Forthcoming in Journal of Financial Economics

Central Bank Communication and the Yield Curve

Matteo Leombroni* Andrea Vedolin† Gyuri Venter‡ Paul Whelan§

Abstract

In this paper, we argue that monetary policy in the form of central bank communication can shape long-term interest rates by changing risk premia. Using high-frequency movements of default-free rates and equity, we show that monetary policy communications by the European Central Bank on regular announcement days led to a significant yield spread between peripheral and core countries during the European sovereign debt crisis by increasing credit risk premia. We also show that central bank communication has a powerful impact on the yield curve outside regular monetary policy days. We interpret these findings through the lens of a model linking information embedded in central bank communication to sovereign yields.

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

JEL Classification: E43, E58, G12

We thank the editor, Bill Schwert, and an anonymous referee for helpful comments and suggestions. We also thank Daniel Buncic, Stefania D'Amico, Paul Ehling, Jean-Sébastien Fontaine, Charles Goodhart, Robin Greenwood, Sven Klingler, Gábor Kőrösi, Lukas Kremens, David Lando, Anh Le, Wolfgang Lemke, David Lucca, Hanno Lustig, Aytek Malkhozov, Charles Martineau, Felix Matthys, Leonardo Melosi, Ali Ozdagli, Lasse Pedersen, Monika Piazzesi, Huw Pill, Gábor Pintér, Ricardo Reis, John Rogers, Dirk Schumacher, Ulf Söderström, Karlye Dilts Stedman, Alireza Tahbaz-Salehi, Hongjun Yan, and seminar and conference participants at various universities and institutions for helpful comments and suggestions. We thank Now-casting Economics Ltd for providing access to their Eurozone Now-casts. Gyuri Venter acknowledges financial support from the Independent Research Fund Denmark (grant no. DFF-8019-00108B). Paul Whelan acknowledges financial support from the FRIC Center for Financial Frictions (grant no. DNRF-102).

*Stanford University, email: leombm@stanford.edu.

†Boston University, NBER, and CEPR, email: avedolin@bu.edu.

‡Warwick Business School, email: gyuri.venter@wbs.ac.uk.

§Copenhagen Business School, email: pawh.fi@cbs.dk.

The financial turmoil of 2007–2008 and the subsequent European debt crisis have fuelled a lively debate about the role of central banks in controlling long-term interest rates. In this paper, we argue that monetary policy communication by central banks can have a dramatic impact on long-term interest rates via a risk premium channel. We establish this by showing that monetary policy communications by the European Central Bank (ECB) led to a significant yield spread between peripheral (Italy and Spain) and core (Germany and France) countries during the European sovereign debt crisis by increasing credit risk premia.

Figure 1 displays cumulative changes in ten-year core and peripheral sovereign yields between 2001 and 2015 on regular ECB monetary policy meeting days, i.e., days when the ECB sets the key interest rates for the Euro area. The plot shows that while core and peripheral yields moved one-for-one on these days before 2009, after the onset of the European debt crisis yields diverged, leading to a significant spread. Importantly, this spread emerged during a period when a series of unconventional measures were implemented to reduce it.[1]

Using high-frequency movements of default-free rates and an equity index, we show that monetary policy communications conducted by the ECB on regular announcement days were responsible for the pattern documented on Figure 1 by increasing credit risk premia. These increases were economically sizable, and, at the very least, amplified sovereign yield volatility, making it harder for the ECB to succeed in reducing peripheral yields faster. However, we also document that speeches by the ECB President outside the regular monetary policy announcements significantly decreased the peripheral-core spread, and together with the announcements of unconventional policies, led to a sizable reduction in the yield spread. Taken together, our findings provide novel evidence that monetary policy in the form of central bank communication can impact long-term interest rates by changing risk premia.

Our empirical strategy exploits two key features of monetary policy announcements in the Eurozone. First, the ECB's protocol for announcing monetary policy decisions allows us to disentangle the component of the policy announcement that contains new information about the future path of interest rates or credit risk—what we refer to as communication shocks—from the announcement of the short-term interest rate. Second, the fact that (current and future) short-term

[1]On 8 August, 2011, and 10 May, 2010, the ECB announced direct purchases of government debt through its *Securities Markets Programme*, and on 6 September, 2012, it announced further purchases via its *Outright Monetary Transactions*; Altavilla, Giannone, and Lenza (2014), and Falagiarda and Reitz (2015) among others, document a significant reduction in the periphery-core spread due to these measures. In January 2015, the ECB launched its expanded *Asset Purchase Programme*; De Santis and Holm-Hadulla (2017) among others, evaluate its effects on financial markets.

interest rates are common across all Eurozone countries implies that any change in yield spreads in response to communication shocks must be due to changes in risk premia as opposed to changes in expectations of future short-term interest rates or term premia.

We start our analysis by developing a theoretical framework that highlights how central bank communication affects risk premia. We consider a currency union of multiple countries, representing the Eurozone. In the model, central bank communication has two dimensions: one about the intended future path of interest rates (forward guidance) and the other about additional policies, such as asset purchases, liquidity supports, or lending and refinancing operations. The two shocks drive investors' perceived probability of a credit event, such as a peripheral default or the breakup of the Eurozone, and hence, impact the premia they demand on risky assets such as sovereign bonds and equity. This mechanism is based on the premise that market participants have imprecise knowledge about either the central bank's reaction function, such as when it would introduce unconventional policies, or about its private signals, as in Romer and Romer (2000) and Nakamura and Steinsson (2018). Then, asset price movements around announcements are informative about market participants' reaction to the new information embedded in these announcements.

The framework first formalizes how to identify interest rate communication shocks (also referred to as forward guidance shocks) from changes in risk-free money market rates around communication events. Further, if equity is also expected to respond to a peripheral default, the equity reaction that is orthogonal to interest rate shocks is informative about risk premia, and provides an identification of pure risk premium shocks of monetary policy communication.

The model also provides hypotheses about the impact of these two types of shocks on sovereign yields. A negative forward guidance shock decreases bond yields uniformly across all sovereigns by signalling lower future interest rates than what the market expected, but at the same time can also increase the required risk premium on all sovereign debt, dampening the effect of the expectation channel. A negative pure risk premium shock, on the other hand, increases credit risky sovereign yields. Overall, interest rate and risk premium shocks can help explain the difference in peripheral and core yield reactions to monetary policy communication.

To perform our empirical analysis, we extract the two monetary policy shocks on ECB announcement days using high-frequency data on money market rates and an equity index. Because the timing of the press conferences is known precisely, we can identify surprises related to the future path of short-term rates using changes in riskfree interest rates with different maturities.

Equity returns, also sampled during ECB press conferences, allow us to extract shocks that are informative about the probability of a future default in the Euro area.

With the two communication shocks in hand, we test the model predictions and document a number of novel results regarding Eurozone yields. First, for our main result, we split our sample into pre-sovereign debt crisis (January 2001 to November 2009, 100 observations) and sovereign debt crisis (December 2009 to December 2014, 61 observations) periods separately. We find that pre-crisis ECB communication affected bond yields of Euro-area countries uniformly. However, we find that, during the crisis, peripheral yields' response to interest rate shocks became muted, while core yields continued to react strongly. Further, while the effect of risk premium shocks was negligible pre-crisis, they became the dominant force driving yield spreads afterwards. We find that interest rate and risk premium shocks explain around 40% of changes in ten-year yield spreads, with risk premium shocks being responsible for the majority of this variation.

Second, using rolling regressions, we confirm that the effect of central bank communication about forward guidance on peripheral bond yields declined during the crisis period while risk premium shocks became increasingly important in driving up yield spreads. Taking into account *only* scheduled announcement days, we find that central bank communication was responsible for a significant wedge that, at its peak around the end of 2013, represented 25% of the total ten-year yield spread. This finding is important since it coincides with a period when unconventional measures were implemented to reduce spreads.

The dramatic difference between the effect of monetary policy communications in the pre-crisis and crisis periods is in line with two distinct regimes in our model, and relates to the literature that links the European debt crisis to self-fulfilling beliefs and multiple equilibria; see, e.g., Corsetti and Dedola (2016), Bocola and Dovis (2019), and Lorenzoni and Werning (2019), among others. According to this interpretation, the period before late 2009 featured a small probability of a credit event and a low sensitivity of this probability to ECB communication shocks. In contrast, after December 2009, negative risk premia shocks, signalling a lower probability of the introduction of necessary "save the Euro" policies, increased agents' perceived probability of a credit event significantly, which in turn drove yield spreads up even further.

Third, we study the link between central bank communication shocks and credit risk premia and document highly significant effects on sovereign CDS and, most importantly, their spread. This finding further corroborates our interpretation of risk premium shocks as being informative about the likelihood of a peripheral default.

Fourth, we investigate whether our results are exclusive to monetary policy announcements during press conferences or can be extended to central bank communication more generally—one of the most prominent being ECB President Draghi's "whatever it takes" speech in 2012 that immediately collapsed the peripheral-core spread and led to a rally in stock markets. To answer this question and to go beyond anecdotal evidence, we construct interest rate and risk premium shocks during speeches by ECB Presidents akin to the procedure around monetary policy press conferences. Using these shocks, we re-run our main analysis and find patterns strikingly similar to standard monetary policy communication. While interest rate and risk premium shocks have no significant effect on the yield spread before 2010, in the crisis period both shocks explain around 35% of the variation of the yield spread on days when ECB Presidents give speeches. These results relate to the broader notion that risk premia due to monetary policy can also be earned outside standard monetary policy announcement days; see, e.g., Neuhierl and Weber (2019). Moreover, we show that ECB President speeches led to a significant reduction in the peripheral-core spread, offsetting the increase in spreads observed on regular ECB announcement days. This effect on the spread is further strengthened once we take into account announcements of unconventional policies: the overall effect—once we combine all announcement and speeches—was a sizable *reduction* of the yield spread. These results stress the relevance of taking into account central bank communication *outside* regular announcement dates.

Fifth, we extend our analysis to the period after the introduction of the ECB Quantitative Easing programme. To this end, we re-estimate our baseline regressions for an extended sample period between 2015-2018 and include a QE-related policy shock that we construct following Swanson (2018) and Altavilla, Brugnolini, Gürkaynak, Motto, and Ragusa (2019). We find that the power of interest rate communication shocks returned to the pre-crisis level: estimated coefficients are highly statistically significant, and these communication shocks are able to explain more than 60% of the variation in both core and peripheral yields. We therefore conclude that the introduction of unconventional monetary policies such as QE resurrected the power of monetary policy communication about interest rates by reducing its risk premium effect.

We perform a number of robustness checks to challenge our main finding by including macroeconomic announcements, changing the sampling frequencies of our left- and right-hand variables, and considering alternative risk premium shocks. Taken together, our findings illustrate that central bank communication can have significant effects on asset prices via a risk premium channel during and outside anticipated monetary policy announcements.

Related Literature. A large literature in macro-finance studies the effects of the U.S. Federal Reserve's monetary policy on the cross-section of assets and market variables such as long-term real and nominal interest rates, equity returns, volatility, and mortgage issuance; see, e.g., Fama (2013), Hanson and Stein (2015), Boyarchenko, Haddad, and Plosser (2017), Hanson, Lucca, and Wright (2018), and Neuhierl and Weber (2019). While our approach is similar in spirit, we complement the above literature along at least two dimensions. First, we highlight the role of monetary policy to influence markets beyond the standard stance of conventional monetary policy, and affect credit risk premia instead of term premia. Second, the unique setting for the transmission of monetary policy in the Eurozone allows us to study central bank communication separately from policy action.

An important literature studies the ECB's action during the European debt crisis. For example, Rogers, Scotti, and Wright (2014), Fratzscher, Lo Duca, and Straub (2016), Haitsma, Unalmis, and de Haan (2016), Koijen, Koulischer, Nguyen, and Yogo (2017, 2020), Krishnamurthy, Nagel, and Vissing-Jorgensen (2018), and De Santis (2019), all document that the unconventional policies of the ECB successfully eased financial conditions in peripheral countries. In contrast to these papers, we study regular monetary policy days and our focus is on the different dimensions of central bank communication. Further, our long time series enables us to document structural breaks in the effect these shocks have on the sovereign yield spread. We also extend our study from regular ECB monetary policy meeting days to President speeches more generally.

The framework that guides our empirical approach is also linked to a literature that explores belief-driven equilibria around the European sovereign debt crisis; see, e.g., Corsetti and Dedola (2016), Bocola and Dovis (2019), Lorenzoni and Werning (2019), and Bacchetta, Perazzi, and van Wincoop (2020). We complement this theoretical literature by providing empirical evidence for a risk premium channel of monetary policy that arises in the "bad equilibria" of these models.

Our paper is also related to the literature that explores the signalling channel of monetary policy: policymakers' actions reveal their private knowledge to market participants, which in turn can have real economic effects; see, e.g., Romer and Romer (2000), Campbell, Fisher, Justiniano, and Melosi (2016), and Nakamura and Steinsson (2018).[2] We add to this literature by extracting

[2]Ellingsen and Soderstrom (2001), Woodford (2012), Campbell, Evans, Fisher, and Justiniano (2012), Gertler and Karádi (2015), Tang (2015), Melosi (2016), Miranda-Agrippino and Ricco (2018), Ai and Bansal (2018), Hansen, McMahon, and

two distinct policy shocks that differentiate between standard interest rate shocks and news related to additional policies that, in the Eurozone setting, manifest as credit risk shocks. Different from this literature, we also argue that our additional policy shocks (or risk-premium shocks) can capture not only superior signals directly about macroeconomic variables, but also information about the implementation of unconventional policies (or the lack thereof), which in turn naturally affect the macroeconomy.

Our identification of ECB communication shocks partially follows Brand, Buncic, and Turunen (2010), who study the effect of monetary policy on Eurozone money market rates; see also Altavilla, Brugnolini, Gürkaynak, Motto, and Ragusa (2019). Our paper is different from theirs along several dimensions. First and foremost, we not only use money market rates but also equity returns to extract two distinct channels of central bank communication, and we show that shocks driving credit risk premia have a much more significant role in explaining sovereign yields than the traditional interest rate shocks since 2009. Second, we study the cross-sectional differences in yield reaction to communication during the European sovereign debt crisis, which is outside the sample period of Brand, Buncic, and Turunen (2010) and not considered by Altavilla, Brugnolini, Gürkaynak, Motto, and Ragusa (2019). Third, we document a more general link between central bank communication and asset prices that is also present when ECB Presidents give speeches.

The rest of the paper is organized as follows. Section I provides a simple theoretical framework to study the impact of monetary policy communication on sovereign yields. Section II presents the various data sources used. Section III describes the institutional setting of ECB monetary policy announcements and outlines the identification of communication shocks. We present our main empirical findings and perform various robustness checks in Sections IV-VI. An Online Appendix gathers additional results omitted from the main paper.

I. Theoretical framework and main implications

Our main premise is that monetary policy communication drives market participants' beliefs about the future path of interest rates as well as the implementation of additional policies, and we build a reduced-form model to study the cross-sectional impact of central bank communication on asset

Tong (2020), Laarits (2019), Andrade, Gaballo, Mengus, and Mojon (2019), and Jarociński and Karádi (2020), among others, discuss further aspects of monetary policy signalling. See also Ehrmann and Fratzscher (2005), Lucca and Trebbi (2011), Schmeling and Wagner (2019), and Neuhierl and Weber (2019), who study the link between central bank tone and asset returns.

prices. Below we describe the model, highlight the mechanism we have in mind, describe how to identify central bank communication shocks, and derive testable predictions. The formal model itself is delegated to the Online Appendix.

While the main mechanism applies in general, to accommodate our empirical application and provide testable implications, we set up a modelling framework that can represent the Euro area. For this purpose, we consider a currency union of multiple countries, and think about a representative agent that trades default-free assets (e.g. OIS swap rates), defaultable sovereign bonds in each country, and an aggregate equity index of the Eurozone.

The central bank (the ECB) has two roles in this economy: it sets the target short rate and communicates to market participants. We posit that central bank communication provides information about future short rates (forward guidance) and additional policies. Our main interpretation of the latter type is signals about the implementation of asset purchase programmes or the lack thereof.[3] Market participants, in turn, update their beliefs about the probability of credit events that we think of as sovereign (mainly peripheral) defaults, or the breakup of the Eurozone. In particular, we would expect credit risk to increase and future equity cash flows to decrease if the ECB signals lower future interest rates because the macroeconomy needs further stimulus, and if market participants find that either the probability or the scope of future asset purchase programmes is insufficient.

In equilibrium, expected excess returns on all assets must compensate investors for the risk they bear: for default-free bonds this is only interest rate risk, whereas sovereign bonds and equity have risk premia that increase in the probability of a credit event and the loss given a credit event (see, e.g., Duffie and Singleton (1999)). As a result, if and only if monetary policy communication is informative about the probability of the credit event and market participants consider peripheral (GIIPS) countries weaker/credit-riskier than core countries such as Germany or France, the risk premium on the former are larger than on the latter; otherwise, there should be no difference.

