consequently, the two-year swap rate dropped from 1.46% to 1.37% within 10 minutes, and then stabilized around this level with no reaction at the press conference. The fact that the market seemed surprised by the interest rate cut is suggested by a question that a journalist asked during the press conference: "President Draghi, welcome to Frankfurt. I have a few questions about today's rate decision, which came as a bit of a surprise. Was the decision unanimous? And can you explain the reasoning behind it [...]?"

These examples illustrate two noteworthy points: First, the importance of using high-frequency data instead of daily data, as most of the market reaction happens within tight windows of several minutes, and second, the fact that central bank "communication" can move asset prices without any specific actions taken.

2 Policy Shocks

A large empirical literature extracts monetary policy shocks from money market rates.[10] One source of difficulty of measuring the actions of monetary policy is related to the fact that policy actions reflect an endogenous response to the macro-economy. To address this endogeneity problem, the literature has proposed the use of structural vector autoregressions (Christiano, Eichenbaum, and Evans (1999)), using changes in interest rates orthogonal to the information contained in internal Federal Reserve forecasts (Romer and Romer (2004)), a heteroskedasticity approach on the variance-covariance matrix of daily yields (Boyarchenko, Haddad, and Plosser (2017)), and identification using high-frequency changes to interest rates around announcements (Cochrane and Piazzesi (2002) and Nakamura and Steinsson (2017)). A second difficulty is separating the effect of target rate changes from any other communication. For example, Gürkaynak, Sack, and Swanson (2005a) propose extracting latent factors using high-frequency yield changes in a narrow window around FOMC announcements but need to impose identifying assumptions in order to disentangle the role of target rate shocks versus so-called "path" shocks. Swanson (2017) extends this approach to include a third "quantitative easing" related factor. We follow the approach based on high-frequency identification, but exploit the fact that the ECB conducts the target rate announcement and the press conference at different points in time. This allows a simple yet clean separation of the channels.

[10]A seminal paper in this field is Kuttner (2001), who proposes measuring the unexpected change in the current policy rate with changes in the price of Federal Funds futures that settles in the month containing the meeting. For a recent survey article on this literature see Buraschi and Whelan (2016).

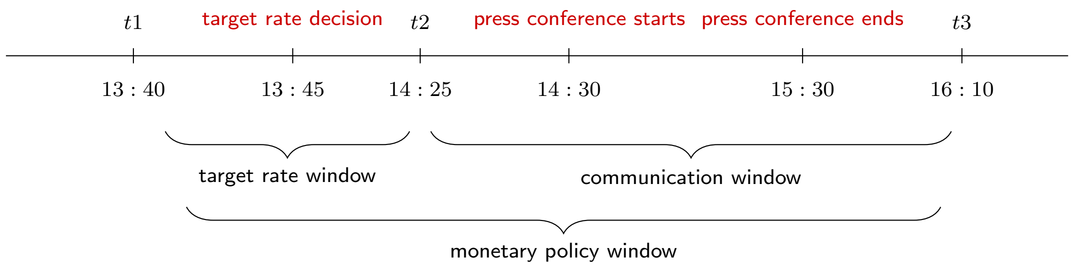


Figure 2. Monetary policy decision window
The figure illustrates the timeline of ECB announcements. All times are in CET.

2.1 Estimation

The target rate window is defined as a 45-minute window bracketing the 13:45 CET announcement, starting at 13:40 and ending at 14:25 CET. The communication window starts at 14:25 CET, and ends at 15:30 CET, 40 minutes after the press conference is over. We refer to the entire window, which encompasses both the target rate and communication windows, as the monetary policy window; see Figure 2.[11]

The policy shocks we extract are a composite measure of high-frequency changes in interest rates with different maturities, which allows us to capture changes in monetary policy beyond the shortest maturity. Moreover, our identification is based on the premise that changes in the policy indicators in these tight windows are dominated by the information about monetary policy contained in the ECB press release and press conference.

Let ΔY denote a $N \times T$ matrix of interest rate changes described by the following dynamics:

$$\Delta Y = F\Omega' + \eta, \tag{1}$$

where N denotes the number of announcements and T the different maturities; F is a $N \times k$ matrix of latent factors, with $k < T$, that drive the variation of rate changes in the relevant period, Ω is a $T \times k$ matrix of factor loadings, and η is a $N \times T$ matrix of idiosyncratic error terms. As it is well-known, the matrix Ω then contains the eigenvectors of the covariance matrix of ΔY, and F is computed as $F = \Delta Y \Omega$.[12] We estimate the latent factors within target and communication windows separately using principal components analysis on the 161 (number of announcements) $\times$ 13 (maturities) matrices of rate changes.

[11]When we shrink the target and communication windows, or introduce a gap of 10 minutes between the target rate and communication windows, all our results remain the same, both quantitatively and qualitatively. Additionally, while there are no other important Eurozone macro announcements during these windows, U.S. jobless claims take place every Thursday at 08:30 ET which corresponds to 14:30 CET. Controlling for the surprise component of these announcements from Bloomberg surveys does not alter our findings. Detailed results are gathered in the Online Appendix.

[12]We normalize the eigenvectors such that the factor loadings sum to one and are therefore interpreted as weights. The first principal component is then a variance-maximizing average.

2.2 Data

The intra-day interest rate data that we employ consist of real-time quotes from Reuters TickHistory. The data are unsmoothed and we filter for mispriced quotes and sample the data at the one-minute interval. We estimate our monetary policy shocks from ΔY's that include overnight index swap rates with maturities ranging between one and twelve months, and swap rates (written on the six-month Euribor) with a two-year maturity. While the primary objective of the ECB is price stability over the medium term, and they state that "it is not advisable to specify ex-ante a precise horizon for the conduct of monetary policy, since the transmission mechanism spans a variable, uncertain period of time," a two-year cutoff can be justified by the ECB implicitly hinting to have a horizon of two to three years by publishing forecasts (including interest rates) with a projection horizon of up to two years (extended to three years as of December 2016).[13]

We find that for both the target and communication windows, the first PC explains more than 86%, and the first two PCs explain more than 93% of the variation. Thus, we restrict our attention to the first two principal components of each.[14]

2.3 Identification

To assess the economic significance of these factors, we regress zero-coupon rate changes, bootstrapped from the swap rate changes of the whole monetary policy window, on the first and second PC of each windows; regression coefficients, corresponding t-statistics, and adjusted R^2s for six maturities are presented in Table 1. The upper panel contains our results for PCs constructed during the target rate window. For PC1, we find that the t-statistics are highly significant from the shortest maturity swap rate (three months) out to five years, as adjusted R^2s decrease from 39% to 4%. The bottom part of the upper panel reports regression results for PC2; notice the significant drop in the explanatory power as well as the lower t-statistics compared to PC1. For intermediate maturities, between six and 24 months, the second PC is insignificant, then becomes negative and significant going out to ten years. The final row of the upper panel reports the change in the R^2, denoted by ΔR^2, when including PC2 in the regression compared to the one that uses only PC1. Since the PCs are orthogonal, this number represents the marginal explanatory power of PC2, and shows that the second factor has little impact on yield changes during the target window.

A similar picture emerges for the communication window in the lower panel. While the first PC is highly significant throughout all maturities, the second PC is marginally significant at the short end, and estimated coefficients are negative and highly significant at the long end. Different from the upper panel, however, coefficients for the first PC display a hump-shaped pattern around the one- and two-year maturity, with a corresponding R^2 of 80%,

[13] See, e.g., http://www.ecb.europa.eu/pub/projections/html/index.en.html.

[14] The Online Appendix contains the exact numbers for the first three PCs of the target, communication, and overall monetary policy windows.

	3	6	12	24	60	120
	Target Window					
PC1	0.77	1.05	1.09	1.05	0.59	0.24
t-stat	(4.26)	(18.75)	(16.30)	(15.91)	(3.90)	(1.55)
PC2	0.18	0.09	−0.06	−0.05	−0.17	−0.11
t-stat	(3.09)	(1.46)	(−0.78)	(−0.66)	(−2.23)	(−1.70)
R^2	38.92	36.79	22.87	20.84	9.65	3.91
ΔR^2	4.96	0.49	−0.27	−0.33	1.45	1.16
	Communication Window					
PC1	0.53	0.82	1.23	1.25	0.98	0.57
t-stat	(10.48)	(19.55)	(44.86)	(41.15)	(24.82)	(9.09)
PC2	0.15	0.02	−0.23	−0.29	−0.59	−0.42
t-stat	(1.95)	(0.23)	(−2.03)	(−2.86)	(−7.06)	(−7.20)
R^2	44.37	58.24	78.36	81.20	75.84	56.67
ΔR^2	2.33	−0.22	2.04	3.17	17.05	16.89

Table 1. Swap rate loadings on PCs

This table reports estimated coefficients from univariate regressions from changes in swap rates during the monetary policy window (i.e., between 13:40 and 16:10 CET) onto the first (PC1) and second (PC2) principal components constructed from swap changes in the target or communication window around ECB monetary policy announcements:

$$\Delta y_t^\tau = \beta_1 \times \text{PC1}_t + \beta_1 \times \text{PC2}_t + \epsilon_t^\tau, \quad \tau = 3, \dots, 120 \text{ months},$$

where PC1_t and PC2_t are either the first and second PC from the target (upper panel) or communication (lower panel) window, respectively, and τ is the maturity. ΔR^2 indicates the change in the adjusted R^2 when adding the second PC. t-statistics are calculated using Newey and West (1987) allowing for serial correlation. Data run between 2001 and 2014.

which then declines slowly to 57% at the ten-year maturity. Similar to the target window results, we find the marginal increase in R^2 from the second PC to be small, especially at the short-end. Taken together, we note that one principal component seems to explain a significant fraction of the variation of interest rate changes during ECB announcement days, whereas the second PC is economically mostly insignificant.

Based on our analysis, in the following, we label PC1 of the target rate window our target rate shock, denote it by $Z_{r,t}$, and interpret it as the unexpected component in the short rate, $r_t - E_{t-1}[r_t]$. Further, we label PC1 of the communication window the communication shock, denote it by $Z_{\theta,t}$, and think about it as one that provides information about short rates some time τ in the future, $E_t[r_{t+\tau}] - E_{t-1}[r_{t+\tau}]$, among other things.

	Z_r	Z_θ
Mean	0.00	0.00
Std Dev	2.18	3.51
Min	−18.53	−14.33
Max	7.26	18.02
Skew	−4.49	0.34
Kurtosis	39.13	10.12
AR(1)	−0.29	−0.16

Table 2. Summary statistics of target and communication shocks

This table presents summary statistics for the target and communication shocks. Target (Z_r) (communication (Z_θ)) shocks are calculated from a principal component analysis applied to swap rate changes with maturities ranging between one-month and two years sampled between 13:40 and 14:25 CET (14:25 and 16:10 CET) on days that the ECB announces its monetary policy. Data run between 2001 and 2014.

2.4 Target and Communication Shocks

We present summary statistics of the target rate and communication shocks in Table 2. Both shocks have a zero mean, i.e., there is no surprise on average. At the same time, the volatility of communication shocks is almost twice as large as that of target shocks. We also note that while target rate shocks feature a negative skewness, the skewness for communication shocks is slightly positive, and both shocks exhibit significant excess kurtosis.

Figure 3 plots the time-series of the target rate and communication shocks. Our first salient observation is that target rate shocks are close to zero most of the time except for some large outliers. Communication shocks, however, display more variation, especially starting in mid 2008 when shocks are mostly negative.

The figure also contains brief annotations that help to explain some of the larger observations. The first one coincides with the May 10, 2001, meeting when the ECB surprisingly cut the refinancing rate by 25bps; reasons for the surprise easing were the disappointing unemployment and industrial production numbers from Germany, published on May 8 and 9, 2001. Our target shock on this day is measured at −18.55bps, implying that the rate cut on this day was largely unanticipated. The second event corresponds to June 5, 2008, when President Trichet hinted at a rate hike at the following meeting; the communication shock is 18.08bps. The third event corresponds to March 3, 2011, when Trichet hinted at a tightening at the next meeting by saying at the press conference that "strong vigilance is warranted." On August 4, 2011 rates were kept constant but market expected announcement of bond purchases for Italy and Spain, the communication shock is −14.33bps. On November 3, 2011, President Draghi surprised the market by a 25bp cut at his first meeting, identified as a −10.65bp target rate shock. Finally, on July 5, 2012, the ECB cut interest rates by 25bps to an all-time low; our target shock is −8.16bps.