Consider now high-frequency intervals around communication events such as ECB press conferences when all non-communication shocks of the model are negligible. Our framework implies that one can identify shocks to the future path of interest rates from default-free rate changes in these

[3]This interpretation is consistent with the idea that monetary policy shocks are surprises about the central bank's reaction to publicly available information, as in Bauer and Swanson (2020). Alternatively, the standard macro literature models central bank communication as revealing the bank's private information about exogenous macro fundamentals such as GDP growth, industrial production, or unemployment, to the public; see, e.g., Romer and Romer (2000), Campbell, Fisher, Justiniano, and Melosi (2016), and Nakamura and Steinsson (2018), among others. While both channels are consistent with our formal model, we focus on the first interpretation due to the time period and the Eurozone setting that we study.

narrow intervals; we will denote these by IR. Moreover, the impact of additional policy shocks can be identified by orthogonalizing high-frequency equity returns with respect to default-free yield changes and taking the residual; we denote these by U.

The above setting has a series of implications about the effect of central bank communication shocks IR and U on the cross-section of sovereign yields. First, we show that sovereign yields of core countries react more to ECB forward guidance shocks than peripherals. Sovereign bond yields are the average expected returns earned through the lifetime of bonds, which equal expected future risk-free rates and risk premia. Therefore, communication shocks about the future path of monetary policy can affect bond yields via two channels.

On one hand, forward guidance shocks provide information about future short rates, so a negative IR shock decreases all bond yields, and this effect is uniform across all countries, because they share the same short rate process. On the other hand, innovations to the future path of interest rates also affect the perceived probability of the credit event: An announcement that policy rates will be low for longer can increase the probability of default by raising the market value of current liabilities and making it less profitable for bondholders to roll over sovereign debt, and can also be interpreted as a signal of weaker future fundamentals (e.g., output or unemployment). These mechanisms increase the risk premia on credit-risky assets such as sovereign bonds.

Because the expectation channel is identical for all countries and the risk premium channel counteracts it, core yields are overall more responsive to interest rate shocks than peripheral yields. Intuitively, German and other core bonds, even in turbulent times, tend to feature small risk premia and thus interest rate shocks have an overall positive impact on their yields. In contrast, in stressful periods the risk premium channel on peripheral bonds can be strong enough to dominate the expectation channel and lead to negligible or even negative overall IR multipliers.

A second result is that negative news about ECB policies, $U < 0$, increase the perceived probability of the credit event and hence the required risk premia; this raises sovereign yields, especially for peripheral countries. Since these additional policy shocks have no expectation effect via influencing future short rates, we refer to them as *pure risk premium shocks* in the rest of the paper.

Notice that the described risk premium channel crucially depends on the sensitivity of market participants' perceived probability to monetary policy shocks. While we take these parameters of the model as given, their value can change across different regimes. In normal times, when the Eurozone is in sound economic and financial condition, we would expect monetary policy communication to have a small effect on credit risk, and as a result, all sovereign bonds react to forward guidance shocks and feature small risk premia. On the other hand, in more turbulent (crisis) times, perceived credit risk is more sensitive to ECB communication. In turn, peripheral sovereign yields can stop reacting to conventional monetary policy, and negative additional policy shocks, which signal a lower probability of the introduction of policies investors deem necessary, drive up the perceived probability of a credit event, further raising yield spreads.

We summarize the above predictions in the following hypotheses:

Hypothesis 1. *In normal times, IR (forward guidance) communication shocks have a positive and uniform impact on all sovereign yields. In crisis times, they have a positive effect on core yields, and a smaller or even negative impact on peripheral yields.*

Hypothesis 2. *In normal times, U (risk premium) communication shocks have a negligible effect on sovereign yields. In crisis times, they have a negative impact on all sovereign yields, which is larger in absolute value for peripheral yields.*

While these predictions are intuitive, it is important to show that they are consistent with a rational framework. For this purpose, we build a reduced-form model of the impact of central bank communication on asset prices in the Online Appendix. In what follows, we perform empirical tests suggested by Hypotheses 1 and 2.

II. Data

Interest Rates Swaps. From Reuters Datascope we collect real-time quotes of overnight index swap rates with maturities ranging between one and twelve months, and swap rates, written on the six-month Euribor, with maturities ranging between two and ten years.

Equity. Additionally, from Reuters Datascope, we obtain high-frequency data on Eurostoxx 50 futures. We use futures data instead of the cash index since futures markets are far more liquid than cash markets. Futures returns are computed on the most liquid (highest volume) contract, which is normally the front month, or, in expiration months, the next to delivery.

Sovereign bond yields. We use daily zero-coupon bond yields of Germany, France, Italy, and Spain, with maturities ranging between three months and ten years, available from Bloomberg. We focus on these four countries as both bond and CDS data coverage for these countries is reliable, and together they account for about 76% of the total GDP of the Eurozone. We also use high-frequency bond yields of the same set of countries available from Reuters Datascope.

Credit risk. To measure the credit risk of each country, we use U.S. dollar-denominated credit default swaps sourced from Markit.

News. For aggregate macroeconomic news about the Eurozone, we rely on Now-casts of current Euro-area GDP. Now-casts are based on a dynamic factor model (see, e.g., Giannone, Reichlin, and Small (2008)) to predict current and next quarter GDP growth and use a large and heterogeneous set of predictors, including both "hard" and "soft" data, ranging from unemployment statistics to consumer surveys. We use changes in the Now-casting predictions between two ECB meetings to proxy for all relevant economic news released within this period.

Announcement dates. Our main sample period runs from 1 January, 2001, to 31 December, 2014. Since January 2015, the press release of the ECB Governing Council policy decision refers to current and future unconventional policy measures, too; see the details in Section III. In addition, January 2015 also marks the beginning of the ECB publishing its monetary policy deliberations. Thus, our main period of interest ends in December 2014 to keep our identification clean. We discuss the impact of the introduction of the Asset Purchase Programme in January 2015 in Section VI. During the 2001-2015 period there is approximately one ECB meeting per month, except for in years 2001 and 2008, with 22 and 13 meetings, respectively. From the 179 announcement days we exclude 18 that were either not followed by a press conference or were unscheduled; these are summarized in the Online Appendix. Our final sample thus consists of 161 announcement days: 18 days when the main refinancing rate was cut, 11 days when the rate was raised, and 132 meetings with no change.

ECB President speeches. We combine data on ECB President speeches from Bloomberg calendar, Bloomberg news, and the ECB website for the 2001 to 2015 period. The Bloomberg economic calendar lists all speeches performed by the ECB President together with the date of the speech. We then match the list of speeches provided by Bloomberg with information from the ECB website, which provides the transcript for a set of speeches. For the purpose of our paper we only use speeches that were covered both by the Bloomberg calendar and by the ECB website. We filter out a small number of speeches such as award ceremonies, openings of museums, book fairs, etc., that were clearly not discussing monetary policy-related issues. Finally, using the Bloomberg news database, we collect the time stamp for the first news of the day that is related to the speech, focussing only on speeches held during typical market trading hours, i.e., between 09:00 and 18:00 CET. This leaves us with 219 ECB President speeches.

III. ECB Governing Council meetings and policy shocks

A large empirical literature extracts monetary policy shocks from money market rates. We follow the approach of Brand, Buncic, and Turunen (2010) based on high-frequency identification, which exploits 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 monetary policy action vis-à-vis communication.

Figure 2 illustrates the timeline of events on days of the meetings of the Governing Council. At 13:45 CET, the ECB publishes a press release announcing its policy rate decision, i.e., the minimum bid rate for the main refinancing operations of the Eurosystem. Then at 14:30 CET, the ECB president and Vice-President hold a press conference, during which they discuss the future path of monetary policy (forward guidance on interest rates) and the state of the Eurozone economy. As our focus is on the effect of ECB communication on asset prices, to allow sufficient time for the market to reflect on rate decisions and information, we define our communication window starting at 14:25 and ending at 15:30 CET, 40 minutes after the press conference finishes.

[Insert Figure 2 here]

The press conference begins with an introductory statement, whose structure has remained the same since the inception of the ECB: 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. Central bank communication therefore not only reveals information about future interest rates but also about the state of the economy. In the following, we draw on the joint dynamics of default-free interest rates and equity during the 1-hour-and-45-minute press conference window to capture the multi-dimensional nature of communication, as described by our theoretical framework.

We form a single composite forward guidance shock from swap rates. Specifically, we measure changes in swap rates with maturities ranging between one month and ten years over the press conference window, then estimate latent factors via principal component analysis on the covariance matrix of the 161 (number of announcements) × 21 (maturities) matrix of rate changes. We find that the first PC explains more than 86%, and the first two PCs together explain more than 93% of the total variation. To assess the economic significance of these factors, we regress zero-coupon rate changes, bootstrapped from swap rate changes, on the first and second PCs. Our regressions reveal that almost all of the variation in bond yields is captured by the first PC and that the second factor has very little impact on yield changes during the communication window. Thus, we take PC_1 as our proxy for the default-free *interest rate communication shock*, denoted by IR.

The equity response, EQ, is simply computed as the log return of the most liquid Eurostoxx 50 futures contract during the same window used to estimate the forward guidance shock. To disentangle the effect of shocks to risk premia that is independent of default-free interest rate shocks, we then estimate an orthogonal component via ordinary least squares (OLS):[4]

$$EQ_t = a + b\ IR_t + \varepsilon_t. \tag{1}$$

In our analysis, we orthogonalize equity shocks with respect to the interest rate shock using the full sample period; however, our results remain the same if we orthogonalize with respect to the different periods. Thus, we obtain pure *risk premium shocks* by

$$U_t \equiv EQ_t - \hat{a} - \hat{b}\ IR_t, \tag{2}$$

where $\hat{a}$ and $\hat{b}$ are the OLS point estimates from (1).

Figure 3 plots the time series of our estimated communication shocks, and Table I presents summary statistics for the full sample and the two subsamples. For the full sample, the interest rate shock is slightly negative at -0.20bps on average (U shocks are zero-mean by construction), and the volatility of risk premium shocks is around 23 times larger than for interest-rate shocks. Comparing pre- and post-December 2009 summary statistics, we find that many characteristics are stable across subsamples. However, the risk premium shocks become more negative as well as more volatile over time.

[4] In the Online Appendix we present estimated coefficients for (1) and a similar, multivariate specification that includes the first 5 principal components of swap rates, for three sample periods (full sample, pre-crisis, and crisis). Our estimates show that for all sample periods there is a low correlation between equity returns and IR, and the maximum R^2 is 12%. Interestingly, unlike Bernanke and Kuttner (2005) for FOMC meetings, we find that IR shocks have on average positive impact on equity returns around ECB press conferences that increases over time, although all estimates are insignificant.

[Insert Table I and Figures 3 and 4 here]

To motivate our approach, we discuss the events and corresponding shocks on two particular days of our sample. On 4 August, 2011, the Governing Council decided to keep interest rates on hold after a previous hike in July, causing market participants to revise down their beliefs about the future path of the policy rate. This resulted in a drop in interest rates, corresponding to a -11bp IR shock, an approximately 3.5-standard-deviation surprise—the largest dovish shock in the crisis period.

Figure 4 shows the reaction of bond and stock markets during the ECB press conference of 2 August, 2012, exactly one week after ECB President Draghi's famous "whatever it takes" speech. During the meeting, the Governing Council decided that "it may undertake outright open market operations of a size adequate to reach its objective." As a result, the spread between peripheral and core ten-year yields experienced the largest one-day increase on any day between 2009 and 2015 (53bps), because, after the speech on 26 July, 2012, the market was expecting nothing short of an announcement of quantitative easing.[5] Figure 4 shows that while the two-year swap rate did not change significantly, EuroStoxx futures dropped by 2.66% during the first half of the press conference. We measure the pure risk premium shock of this conference at -247bps, which corresponds to a three-standard-deviation surprise—the largest negative U shock in the sample.

Our proposed economic channel links the information embedded in central bank communication to these swap, equity, and sovereign yield changes. In the following, we study their relationship more formally, and use the above two numerical examples, IR = -11bps and U = -247bps, to illustrate the economic significance of our results.

IV. Central bank communication and sovereign yields

A. Core versus peripheral yields

We regress daily changes of core and peripheral bond yields on IR and U shocks for the pre-sovereign debt crisis (January 2001 to November 2009, 100 observations) and sovereign debt crisis

[5] The press headline that day read: "ECB disappoints. The council is clearly not in agreement on what can or will be deployed, and there are clearly a number of council members who are making further ECB action contingent on governments delivering on their side of the equation and therefore whatever the ECB does will not be QE." When asked during the Q&A, President Draghi stated that the move "was approved unanimously today with one exception and it was not me." Bundesbank Chief Jens Weidmann allegedly voicing his reservations about bond-buying caused uncertainty about future ECB monetary policy.

(December 2009 to December 2014, 61 observations) periods separately.[6]

Yields are defined as the arithmetic average of German and French yields, and peripheral yields are defined as the arithmetic average of Italian and Spanish yields; we report individual country regressions in the Online Appendix. Formally, as suggested by our theoretical framework, we run

$$\Delta y_{i,t}^{\tau} = a_i^{\tau} + b_i^{\tau} IR_t + c_i^{\tau} U_t + \epsilon_{i,t}^{\tau}, \tag{3}$$

where $\Delta y_{i,t}^{\tau}$ are daily zero-coupon yield changes for $i = c, p$ (core and periphery), with maturities $\tau = 3, \ldots, 120$ months, and we compare the obtained core and peripheral coefficients.

Figure 5 visualizes our results. The left panels plot the effect of interest rate (upper left panel) and risk premium shocks (lower left panel) before December 2009. We find that before the European sovereign debt crisis, coefficients for the interest rate shock are statistically different from zero for all maturities, and estimated coefficients for core and peripheral countries are virtually the same, indicating that monetary policy did not have a differential effect. For example, for any negative 11bp forward guidance shock, there is an 18bp decrease in two-year bond yields and an 8bp drop in ten-year yields, for both core and peripheral countries. Pure risk premium shocks, on the other hand, do not have a significant effect on bond yield changes as estimated coefficients are insignificant at all maturities.

[Insert Figure 5 and Table II here]

The right panels present results from the crisis subsample, the main focus of our paper. Interestingly, interest rate shocks have a differential effect on core versus peripheral countries in this period: for core countries we find virtually the same hump-shaped pattern as in the first part of the sample, but peripheral countries are affected much less; in fact, estimated coefficients beyond the one-year maturity are indistinguishable from zero. In particular, we find that for any dovish 11bp surprise, two-year core yields drop by 17bps, whereas the effect on a two-year peripheral yield is a 2bp increase and statistically insignificant. This pattern extends to longer maturities: for ten-year bonds, the corresponding numbers are a 10bp core drop and a 4bp peripheral increase.

[6] A formal analysis, following Bai and Perron (1998, 2003), identifies three break points during the 2001-2018 period. The first is in December 2009, which was the first ECB meeting where Greek default was mentioned. The second occurs mid-2012, in the run-up to the "whatever it takes" speech of ECB President Mario Draghi. The third break, in December 2014, marks the end of our "crisis" sample, after which the ECB (i) introduced the PSPP programme and (ii) changed its communication strategy by releasing some information about unconventional policies together with the monetary policy decision at 13:45 CET. Treating the 2009-2012 and 2012-2014 periods separately does not have a qualitative impact on our results. Exhaustive estimation details are gathered in the Online Appendix.

We can compare these numbers to those documented in the literature for US Treasury bonds. For example, Nakamura and Steinsson (2018) find that any 100bp increase in their policy shock (which the authors interpret as a forward guidance shock) increases ten-year Treasury yields by 38bps. Since their largest (in absolute values) shock is a 13bp drop, this implies a 5bp decrease in ten-year yields—close to our pre-crisis or crisis core estimates but larger than the crisis peripheral effect. Hanson and Stein (2015) report similar economic magnitudes for forward guidance shocks and their effects on real yields.

Estimated coefficients on risk premium shocks for core countries are insignificant at all maturities except at the shortest maturity. For peripheral yields, however, we find highly statistically significant estimates, which increase (in absolute value) with the maturity. To evaluate the effect of risk premium shocks on peripheral yields, we refer to the event documented in Figure 4: a negative 247bp pure risk premium shock increases two-year peripheral yields by $247 \times 7.50/100 = 19$bps and ten-year peripheral yields by $247 \times 9.17/100 = 23$bps.

To highlight the effect of the shocks on the yield spread, defined as the difference between peripheral and core yields, we turn to Table II, which presents estimated coefficients for core and peripheral countries during the crisis. We find that interest rate shocks have a statistically significant effect on the spread for maturities ranging from two to ten years, with the largest effect for the intermediate maturities around two years. For U shocks, we find that the estimated coefficients are again significant for maturities ranging between two and ten years, and coefficients increase (in absolute value) with the maturity. The last line of the table also reports the change in adjusted R^2 when adding the risk premium shock to the regression. We notice that the latter contributes the majority to the variation in bond yield changes, with its incremental R^2s ranging between 1% and 32% for maturities above one year. Repeating the same calculation as above, we find that a -11bp IR shock increases the two-year (ten-year) yield spread by 19bps (14bps), whereas a -247bp U shock increases the two-year (ten-year) yield spread by 19bps (26bps). Therefore, while forward guidance and risk premium shocks have approximately the same effect on two-year yields, the latter have a twice as large impact on very long term sovereign bond yields. This finding is also related to Altavilla, Brugnolini, Gürkaynak, Motto, and Ragusa (2019), who find that monetary policy shocks extracted from default-free interest rates alone have small impact on long-term bonds during the crisis period — we show that in this period most of the variation is risk-premium-related.

In a recent paper, Bauer and Swanson (2020) argue that because the Federal Reserve and market participants pay attention to the same news, macro news are an omitted variable in regressions similar to (3), and including them drives out monetary policy shocks, questioning the so-called "Fed information effect" documented in Nakamura and Steinsson (2018). To address the concern that similar mechanisms are at work in the Euro area, too, in the Online Appendix we revisit the findings of Table II but also include changes in Now-casts as a proxy, available in real-time and computed from a large panel of macroeconomic indicators, for the omitted macro news variable.[7] We find that controlling for news does not affect our main result: regression coefficients are virtually the same as in Table II, and the significance levels and regression R^2s are hardly affected. This suggests that in the case of the Eurozone, central bank communication still provides information relevant for sovereign bond pricing beyond publicly available information.

The above results indicate a regime change in terms of central bank communication from the pre-crisis to crisis period that led to significantly different patterns in sovereign yields' reaction to monetary policy shocks. In particular, the pre-crisis regression coefficients are consistent with an economy in which either there are no major differences between core and peripheral countries' economies, or monetary policy communication does not contain significant new information about the state of the economy and hence credit risk. On the other hand, our results suggest that during the crisis investors paid special attention to the health of the sovereign economies, with a particularly sharp disconnect between core (e.g., Germany and France) and peripheral economies (e.g., Italy and Spain). It is also reasonable to assume that during this period, in case of a peripheral default or an Eurozone breakup, bonds issued by peripheral countries would have been more exposed to credit losses, potential redenomination, and liquidity risks, i.e., less valuable than bonds issued by core countries. Thus, these results confirm the predictions of Hypotheses 1-2.

The regime change around the December 2009 ECB meeting, the first one during which Greek default was mentioned, suggests that the failure of forward guidance to impact peripheral yields and the dominance of U shocks might not be exclusively due to worsening fundamentals. In fact, this dramatic change is consistent with the recent literature that links the European debt crisis to self-fulfilling beliefs and multiple equilibria (see Corsetti and Dedola (2016), Bocola and Dovis

[7]In the Online Appendix, we also present regression results from changes in expected output of core and peripheral countries on our monetary policy shocks and the news shock, similar to Bauer and Swanson (2020). We find that estimated coefficients for U and IR shocks are positive for both countries. However, the coefficients are not precisely estimated: U shock coefficients - while larger for peripheral countries - are statistically significant for core countries while IR are statistically significant only for peripheral countries.

(2019), Lorenzoni and Werning (2019), and Bacchetta, Perazzi, and van Wincoop (2020), among others). In our framework, the pre-crises results correspond to a "good" equilibrium in which all sovereign bonds react to forward guidance shocks and feature small risk premia. The post-December 2009 results, on the other hand, correspond to a "bad" equilibrium in which peripheral sovereign yields stop reacting to conventional monetary policy, and negative state-of-the-economy shocks, which signal a lower probability of the introduction of policies investors deem necessary, drive up the perceived probability of a credit event, and yield spreads rising further and getting disconnected from fundamentals.

B. Communication effects in the time series

In order to get a better understanding of the time-series behavior of the regime change noted earlier, Figure 6 depicts estimated coefficients and R^2s from rolling-window regressions of ten-year bond yield changes of core and peripheral countries on interest rate (upper panels) and risk premium shocks (lower panels). We find that the effect of IR shocks on core countries' yields remains remarkably stable throughout the whole period as estimated coefficients wiggle around 0.8. The effect on peripheral yields, however, starts to weaken in 2011 and becomes zero and insignificant in 2013. The effect of U shocks is virtually the same for core and peripheral countries until 2012, when the two start to diverge. While the effect on core countries continues to be insignificant, the effect on peripheral yields strengthens as estimated coefficients become negative. A similar pattern emerges for the univariate R^2s: For core yields, interest rate shocks explain on average around 30% of the variation. For peripheral countries, the R^2 drops significantly in 2011 and converges to zero. Risk premium shocks, on the other hand, display exactly the opposite behavior: while the R^2 is close to zero until the crisis for both core and peripheral yields, the effect on the latter increases during the crisis, reaching an R^2 of 35% at the end of our sample. These results again suggest a radical change in how peripheral countries were perceived by market participants even on ECB days.

[Insert Figure 6 here]

C. Economic significance and the yield spread

Since the onset of the crisis in 2009, 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, by (iii) introducing a series of unconventional measures such as its Securities Markets Programme and Outright Monetary Transactions, and, since January 2015, by (iv) introducing quantitative easing in the form of its permanent 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.

To evaluate the realized effect and overall economic magnitude 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. We compute the implied spread by multiplying realized shocks with the difference in real-time policy loadings displayed in Figure 6, and add them up over time. The resulting spread is depicted in Figure 7. Strikingly, we find that IR and U shocks had a consistently positive effect on the yield spread starting at the onset of the crisis in 2010. Indeed, the cumulative sum increases up to 50bps in late 2013 and has since then been declining. Economically, this effect is large: At the end of 2013, the ten-year core-periphery yield spread was 213bps, so at its peak the spread due to communication represented around a quarter of the total yield spread.

[Insert Figure 7 here]

D. Credit risk

Next, to study whether monetary policy communication drives the yield spread through a credit risk channel, we run the regressions

$$\Delta CDS_{i,t} = a_i + b_i \; IR_t + c_i \; U_t + \epsilon_{i,t},$$

where $\Delta CDS_{i,t}$is the change in the five-year CDS rate of country i. Table III contains the results for the four individual countries, core and peripheral CDSs, and their spread. We find that estimated coefficients for IR and U shocks are significant and negative. In particular, a hypothetical negative 11bp IR shock increases the five-year peripheral-core CDS spread by 12bps, whereas a hypothetical negative 247bp U shock increases the difference in CDS rates by 23bps. Given that on average IR and U shocks are negative after December 2009, this implies that both shocks significantly increase the credit risk premium spread between peripheral and core countries, and the majority of this difference is driven by the U shock itself.[8]

[Insert Table III here]

Our empirical results have two implications regarding the model described in Section I. First, monetary policy communication does not only seem to be an important driver of investors' beliefs about future interest rates, but also about perceived credit risk, which supports our modelling assumptions and interpretations. Second, the U shocks that we back out from equity changes are essentially the main drivers of credit risk premia. Since they have no effect on expectations by construction, they can indeed be interpreted as sovereign credit risk premium shocks of ECB communication.

E. Are ECB days special?

Our main results presented in Table II are based exclusively on days when the ECB makes its monetary policy announcement. It is natural to ask whether the relationship between sovereign bond yields and shocks extracted from risk-free interest rates and equity is different on ECB days relative to all other days. To study this question in more detail, we construct interest rate shocks by repeating the principal component analysis of risk-free interest rates in high frequency during the communication window on all days from 2010 to 2015. Similarly, we construct risk premium shocks from equity returns sampled in the same period on all days. Using these two shocks, we re-run our main regression augmented by a dummy, $\mathbb{1}_{\text{ECB},t}$, that takes the value of one on days when the ECB makes its monetary policy announcement and zero otherwise:

$$\Delta\left(y^{\tau}_{p,t} - y^{\tau}_{c,t}\right) = a^{\tau}_1 + a^{\tau}_2 \mathbb{1}_{\text{ECB},t} + b^{\tau}_1\ IR_t + c^{\tau}_1\ U_t + b^{\tau}_2\ IR_t \times \mathbb{1}_{\text{ECB},t} + c^{\tau}_2\ U_t \times \mathbb{1}_{\text{ECB},t} + \epsilon^{\tau}_t.$$

We present the results in Table IV for sovereign yields and in Table V for CDS.

[Insert Tables IV and V here]

[8] As an additional test for credit risk channel, we can look at corporate credit spreads directly. To this end, we collect Markit iBoxx EUR price indices from Bloomberg, and obtain the following estimates for the crisis period:

$$\Delta\left(\log BBB_t - \log AAA_t\right) = a + \underset{(6.00)}{3.42}\ IR_t + \underset{(4.58)}{9.13}\ U_t + \epsilon_t, \quad \bar{R}^2 = 40.17\%$$

Since the left-hand side variables are price indices and not yields, more negative shocks increase the corporate yield spread, in line with the results of Table III.

Except for the short end, changes in sovereign yields are not significantly different on ECB days than other days as indicated by the insignificant estimates on the dummy variable. The estimated coefficients on the IR and U shocks are negative and highly statistically significant, just as in Table II; the negative relationship between yield spreads and monetary policy shocks is significant in the crisis period even on days when the ECB does not announce its monetary policy. However, estimated coefficients on the interaction terms are also significant for long maturities, indicating that the relationship between communication shocks and yield spreads is "special" on days when the Governing Council hold their meetings. For a comparison of the magnitudes, note that a hypothetical negative 11bp IR shock increases the ten-year peripheral-core yields spread by 14bps on normal days and by 32bps on ECB days, whereas a hypothetical negative 247bp U shock increases the peripheral-core yields spread by 8bps on normal days and by 25bps on ECB days—a three times larger effect. A similar pattern emerges for CDS: negative forward guidance and risk premium shocks increase the credit risk of peripheral countries relative to core countries, especially on ECB days.

F. Alternative risk premium shocks

In our framework, the nature of risk premium shocks is information about the implementation of unconventional policies (or the lack thereof) to the market. Our shocks are calculated from equity returns, but one might argue that other asset prices capture changes in risk better around monetary policy announcements. For example, Rogers, Scotti, and Wright (2014) use changes in the spread between ten-year Italian and German bond yields to study the reaction of exchange rates and equity returns around ECB monetary policy announcements, and Bekaert, Hoerova, and Lo Duca (2013) argue that equity-implied volatility is strongly related to the stance of the US Federal Reserve's monetary policy and investors' risk aversion.

In the following, we construct a composite measure from Eurostoxx returns and changes in two implied volatilities, and study the impact of this alternative shock on bond spreads during the crisis. To this end, we collect data on the VSTOXX, an implied volatility index from options written on the Eurostoxx, and extract an implied volatility measure from the cross-section of options written on the EUR/USD exchange rate. Using the first principal component of these implied volatilities and our equity returns, and orthogonalizing the variable with respect to our IR shock as in (2), we calculate an alternative risk premium shock, which we denote by C.

Table VI summarizes estimated coefficients from regressing peripheral-core yield spreads on the interest rate shock, IR, and the new risk premium shock, C. We notice that all estimates for C are positive and highly statistically significant for long maturities; higher risk premium shocks lead to higher yield spreads. In terms of the IR coefficients and R^2s, we find the numbers to be very similar to those reported in Table II. Overall, we conclude that our results are robust to the set of assets we choose to construct risk premium shocks from.

[Insert Table VI here]

G. Robustness

We perform a host of robustness checks to challenge our main result; to save space, we defer exhaustive details and results of these tests to the Online Appendix. First, we study the effect of other macroeconomic announcements on our results. Second, we explore the impact of varying the high-frequency window length to identify our monetary shocks. Third, we use high frequency changes in bond yields instead of daily changes in our sovereign regressions. Fourth, we reconstruct our monetary policy communication shocks separately in the two relevant subsamples and check whether they alter our results. Finally we estimate our sovereign regression using bootstrapped standard errors to take into account the extra sampling variation due to the construction of our shocks. We find that our results are virtually unchanged in all the different robustness specifications.

V. ECB President speeches

One natural question is whether our results about press conferences extend to other forms of central bank communication. This question is also related to a recent literature that argues that a large fraction of risk premia earned on asset prices due to monetary policy occur outside of standard announcement days; see, e.g., Neuhierl and Weber (2019). The communication event that has gained most traction is undoubtedly the "whatever it takes" speech by ECB President Mario Draghi at an investors' conference in London on 26 July, 2012. The consensus view in the literature is that the speech marked the beginning of the Outright Monetary Transaction (OMT) program intended to lower the high borrowing costs of peripheral countries; see, e.g., Acharya, Eisert, Eufinger, and Hirsch (2019). The upper panels of Figure 8 illustrate the asset price reaction on that day for the two-year swap rate as well as the Eurostoxx index. While we notice an increase in the two-year swap rate, this was dwarfed by the sharp increase in the equity index, with a daily return of almost 5%. The lower two panels, on the other hand, depict the well-known result that during the days that followed the speech, neither German nor French yields moved much, while peripheral yields, as well as the spread, decreased significantly.

[Insert Figure 8 here]

A. Core versus peripheral yields

In the following, we want to understand whether other central bank speeches command similar reactions in asset prices, or whether 26 July, 2012, marked a special day. To this end, we collect data on ECB President speeches outside the ECB announcement days as described in Section II, and we apply the same identification to President speeches to back out two communication shocks as described in Section III for ECB press conferences. Figure 9 plots the IR and U shocks that we obtain for President speeches, and it underscores nicely the importance of including risk premium shocks into the analysis. For example, the upper panel indicates that the forward guidance shock of 26 July, 2012, does not signal a special event at all. In the lower panel, however, where we plot U shocks, this day clearly stands out.

With the President shocks at hand, we study the effect of these speeches on sovereign bond yields. To this end, we run the same regressions as in (3) but using the IR and U shocks obtained around speeches. The estimated regression coefficients are plotted on Figure 10, and Table VII contains estimated coefficients for the yield spreads.

We notice a strikingly similar pattern compared to our baseline results presented on Figure 5: interest rate communication shocks have a significantly positive hump-shaped effect on all sovereign yields before December 2009, and on core yields during the crisis period, but the coefficients are insignificant for the periphery during the crisis. Moreover, loadings on risk premium shocks are insignificant for all countries pre-crisis, and for core countries during the crisis, but are negative and large in absolute value for peripherals during the crisis.

The results in Table VII indicate that while pre-crisis there was almost no significant reaction of the yield spread to either IR or U shocks, during the crisis estimated coefficients are significant. To compare the economic size of the estimates, we can again use the largest shocks in the sample to study the effects of forward guidance and risk premia shocks on yields. For both shocks, the largest shocks occurred during the "whatever it takes" speech in July 2012: we find an IR shock of 2.63bps and a U shock of 261bps (these correspond to a two-standard-deviation and a 4.69-standard-deviation surprises, respectively). As a result, we should see a $2.63 \times 3.29 = 9$bp drop in the ten-year yield spread due to the interest rate shock realization, and a $261 \times 5.58/100 = 15$bp drop due to the risk premium shock realization. On that day, the spread between peripheral and core yields decreased by 40bps. Forward guidance and risk premium shocks thus contributed to more than half of the overall reduction.

While we measure IR and U shocks on regular monetary days and during President speeches the same way, these events can contain different types of information, so one should expect a different impact on sovereign yields, too. Comparing our estimates of Tables II and VII, we find that the two shocks contribute approximately the same to the overall variation in the ten-year yield spread, at around 35%. However, while on regular monetary policy days most of the explanatory power comes from risk premia shocks, forward guidance shocks contribute a bigger fraction to the overall R^2 during President speeches (10% compared to 32%).

[Insert Figures 9 and 10 and Tables VII and VIII here]

We also study the relationship between credit risk and President speeches in Table VIII. The results are somewhat similar to Table III. We find that, when the ECB President gives a speech, an IR shock of 2.63bps leads to a $2.63 \times 2.15 = 6$bp drop in the CDS peripheral-core spread. On the other hand, a hypothetical 261bp pure risk premium decrease the spread by $261 \times 5.78/100 = 15$bps. Overall, our results indicate that central bank communication has a significant effect on asset prices not just around monetary policy announcements but also during other ECB President speeches.

B. Economic significance

In Section IV, we argued that ECB communication on its regular monetary policy announcement days contributed to an increasing yield spread between core and peripheral countries, and this spread emerged during a period when a series of unconventional measures were implemented to reduce it. Therefore, we also want to study the combined effect of ECB regular announcement days with ECB President speeches and unconventional announcement days.

The upper panel of Figure 11 extends the cumulative changes in yields and the periphery-core spread of Figure 1 to include days when the ECB President gives speeches. While we find that between 2010-2012 the yield spread increased, by the end of the sample the communication effects of regular announcement days were completely offset by the reduction due to ECB president speeches.

Further, the lower panel of Figure 11 adds days when unconventional monetary policies were announced. As documented by Krishnamurthy, Nagel, and Vissing-Jorgensen (2018), the Securities Markets Programme announcements led to significant drops in the peripheral bond yields and hence the periphery-core spreads. Once we combine all the announcements days, we find that the ECB successfully *narrowed* the spread between peripheral and core countries. Nevertheless, our results show that ECB communication on regular announcement days partially offset some of these effects. The temporary increases in default risk premia and peripheral yields due to the ECB's communication on regular monetary policy days, both between 2009 and mid-2010 and throughout 2013, were economically sizeable, and at the very least increased sovereign yield volatility and made it harder for the ECB to succeed in bringing down peripheral yields quicker.