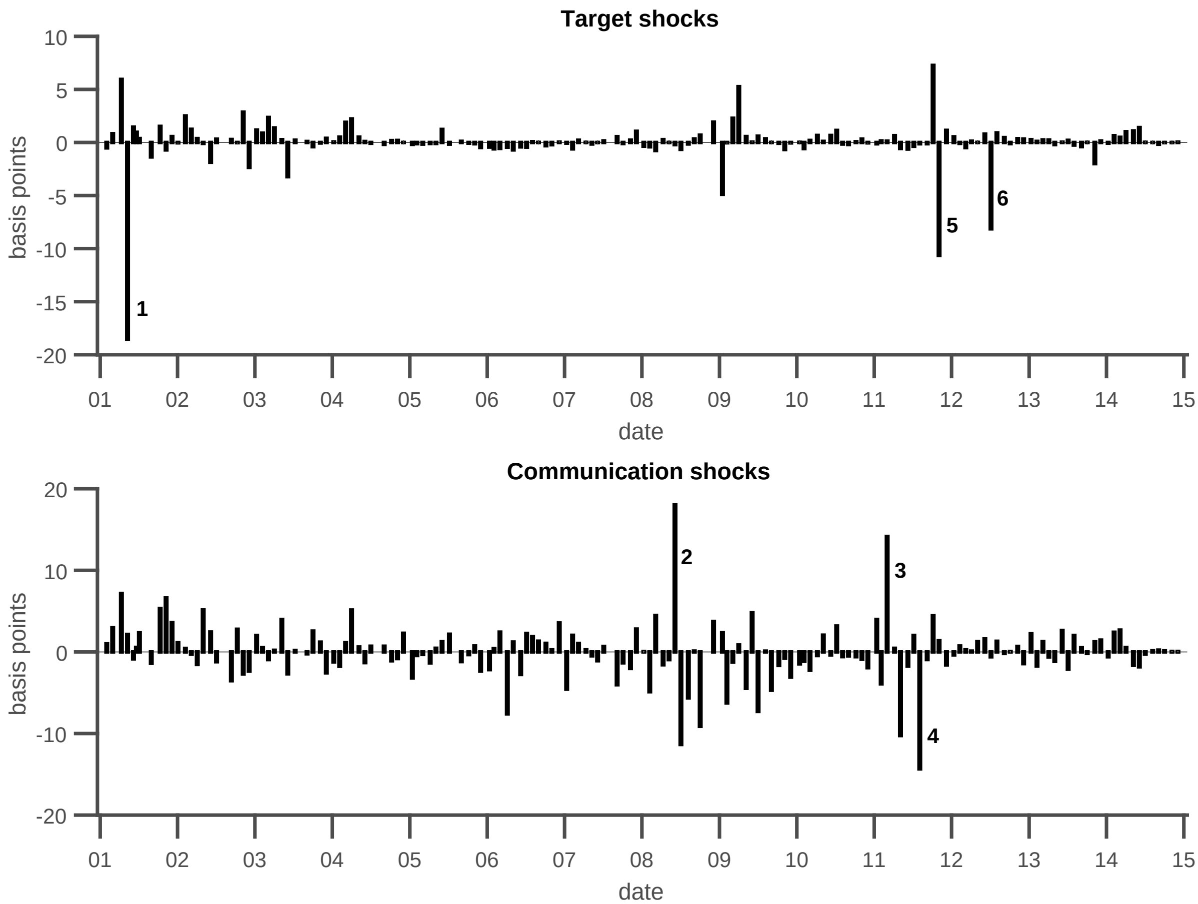


Figure 3. Time series of target and communication shocks

This figure plots target (upper panel) and communication (lower panel) shocks between 2001 and 2014. 1) May 10, 2001: surprise 25bps cut after dismal industrial production and unemployment numbers from Germany. 2) June 5, 2008: President Trichet announces rate hike for next meeting. 3) March 3, 2011: President Trichet announces interest rate hike at next meeting. 4) August 4, 2011: Rates were kept constant but market expected announcement of bond purchases for Italy and Spain. 5) November 3, 2011: Surprise 25bps cut at President Draghi's first meeting. 6) July 5, 2012: 25bps cut to an all-time low to 0.75%.

3 Empirical Analysis

In the following, we study the effect of target rate and communication shocks on bond yield changes for different maturities on ECB monetary policy announcement days. Our two main empirical findings are as follows: First, while before the 2009 crisis monetary policy had a uniform effect on bond yields of core and peripheral countries, peripheral countries' bond yield reaction to monetary policy becomes muted and even insignificant after 2009. As a consequence, ECB monetary policy, especially communication, drove a wedge between peripheral and core countries' yields in this period. Second, we link the wedge between core and peripheral bond yields to an emergence of a credit and redenomination risk premium.

3.1 Data

We use data from different sources. To save space, we report all summary statistics in the Online Appendix.

Bond yields: We use daily bond yields of Germany, France, Italy, and Spain, with maturities ranging between three months and 10 years, available from Bloomberg.[15] To keep the number of results manageable, we also refer to 'core' ('periphery') yields as simple averages of the bond yields of Germany and France (Italy and Spain).[16]

Inflation Risk: We obtain daily mid-quotes on inflation-linked coupon yields for Germany, France, Italy, and Spain from Bloomberg, and, following Ermolov (2017), estimate a Nelson-Siegel model in order to back out constant-maturity zero-coupon real yields. Details of the estimation and maturity structure of real European debt are given in the Online Appendix.[17]

Market Risk: We obtain daily returns on German (DAX), French (CAC 40), Italian (FTSE MIB), and Spanish (IBEX 35) equity market indices to measure market risk.

Illiquidity Risk: To measure bond market illiquidity, we estimate the noise measure of Hu, Pan, and Wang (2013) for all four countries from bond level transaction data available from BrokerTec and MTS. Illiquidity is defined as average squared deviations of observed government bond yields from a smoothed yield curve.[18]

Credit risk: To measure the credit risk of each country, we use Euro- and U.S. dollar-denominated credit default swaps (CDS) available from Markit. Sovereign CDS pay off in case of a sovereign default. Outright default, however, is only one of the possible scenarios that are considered a credit event. One important concern during the European debt crisis was that a redenomination of liabilities by one of the Eurozone members into a pre-Euro currency could trigger a CDS payout. There are two types of CDS contracts which define a credit event differently. Under the ISDA 2003 definition, redenomination does not trigger a credit event as long as it involves a G7 currency. The newer definition (ISDA 2014) limits this to the currencies of Canada, Japan, Switzerland, the United Kingdom, the United States, and the Eurozone. All our data are ISDA 2003 contracts.

Redenomination risk: U.S. dollar-denominated Eurozone CDS typically display higher spreads than Euro-denominated CDS.[19] The difference between U.S. dollar and Euro-denominated CDS is called a CDS quanto spread:

$$\text{CDS quanto}_{i,t} = \text{CDS}(\$)_{i,t} - \text{CDS}(€)_{i,t}.$$

[15]We focus on these four countries as both bond and CDS data coverage for these countries is reliable.

[16]Our results remain qualitatively the same when we use a GDP-weighted average.

[17]Ermolov (2017) estimates end-of-month real term structures excluding Italy and Spain since the focus of his paper is on default free real yields. We estimate daily yields and include both Italy and Spain.

[18]We thank Matthias Rupprecht for sharing the data with us.

[19]Imagine an investor bought an Italian CDS denominated in Euros. Upon Italy's default, the Euro would immediately depreciate vis-à-vis the U.S. dollar. U.S. dollar-denominated CDS are hence a better hedge than an equivalent Euro-denominated CDS. Mano (2013) provides empirical evidence that currencies indeed tend to depreciate in sovereign defaults.

Upon default, buyers of CDS quantos are paid $(100 - \text{recovery rate}) \times \frac{\$}{€}\ \%$ change, which means that buyers get compensated for any depreciation of the Euro against the U.S. dollar and the recovery value (see, e.g., Lando and Nielsen (2017)). The value of a quanto spread is hence determined by two factors: i) the expected change in the exchange rate following a default, and ii) the correlation between the exchange rate and the CDS spread (whether there is a default or not). We label the interaction between a country's likelihood of default and an associated currency devaluation "redenomination risk" (see, e.g., DeSantis (2015)).

3.2 Swap Yields

Before moving to sovereign bond yields, we explore the impact of monetary policy shocks on changes in daily default-free zero-coupon bond yield and forward rates, bootstrapped from swap rates. We are mostly interested in whether monetary policy shocks, estimated from short-term yields, have an effect on long-maturity yields. Standard expectations hypothesis suggests that movements in short rates should only have a minor impact on long-maturity interest rates, unless shocks to short rates are extremely persistent.

To examine the effect of target and communication shocks on zero-coupon yields and forwards, we run multivariate regressions from rate changes on our proxies of policy shocks:

$$\Delta y_t^\tau = \alpha^\tau + \beta_r^\tau Z_{r,t} + \beta_\theta^\tau Z_{\theta,t} + \epsilon_t^\tau \text{ and } \Delta f_t^\tau = \alpha^\tau + \beta_r^\tau Z_{r,t} + \beta_\theta^\tau Z_{\theta,t} + \epsilon_t^\tau,$$

where Δy_t^τ (Δf_t^τ) are daily zero-coupon yield (forward) changes with maturities $\tau = 3, \ldots, 120$ ($\tau = 12, \ldots, 120$) months. Table 3 collects the results.

Target shocks have a significant effect on swap rate changes, especially at the short end, and the effect dies out as the maturity prolongs. Estimated coefficients for communication shocks are also highly statistically different from zero for all maturities, and the effect is largest for the one- and two-year maturities, and decreases with maturity afterwards. Economically, we find that for any 100bp change in the target shock, there is a 71bp change in the two-year yield, whereas communication shocks of the same size induce changes of 143bps to the one-year yield and 140bps to the two-year yield. For the ten-year rate, the effect of target shocks declines to 13bps, however, the effect of communication shocks is still statistically and economically large, with a yield response of 65bps for any 100bp shock.

To evaluate the importance of central bank communication on zero-coupon yields, the penultimate row of each panel in Table 3 reports the adjusted R^2s of our regressions when we include both monetary policy shocks, while the last row reports the increase in the R^2s compared to a univariate regression that only uses the target rate shock as right-hand-side variable. Our findings suggest that, except for very short maturities, communication shocks are an order of magnitude more important than target rate shocks to explain the variation in yields: the change in the R^2s ranges between 16% at the ten-year maturity and 66% at the one-year maturity, representing 100% and 80% of the variation in these bond yields, respectively.

Our results are comparable to the earlier literature that documents a strong impact of U.S.