[Insert Figure 11 here]

VI. Quantitative Easing and re-connecting monetary policy

Our previous results indicate that during the 2009-2014 period, even around the time of the announced unconventional monetary policy measures, communication on the ECB monetary policy meeting days significantly increased yield spreads, which at the very least made it harder for the ECB to succeed in bringing down peripheral yields. Following the end of our main sample, in December 2014, the ECB announced the decision to launch its permanent quantitative easing, called the Asset Purchase Programme, and one natural question is whether and how this affected the transmission of monetary policy communication to asset prices.

To this end, we extend our analysis to the 2015-2018 period and we augment the set of our monetary policy shocks following Swanson (2018) and Altavilla, Brugnolini, Gürkaynak, Motto, and Ragusa (2019) to construct a QE-related policy shock. These authors argue that with the introduction of QE, there exists a third dimension to monetary policy communication that is independent of the "standard" target and forward guidance shocks. We follow the authors' procedure and we extract three principal components from the cross-section of high-frequency changes in the communication window and impose the following factor rotation: (i) the second and third (when the third factor is present) factors do not load on the one-month OIS; (ii) the rotation is such that the third factor has the smallest variance in the pre-crisis period. The latter enforces the factor unimportant in the pre-crisis period. As Altavilla, Brugnolini, Gürkaynak, Motto, and Ragusa (2019) note, this factor should only contribute to the movements in the long-end of the yield curve, and only be active post-2014, leading to the "QE factor" label.

[Insert Table IX here]

Table IX collects the results of regressions of core and peripheral yields as well as their spread in the post-2014 period. Comparing estimated coefficients to those estimated during the crisis period (Table II), we find that the effect of monetary policy communication returned to almost pre-crisis levels: regression coefficients of both types of shocks are of the same magnitude for core and peripheral yields, and IR shocks feature extremely high t-statistics. In terms of R^2, our communication shocks explain on average more than 60% of the variation in peripheral yields, while the QE shock explains an additional ∼2%, and only at the long end, in line with the interpretation in Altavilla, Brugnolini, Gürkaynak, Motto, and Ragusa (2019).[9] Regarding yield spreads, the bottom panel shows that our communication shocks as well as the QE factor are not significant at any maturity.

Overall, these findings also suggest that the muted sensitivities of peripheral bond yields to forward guidance and the extreme sensitivity to U shocks during the crisis should be ascribed to the risk premium effect of monetary policy communication in that period, rather than measurement errors or other confounding effects. Further, in reference to our model and interpretation, the introduction of the APP can be seen as a commitment by the ECB strong enough to eliminate the "bad" equilibrium of the crisis period and collapse yield spreads.

VII. Conclusion

The recent ECB press conference meeting of 12 March, 2020, was a stark reminder that monetary policy communication matters. When ECB President Christine Lagarde mentioned that it is not the ECB's job to "close the spread" between bonds of different member states, asset markets

[9]Note that our IR communication shocks are not orthogonal to Altavilla, Brugnolini, Gürkaynak, Motto, and Ragusa (2019)'s QE factor. Therefore, our findings do not imply that QE shocks are not relevant in this sample. Rather, they suggest that our interest rate and risk premium shocks capture most of the QE effects. We provide a more formal comparison between our monetary policy shocks and those of the authors in the Online Appendix.

reacted promptly: the ten-year yield on Italian sovereigns jumped from 117bps to 174bps whereas for Germany it remained at -74bps, implying an 35% increase in the spread. At the same time, the Eurostoxx index fell by 13%. In this paper, we offer a formal treatment of how central bank communication affects the cross-section of asset prices, and provide evidence for the presence of a central bank communication risk premium channel.

We make four novel contributions. First, drawing on the joint dynamics between interest rates and an equity index sampled during a narrow window around ECB press conferences, we construct monetary policy shocks related to two distinct channels of central bank communication: the path of interest rates (forward guidance) and credit risk premia in the Eurozone.

Using these shocks, we show that in the pre-crisis period (January 2001 to November 2009), forward guidance shocks were the important communication instrument and had a uniform effect on core and peripheral bond yields. In contrast, during the sovereign debt crisis period (December 2009 to December 2014), core bonds only reacted to forward guidance shocks and peripheral yields were driven almost exclusively by credit risk premium shocks, leading to a significant wedge between core and peripheral yields.

We also show that our results are not exclusive to ECB press conferences during monthly monetary policy announcements, but more generally whenever ECB Presidents give speeches, and demonstrate that President speeches and unconventional policy announcements managed to be effective and overcome the negative effect of ECB standard monetary policy announcements on the yield spread. Finally, we show that the introduction of unconventional monetary policy in 2015 restored the transmission of monetary policy communication on sovereign yields as core and peripheral bonds again reacted homogeneously to communication shocks.

The recent events of 2020 have again highlighted the importance of studying monetary policy beyond setting risk-free interest rates, as is standard in the literature. For example, while the forward guidance shock does not indicate a significant move on 12 March, 2020, we observe a -215bp (almost three-standard-deviation) risk premium shock. To facilitate research in this exciting area, we will keep an up-to-date time series of our monetary policy shocks on our webpages.

VIII. Tables

	Mean	Std	Min	Max	Skew	Kurt	AR(1)
				Full sample			
IR	-0.20	3.19	-13.43	14.34	-0.11	8.01	-0.24
U	-0.00	72.73	-247.32	180.24	-0.31	4.20	-0.09
				Pre-crisis			
IR	-0.19	3.29	-13.43	14.34	0.03	7.78	-0.26
U	2.76	64.71	-187.37	173.79	-0.04	4.15	-0.15
				Crisis			
IR	-0.20	3.03	-11.77	10.79	-0.41	8.35	-0.20
U	-4.53	84.64	-247.32	180.24	-0.42	3.70	-0.02

Table I. Summary statistics of monetary policy communication shocks

This table presents summary statistics for interest rate communication shocks (IR) and pure risk premium shocks (U) in basis points (bp). IR is the first principal component from a principal component analysis applied to swap rate changes during the communication window with maturities ranging between one month and ten years. U is the residual when regressing Eurostoxx 50 futures returns during the communication window on IR. The communication window spans the ECB press conference between 14:25 and 16:10 CET on ECB announcement days. The full sample runs from January 2001 to December 2014 (161 announcements), pre-crisis runs from January 2001 to November 2009 (100 announcements), and crisis runs from December 2009 to December 2014 (61 announcements).

	3	6	12	24	36	48	60	72	84	96	108	120
						Core						
IR	0.64	0.99	1.23	1.52	1.52	1.47	1.42	1.31	1.19	1.08	0.99	0.94
	(5.90)	(6.14)	(7.09)	(7.55)	(8.61)	(8.18)	(7.66)	(7.39)	(7.16)	(6.75)	(6.43)	(6.18)
$U(\times 10^{-2})$	0.87	-0.34	0.33	0.18	0.53	0.53	0.67	0.88	1.03	1.22	1.33	1.27
	(2.04)	(-0.89)	(1.04)	(0.35)	(0.87)	(0.71)	(0.78)	(1.05)	(1.24)	(1.50)	(1.63)	(1.58)
$\overline{R}^2$	17.40	27.16	63.07	60.08	59.00	54.40	48.09	46.95	44.63	41.91	38.74	36.30
ΔR^2	-0.09	-2.18	-0.87	-1.26	-0.82	-0.97	-0.88	-0.10	0.76	2.17	3.23	2.93
						Periphery						
IR	0.60	0.66	0.74	-0.21	-0.25	-0.29	-0.31	-0.31	-0.35	-0.33	-0.34	-0.34
	(2.09)	(1.54)	(1.83)	(-0.50)	(-0.59)	(-0.75)	(-0.82)	(-0.87)	(-1.06)	(-1.04)	(-1.08)	(-1.08)
$U(\times 10^{-2})$	0.66	-0.83	-2.45	-7.50	-8.77	-9.04	-9.27	-8.90	-9.53	-9.15	-9.43	-9.17
	(0.88)	(-0.67)	(-1.74)	(-3.42)	(-4.08)	(-4.06)	(-4.08)	(-4.02)	(-3.65)	(-3.54)	(-3.35)	(-3.38)
$\overline{R}^2$	15.93	12.48	5.60	16.43	20.92	23.65	25.14	25.49	29.25	28.91	30.22	29.79
ΔR^2	-1.59	-1.79	0.31	16.41	20.91	23.61	25.09	25.41	28.85	28.30	29.41	28.90
						Periphery−Core spread						
IR	-0.04	-0.33	-0.49	-1.74	-1.77	-1.77	-1.73	-1.62	-1.55	-1.41	-1.34	-1.27
	(-0.18)	(-0.64)	(-1.20)	(-4.27)	(-4.46)	(-4.36)	(-4.14)	(-3.88)	(-3.88)	(-3.73)	(-3.55)	(-3.47)
$U(\times 10^{-2})$	-0.21	-0.49	-2.78	-7.68	-9.29	-9.57	-9.95	-9.78	-10.55	-10.37	-10.76	-10.44
	(-0.32)	(-0.41)	(-2.09)	(-3.85)	(-4.64)	(-4.29)	(-4.08)	(-4.02)	(-3.54)	(-3.47)	(-3.28)	(-3.30)
$\overline{R}^2$	0.85	-0.59	2.18	24.67	29.21	31.74	33.11	34.12	37.30	37.50	38.18	37.44
ΔR^2	-3.23	-3.09	0.84	15.12	20.59	22.90	24.82	26.30	30.31	31.28	32.81	32.29

Table II. Core versus peripheral yield responses during the crisis

This table reports the results of multivariate regressions of zero-coupon one-day changes in core yields versus peripheral yields of different maturities (months) on IR and U communication shocks:

$$\Delta y^{\tau}_{i,t} = a^{\tau}_i + b^{\tau}_i IR_t + c^{\tau}_i U_t + \epsilon^{\tau}_{i,t}, \quad \tau = 3, \ldots, 120 \text{ months.}$$

Core yields are defined as the average of Germany and France and peripheral yields defined as the average of Italy and Spain. t-statistics reported in parenthesis are calculated using HAC standard errors. ΔR^2 is the change in the adjusted R^2 when adding U shocks to a univariate regression that uses only the IR shocks. Data run from December 2009 to December 2014.

	Germany	France	Italy	Spain	Core	Periphery	P−C
IR	-0.28	-0.50	-1.55	-1.48	-0.39	-1.52	-1.12
	(-2.32)	(-3.85)	(-4.42)	(-3.69)	(-3.73)	(-4.16)	(-3.61)
$U(\times 10^{-2})$	-1.11	-2.59	-10.72	-11.23	-1.85	-10.97	-9.12
	(-2.63)	(-3.19)	(-4.20)	(-3.86)	(-3.16)	(-4.04)	(-3.90)
$\overline{R}^2$	16.06	28.36	36.01	36.48	25.91	36.87	36.29
ΔR^2	8.21	20.51	28.16	28.62	18.05	29.01	28.43

Table III. Credit risk reaction during the crisis

This table reports estimated coefficients from the regression of changes in the five-year CDS rates on IR and U communication shocks:

$$\Delta CDS_{i,t} = a_i + b_i IR_t + c_i U_t + \epsilon_{i,t},$$

where $\Delta CDS_{i,t}$ is the change in the five-year CDS rate for country i. t-statistics reported in parenthesis are calculated using HAC standard errors with 2 lags. ΔR^2 is the change in the adjusted R^2 when adding U shocks to a univariate regression on IR shocks. Data run from December 2009 to December 2014.

	3	6	12	24	36	48	60	72	84	96	108	120
IR	-0.23	-0.49	-0.82	-1.27	-1.38	-1.41	-1.46	-1.47	-1.39	-1.32	-1.28	-1.23
	(-0.70)	(-1.48)	(-2.45)	(-2.87)	(-3.21)	(-3.36)	(-3.63)	(-3.86)	(-3.67)	(-3.62)	(-3.61)	(-3.56)
$U(\times 10^{-2})$	-0.85	-1.13	-1.17	-3.65	-3.60	-3.53	-3.59	-3.34	-3.21	-3.15	-3.15	-3.15
	(-1.28)	(-1.41)	(-1.52)	(-3.93)	(-4.07)	(-4.31)	(-4.67)	(-4.54)	(-4.56)	(-4.77)	(-4.85)	(-4.99)
$\mathbb{1}_{\text{ECB}}$	-1.43	-1.03	-0.99	-1.40	-1.53	-1.47	-1.66	-1.63	-1.34	-1.21	-1.22	-1.13
	(-1.50)	(-1.04)	(-0.75)	(-0.96)	(-0.97)	(-0.95)	(-1.07)	(-1.11)	(-0.94)	(-0.88)	(-0.89)	(-0.82)
$IR \times \mathbb{1}_{\text{ECB}}$	0.10	0.01	-0.11	-1.54	-1.77	-1.81	-1.82	-1.66	-1.82	-1.73	-1.76	-1.69
	(0.24)	(0.02)	(-0.16)	(-1.77)	(-2.28)	(-2.50)	(-2.57)	(-2.44)	(-2.65)	(-2.58)	(-2.52)	(-2.51)
$U \times \mathbb{1}_{\text{ECB}}(\times 10^{-2})$	0.64	0.68	-1.56	-3.85	-5.51	-5.86	-6.18	-6.27	-7.18	-7.07	-7.47	-7.16
	(0.65)	(0.43)	(-0.77)	(-1.28)	(-2.07)	(-2.40)	(-2.62)	(-2.76)	(-3.04)	(-3.04)	(-2.97)	(-2.96)
$\overline{R}^2$	0.01	0.41	1.20	5.39	6.50	7.13	7.94	8.27	8.97	9.07	9.40	9.31

Table IV. Sovereign yield spreads on ECB versus non-ECB days

This table reports the results of multivariate regressions of zero-coupon one-day changes in peripheral minus core yields of different maturities (months) on IR and U communication shocks as well as an ECB dummy variable that takes the value of one on days that the ECB announces its monetary policy and zero otherwise, and an interaction term with each communication shock:

$$\Delta\left(y^{\tau}_{p,t} - y^{\tau}_{c,t}\right) = a^{\tau}_1 + a^{\tau}_2 \times \mathbb{1}_{\text{ECB},t} + b^{\tau}_1\ IR_t + c^{\tau}_1\ U_t + b^{\tau}_2\ IR_t \times \mathbb{1}_{\text{ECB},t} + c^{\tau}_2\ U_t \times \mathbb{1}_{\text{ECB},t} + \epsilon^{\tau}_t, \quad \tau = 3, \ldots, 120 \text{ months.}$$

t-statistics reported in parenthesis are calculated using HAC standard errors with 2 lags. Data run from December 2009 to December 2014.

	Core	Periphery	P−C
IR	-0.37	-1.25	-0.88
	(-3.46)	(-3.18)	(-2.71)
$U(\times 10^{-2})$	-0.73	-3.48	-2.75
	(-3.43)	(-4.00)	(-3.90)
$\mathbb{1}_{\text{ECB}}$	-0.20	-2.13	-1.93
	(-0.65)	(-1.43)	(-1.49)
$IR \times \mathbb{1}_{\text{ECB}}$	-0.28	-1.96	-1.68
	(-1.41)	(-2.66)	(-2.82)
$U \times \mathbb{1}_{\text{ECB}}(\times 10^{-2})$	-1.09	-7.34	-6.26
	(-1.51)	(-2.78)	(-3.01)
$\overline{R}^2$	5.96	8.17	7.54

Table V. Credit risk on ECB versus non-ECB days

This table reports the results of multivariate regressions of changes in the five-year CDS rates on IR and U communication shocks as well as an ECB dummy variable that takes the value of one on days that the ECB announces its monetary policy and zero otherwise, and an interaction term with each communication shock:

$$\Delta CDS_{i,t} = a_{1,i} + a_{2,i} \times \mathbb{1}_{\text{ECB},t} + b_{1,i}\ IR_t + c_{1,i}\ U_t + b_{2,i}\ IR_t \times \mathbb{1}_{\text{ECB},t} + c_{2,i}\ U_t \times \mathbb{1}_{\text{ECB},t} + \epsilon_{i,t}.$$

t-statistics reported in parenthesis are calculated using HAC standard errors with 2 lags. Data run from December 2009 to December 2014.

	3	6	12	24	36	48	60	72	84	96	108	120
IR_t	-0.00	-0.36	-0.48	-1.62	-1.54	-1.54	-1.49	-1.40	-1.30	-1.15	-1.07	-1.00
	(-0.00)	(-0.69)	(-1.10)	(-4.76)	(-4.13)	(-3.52)	(-3.18)	(-3.04)	(-2.98)	(-2.81)	(-2.65)	(-2.55)
C_t	0.75	0.51	2.37	3.51	3.90	3.80	3.73	3.51	3.41	3.28	3.25	3.29
	(1.99)	(1.25)	(3.41)	(5.12)	(4.99)	(4.73)	(4.50)	(4.30)	(4.13)	(4.13)	(3.94)	(4.06)
$\overline{R}^2$	13.01	3.23	26.19	42.97	45.10	45.42	43.21	40.61	37.74	36.62	34.89	36.21
ΔR^2	4.82	-0.77	24.45	32.64	36.70	36.51	34.86	32.78	30.73	30.55	29.64	31.29

Table VI. Alternative risk premium shock and yield spreads

This table reports the results of multivariate regressions of zero-coupon one-day changes in peripheral and core yield spreads of different maturities (months) on IR and C communication shocks:

$$\Delta\left(y^{\tau}_{p,t} - y^{\tau}_{c,t}\right) = a^{\tau} + b^{\tau} IR_t + c^{\tau} C_t + \epsilon^{\tau}_t, \quad \tau = 3, \ldots, 120 \text{ months}.$$

Core yields are defined as the average of Germany and France and peripheral yields defined as the average of Italy and Spain. t-statistics reported in parenthesis are calculated using HAC standard errors with 2 lags. ΔR^2 is the change in the adjusted R^2 when adding C shocks to a univariate regression on IR shocks. Data run from December 2009 to December 2014.

	3	6	12	24	36	48	60	72	84	96	108	120
						Pre-crisis						
IR	0.09	-0.10	-0.37	-0.09	-0.14	-0.08	-0.04	-0.07	-0.07	-0.08	-0.14	-0.10
	(0.49)	(-0.63)	(-1.93)	(-1.12)	(-1.68)	(-1.02)	(-0.59)	(-1.05)	(-1.02)	(-0.90)	(-1.66)	(-0.97)
$U(\times 10^{-2})$	-0.20	-0.53	0.04	-0.69	-0.74	-0.58	-0.62	-0.44	-0.19	-0.20	-0.18	-0.14
	(-0.63)	(-1.60)	(0.12)	(-2.51)	(-2.41)	(-2.01)	(-2.21)	(-1.72)	(-0.82)	(-0.82)	(-0.61)	(-0.43)
$\overline{R}^2$	-0.55	2.62	4.21	6.51	5.41	3.60	3.06	2.09	-0.23	0.01	1.53	0.16
ΔR^2	-1.12	1.37	-1.32	4.36	3.13	1.61	1.59	0.36	-1.06	-0.95	-1.04	-1.20
						Crisis						
IR	-0.93	-1.55	-1.27	-4.29	-4.33	-4.01	-3.93	-3.79	-3.58	-3.48	-3.33	-3.29
	(-0.90)	(-1.95)	(-1.33)	(-2.94)	(-2.82)	(-2.76)	(-3.04)	(-3.31)	(-3.45)	(-3.75)	(-3.79)	(-3.79)
$U(\times 10^{-2})$	-6.31	-6.08	-7.76	-11.14	-9.57	-9.20	-8.62	-7.81	-6.80	-6.18	-5.80	-5.58
	(-2.69)	(-2.08)	(-1.75)	(-3.21)	(-2.78)	(-3.09)	(-3.17)	(-3.14)	(-3.22)	(-3.06)	(-2.85)	(-2.88)
$\overline{R}^2$	10.40	14.26	21.89	40.05	36.13	38.69	39.61	40.38	39.27	37.36	36.73	35.98
ΔR^2	5.49	7.05	13.39	16.67	12.57	14.18	13.80	13.42	12.14	10.72	10.21	9.71

Table VII. President speeches and yield spreads

This table reports the results of multivariate regressions of zero-coupon one-day changes in peripheral and core yield spreads of different maturities (months) on IR and U communication shocks during ECB President speeches which are not standard monetary policy announcements:

$$\Delta\left(y^{\tau}_{p,t} - y^{\tau}_{c,t}\right) = a^{\tau} + b^{\tau} IR_t + c^{\tau} U_t + \epsilon^{\tau}_t, \quad \tau = 3, \ldots, 120 \text{ months.}$$

Core yields are defined as the average of Germany and France and Peripheral yields defined as the average of Italy and Spain. t-statistics reported in parenthesis are calculated using HAC standard errors with 2 lags. ΔR^2 is the change in the adjusted R^2 when adding U shocks to a univariate regression on IR shocks. Pre-crisis runs from January 2001 to November 2009. Crisis runs from December 2009 to December 2014.

	Germany	France	Italy	Spain	Core	Periphery	P−C
IR	-0.37	-0.85	-2.93	-2.58	-0.61	-2.76	-2.15
	(-3.58)	(-2.87)	(-2.64)	(-2.60)	(-3.33)	(-2.80)	(-2.58)
$U(\times 10^{-2})$	-1.26	-1.43	-6.74	-7.51	-1.34	-7.13	-5.78
	(-5.65)	(-2.58)	(-3.64)	(-4.54)	(-4.07)	(-4.27)	(-4.04)
$\overline{R}^2$	36.01	15.90	26.02	31.00	23.32	30.12	28.92
ΔR^2	18.44	-1.67	8.45	13.43	5.75	12.55	11.35

Table VIII. President speeches and credit risk

This table reports estimated coefficients from the regression of changes in the five-year CDS rates on IR and U communication shocks sampled during ECB President speeches:

$$\Delta CDS_{i,t}^{\tau} = a_i^{\tau} + b_i^{\tau} IR_t + c_i^{\tau} U_t + \epsilon_{i,t}^{\tau}, \quad \tau = 60, \ldots, 120 \text{ months},$$

where $\Delta CDS_{i,t}^{\tau}$ is the change in the two-year (top panel) or five-year (bottom panel) CDS rate for country i. t-statistics reported in parenthesis are calculated using HAC standard errors with 2 lags. R^2 reports the adjusted R-squared. ΔR^2 is the change in the adjusted R^2 when adding U shocks to a univariate regression on IR shocks. Data run from December 2009 to December 2014.

	3	6	12	24	36	48	60	72	84	96	108	120
						Core						
IR	0.35	0.54	0.74	1.38	1.72	2.06	2.31	2.49	2.68	2.81	2.90	2.92
	(2.73)	(4.28)	(4.59)	(8.93)	(11.90)	(13.89)	(16.27)	(17.23)	(18.17)	(15.49)	(13.70)	(12.58)
$U(\times 10^{-2})$	-1.21	-1.53	-1.96	-2.59	-2.73	-2.82	-2.69	-2.56	-2.36	-2.11	-1.96	-1.78
	(-3.06)	(-4.61)	(-4.81)	(-9.23)	(-8.40)	(-7.32)	(-6.36)	(-5.98)	(-5.03)	(-4.18)	(-3.47)	(-3.11)
QE	-0.36	-0.39	-0.35	-0.47	-0.37	-0.24	-0.05	0.19	0.45	0.69	0.93	1.00
	(-3.10)	(-3.46)	(-2.86)	(-2.55)	(-1.65)	(-0.92)	(-0.16)	(0.61)	(1.39)	(1.84)	(2.16)	(2.23)
$\overline{R}^2$	46.94	65.01	64.51	70.74	71.80	73.50	74.52	75.79	77.60	76.10	74.11	73.09
ΔR^2	7.65	7.06	2.57	1.91	0.29	-0.55	-0.93	-0.70	0.18	1.27	2.63	3.07
						Periphery						
IR	0.36	0.43	0.66	1.51	1.98	2.39	2.63	2.77	2.91	3.09	3.31	3.30
	(4.34)	(4.58)	(5.08)	(7.08)	(7.98)	(7.85)	(7.47)	(7.55)	(7.38)	(7.58)	(7.82)	(7.36)
$U(\times 10^{-2})$	-0.08	-0.35	-0.98	-1.62	-1.98	-2.28	-2.58	-2.54	-2.34	-2.64	-2.89	-2.70
	(-0.59)	(-1.92)	(-1.81)	(-2.58)	(-2.76)	(-2.99)	(-3.04)	(-2.86)	(-2.49)	(-2.70)	(-2.87)	(-2.60)
QE	0.10	0.08	0.27	0.24	0.18	0.32	0.44	0.64	0.76	0.85	0.97	0.99
	(0.94)	(0.46)	(1.11)	(0.84)	(0.55)	(0.81)	(0.99)	(1.54)	(1.71)	(2.03)	(2.40)	(2.25)
$\overline{R}^2$	41.25	49.70	33.99	62.72	64.17	65.13	63.42	62.76	61.75	62.50	64.13	61.75
ΔR^2	-0.76	-1.22	-0.47	-0.77	-1.11	-0.80	-0.62	0.01	0.40	0.66	1.06	1.03
						Periphery−Core Spread						
IR	0.01	-0.11	-0.08	0.14	0.26	0.33	0.32	0.28	0.23	0.27	0.41	0.38
	(0.10)	(-0.75)	(-0.46)	(0.65)	(0.96)	(0.97)	(0.80)	(0.66)	(0.54)	(0.60)	(0.86)	(0.74)
$U(\times 10^{-2})$	1.13	1.18	0.99	0.97	0.74	0.54	0.11	0.02	0.02	-0.53	-0.93	-0.92
	(2.76)	(2.61)	(1.26)	(1.55)	(1.17)	(0.88)	(0.16)	(0.02)	(0.03)	(-0.66)	(-1.14)	(-1.07)
QE	0.46	0.47	0.61	0.71	0.55	0.57	0.49	0.45	0.31	0.16	0.04	-0.02
	(3.34)	(2.51)	(2.62)	(2.05)	(1.27)	(1.10)	(0.87)	(0.87)	(0.67)	(0.37)	(0.08)	(-0.03)
$\overline{R}^2$	39.67	34.39	11.62	27.71	21.39	24.44	20.20	19.91	19.13	18.82	19.07	14.94
ΔR^2	17.78	12.58	8.17	9.92	2.72	1.81	-0.06	-0.66	-1.84	-2.70	-2.98	-3.15

Table IX. Core versus peripheral yield responses post 2014 with QE shocks

This table reports the results of multivariate regressions of zero-coupon one-day changes in core yields versus peripheral yields of different maturities (months) on IR and U communication shocks as well as QE shocks:

$$\Delta y^{\tau}_{i,t} = a^{\tau}_i + b^{\tau}_i IR_t + c^{\tau}_i U_t + d^{\tau}_i QE_t + \epsilon^{\tau}_{i,t}, \quad \tau = 3, \ldots, 120 \text{ months}.$$

Core yields are defined as the average of Germany and France and Peripheral yields defined as the average of Italy and Spain. t-statistics reported in parenthesis are calculated using HAC standard errors with 2 lags. ΔR^2 is the change in the adjusted R^2 when adding QE shocks to the regression that only uses IR and U shocks. Data run from January 2015 to September 2018.

IX. Figures

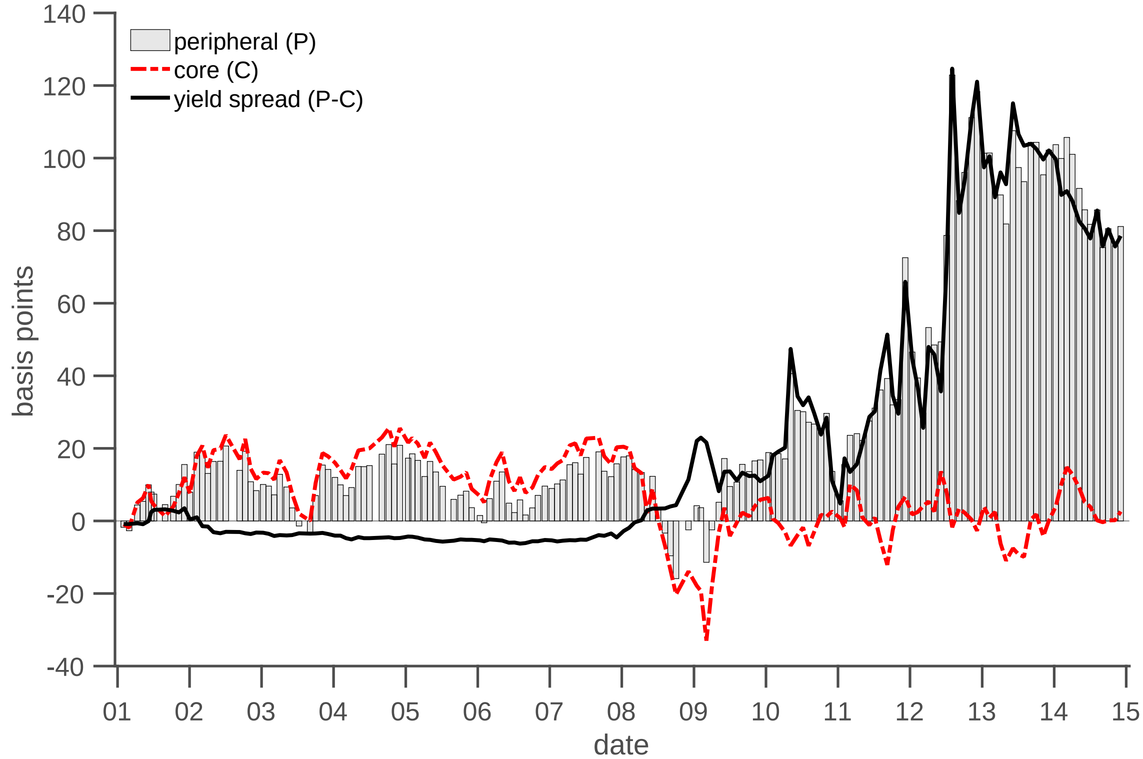

Figure 1. European sovereign bond yield changes on ECB monetary policy days
This figure displays cumulative one-day changes in ten-year yields for core (average of Germany and France) and peripheral (average of Italy and Spain) bonds, as well as the spread between peripheral and core bonds only on European Central Bank meeting days.

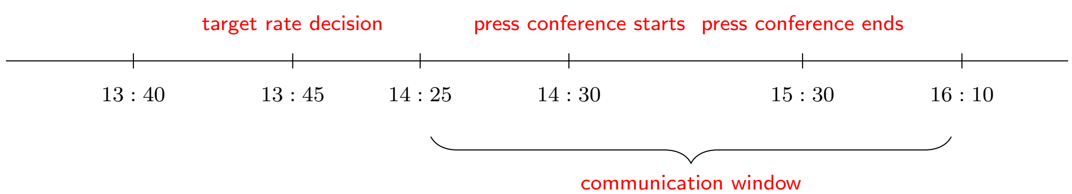

Figure 2. Monetary policy decision window

This figure illustrates the time-line of ECB monetary policy announcements. All times are in Central European Time (CET).

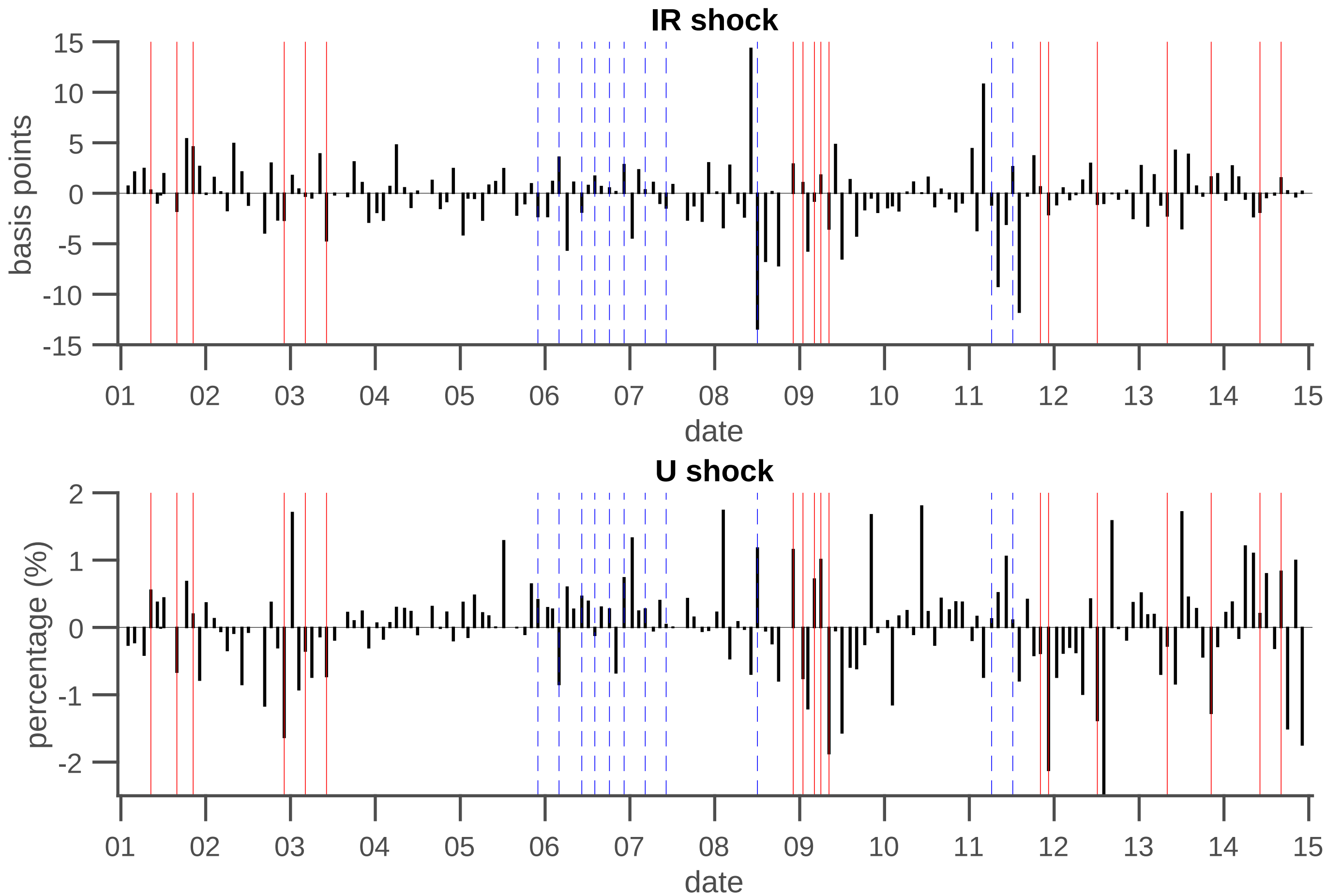

Figure 3. Time series of communication shocks

This figure plots communication shocks extracted from interest rates and equity reactions in a tight window around ECB press conferences. Data run from January 2001 to December 2014. Dashed blue lines indicate rate hikes and bold red lines indicate rate cuts.