	3	6	12	24	60	72	84	96	108	120
					Swap Rates					
Z_r	1.07	1.01	1.01	0.71	0.46	0.32	0.25	0.18	0.10	0.13
t-stat	(17.33)	(15.77)	(8.67)	(5.70)	(3.16)	(2.08)	(1.65)	(1.14)	(0.61)	(0.72)
Z_θ	0.62	0.96	1.43	1.40	1.19	1.08	0.92	0.74	0.64	0.65
t-stat	(8.25)	(13.37)	(20.22)	(15.82)	(10.34)	(9.78)	(9.09)	(5.85)	(5.25)	(4.68)
R^2	72.16	80.89	81.15	63.17	43.52	38.61	30.45	22.93	17.85	16.96
ΔR^2	31.97	54.48	65.98	56.08	40.34	36.80	29.14	22.14	17.54	16.53
					Forward Rates					
Z_r			1.01	0.41	0.25	-0.41	-0.11	-0.36	-0.57	0.40
t-stat			(8.67)	(2.60)	(1.03)	(-1.77)	(-0.36)	(-1.02)	(-1.88)	(0.68)
Z_θ			1.43	1.36	0.84	0.53	-0.05	-0.49	-0.14	0.67
t-stat			(20.22)	(10.06)	(5.26)	(2.50)	(-0.09)	(-0.86)	(-0.37)	(1.16)
R^2			81.15	41.15	13.02	6.76	0.09	2.73	1.74	2.36
ΔR^2			65.98	39.16	12.40	5.66	0.03	2.19	0.23	2.02

Table 3. Swap and forward rate response to target and communication shocks

This table reports the results of multivariate regressions of zero-coupon one-day changes in swap rates (upper panel) and forward rates (lower panel) across different maturities on target ($Z_{r,t}$) and communication ($Z_{\theta,t}$) shocks on days when the ECB announces their monetary policy. t-statistics are calculated using Newey and West (1987). ΔR^2 indicates the change in the adjusted R^2 when we add communication shocks, Z_θ, to the regression. Data run between 2001 and 2014.

monetary policy shocks on long-term nominal and real yields. For example, Cochrane and Piazzesi (2002) find that a 100bp increase in the one-month Eurodollar rate around FOMC announcements is associated with a 52bp increase in the ten-year nominal Treasury yield. Similarly, Hanson and Stein (2015) find that a 100bp change in the two-year nominal yield measured on FOMC announcement days leads to a 42bp change in ten-year forward real interest rates. Hanson, Lucca, and Wright (2018) document strong effects for ten-year bond yield changes in the U.S., United Kingdom, Germany, and Canada in response to monetary policy shocks.

Zero-coupon bond yields are the average of one-year forward rates over the maturity of a bond, while forward rates are the risk-neutral expectation of future short rates, so it is interesting to translate our results to the space of forward rates. The lower panel of Table 3 shows that the reaction of forward rate changes to both types of monetary policy shocks are significant up to a maturity of seven years. For example, the one-year forward rate five years ahead moves by almost 50bps as a response to a 100bp communication shock. To summarize, we find that changes in short-term rates have significant effects on long-term interest rates.

Finally, we study if monetary policy shocks have a lasting effect on bond yields beyond the one-day horizon, i.e., whether monetary policy shocks are transitory or permanent in nature. A recent debate discusses this question in the context of forward guidance (in the U.S.) and finds that these effects can be relatively short-lived (see, e.g., Woodford (2012) or Swanson

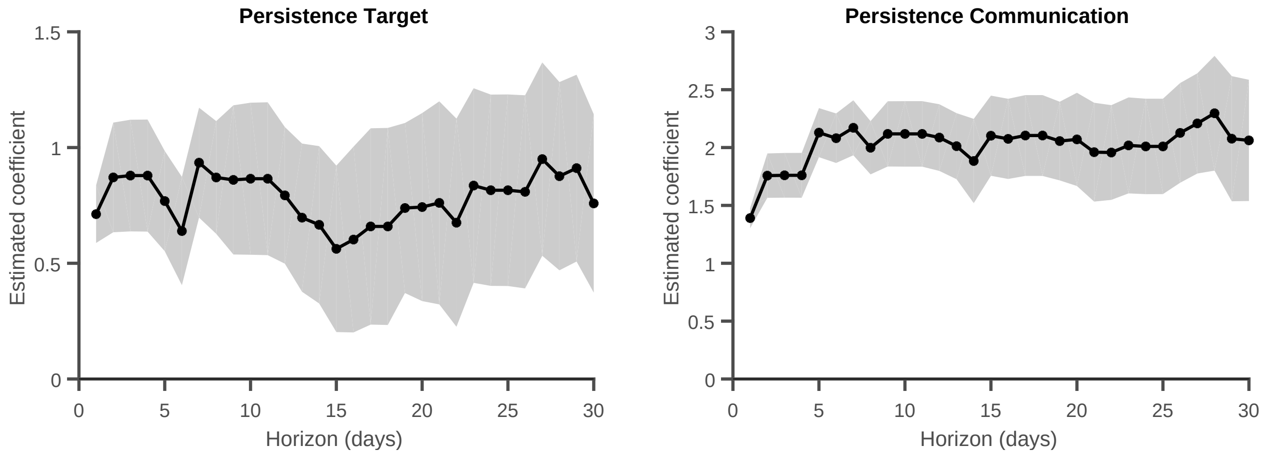


Figure 4. Two-year swap yield response to monetary policy shocks at different horizons
This figure plots the response of two-year bond yields at horizons ranging from 1 to 30 days for the target rate (left panel) and communication (right panel) shock on ECB announcement days. Confidence intervals are based on Newey and West (1987) standard errors. Data run between 2001 and 2014.

(2017)). This is reinforced in Hanson, Lucca, and Wright (2018), who argue that in the presence of slow-moving capital, the transmission of monetary policy is far more short-lived than one might conclude from high-frequency evidence. The intuition is that while asset prices move around the time when the central bank announces its monetary policy, changes in risk premia will be arbitraged away eventually as arbitrageurs react to the announcement and adjust their positions, but this process may take time. To assess the impact of target and communication shocks over longer horizons, we follow the approach of Swanson (2017) and estimate regression (2) for horizons up to 30 days.[20] The corresponding results for the two-year yield are plotted on Figure 4. We note that for target shocks, swap rates are significantly affected up to a horizon of 30 days, but confidence intervals become larger after ten days. Moreover, the size of the estimated coefficient remains stable across the full horizon. Communication shocks have a more persistent effect as estimated coefficients are highly significant out to 30 days. Even more striking, the impact of communication increases over time, with the point estimate rising from 1.5 for a one-day horizon to a level of 2.2 for 30 days; a 50% increase. This is an important result since, to the extent that communication shocks can be interpreted as a form of forward guidance, it suggests monetary policy can have long-lasting effects.[21]

3.3 Sovereign Yields

Next we turn our attention to how ECB monetary policy affects bond yields in the cross-section of Eurozone countries, the main focus of our paper. To this end, we regress changes

[20]We choose a horizon of 30 days as ECB announcements take place approximately every 30 days.
[21]This result echoes the findings in Brooks, Katz, and Lustig (2017), who find initial under- and then over-reaction of Treasury and corporate bond yields in response to changes in the Federal funds rate.

in bond yields of country i onto target rate and communication shocks jointly:

$$\Delta y_{i,t}^{\tau} = \alpha_i^{\tau} + \beta_{i,r}^{\tau} Z_{r,t} + \beta_{i,\theta}^{\tau} Z_{\theta,t} + \epsilon_{i,t}^{\tau}, \tag{2}$$

where $\Delta y_{i,t}^{\tau}$ is the daily yield change of country i with maturity τ ranging from three months to ten years. Figure 5 summarizes the results for Germany, France, Italy, and Spain.

There are two main findings. First, we note that the effect of target rate shocks is generally decreasing with maturity for both core and peripheral countries, however, the effect on peripheral countries is not statistically different from zero, especially for longer maturities. Second, the effect of communication shocks is most pronounced for intermediate maturities and orders of magnitude larger than target shocks: coefficients are small at the short-end of the term structure, increasing until the two-year maturity, and then decreasing again as maturity lengthens. Comparing the reaction of core versus peripheral countries, we find the former to be affected more by both target and communication shocks than the latter. For example, for any 100bps increase in the communication shock, there is an approximately 140bps increase in the two-year yields of Germany and France, whereas for Italy and Spain the effect is less than 100bps. Moreover, comparing statistical significance, we find that coefficients are more precisely estimated for the core countries than peripheral countries. These observations are interesting since heterogeneous responses to policy shocks have important implications for both asset pricing and ECB policy making.

3.4 Sovereign Spreads

Against the backdrop of our previous result, we next focus on two different aspects of ECB monetary policy. First, we want to study whether monetary policy has affected sovereign bond yields differently in the cross section, and second, whether the effect has changed over time. To this end, for each maturity, we define core (peripheral) yields to be the average yield of Germany and France (Italy and Spain). We first run regression (2) for the pre-crisis (January 2001 to February 2009, 91 observations) and post-crisis (March 2009 to December 2014, 70 observations) periods separately, and report the results in Figure 6.[22]

The upper two panels plot the effect of target rate (left panel) and communication shocks (right panel) when the sample ends in February 2009. We find that before the 2008-2009 global financial crisis, estimated coefficients for core and peripheral countries are virtually the same, indicating that monetary policy did not have a differential effect on these countries. Coefficients for target rate shocks are statistically different from zero for both types of countries, and the point estimates for communication shocks on peripheral yields are significantly larger than those documented for the full sample. For example, for any 100bps change in the communication shock, there is a 144bp change in two-year bond yields for both core and peripheral countries.

[22]We start our crisis sample in March 2009, as this was the time when yields of core and peripherals started to significantly diverge. All of our results also hold when we start the sample in January 2009, for example.

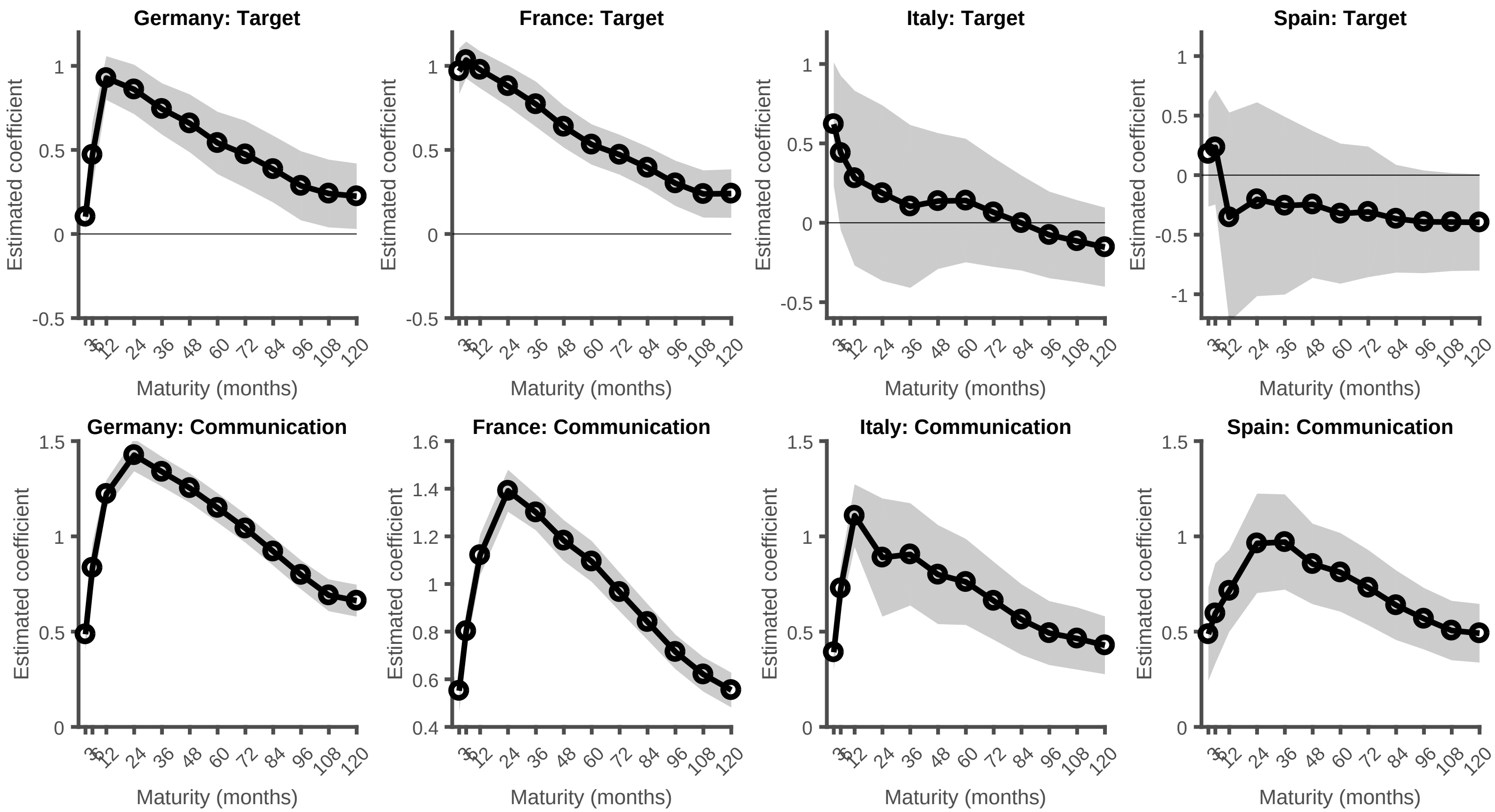


Figure 5. Core and peripheral yield response to target and communication shocks

This figure plots the response of core (= Germany and France) and peripheral (= Italy and Spain) countries' bond yields at different maturities for a target rate (upper panels) and communication (lower panels) shock on ECB announcement days. Confidence intervals are based on Newey and West (1987) standard errors. Data run between 2001 and 2014.