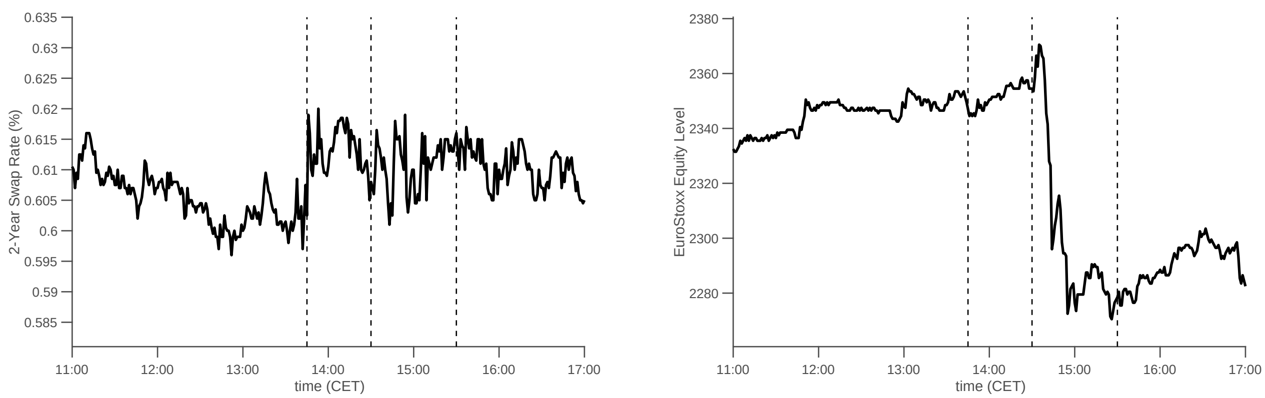

Figure 4. Intraday asset price reaction to ECB communication

This figure displays the response of two-year swap rates and the Eurostoxx index during the 2 August, 2012, ECB press conference. The dashed lines mark the start of the target rate announcement (13:45 CET), and the start (14:30 CET) and end (15:30 CET) of the press conference, respectively.

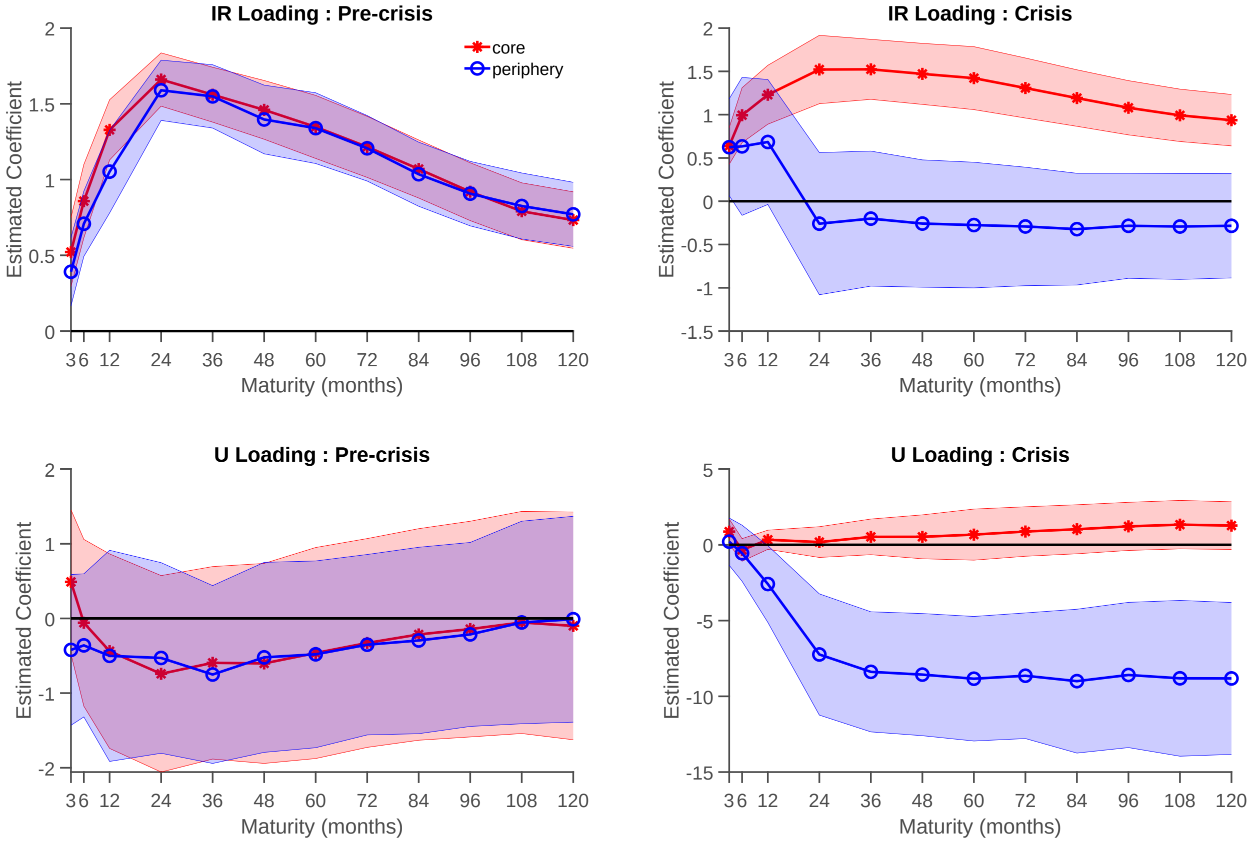

Figure 5. Core and peripheral yield responses before and during the crisis
This figure plots the response of core and peripheral yields at different maturities for IR and U shocks around ECB press conferences:

$$\Delta y_{i,t}^{\tau} = a_i^{\tau} + b_i^{\tau} IR_t + c_i^{\tau} U_t + \epsilon_{i,t}^{\tau}, \quad \tau = 3, \ldots, 120 \text{ months}.$$

Data run from January 2001 to November 2009 on the left panels, and from December 2009 to December 2014 on the right panels. Bands display 95% confidence intervals computed using HAC standard errors with 2 lags.

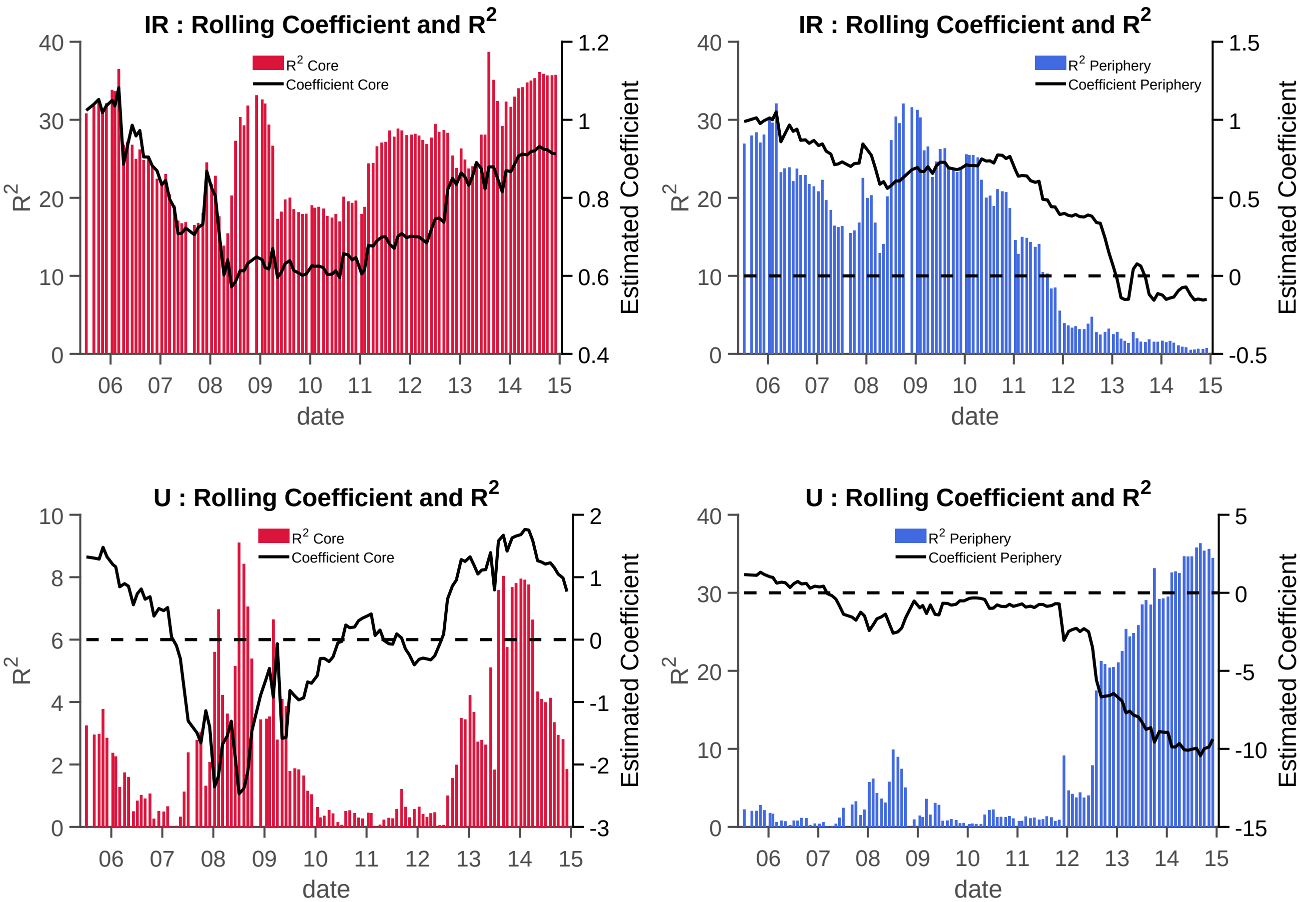

Figure 6. Rolling regression estimates

The upper panel plots the rolling betas and the rolling adjusted R^2s from regressions of core (left) and peripheral (right) ten-year bond yields on the IR communication shocks in univariate regressions. The lower panel plots the rolling betas and the rolling adjusted R^2s from regressions of core (left) and peripheral (right) ten-year bond yields on the U communication shocks in univariate regressions. The window size for the rolling regression is set to 50 months.

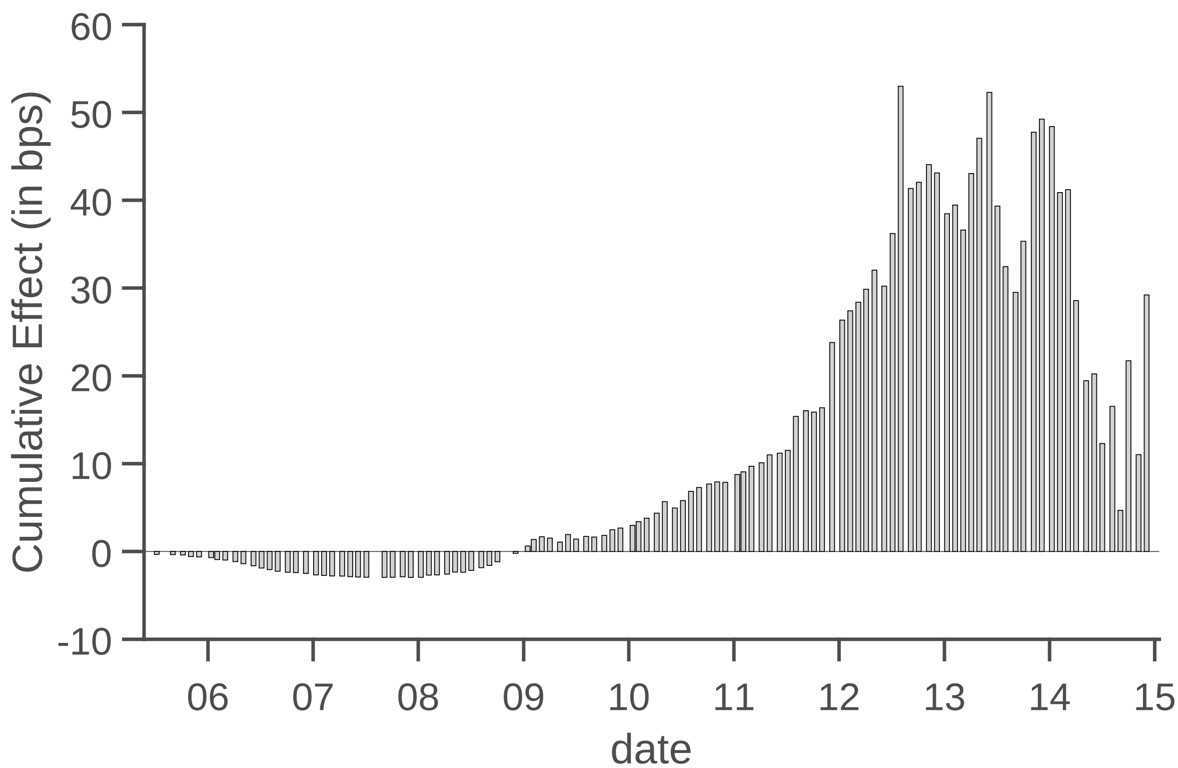

Figure 7. Cumulative effect of communication

This figure plots the cumulative effect of IR and U communication shocks on the spread between ten-year peripheral and core bond yields. The cumulative effect is computed from multivariate regression loadings estimated using a window size set to 50 months, as in Figure 6. The loadings are then multiplied by date t shocks and the overall effect computed by summing the fitted values over time.

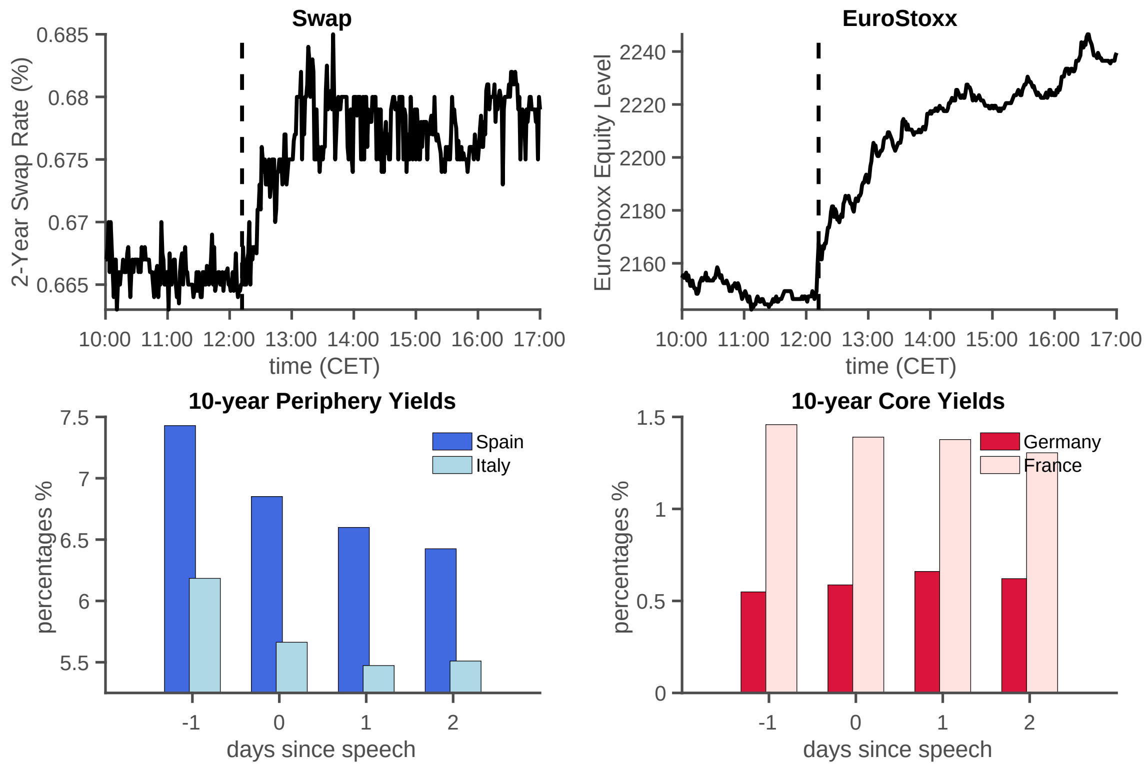

Figure 8. Intraday asset price reaction to "Whatever it takes" on 26 July, 2012
The upper two panels depict the two-year swap rate and the Eurostoxx index from 11:00 to 17:00 CET on 26 July, 2012. The dashed lines mark the beginning of ECB President Mario Draghi's speech at the Global Investment Conference in London. The lower two panels show the level and changes in yield spreads defined as the difference between the ten-year yield on peripheral and core countries one day before the speech and two days after.

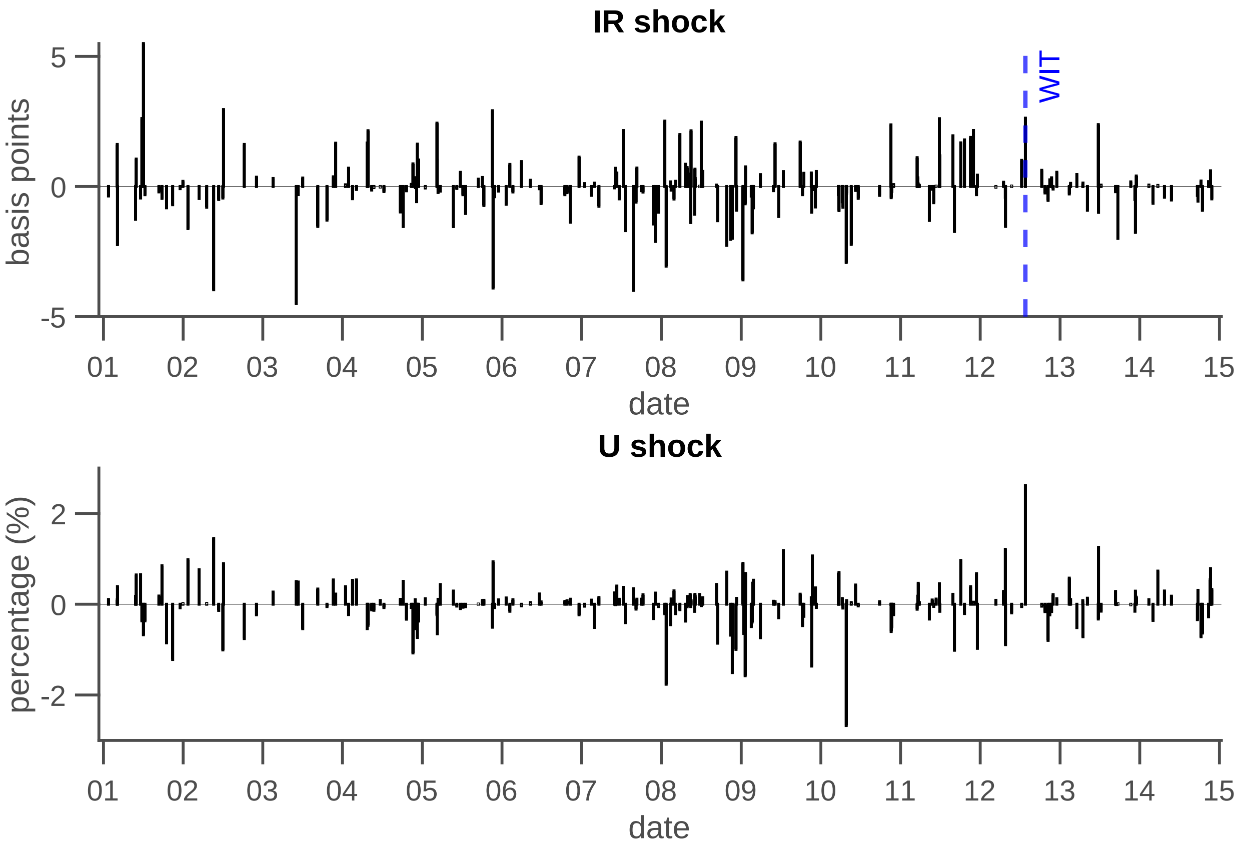

Figure 9. Time series of President speech shocks

This figure plots communication shocks extracted from interest rates and equity reactions in a tight window around speeches by the ECB President. Data run from January 2001 to December 2014.

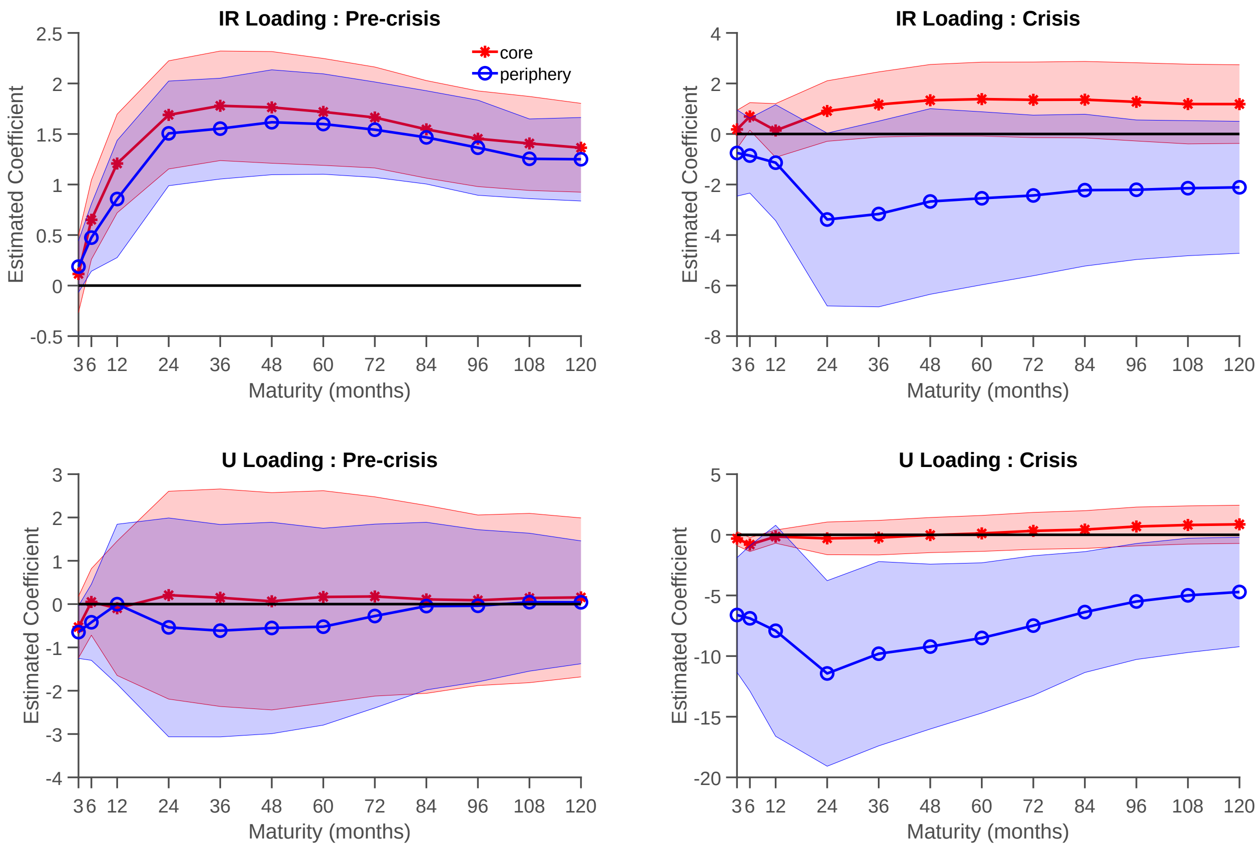

Figure 10. Core and peripheral yield responses to President speeches
This figure plots the response of core and peripheral countries' bond yields at different maturities for IR_t and U_t shocks around ECB President speeches:

$$\Delta y_{i,t}^{\tau} = a_i^{\tau} + b_i^{\tau} IR_t + c_i^{\tau} U_t + \epsilon_{i,t}^{\tau}, \quad \tau = 3, \ldots, 120 \text{ months}.$$

Data run from January 2001 to November 2009 on the left panels and from December 2009 to December 2014 on the right panels. Bands display 95% confidence intervals computed using HAC standard errors with 2 lags.

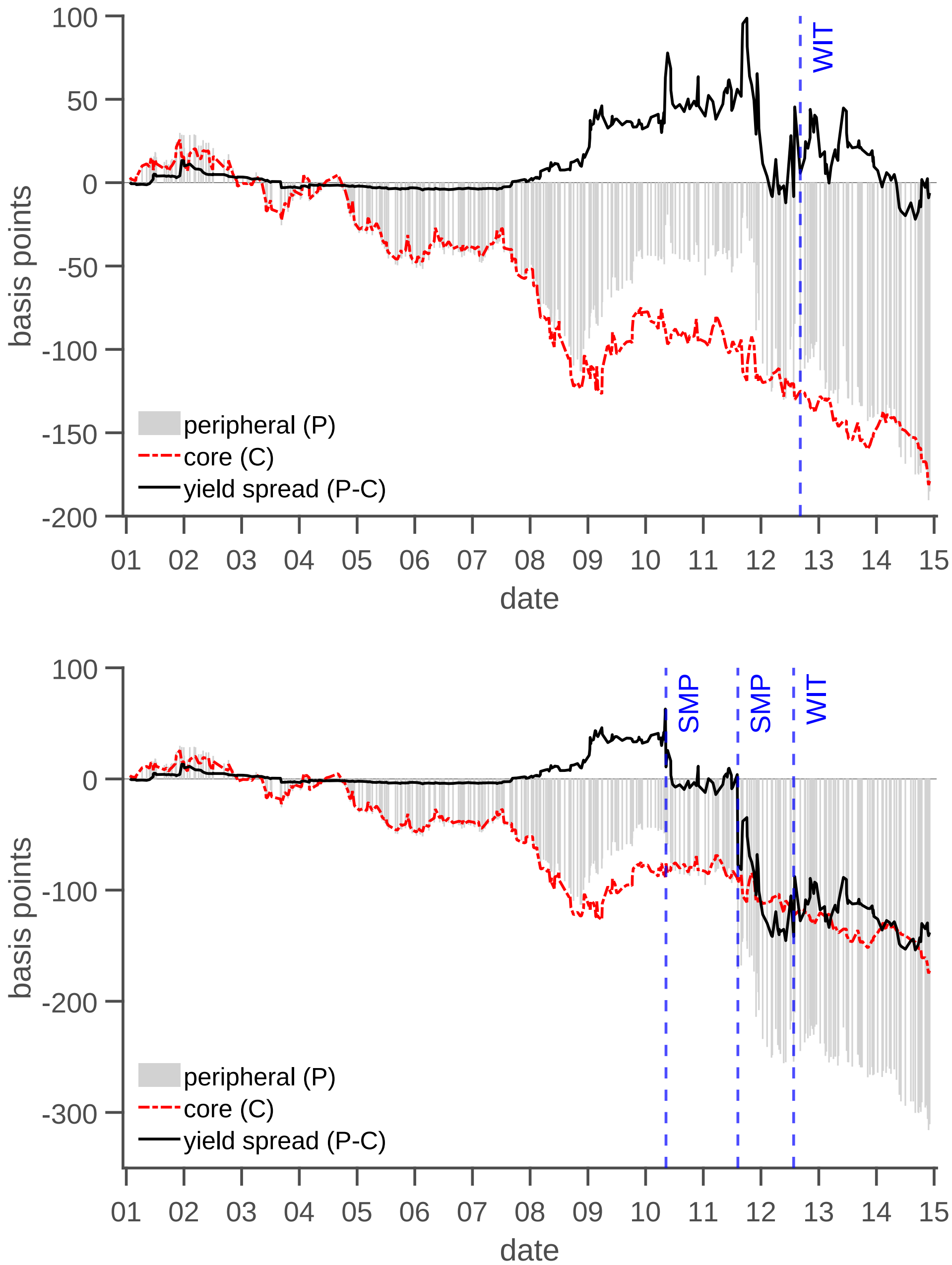

Figure 11. Cumulative yield spreads on ECB days, President speeches, and UMP
This upper panel displays cumulative one-day changes in ten-year yields for core (average of Germany and France) and peripheral (average of Italy and Spain) bonds, as well as the spread between peripheral and core bonds on European Central Bank meeting days and days when the ECB President gives speeches. The lower panel adds days when unconventional monetary policies were announced.

References

Acharya, Viral V., Tim Eisert, Christian Eufinger, and Christian Hirsch, 2019, Whatever it takes: The real effects of unconventional monetary policy, *Review of Financial Studies* 32, 3366–3411.

Ai, Hengjie, and Ravi Bansal, 2018, Risk preferences and the macroeconomic announcement premium, *Econometrica* 86, 1383–1430.

Altavilla, Carlo, Luca Brugnolini, Refet S. Gürkaynak, Roberto Motto, and Giuseppe Ragusa, 2019, Measuring euro area monetary policy, *Journal of Monetary Economics* 108, 162–179.

Altavilla, Carlo, Domenico Giannone, and Michele Lenza, 2014, The financial and macroeconomic effects of omt announcements, Working Paper, ECB.

Andrade, Philippe, Gaetano Gaballo, Eric Mengus, and Benoit Mojon, 2019, Forward guidance and heterogeneous beliefs, *AEJ: Macroeconomics* 11, 1–29.

Bacchetta, Philippe, Elena Perazzi, and Eric van Wincoop, 2020, Self-fulfilling debt crises: Can monetary policy really help?, NBER Working Paper Series 21158.

Bai, Jushan, and Pierre Perron, 1998, Estimating and testing linear models with multiple structural changes, *Econometrica* 66, 47–78.

———, 2003, Computation and analysis of multiple structural change models, *Journal of Applied Econometrics* 18, 1–22.

Bauer, Michael D., and Eric T. Swanson, 2020, The fed's response to economic news explains the 'fed information effect', Working Paper, Federal Reserve Bank of San Francisco.

Bekaert, Geert, Marie Hoerova, and Marco Lo Duca, 2013, Risk, uncertainty and monetary policy, *Journal of Monetary Economics* 60, 771–788.

Bernanke, Ben S., and Kenneth N. Kuttner, 2005, What explains the stock market's reaction to federal reserve policy?, *Journal of Finance* 60, 1221–1257.

Bocola, Luigi, and Alessandro Dovis, 2019, Self-fulfilling debt crises: A quantitative analysis, *American Economic Review* 109, 4343–4377.

Boyarchenko, Nina, Valentin Haddad, and Matthew C. Plosser, 2017, Market confidence and monetary policy, Working Paper, Federal Reserve Bank of New York.

Brand, Claus, Daniel Buncic, and Jarkko Turunen, 2010, The impact of ecb monetary decisions and communication on the yield curve, *Journal of the European Economic Association* 8, 1266–1298.

Campbell, Jeffrey R., Charles L. Evans, Jonas D. M. Fisher, and Alejandro Justiniano, 2012, Macroeconomic effects of federal reserve forward guidance, *Brookings Papers on Economic Activity* 44, 1–80.

Campbell, Jeffrey R., Jonas D. M. Fisher, Alejandro Justiniano, and Leonardo Melosi, 2016, Forward guidance and macroeconomic outcomes since the financial crisis, in Inc. National Bureau of Economic Research, ed.: *NBER Macroeconomics Annual 2016* vol. 31.

Corsetti, Giancarlo, and Luca Dedola, 2016, The mystery of the printing press: Monetary policy and self-fulfilling debt crises, *Journal of the European Economic Association* 14, 1329–1371.

De Santis, Roberto A., 2019, Redenomination risk, *Journal of Money, Credit and Banking* 51, 2173–2206.

De Santis, Roberto A, and Fédéric Holm-Hadulla, 2017, Flow effects of central bank asset purchases on euro area sovereign bond yields: evidence from a natural experiment, Working Paper, ECB.

Duffie, Darrell, and Kenneth J. Singleton, 1999, Modeling term structures of defaultable bonds, *Review of Financial Studies* 12, 687–720.

Ehrmann, Michael, and Marcel Fratzscher, 2005, How should central banks communicate?, Working paper, ECB.

Ellingsen, Tore, and Ulf Soderstrom, 2001, Monetary policy and market interest rates, *American Economic Review* 91, 1594–1607.

Falagiarda, Matteo, and Stefan Reitz, 2015, Announcements of ecb unconventional programs: Implications for the sovereign spreads of stressed euro area countries, *Journal of International Money and Finance* 53, 276–295.

Fama, Eugene F., 2013, Does the fed control interest rates?, *The Review of Asset Pricing Studies* 3, 180–199.

Fratzscher, Marcel, Marco Lo Duca, and Roland Straub, 2016, Ecb unconventional monetary policy actions: Market impact, international spillovers and transmission channels, *IMF Economic Review* 64, 36–74.

Gertler, Mark, and Péter Karádi, 2015, Monetary policy surprises, credit costs, and economic activity, *American Economic Journal: Macroeconomics* 7, 44–76.

Giannone, Domenico, Lucrezia Reichlin, and David Small, 2008, Nowcasting: The real-time informational content of macroeconomic data, *Journal of Monetary Economics* 55, 665–676.

Haitsma, Reinder, Deren Unalmis, and Jakob de Haan, 2016, The impact of the ecb's conventional and unconventional monetary policies on stock markets, *Journal of Macroeconomics* 48, 101–116.