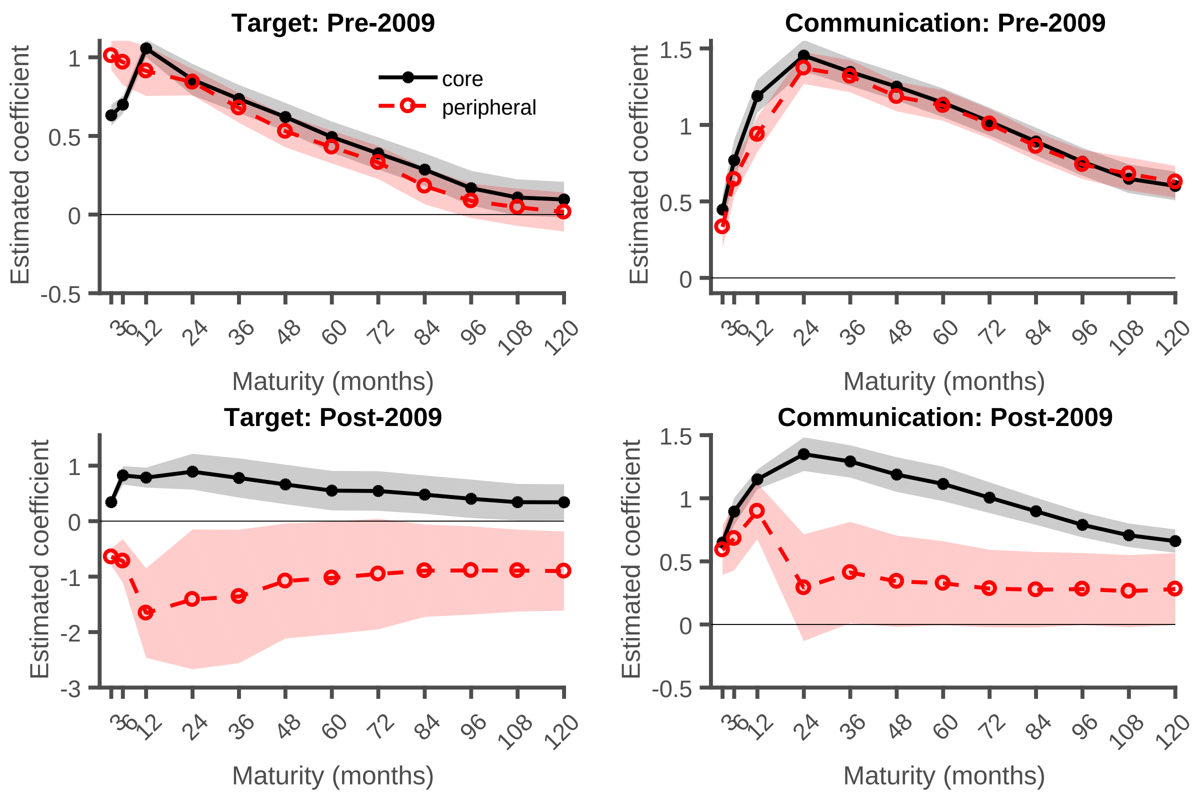


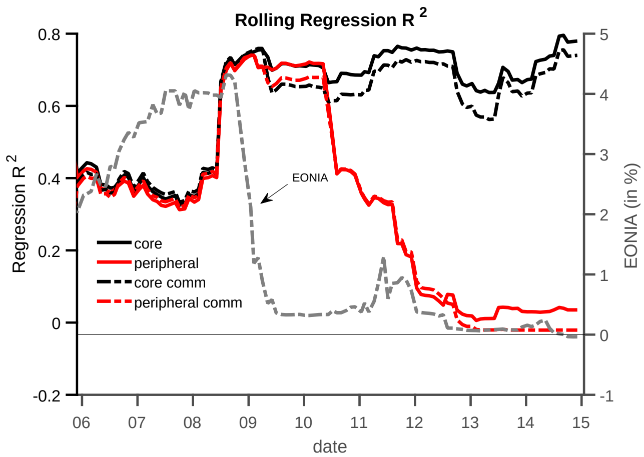
Figure 6. Core and peripheral yield response before and after the onset of the crisis
This figure plots the response of core (solid) and peripheral (dashed line) countries' bond yields at different maturities for target (left) and communication (right) shocks on ECB announcement days:

$$\Delta y^{\tau}_{i,t} = \alpha^{\tau}_i + \beta^{\tau}_{i,r} Z_{r,t} + \beta^{\tau}_{i,\theta} Z_{\theta,t} + \epsilon^{\tau}_{i,t}, \quad \tau = 3, \ldots, 120 \text{ months.}$$

90% confidence intervals are based on Newey and West (1987) standard errors. Data run from January 2001 to February 2009 on the upper panels and from March 2009 to December 2014 on the lower panels.

The lower two panels present results for the March 2009 to December 2014 period. We find that target rate shocks have a differential effect on core versus peripheral countries: estimated coefficients for core countries are similar for most maturities and even slightly larger at the long end of the yield curve than before, while peripheral countries' coefficients are now negative and significant out to three years. Regarding communication shocks, for core countries we again find virtually the same hump-shaped pattern as in the pre-2009 period, but peripheral countries are affected much less. For example, for a 100bp communication shock post 2009 there is a 142bp change in the two-year yield for core countries, just as in the pre-crisis period, whereas the effect on a two-year peripheral yield is only around 40bps. Moreover, peripheral point estimates of communication shocks are only borderline significant for maturities exceeding five years.

In order to understand this result better, the left panel of Figure 7 depicts adjusted R^2s from rolling-window regressions of two-year bond yield changes of core and peripheral



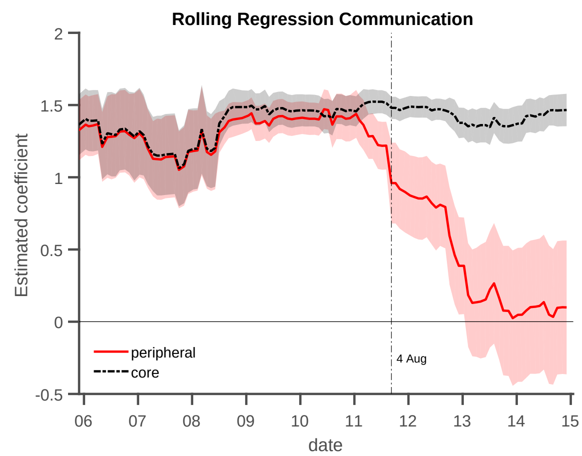


Figure 7. Rolling R^2 and regression coefficients

The left panel plots the rolling adjusted R^2 from regressing core and peripheral two-year bond yields on the target and communication shock (bold lines). The dashed lines present the adjusted R^2 when controlling only for communication shocks. The right axis depicts the EONIA rate (in percent). The right panel plots regression coefficients from rolling regressions of core and peripheral bond yields on the communication shock. The window size for the rolling window is set to 50 months.

countries on target and communication shocks (bold lines) and for communication shocks only (dashed lines).[23] We notice two interesting features. First, before the crisis, monetary policy shocks accounted for around 40% of the variation of bond yield changes of both core and peripheral countries. Mid 2008, the adjusted R^2 doubles to 80% which coincides with the beginning of the ECB's dovish monetary policy and several cuts in the target rate as illustrated by the decreasing EONIA rate. While the high R^2 persists throughout the crisis for core countries, there is a complete breakdown in the effect of monetary policy on peripheral bond yields starting in 2010: the adjusted R^2 decreases from 80% to 40% in the first half of 2010 and then subsequently reaches zero in 2012. Second, we find that almost *all* of the variation is explained by the communication shocks themselves: The difference between the total R^2 and the R^2 from using communication shocks only is virtually zero.

We further explore these events in the right panel of Figure 7, where we plot rolling estimates of coefficients on communication shocks for core and peripheral countries' two-year bond yield changes. Indeed, we find the effect on core countries' bond yields to remain very stable throughout the 2008 to 2015 period. Peripheral countries' bond yields, however, become virtually insensitive to communication shocks starting in 2011 as the estimated coefficient starts to drift downwards and becomes insignificant at the end of 2012.

One particularly large drop happened on August 4, 2011. On that day, the Governing Council decided to keep interest rates unchanged, however, market participants expected an announcement about purchases of Italian and Spanish bonds which did not materialize.[24]

[23] We use a rolling window of 50 months. Results look qualitatively the same with different window lengths.

[24] This is best reflected in the Q&A session, when several questions are directly related to bond purchases of Italy and Spain.

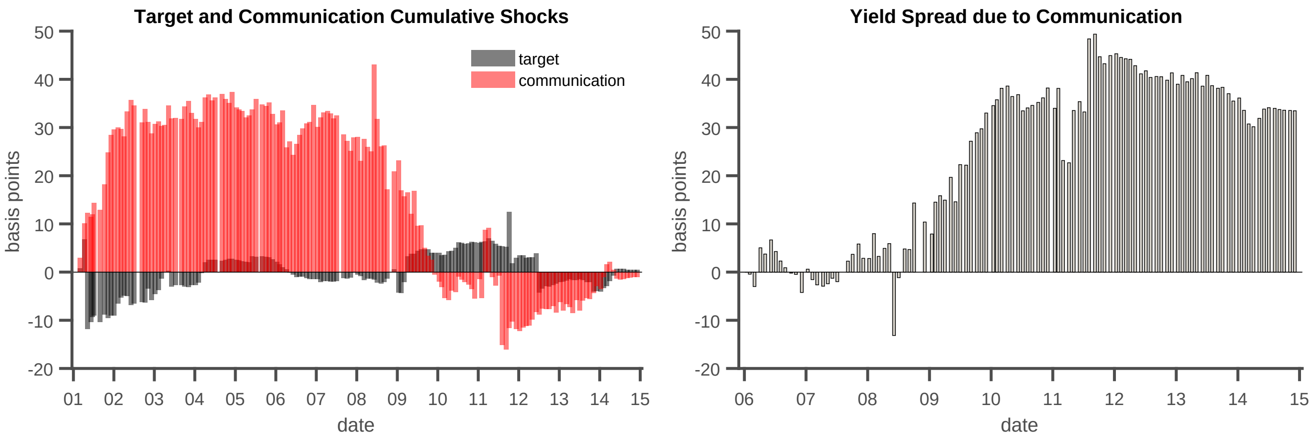


Figure 8. Cumulative monetary policy shocks and the effect on the yield spread

The left figure plots cumulative target and communication shocks from January 2001 to December 2014. The right panel plots the difference between the product of the cumulative communication shock and the rolling regression coefficient for peripheral bond yield changes on communication shocks from Figure 7 and the product of the cumulative communication shock and the rolling regression coefficient for core bond yield changes on communication shocks from Figure 7.

On the same day, José Manuel Barroso, the President of the European Commission, warned of contagion from peripheral to core countries, and he called for Europe's leaders to re-assess the financial stability mechanisms designed to hold the Eurozone together.[25]

3.5 Communication Effects

Since the onset of the crisis in 2008, the ECB has tried to ease distress in financial markets and to reduce sovereign spreads by (i) drastically lowering its target rate, (ii) providing unprecedented amounts of liquidity support against a broader set of assets used as collateral, and since January 2015, by (iii) introducing quantitative easing in the form of the Asset Purchase Programme. Our results so far suggest that conventional monetary policy in the form of central bank communication is also a driver of the yield spread, as its impact is quantitatively larger on core countries than on peripheral countries.

To evaluate the exact effect and economic significance of this channel, we calculate the size and direction of the spread implied by monetary policy shocks, and compare it to the time-series of the yield spread between core and peripheral countries. The left panel of Figure 8 plots the cumulative target and communication shocks for the entire period. There are two noteworthy observations. First, the variation in target rate shocks is quantitatively much smaller than in communication shocks, in line with our observation from Figure 3. Second,

[25]This weekend was particularly eventful for the Eurozone. On August 5, ECB President Trichet, together with Mario Draghi, wrote a secret letter to the Italian government in which they pushed for structural reforms "to be implemented as soon as possible," thereby implicitly tying the ECB's support to the implementation of these measures (the letter was leaked in September). On the same day, the Italian Prime Minister announced new measures to reduce the deficit and hasten economic reform. Finally, on August 7, a Sunday, the ECB announced that the Securities Markets Programme would also include Spain and Italy.

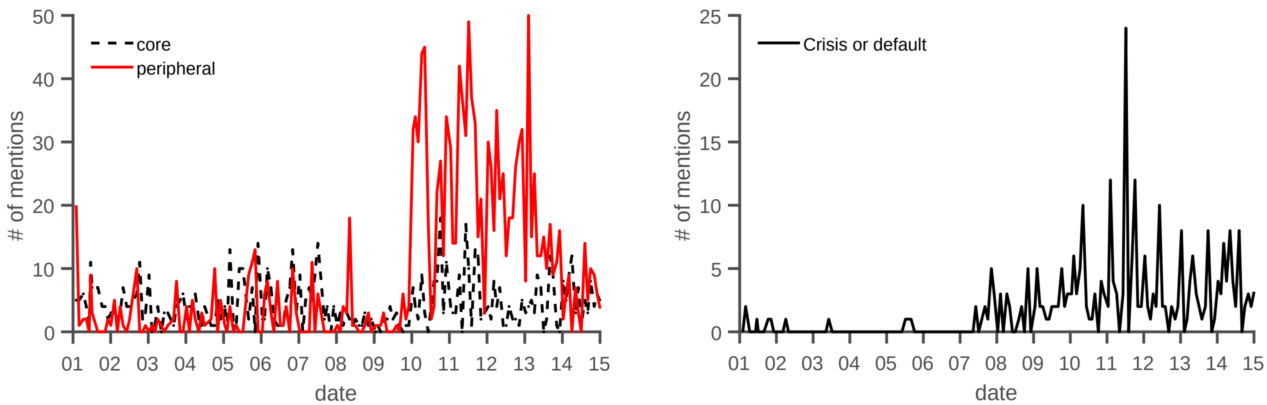


Figure 9. Textual analysis of press conference transcripts

The left panel plots the number of mentions of core versus peripheral countries during ECB press statements. The right panel plots the number of mentions of "crisis" or "default". 'Peripheral' words include: *Italy, Spain, Greece, Portugal, Ireland* and *periphery*. 'Core' words include: *Belgium, France, Germany, Netherlands* and *core*. 'Crisis' words include: *crisis* and *default*.

until 2009, communication shocks cumulatively had a positive effect, while target rate shocks were on average slightly negative. The sign switches in the beginning of 2009, when target shocks become positive and communication shocks turn negative; that is, the target rate was set systematically higher than what the market expected, whereas communication about the future path of interest rates was lower than what had been expected.[26] Combining this insight with the estimated regression coefficients for core and peripheral countries, we can derive the cumulative effect of monetary policy shocks on yield spreads during the crisis period.

The right panel of Figure 8 shows the impact of communication shocks for the two-year maturity. We calculate this implied spread by multiplying realized shocks with the difference in real-time policy loadings displayed in Figure 7, and add them up over time. Strikingly, we find that communication shocks had a positive effect on the yield spread; it increased between January 2009 until Spring 2011 when ECB President Trichet announced a rate hike for the next meeting and peaking at the end of 2011 at almost 50bps, and then slightly decreased until the end of 2014. Economically, this effect is large: in September 2011, the two-year core-periphery yield spread was 270bps, so at its peak the spread due to communication represented around 20% of the total yield spread.

The "regime switch" in terms of central bank communication can also be illustrated in Figure 9, where we plot the number of mentions of core and peripheral countries (left panel), as well as the number of mentions of "default" and "crisis" during the ECB press conference.[27]

[26]The U.S. Federal Reserve lowered its policy interest rate from 5.25% in September 2007 to 0-0.25% in December 2008 and at the same time also initiated quantitative easing. The ECB's first reaction, in July 2008, was to raise the main refinancing rate. After the Lehman bankruptcy in September 2008, the ECB joined an internationally coordinated rate reduction on 8 October. The ECB's slow pace of rate cuts was interrupted by two more hikes - in April and July 2011. The policy rate was brought to near-zero only in November 2013, five years after the U.S. Federal Reserve.

[27]We use a web-scraping algorithm to download transcripts of ECB press conferences and we use basic text

We notice that starting 2010 and in particular in the summer of 2011, peripheral countries are mentioned a multiple times more often than core countries. Moreover, we observe a large spike in default- or crisis-related mentions in the summer of 2011 as well.

4 Potential Risk Premium Channels

Standard textbook algebra reveals that nominal bond yields are equal to the sum of expected nominal short rates, inflation risk premia, and real risk premia, so a natural question is whether our findings are due to changes in expected short rates or in risk premia:[28]

$$y_{i,t}^{\tau} = \underbrace{\mathrm{E}_t\left[\frac{1}{\tau}\sum_{k=1}^{\tau}(r_{i,t+k}^{r} + \pi_{i,t+k})\right]}_{\substack{\text{expected nominal}\\ \text{short rates}}} + \underbrace{\text{Inflation Risk Premia}_{i,t}}_{\mathrm{IRP}_{i,t}} + \underbrace{\text{Real Risk Premia}_{i,t}}_{\mathrm{RRP}_{i,t}} \tag{3}$$

where $r_{i,t+k}^{r}$ denotes the real short rate and $\pi_{i,t+k}$ is the rate of inflation of country i, k periods ahead. For this reason, Eurozone bond markets provide a unique opportunity to test whether monetary policy communication can affects risk premia: observing a cross-section of Euro-area yields one can difference out expectation components since expected nominal short rates are the same for all countries. Specifically, around ECB announcement days and across countries, we can write changes in the yield spread between peripheral and core countries as follows:

$$\Delta\left(y_{\text{per},t}^{\tau} - y_{\text{core},t}^{\tau}\right) = \Delta\left(\mathrm{RRP}_{\text{per},t}^{\tau} - \mathrm{RRP}_{\text{core},t}^{\tau}\right) + \Delta\left(\mathrm{IRP}_{\text{per},t}^{\tau} - \mathrm{IRP}_{\text{core},t}^{\tau}\right), \tag{4}$$

where the first component on the right-hand side refers to changes in real risk premia and the second component to changes in inflation risk premia. These risk premia can arise from a number of alternative channels, as illustrated by ECB President Mario Draghi's speech at an investor conference in London on July 26, 2012, that became (in)famous for the sentence "Within our mandate, the ECB is ready to do whatever it takes to preserve the euro." In this speech, he specifically mentions the divergence of peripheral and core bond yields, and ascribes the resulting risk premia to three drivers: "Then there's another dimension to this that has to do with the premia that are being charged on sovereign states borrowings. These premia have to do, as I said, with default, with liquidity, but they also have to do more and more with convertibility, with the risk of convertibility."[29]

Motivated by this observations we consider a set of alternative explanations to rationalize the wedge in monetary policy responses: (i) inflation risk; (ii) market risk; (iii) illiquidity risk;

analysis tools to count words. 'Peripheral' words include *Italy, Spain, Greece, Portugal, Ireland* and *periphery*. 'Core' words include *Belgium, France, Germany, Netherlands* and *core*. 'Crisis' words include *crisis* and *default*.

[28]This decomposition holds exactly under the assumption of log-normality.

[29]See `http://www.ecb.europa.eu/press/key/date/2012/html/sp120726.en.html` for a full transcript of the speech.

	Germany		Italy		Spread	
	60	120	60	120	60	120
Z_r	-0.48	0.80	-0.05	0.97	0.43	0.17
t-stat	(-1.14)	(4.51)	(-0.02)	(1.36)	(0.27)	(0.25)
Z_θ	0.45	0.04	-0.20	-0.557	-0.65	-0.60
t-stat	(3.11)	(0.21)	(-0.15)	(-0.78)	(-0.46)	(-0.96)
R^2	21.85	2.48	-2.93	7.46	-2.73	8.58

Table 4. Break-even inflation rates

This table reports estimated coefficients from the regression

$$\Delta(y_{i,t}^{\tau} - y_{i,t}^{r,\tau}) = \alpha_i^{\tau} + \beta_{i,r}^{\tau} Z_{r,t} + \beta_{i,\theta}^{\tau} Z_{\theta,t} + \epsilon_{i,t}$$

where $y_{i,t}^{\tau}$ and $y_{i,t}^{r,\tau}$ are five- or ten-year nominal and real yields, respectively. In turn, $\Delta(y_{i,t}^{\tau} - y_{i,t}^{r,\tau})$ is equal to break-even inflation rates which are the sum of expected inflation and an inflation risk premium. t-statistics are calculated using Newey and West (1987). Data run from August 2010 to December 2014.

(iv) credit risk; and (v) redenomination risk. The sample we consider runs from August 2010 to December 2014, determined by the CDS quanto spreads, our proxy for redenomination risk, which take values of zero before August 2010.

To study the role of inflation risk, note that real yields are equal to the sum of expected real short rates and real risk premia: $y_{i,t}^{r,\tau} = \mathrm{E}_t\left[\frac{1}{\tau}\sum_{k=1}^{\tau} r_{i,t+k}^{r}\right] + \mathrm{RRP}_{i,t}$. Thus, for country k, differences between nominal yields and real yields reveal inflation expectations and inflation risk premia

$$BE_{i,t}^{\tau} = y_{i,t}^{\tau} - y_{i,t}^{r,\tau} = \underbrace{\mathrm{E}_t\left[\frac{1}{\tau}\sum_{k=1}^{\tau} \pi_{i,t+k}\right]}_{\text{expected inflation}} + \mathrm{IRP}_{i,t}. \quad (5)$$

Then, to assess the role of inflation risk premia, we estimate daily break-even inflation rates and regress changes in these rates on policy shocks

$$\Delta BE_{i,t}^{\tau} = \alpha_i^{\tau} + \beta_{i,r}^{\tau} Z_{r,t} + \beta_{i,\theta}^{\tau} Z_{\theta,t} + \epsilon_{i,t}^{\tau}. \quad (6)$$

Table 4 reports estimates for Germany and Italy, representing core and periphery, since real term structures for Spain are only available for a short period at the end of our sample.[30]

For German break-even rates, point estimates for target shocks are mostly insignificant, while estimates for communication shocks are positive and highly significant at the five-year maturity, then decline in magnitude and significance out to ten-years. The R^2s range between 22% at the five-year maturity to 3% at the ten-year maturity. Regarding Italian

[30]We only report results for the five- and ten-year maturities. Other maturities look quantitatively the same. Real French yields are also available, and the results for this term structure are quantitatively similar to Germany. Results are reported in the Online Appendix.

	Equity			Illiquidity		
	Core	Peripheral	Spread	Core	Peripheral	Spread
Z_r	0.21	0.34	0.13	0.98	-1.24	-2.22
t-stat	(2.52)	(1.94)	(1.35)	(0.82)	(-0.27)	(-0.44)
Z_θ	0.14	0.14	-0.00	-0.05	-1.10	-1.05
t-stat	(1.13)	(1.26)	(-0.07)	(-0.02)	(-0.25)	(-0.26)
R^2	12.57	15.65	2.42	7.40	11.62	8.10
	CDS			Quanto		
	Core	Peripheral	Spread	Core	Peripheral	Spread
Z_r	-0.19	-2.58	-2.39	-0.29	-0.29	0.00
t-stat	(-0.52)	(-1.19)	(-1.31)	(-1.70)	(-1.00)	(0.03)
Z_θ	-0.28	-1.01	-0.73	0.00	-0.16	-0.16
t-stat	(-2.65)	(-3.11)	(-2.71)	(0.03)	(-2.40)	(-2.02)
R^2	3.79	5.95	5.86	6.18	8.88	2.43

Table 5. Different risk premium channels

This table reports estimated coefficients from the regression

$$\Delta X_{i,t} = \alpha_i + \beta_{i,r} Z_{r,t} + \beta_{i,\theta} Z_{\theta,t} + \epsilon_{i,t}$$

where i is core or peripheral, and $X_{i,t}$ are equity market indices, illiquidity proxies, CDS spreads, and CDS quanto spreads described and discussed in the main body of the paper. t-statistics are calculated using Newey and West (1987). Data run from August 2010 to December 2014.

break-even rates, we find insignificant loadings for both target and communication shocks, and the R^2s in these regressions are close to zero. The last two columns test the response of differences in break-even rates between Germany and Italy to policy shocks. Our point estimates do not display any statistical significant, and the R^2s remain very low. Overall, our results are in line with evidence in Nakamura and Steinsson (2017), who find an insignificant response of U.S. break-even rates to monetary policy shocks.

One limitation of this analysis is that without a model we cannot separate the effect of monetary policy shocks on inflation expectations and inflation risk premia. But as we find no significant cross-sectional difference for break-even inflation for the five- and ten-year horizons, we conclude that the yield wedge is unlikely to come from inflation risk premia.

Turning to alternative channels, in Table 5 we report results for the regression

$$\Delta X_{i,t} = \alpha_i + \beta_{i,r} Z_{r,t} + \beta_{i,\theta} Z_{\theta,t} + \epsilon_{i,t}, \tag{7}$$

where i refers to core or periphery, and $X_{i,t}$ are proxies for equity index returns, illiquidity, CDS spreads, and CDS quanto spreads, with data sources discussed in Section 3.1.[31]

[31] In line with the literature, we use two-day changes (see, e.g., Krishnamurthy, Nagel, and Vissing-Jorgensen

First, considering the reaction of equity markets, we find a statistically significant positive relationship with target shocks: the t-statistics for core and periphery are 2.52 and 1.94, with adjusted R^2s of 13% and 16%, respectively. In itself, this result is interesting since it has the opposite sign to what Bernanke and Kuttner (2005) obtain for U.S stock market reactions around FOMC announcements.[32] More importantly, we find no statistically significant effect of communication, so we rule this channel out as an explanation.

Second, we find no significant relationship between bond market illiquidity and monetary policy shocks: Neither target nor communication shocks have a significant effect on bond illiquidity of core and peripheral countries.

Third, considering the effect on credit risk, we find a statistically insignificant response of CDS to target rate shocks, but a strong response to communication shocks. The t-statistics suggest significance at the 1% level and point estimates are negative; thus, negative communication shocks increase the perceived probability of default for both core and peripheral countries. Economically, the loading of the peripheral CDS is four times larger than that of the core, and the difference is statistically significant with a t-statistic of -2.71. The point estimate on the CDS spread implies that a hypothetical 100bp negative communication shock raises the spread between peripheral and core CDS premia by 73bps. This finding demonstrates that financial markets interpret some dimension of central bank communication in terms of default likelihoods, which has important policy implications.

However, while important, we argue that the differential effect of communication is unlikely to be just a reflection of changes in credit risk. In order to show this, in Figure 10 (left panel) we plot the CDS spreads of core and peripheral countries. We notice the divergence of the two time-series in the beginning of 2009, whereas, recall, the divergence of the sensitivity of core and peripheral bond yields with respect to communication shocks happens in late 2010 (see Figure 7).

Next, we explore the impact of monetary policy shocks on CDS quanto spreads. Recall that CDS quantos are defined as the difference between spreads on CDS denominated in different currencies, a component which captures redenomination risk. Therefore, they are a vehicle that proxies for the risk premium associated not simply to credit but also a Eurozone breakup, at which point redenomination risk will be realized. Interestingly, the yield spread divergence due to communication shocks coincides with the divergence of the core and peripheral CDS quantos, depicted in the right panel of Figure 10. Before August 2010, there is no difference between CDS spreads denominated in USD and EUR, and hence the CDS quanto spread is zero. Spreads then start to increase and peak at around 100bps for peripherals and 75bps for core countries mid 2012.

To test the link between CDS quantos and monetary policy, the final columns of Table 5 report regression results from changes in CDS quantos on the monetary policy shocks. We notice that target rate shocks affect quantos on neither core nor peripheral

(2018)).

[32] In that paper, the authors argue the response of equity is unrelated to real interest rates but is due to the discount rate channel rising faster than the cash flow channel. In the Eurozone, it appears, the opposite is true.

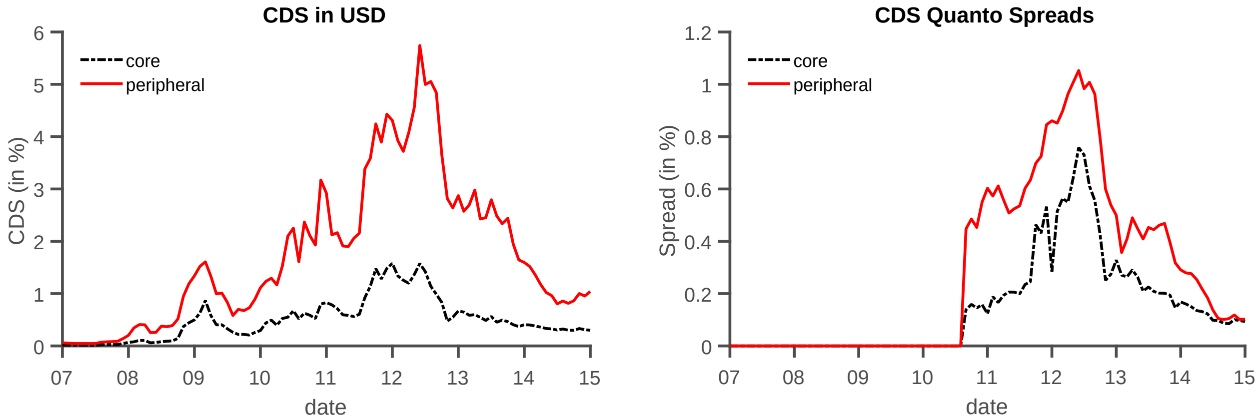


Figure 10. CDS in USD and CDS quanto spreads

The left panel plots credit default swaps in USD for core and peripheral countries in percent. The right panel plots CDS quanto spreads of core and peripheral countries in percent. CDS quanto spreads are defined as the difference in CDS contracts denominated in USD and EUR. Data are monthly.

countries. Similarly, we find no significant effect from communication shocks on quantos of core countries. Peripheral quanto spreads, however, load significantly negatively on communication shocks. Since communication shocks tend to be negative in the post-crisis period, we find that communication shocks increased the breakup or redenomination risk premium of peripheral countries, while they did not affect risk premia on core countries. Communication shocks also significantly increase the quanto spread between peripheral and core countries with an associated t-statistic of -2.02.

Given these findings, we adjust our baseline regression (2) to

$$\Delta y^{\tau}_{\mathrm{i},t} = \alpha^{\tau}_{i} + \beta^{\tau}_{\mathrm{i},r} Z_{r,t} + \beta^{\tau}_{\mathrm{i},\theta} Z_{\theta,t} + \beta^{\tau}_{\mathrm{i},X} \Delta X_{i,t} + \epsilon^{\tau}_{\mathrm{i},t}, \tag{8}$$

where $\Delta X_{i,t}$ is the two-day change in the average CDS swap or CDS quanto spread of core and periphery countries. Table 6 reports regression results. We find that the estimated coefficients for communication shocks in the post-crisis period, $\beta^{\tau}_{\mathrm{per},\theta}$ and $\beta^{\tau}_{\mathrm{core},\theta}$, are more aligned when controlling for either CDS spreads or CDS quantos than the results of Figure 6 suggested. Interestingly, we find that the estimated coefficients on CDS and CDS quantos are not significant for core countries, whereas coefficients for the peripheral are all highly statistically significant. Moreover, increases in the R^2s from adding CDS or CDS quantos are very large for peripheral bond yields, especially at longer maturities, where it reaches 67%.

	3	6	12	24	60	120		3	6	12	24	60	120
	Core							Peripheral					
Z_r	0.49	1.08	0.610	0.63	0.88	0.86	Z_r	-1.09	-2.20	-2.58	-2.64	-1.41	-0.74
t-stat	(3.63)	(4.06)	(6.18)	(3.46)	(2.44)	(3.19)	t-stat	(-6.46)	(-7.14)	(-3.88)	(-2.67)	(-4.17)	(-2.82)
Z_θ	0.51	0.89	1.29	1.60	1.14	0.51	Z_θ	0.93	1.13	1.08	1.05	1.060	0.89
t-stat	(7.57)	(6.34)	(9.63)	(14.35)	(4.86)	(2.60)	t-stat	(3.33)	(2.95)	(4.09)	(3.40)	(6.55)	(6.57)
CDS	0.16	-0.32	-0.12	-0.21	-0.38	-0.38	quanto	0.13	0.21	0.34	0.61	0.72	0.62
t-stat	(2.13)	(-1.06)	(-0.95)	(-1.37)	(-1.70)	(-1.73)	t-stat	(2.54)	(3.26)	(3.50)	(4.46)	(9.78)	(19.16)
R^2	34.55	29.30	71.30	70.66	43.80	18.53	R^2	40.04	52.70	47.19	52.93	80.76	74.59
ΔR^2	2.28	1.20	0.11	0.77	2.72	2.85	ΔR^2	12.86	16.14	22.26	36.64	67.23	67.27
	Core							Peripheral					
Z_r	0.52	1.02	0.66	0.69	0.97	0.97	Z_r	-1.11	-2.35	-2.83	-3.17	-1.99	-1.29
t-stat	(4.78)	(4.98)	(8.63)	(2.55)	(1.91)	(2.16)	t-stat	(-8.57)	(-5.96)	(-3.10)	(-2.11)	(-2.12)	(-2.21)
Z_θ	0.49	0.92	1.33	1.70	1.25	0.63	Z_θ	0.97	1.14	1.09	1.02	1.04	0.86
t-stat	(7.75)	(5.91)	(8.87)	(15.27)	(6.46)	(3.66)	t-stat	(3.16)	(2.74)	(3.95)	(4.28)	(6.88)	(3.23)
CDS	0.58	-1.14	0.21	0.17	0.12	0.27	quanto	1.36	1.61	2.57	4.18	5.16	4.18
t-stat	(3.16)	(-1.48)	(1.00)	(0.85)	(0.23)	(0.44)	t-stat	(3.06)	(2.83)	(3.33)	(4.82)	(7.52)	(5.11)
R^2	40.25	32.97	70.98	69.43	39.93	14.36	R^2	44.01	47.78	39.82	36.71	55.50	44.48
ΔR^2	7.98	4.87	-0.22	-0.46	-1.16	-1.33	ΔR^2	16.83	11.22	14.89	20.42	41.97	37.16

Table 6. Bond yield response with CDS or quantos

This table reports estimated coefficients from regressing daily bond yield changes of core and peripheral countries onto monetary policy shocks and changes in five-year CDS (left panels) or quantos (right panels) for core and peripheral countries:

$$\Delta y^{\tau}_{i,t} = \alpha^{\tau}_{i} + \beta^{\tau}_{i,r} Z_{r,t} + \beta^{\tau}_{i,\theta} Z_{\theta,t} + \beta^{\tau}_{i,X} \Delta X_{i,t} + \epsilon^{\tau}_{i,t}, \quad \tau = 3, \ldots, 120 \text{ months},$$

where $\Delta X_{i,t}$ is the two-day change in either core or peripheral CDS spread or quanto. t-statistics are calculated using Newey and West (1987). ΔR^2 reports the change in the adjusted R^2 when adding the CDS swap or quanto as a control variable. Data run from September 2010 to December 2014.

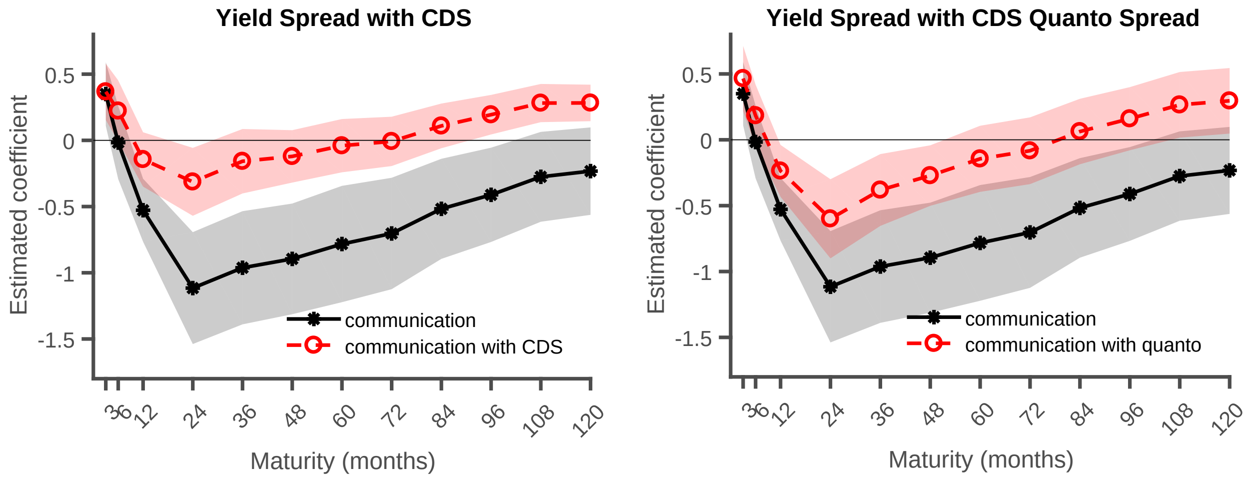


Figure 11. Peripheral-core yield spread controlling for CDS or quanto spreads

This figure plots estimated coefficients from a multivariate regression from changes in the yield spread defined as the difference in bond yield changes of peripheral and core countries' bonds on target and communication shocks as well as CDS spreads (left panel) and CDS quanto spreads (right panel). Confidence intervals are based on Newey and West (1987) standard errors. Data run between August 2010 and December 2014.

To test more formally whether the estimated coefficients on communication shocks are the same (i.e., whether their difference is statistically different from zero) once controlling for breakup or redenomination risk, we run regressions from changes in yield spreads, defined as the difference between peripheral and core countries' yields, on target and communication shocks, as well as CDS spreads or CDS quantos. We plot the estimated coefficients together with the 90% confidence bounds on Figure 11 when controlling for CDS (left) and CDS quanto spreads (right panel). The bold line presents estimated coefficients when only controlling for the monetary policy shocks. In line with our findings from Figure 6 and our earlier discussion, we notice that communication shocks significantly increased the spread for almost all maturities. Once we control for the CDS or CDS quanto spreads, however, estimated coefficients (dashed line) are not significantly different from zero, except at the two-year maturity. Hence, we conclude that once we control for the "missing risk premium", the effect of central bank communication on yields of core and peripheral countries is not that different anymore.

4.1 Robustness: Comparison with Alternative Shocks

Before turning to our theoretical model, one might worry that our main results are driven by the way we construct the monetary policy shocks. In the following, we use two alternative approaches to construct the target and communication shocks and find our results confirmed.

In their seminal paper, Gürkaynak, Sack, and Swanson (2005a) identify policy shocks using principal component analysis on futures rates with maturities up to one year in a tight window bracketing FOMC target rate announcements. In the setup of Gürkaynak, Sack, and Swanson (2005a), the principal components have no structural interpretation a priori since, for example, both factors are correlated with changes in the Federal funds rate. As rate announcements and other potential dimensions of monetary policy (e.g., forward guidance) happen at the same time in the U.S., the authors propose an identification strategy by restricting the second factor to have no effect on the short-end of the yield curve after a rotation. In other words, their second factor moves interest rates for the upcoming year without changing the current Federal funds rate.

Our approach allows for a separate identification of target rate and communication shocks by making use of an institutional feature of ECB policy announcements, namely that the target rate announcement and press conference take place separately. Our latent factors, F, are estimated from (1) separately around the target rate announcement and the press conference, and our approach does not rely on imposing any restrictions. To save space, the Online Appendix presents a comparison between the approach in Gürkaynak, Sack, and Swanson (2005a) and our identification strategy. Interestingly, we find that when using the Gürkaynak, Sack, and Swanson (2005a) "path" shocks instead of our communication shocks, results are very similar to the ones presented here. We view this results as an external validation for the rotated latent factor approach of Gürkaynak, Sack, and Swanson (2005a).

Alternatively, one could construct target and communication shocks from the short-end and the slope of the term structure of money market rates directly. To this end, we define target shocks as changes in the OIS one-month rate sampled in the monetary policy window, i.e. from 13:40 to 16:10 CET and communication shocks are defined as changes in the difference between the OIS 12-month and one-month rate sampled in the monetary policy window. All results are collected in the Online Appendix and we re-confirm our main findings.

5 Model

To understand the mechanism behind our baseline empirical results, we propose a three-period overlapping-generations equilibrium term structure model, in the spirit of Vayanos and Vila (2009), Greenwood and Vayanos (2014), Hanson and Stein (2015), and Malkhozov, Mueller, Vedolin, and Venter (2016).

5.1 Bond market

Time is indexed by $t = 0, 1, 2$ and 3. Agents, described below, make investment decisions at dates 1 and 2, and by date 3 all assets pay out. We look at the relationship between monetary policy shocks and bond yields as of date 0.

We consider a world economy with two countries of a currency union, e.g. the Eurozone, referred to as core and peripheral and indexed by $i = c, p$. At dates $t = 1$ and 2, agents have access to a global riskless asset that also constitutes one-period bonds of both countries, and this asset pays a net return of r_t at time $t+1$. At date 1, agents can also trade two-period (long-term) bonds of both countries. The yield-to-maturity of the long-term bond of country i that has a face value of one Euro, the currency unit, at $t = 3$ is denoted by $y^2_{i,1}$, and the risky one-period net return on this bond, between dates 1 and 2, is denoted by $R_{i,2}$. For simplicity, we assume that bonds are in positive and fixed Euro supply $s_{i,t} = s_i > 0$ for $i = c, p$.[33] Two-period bonds then become one-period riskless bonds by $t = 2$.

The risk-free rate r_t, which equals the yield (and return) on the one-period bond of both countries at date t, is assumed to be exogenously given, and its dynamics under the physical probability measure follows

$$r_{t+1} = \mathrm{E}_t \left[r_{t+1} \right] + Z_{r,t+1}, \tag{9}$$

where $Z_{r,t+1}$ are i.i.d. random variables with mean zero and variance σ^2_r, and the deterministic part of the short rate, $\mathrm{E}_t \left[r_{t+1} \right]$, is assumed to be an increasing function of r_t and a variable θ_t that follows

$$\theta_{t+1} = \mathrm{E}_t \left[\theta_{t+1} \right] + Z_{\theta,t+1}, \tag{10}$$

with $Z_{\theta,t+1}$ i.i.d. random variables with mean zero and variance σ^2_θ, also independent of all $Z_{r,t}$s. Formally, we write $\mathrm{E}_t \left[r_{t+1} \right] = f \left(r_t, \theta_t \right)$ with $\partial f \left(r_t, \theta_t \right) / \partial r_t > 0$ and $\partial f \left(r_t, \theta_t \right) / \partial \theta_t > 0$.[34] We interpret r_t as the target rate set by the central bank and θ_t as information provided by the central bank that shapes the future path of interest rates. Thus, $Z_{r,t}$ are changes to the target rate unexpected by investors, and $Z_{\theta,t}$ stand for communication shocks that provide information about the future path of interest rates.

We assume that the Eurozone that consists of the core and the peripheral country can break up. Formally, this is triggered at $t = 2$ by the random variable $Z_{b,2}$ that takes the value of 1 with conditional probability λ_1 and is zero otherwise, independent of all $Z_{r,t}$s and $Z_{\theta,t}$s. Then, from its definition, $\mathrm{E}_1 \left[Z_{b,2} \right] = \mathrm{E}_1 \left[Z^2_{b,2} \right] = \lambda_1$ and $\mathrm{Var}_1 \left[Z_{b,2} \right] = \lambda_1 - \lambda^2_1$. To keep the model simple, we make the linear approximation $\mathrm{Var}_1 \left[Z_{b,2} \right] \approx \lambda_1$, which would be exact in a continuous-time framework, and is approximately true when λ_1 is close to zero. Hence, we write $\mathrm{E}_1 \left[Z_{b,2} \right] = \mathrm{Var}_1 \left[Z_{b,2} \right] = \lambda_1$.

While known at date 1, λ_1 is random as of date 0; in particular, we want to capture that monetary policy shocks realized at date 1 also provide information about the future of the

[33] It would be straightforward to introduce time-varying or even stochastic supply into the model (see, e.g., Greenwood and Vayanos (2014)). However, this generalization would increase the technical complexity without any significant additional insight.

[34] A special case would be a mean-reverting process with $\mathrm{E}_t \left[r_{t+1} \right] = r_t + \kappa_r \left(\theta_t - r_t \right)$ and $0 < \kappa_r < 1$, for which $\partial f \left(r_t, \theta_t \right) / \partial r_t = 1 - \kappa_r$ and $\partial f \left(r_t, \theta_t \right) / \partial \theta_t = \kappa_r$ are both positive.

Eurozone and affect the perceived breakup probability λ_1.[35] Formally, we write

$$\lambda_1 = \mathrm{E}_0\left[\lambda_1\right] + Z_{\lambda,1} + \eta_r Z_{r,1} + \eta_\theta Z_{\theta,1}, \tag{11}$$

where the random variable $Z_{\lambda,1}$ has mean zero and variance σ_λ^2, is independent of all $Z_{r,t}$s, $Z_{\theta,t}$s, and $Z_{b,t}$, and we have $\eta_r, \eta_\theta < 0$. This assumption captures that market participants interpret negative target rate shocks (i.e., target rates lower than what the market expects) and negative communication shocks (i.e., future rates staying low longer as the market expects) as bad news that increase the perceived probability of a breakup.[36]

If the Eurozone breaks up, returns on long-term bonds are affected: we assume that in this case agents cannot capture the full intrinsic value of long-term bonds due to, e.g., search or transaction costs, lower liquidity, or a change in monetary policy of the now independent central banks. That is, long-term bonds, if not held until maturity, are subject to both interest rate risk and break-up risk. We model the latter as a proportional loss of value with multiplicative coefficients γ_i, $i = c, p$, that vary across bonds. In line with the general view that in case of a Eurozone breakup bonds issued by peripheral countries would be more exposed to credit, (potential) redenomination, and liquidity risks, and hence less valuable than bonds issued by core countries, we assume that the losses are expected to be larger on peripheral bonds for all agents: $\gamma_p > \gamma_c > 0$.[37]

Bonds are held by a unit mass of competitive and identical agents that we refer to as banks.[38] Banks live for one period; they choose optimal bond holdings at time t to trade off the mean and variance of their terminal wealth at $t+1$. They can trade all core and peripheral bonds without any restrictions. By no arbitrage, returns between dates 2 and 3 on all bonds are r_2, so the only non-trivial investment decision banks face is at $t = 1$. If banks of period 1

[35]We have in mind a setting where the central bank has superior information about the fundamentals of the economy, and through its decisions, can affect some important macro variables, including the probability of breakup. If the central bank picks r_t and θ_t as solutions to an optimization problem subject to their information set, changes to r_t and θ_t will provide information to market participants. In Section OA-6 of the Online Appendix we provide a simple model as a microfoundation for this assumption.

[36]The framework presented here could also accommodate country-specific credit risk for a more realistic modelling. However, this generalization would increase the technical complexity without any significant additional insight.

[37]The assumption on the level and nature of losses at date 2 is not crucial for our results. First, this is equivalent to assuming that agents learn before date 2 that the terminal bond payoffs drop to $e^{-\gamma_c}$ and $e^{-\gamma_p}$ instead of one in case of the breakup. Second, we could also allow for core country bonds to get stronger when peripheral countries exit the Eurozone in the form of $\gamma_p > 0 > \gamma_c$. This would only shift the level of equilibrium yields, but would not affect our qualitative predictions regarding the cross-section of yields. Third, our approach could also be extended to uncertain losses given breakup. One sufficient condition for our results to remain qualitatively similar is that the expectation and variance of the peripheral loss is at least as large as for core losses: $\mathrm{E}_1\left[\gamma_p\right] > \mathrm{E}_1\left[\gamma_c\right] > 0$ and $\mathrm{Var}_1\left[\gamma_p\right] > \mathrm{Var}_1\left[\gamma_c\right]$.

[38]Banks might be heterogeneous in terms of the potential losses suffered if they are based in core and peripheral countries. Hence, in Section OA-7 of the Online Appendix, we construct a model that allows for investor heterogeneity in the γ_is. Under an additional mild assumption we obtain that upon negative monetary policy shocks, holdings also exhibit home bias, i.e., agents sell (short) foreign bonds and purchase home-country bonds instead, in line with the findings of, e.g., Gennaioli, Martin, and Rossi (2014), Chari, Dovis, and Kehoe (2016), and Becker and Ivashina (2018). See also Farhi and Tirole (2017).

are born with wealth w_1 and $x_{i,1}$ denotes their Euro investment in long-term country-i bonds, $i = c, p$, their budget constraint becomes

$$w_2 = w_1 (1 + r_1) + \sum_{i=c,p} x_{i,1} (R_{i,2} - r_1), \tag{12}$$

where one-period bond returns are

$$R_{i,2} = 2y_{i,1}^2 - r_2 - \gamma_i Z_{b,2}, \tag{13}$$

and the optimization problem is given by

$$\max_{\{x_{i,1}\}_{i=c,p}} \mathrm{E}_1 [w_2] - \frac{\alpha}{2} \mathrm{Var}_1 [w_2], \tag{14}$$

with $\alpha \geq 0$ coefficient of risk aversion. Finally, the market-clearing condition is

$$x_{i,1} = s_i \tag{15}$$

for $i = c, p$.

5.2 Equilibrium

Combining (9) and (12)-(14), we obtain that banks' optimization problem is equivalent to

$$\begin{aligned} &\max_{\{x_{i,1}\}_{i=c,p}} \sum_{i=c,p} x_{i,1} (\mathrm{E}_1 [R_{i,2}] - r_1) - \frac{\alpha}{2} \mathrm{Var}_1 \left[\sum_{i=c,p} x_{i,1} R_{i,2} \right] \\ &= \sum_{i=c,p} x_{i,1} (\mathrm{E}_1 [R_{i,2}] - r_1) - \frac{\alpha}{2} \left[(x_{c,1} + x_{p,1})^2 \sigma^2 + (\gamma_c x_{c,1} + \gamma_p x_{p,1})^2 \lambda_1 \right], \end{aligned}$$

where $\mathrm{E}_1 [R_{i,2}] = 2y_{i,1}^2 - E_1 [r_2] - \gamma_i \lambda_1$ denotes the expected return on the two-period bonds. Deriving the first-order conditions and imposing market clearing (15), it follows that equilibrium expected excess returns must compensate agents for the interest rate risk and break-up risk they hold:

$$\mathrm{E}_1 [R_{i,2}] - r_1 = \alpha \sigma^2 (s_c + s_p) + \alpha \gamma_i (\gamma_c s_c + \gamma_p s_p) \lambda_1,$$

increasing in λ_1 and γ_i. From here, we obtain the following result:

Theorem 1. *In the term structure model described above, date-*1 *long-term equilibrium bond yields are given by:*

$$y_{i,1}^2 = \frac{r_1 + E_1 [R_{i,2}]}{2} = \frac{r_1 + f (r_1, \theta_1)}{2} + \frac{1}{2} \alpha \sigma^2 (s_c + s_p) + \frac{1}{2} g (\gamma_i) \lambda_1, \tag{16}$$

where $g(\gamma_i) \equiv \gamma_i [1 + \alpha(\gamma_c s_c + \gamma_p s_p)]$ *that satisfies* $g(\gamma_c) < g(\gamma_p)$.

5.3 Model Predictions

We summarize our model predictions regarding the effect of target and communication shocks on bond yields across countries in three propositions that correspond to our baseline tests presented in the empirical analysis. For this, we consider running theoretical multivariate regressions, viewed as of date 0, of country-i bond yield changes on the target and communication shocks corresponding to our empirical regression (2):

$$\Delta y_{i,1}^2 = y_{i,1}^2 - \mathrm{E}_0\left[y_{i,1}^2\right] = \alpha_i + \beta_{i,r} Z_{r,1} + \beta_{i,\theta} Z_{\theta,1} + \varepsilon_{i,1}, \tag{17}$$

and on the target and communication shocks while also controlling for the innovations in our proxy of breakup risk, $\Delta\lambda_1 \equiv \lambda_1 - \mathrm{E}_0[\lambda_1] = Z_{\lambda,1} + \eta_r Z_{r,1} + \eta_\theta Z_{\theta,1}$ corresponding to our empirical regression (8):

$$\Delta y_{i,1}^2 = y_{i,1}^2 - \mathrm{E}_0\left[y_{i,1}^2\right] = \alpha_i' + \beta_{i,r}' Z_{r,1} + \beta_{i,\theta}' Z_{\theta,1} + \beta_{i,\lambda}' \Delta\lambda_1 + \varepsilon_{i,1}. \tag{18}$$

Equation (16) implies the following regression coefficients:[39]

Lemma 1. *Running the theoretical regression (17), the regression coefficients are*

$$\beta_{i,r} = \frac{1}{2}\left[1 + \frac{\partial f(r_1, \theta_1)}{\partial r_1} + g(\gamma_i)\eta_r\right] \text{ and } \beta_{i,\theta} = \frac{1}{2}\left[\frac{\partial f(r_1, \theta_1)}{\partial \theta_1} + g(\gamma_i)\eta_\theta\right].$$

Running the theoretical regression (18), the regression coefficients are

$$\beta_{i,r}' = \frac{1}{2}\left[1 + \frac{\partial f(r_1, \theta_1)}{\partial r_1}\right], \beta_{i,\theta}' = \frac{1}{2}\frac{\partial f(r_1, \theta_1)}{\partial \theta_1}, \text{ and } \beta_{i,\lambda}' = \frac{1}{2} g(\gamma_i).$$

Lemma 1 leads to the following testable predictions:

Proposition 1. *The impact of target shocks in regression (17) is always higher on core country yields than on peripheral yields:* $\beta_{c,r} > \beta_{p,r}$. *Moreover, there exists a constant* $\bar{\eta}_r < 0$ *such that the* $\beta_{i,r}$, $i = c, p$, *coefficients are positive as long as* $\bar{\eta}_r < \eta_r < 0$.

Proposition 2. *The impact of communication shocks in regression (17) is always higher on core country yields than on peripheral yields:* $\beta_{c,\theta} > \beta_{p,\theta}$. *Moreover, there exists a constant* $\bar{\eta}_\theta < 0$ *such that the* $\beta_{i,\theta}$, $i = c, p$, *coefficients are positive as long as* $\bar{\eta}_\theta < \eta_\theta < 0$.

[39] As the target and communication shocks are uncorrelated in the model, univariate regressions of yield changes on either the target or the communication shocks would yield the same regression coefficients as the multivariate one. Moreover, running the theoretical regressions on the variables, e.g. on r_t instead of the shock $Z_{r,t}$, would not affect coefficients.

Proposition 3. *The impact of communication shocks in regression (18) is positive and uniform across countries:* $\beta'_{c,\theta} = \beta'_{p,\theta} > 0$*. Thus, controlling for breakup risk, central bank communication has the same effect on core and peripheral country yields. Further,* $0 < \beta'_{c,\lambda} < \beta'_{p,\lambda}$.

5.4 Discussion

Bond yields are the average expected returns earned through the lifetime of bonds, which in turn depend on expected future risk-free rates and risk premia. Therefore, when the central bank announces changes to either the current target rate or the intended future path of monetary policy, bond yields can be affected via two channels.

A direct effect operates through the expectation channel, and it is uniform across all countries, because they share the same target rate process. A negative current target rate shock decreases all future expected target rates. Thus, as a response, bond yields go up. Similarly, communication shocks provide information about intended future target rates: a negative communication shock implies that future target rates are to be lower than previously expected. Hence, a negative shock to θ_t also decreases all yields through the expectation channel.

The second, indirect effect, works through the risk premium channel: by signalling about the probability of suffering losses on bond holdings, monetary policy shocks can effectively manifest as demand shocks for risk-averse banks. In our model, a negative target or communication shock is interpreted as bad news: it makes banks less willing to hold long-term bonds compared to one-period bonds. As long-term bonds are risky, banks, who still have to hold them in equilibrium, demand a higher risk premium. Overall, negative monetary policy shocks lower rates via the expectation channel but raise them via the risk premium channel: the direct and indirect effects go in opposite directions, as captured by the negative signs of $g(\gamma_i)\,\eta_r$ and $g(\gamma_i)\,\eta_\theta$.

The heterogeneity in the impact of monetary policy shocks on bond yields across countries is driven by the fact that banks expect to suffer larger losses on peripheral long-term bonds than on core long-term bonds, so the risk premium they demand must be higher, as captured by $g(\gamma_p) > g(\gamma_c)$. Given that the expectation channel is identical for bonds of the two countries, and that the risk premium channel goes the opposite direction as the expectation channel, we obtain that core country bonds are more responsive to communication shocks than peripheral bonds. Once we control for breakup risk in our regressions, however, this heterogeneity in the coefficients disappears. Since banks suffer larger losses on peripheral bonds in case of breakup, peripheral bond returns and yields are more exposed to breakup risk. We conclude that our model provides an understanding of how target and communication shocks can affect the term structure of yields in equilibrium across countries within a monetary union.

6 Conclusion

Central bank communication has taken centre stage in both popular and academic literature since the advent of the 2008 financial crisis. In this paper, we exploit high-frequency data on Eurozone money market rates to identify separately monetary policy actions from monetary policy communication and study its effect on the cross-section of sovereign bond yields in the Euro-area.

We document the following findings. Target rate shocks affect short-term interest rates more than long-term interest rates, consistent with what has been documented in the U.S. However, there is an additional effect of central bank communication that has a strong impact at intermediate maturities bond yields and which is hump shaped in maturity. Dissecting the time series, our main result concerns the effect of monetary policy pre- and post European debt crisis. While monetary policy had a uniform effect on core and peripheral bond yields pre-crisis, we document dramatic differences post-2009. In particular, while communication shocks significantly lowered yields of core countries, peripheral countries' bond yields were immune against communication which led to a significant increase in the periphery-core wedge. This finding shows that communication shocks offset some of the effects of the ECB's monetary policy tools aiming at easing the funding squeeze of peripheral countries.

We empirically link the periphery-core wedge to an emergence of an Euro-area breakup and credit risk premium which offset the dovish monetary policy since 2009. Controlling for the "missing risk premium" as captured by CDS or CDS quantos, central bank communication affects core and peripheral bond yields in virtually the same way.

We rationalize our empirical findings in a setting where central bank communication has a signalling effect. Surprise tightenings or loosening provide information to the market about the expected health of the Eurozone economy, in particular of peripheral countries. Monetary policy induces demand shocks in the fixed-income market, and thus generates risk premia in equilibrium. When the central bank announces changes to the current target rate or the intended future path of monetary policy, it has a direct effect on bond yields through an expectation channel, but also an indirect one, by influencing the perceived probability of the Eurozone breakup. We show that such an economy is capable of rationalizing our cross-country findings, and thus provides a potentially new transmission channel through which monetary policy operates.

Our paper documents that central bank communication can have large effects on asset prices but remains agnostic about the specific contents of the communication. In our model, risk-averse agents reallocate their portfolios depending on the signal received. At the same time, it is well known that central banks rely on asset prices to steer the economy. The two-way flow between monetary policy and asset prices is what Morris and Shin (2018) dub the "reflection problem." Studying in more detail the type of communication and the feedback between asset prices and communication in the data and theory remains a challenging topic that we leave for future research.

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