Hansen, Stephen, Michael McMahon, and Matthew Tong, 2020, The long-run information effect of central bank communication, *Journal of Monetary Economics, forthcoming*.

Hanson, Samuel G., David O. Lucca, and Jonathan H. Wright, 2018, The excess sensitivity of long-term rates: A tale of two frequencies, Working Paper, Harvard Business School.

Hanson, Samuel G., and Jeremy C. Stein, 2015, Monetary policy and long-term real rates, *Journal of Financial Economics* 115, 429–448.

Jarociński, Marek, and Péter Karádi, 2020, Deconstructing monetary policy surprises: The role of information shocks, *AEJ: Macroeconomics* 12, 1–43.

Koijen, Ralph S. J., Francois Koulischer, Benoit Nguyen, and Motohiro Yogo, 2017, Euro-area quantitative easing and portfolio rebalancing, *American Economic Review P&P* 107, 621–627.

——— , 2020, Inspecting the mechanism of quantitative easing in the euro area, *Journal of Financial Economics, forthcoming.*

Krishnamurthy, Arvind, Stefan Nagel, and Annette Vissing-Jorgensen, 2018, Ecb policies involving government bond purchases: Impact and channels, *Review of Finance* 22, 1–44.

Laarits, Toomas, 2019, Pre-announcement risk, Working Paper, New York University.

Lorenzoni, Guido, and Ivan Werning, 2019, Slow moving debt crises, *American Economic Review* 109, 3229–3263.

Lucca, David O., and Francesco Trebbi, 2011, Measuring central bank communication: An automated approach with application to fomc statements, Working Paper, Federal Reserve Bank of New York.

Melosi, Leonardo, 2016, Signalling effects of monetary policy, *Review of Economic Studies* 84, 853–884.

Miranda-Agrippino, Silvia, and Giovanni Ricco, 2018, The transmission of monetary policy shocks, CEPR Discussion Papers 13396.

Nakamura, Emi, and Jón Steinsson, 2018, High frequency identification of monetary non-neutrality, *Quarterly Journal of Economics* 133, 1283–1330.

Neuhierl, Andreas, and Michael Weber, 2019, Monetary policy communication, policy slope, and the stock market, *Journal of Monetary Economics* 108, 140–155.

Rogers, John H., Chiara Scotti, and Jonathan H. Wright, 2014, Evaluating asset-market effects of uncoventional monetary policy: A multi-country review, *Economic Policy* 29, 749–799.

Romer, Christina D., and David H. Romer, 2000, Federal reserve information and the behavior of interest rates, *American Economic Review* 90, 429–457.

Schmeling, Maik, and Christian Wagner, 2019, Does central bank tone move asset prices?, Working Paper, Goethe University Frankfurt.

Swanson, Eric T., 2018, Measuring the effects of federal reserve forward guidance and asset purchases on financial markets, Working Paper, University of California.

Tang, Jenny, 2015, Uncertainty and the signaling channel of monetary policy, Working Paper, Federal Reserve Bank of Boston.

Woodford, Michael, 2012, Methods of policy accommodation at the interest-rate lower bound, *The Changing Policy Landscape: Federal Reserve Bank of Kansas City Symposium Proceedings from Jackson Hole, Wyoming* pp. 185–288.

ONLINE APPENDIX
Central Bank Communication and the Yield Curve
– Not for Publication –

This Online Appendix consists of several sections. Section OA-I presents a reduced-form continuous-time model under the risk-neutral measure that rationalizes our theoretical framework and derives formally the hypotheses. Section OA-II presents tables omitted in the main part of the paper. Section OA-III studies the effect of monetary policy shocks on survey expectations about future economic activity. Section OA-IV performs a set of robustness results for our main results. Finally, Section OA-V discusses the relation to Altavilla, Brugnolini, Gürkaynak, Motto, and Ragusa (2019).

OA-I. Model

A. Setup

Assets. We consider a continuous-time economy with multiple countries, indexed by $i = 1, ..., I$, of a currency union that represents the Eurozone. At each date t, there are four types of assets that agents can invest in: (i) an instantaneously riskless asset that pays a net return of r_t, (ii) a continuum of zero-coupon default-free bonds (e.g. OIS swap rates) with time-to-maturities $\tau \in (0, \infty]$, (iii) a continuum of zero-coupon defaultable sovereign bonds in each country i with maturities $\tau \in (0, \infty]$, and (iv) an aggregate equity index of the Eurozone.

Monetary policy and beliefs. The central bank has two roles in this economy: it sets the target short rate and communicates, i.e., reveals information to market participants. We posit that central bank communication provides information both about future short rates and the state of the economy, and that monetary policy action and communication, as perceived by the public, lead to a reduced form representation given by

$$dr_t = \kappa_r \left(\bar{r} + f_t - r_t\right) dt + \sigma_r dB_{r,t}, \tag{OA-1}$$

$$df_t = -\kappa_f f_t dt + \sigma_f dB_{f,t}, \text{ and} \tag{OA-2}$$

$$du_t = -\kappa_u u_t dt + \sigma_u \left(\rho dB_{f,t} + \sqrt{1-\rho^2} dB_{u,t}\right), \tag{OA-3}$$

with $dB_{i,t}$, $B_{f,t}$ and $B_{u,t}$ pairwise independent Brownian motions under the risk-neutral probability measure, and $\kappa_i \in (0, 1)$ speed of mean reversion and $\sigma_i > 0$ volatility parameters, $i = r, f, u$.

Equations (OA-1)-(OA-2) describe the dynamics of the short rate r_t. In particular, r_t mean-reverts to $\bar{r} + f_t$, which is itself stochastic around the true long-run mean $\bar{r} > 0$. In turn, central bank communication is represented by the two-dimensional process (f_t, u_t). The first component, f_t, is a form of forward guidance, i.e., information about the future path of short rates. The second component, u_t, is interpreted as information revealed by the central bank about the state of the economy not entirely spanned by forward guidance. The process u_t can have at least two interpretations in this setting.

Our leading interpretation is that the second dimension of central bank communication provides information about the implementation of asset purchase programmes or the lack thereof, therefore, u_t is determined by the likelihood and magnitude of these purchase programmes as perceived by the public. In turn, these programmes are expected to impact future macroeconomic fundamentals. If, for example, the ECB purchases lower the yield on (peripheral) bond yields, these countries can easier roll over their debt, making default and the following economic and financial inefficiencies less likely.

This interpretation is consistent with the idea that the central bank does not have better information than the public, and instead monetary policy shocks are surprises about the central bank's reaction to publicly available information, as in Bauer and Swanson (2020). With this interpretation at hand, we do not have a prior on what sign parameter ρ should have, so we just think about it as being equal to zero.

An alternative interpretation is motivated by the seminal work of Romer and Romer (2000). In particular, we could posit the existence of asymmetric information between the ECB and market participants about macro variables such as aggregate output growth, inflation, unemployment; see also Campbell, Fisher, Justiniano, and Melosi (2016) and Nakamura and Steinsson (2018). Thus, the central bank, during communication events such as press conferences or President speeches, reveals information about the future path of interest rates, which in turn partially reveals its private signal about macro processes to the public.

In this mechanism, the coefficient ρ should capture that news about the future path of interest rates can be also interpreted positively or negatively about the Eurozone economy. For example, an announcement that policy rates will be low for longer can be either interpreted optimistically as a signal of a more accommodative future stance (also referred to as Odyssean forward guidance), or pessimistically as a signal of weaker current and future fundamentals (i.e., Delphic forward guidance). As documented, e.g., in Nakamura and Steinsson (2018) for the U.S. and Andrade and Ferroni (2019) for the Euro area, after the Great Recession, dovish monetary policy induced a worse macroeconomic outlook as it led expected output to drop and expected unemployment to increase; Nakamura and Steinsson (2018) interpret this as the "Fed information effect." In the context of our model, the reduced-form characterization of the signalling effect dominating the standard monetary policy channel would be captured by having a correlation coefficient $\rho > 0$.[1]

Credit risk. Returns on sovereign bonds are affected by credit events that we think of as sovereign (mainly peripheral) defaults or the breakup of the Eurozone. Formally, a credit event is triggered by a jump of an unpredictable counting process Z_t that has risk-neutral stochastic intensity λ_t that follows

$$d\lambda_t = \kappa_\lambda \left(\bar{\lambda} - w_{\lambda,f} f_t - w_{\lambda,u} u_t - \lambda_t\right) dt + \sigma_\lambda dB_{\lambda,t}, \tag{OA-4}$$

[1] In a previous version of the paper, we provided a microfoundation to the setting described by (OA-1)-(OA-3) based on this signalling channel interpretation of monetary policy communication, to highlight the determinants of this correlation between f_t and u_t. The details are available upon request. We also solved an equilibrium model of the financial market that led to the risk-neutral specification of (OA-1)-(OA-3). These are available from the authors upon request.

where $B_{\lambda,t}$ is independent of all other random variables. Importantly, central bank communication can affect credit risk, too: to capture that bad news about the Eurozone economy increase the perceived default probability, we think about the loading on u_t to satisfy $w_{\lambda,u} > 0$. Further, interest rates communicated to be kept lower than what market participants thought before, $f_t < 0$, can increase the default probability following a standard Merton (1974)-type logic: lower rates increase the market value of liabilities, which, as long as the value of assets is unaffected, decreases the distance-to-default; this means $w_{\lambda,f} > 0$.

Importantly, market participants update their beliefs about the probability of credit events that we think of as sovereign (mainly peripheral) defaults, or the breakup of the Eurozone. In particular, we would expect credit risk to increase with lower future interest rates, as it increases the market value of liabilities and makes market participant less likely to roll over their debt at those lower rates ($w_{\lambda,f} > 0$), or if market participants find that either the probability or the scope of future asset purchase programmes is insufficient ($w_{\lambda,u} > 0$). In the alternative interpretation, we would expect credit risk to increase when the ECB signals lower future interest rates because the macroeconomy needs further stimulus (again, $w_{\lambda,u} > 0$; $w_{\lambda,f} > 0$ is not needed in this case).

In case of a credit event, e.g. if a peripheral country defaults, payoffs on all sovereign bonds can be affected: agents cannot capture the full intrinsic value of assets due to the actual default and frictions in the subsequent credit auction, search or transaction costs, lower liquidity, or a change in monetary policy by the then independent central banks (see, e.g., Du and Zhu (2017) and Markit (2010)). We model this effect as a drop in the face value from one unit of the currency to $e^{-\gamma_i}$, measured by the non-negative coefficients γ_i, $i = 1, ..., I$.

Intuitively, there is a significant difference among the strengths of sovereign economies, with a particularly sharp disconnect between core (e.g., Germany and France) and peripheral economies (e.g., Italy and Spain). More specifically, in case of a peripheral default or the Eurozone breakup bonds issued by peripheral countries would be more exposed to credit losses, potential redenomination, and liquidity risks, and hence less valuable than bonds issued by core countries. In context of our model, this corresponds to $\gamma_p \geq \gamma_c \geq 0$.

Equity. We assume that equity pays a dividend yield δ_t that follows the process

$$d\delta_t = \kappa_\delta \left(\bar{\delta} + w_{\delta,u} u_t - \delta_t\right) dt + \sigma_\delta dB_{\delta,t}, \tag{OA-5}$$

where $B_{\delta,t}$ is independent of all other random variables.[2] We allow for central bank communication to affect the dividend yield process, too; in particular, when the ECB releases pessimistic signals about the Euro-area macroeconomy, expected future productivity and dividends decrease, i.e., $w_{\delta,u} \geq 0$. Further, in case of a credit event, equity prices drop to a fraction of $e^{-\gamma_e}$, $\gamma_e \geq 0$. Thus, the coefficient $w_{\delta,u}$ captures the effect of monetary policy signalling in terms of cash-flow news, while $w_{\lambda,u}$ and γ_e capture that monetary policy signalling, by driving the perceived probability of the credit event, can affect the required equity risk premium, too.

B. *Asset prices*

The model solution is fairly standard, and the following theorem collects our results:

[2] Our approach to assume an exogenous dividend yield process instead of a dividend growth process is only to obtain exact exponential-affine stock prices and to simplify the analysis, and is not necessary for the qualitative results.

Theorem OA- 1. *In the model described above, zero-coupon default-free bond prices, sovereign bond prices, and equity prices are given by*

$$P_t^\tau = e^{-[A(\tau)+B(\tau)r_t+C(\tau)f_t]}, \tag{OA-6}$$

$$P_{i,t}^\tau = e^{-[A_i(\tau)+B_i(\tau)r_t+C_i(\tau)f_t+D_i(\tau)u_t+E_i(\tau)\lambda_t+\gamma_i Z_t]}, \text{ and} \tag{OA-7}$$

$$P_{e,t} = e^{F_e\delta_t - A_e t - B_e r_t - C_e f_t - D_e u_t - E_e \lambda_t - \gamma_e Z_t}, \tag{OA-8}$$

where

$$B(\tau) = B_i(\tau) = \frac{1-e^{-\kappa_r\tau}}{\kappa_r}, \tag{OA-9}$$

$$C(\tau) = \frac{1-e^{-\kappa_f\tau}}{\kappa_f} + \frac{e^{-\kappa_f\tau}-e^{-\kappa_r\tau}}{\kappa_f-\kappa_r}, \tag{OA-10}$$

$$C_i(\tau) = \frac{1-e^{-\kappa_f\tau}}{\kappa_f} + \frac{e^{-\kappa_f\tau}-e^{-\kappa_r\tau}}{\kappa_f-\kappa_r} - \gamma_i w_{\lambda,f}\left(\frac{1-e^{-\kappa_f\tau}}{\kappa_f} + \frac{e^{-\kappa_f\tau}-e^{-\kappa_\lambda\tau}}{\kappa_f-\kappa_\lambda}\right), \tag{OA-11}$$

$$D_i(\tau) = -\gamma_i w_{\lambda,u}\left(\frac{1-e^{-\kappa_u\tau}}{\kappa_u} + \frac{e^{-\kappa_u\tau}-e^{-\kappa_\lambda\tau}}{\kappa_u-\kappa_\lambda}\right), \tag{OA-12}$$

$$E_i(\tau) = \gamma_i\frac{1-e^{-\kappa_\lambda\tau}}{\kappa_\lambda}, \text{ and} \tag{OA-13}$$

$$B_e = \frac{1}{\kappa_r} > 0,\ C_e = \frac{1-\gamma_e w_{\lambda,f}}{\kappa_f},\ D_e = -\frac{w_{\delta,u}+\gamma_e w_{\lambda,u}}{\kappa_u} \le 0,\ E_e = \frac{\gamma_e}{\kappa_\lambda} \ge 0, \text{ and } F_e = \frac{1}{\kappa_\delta} > 0. \tag{OA-14}$$

The functions $A(\tau)$ and $A_i(\tau)$, and constant A_e are given by (OA-27), (OA-33), and (OA-35) below.

The proof is provided in Section E.

C. Identification of communication shocks

To identify monetary policy communication shocks in the model and later in the data, we use asset prices directly. Consider high-frequency changes around communication events such as ECB press conferences when, formally, all non-communication shocks of the model are negligible: dt, $dB_{r,t}, dB_{\delta,t}, dB_{\lambda,t} \approx 0$. Then, we obtain the following straightforward result:

Proposition 1. *Risk-free yield changes around communication events are given by $dy_t^\tau = \beta_f^\tau dB_{f,t}$, where $\beta_f^\tau = \frac{C(\tau)}{\tau}\sigma_f$ are positive and hump-shaped across maturities.*[3]

Moreover, equity returns around communication events are given by $d(\log P_{e,t}) = \beta_{e,f}dB_{f,t} + \beta_{e,u}dB_{u,t}$, where $\beta_{e,f} = -C_e\sigma_f - D_e\sigma_u\rho$ and $\beta_{e,u} = -D_e\sigma_u\sqrt{1-\rho^2} \ge 0$. If either $w_{\delta,u} > 0$ or $w_{\lambda,u} > 0$, then $\beta_{e,u} > 0$.

[3]Formally, we call a function h hump-shaped across maturities if $\lim_{\tau\to 0} h(\tau) = \lim_{\tau\to\infty} h(\tau) = 0$ and there exists a $\tau_1 > 0$ such that $h'(\tau) > 0$ for all $\tau < \tau_1$ and $h'(\tau) < 0$ for all $\tau > \tau_1$. Moreover, $h(\tau)$ is wave-shaped across maturities if $\lim_{\tau\to 0} h(\tau) = \lim_{\tau\to\infty} h(\tau) = 0$ and there exist $0 < \tau_1 < \tau_2$ such that either $h'(\tau) > 0$ for all $0 < \tau < \tau_1$, $h'(\tau) < 0$ for all $\tau_1 < \tau < \tau_2$, and $h'(\tau) > 0$ for all $\tau > \tau_2$, or $h'(\tau) < 0$ for all $0 < \tau < \tau_1$, $h'(\tau) > 0$ for all $\tau_1 < \tau < \tau_2$, and $h'(\tau) < 0$ for all $\tau > \tau_2$. Finally, h is U-shaped if $-h$ is hump-shaped. It is easy to see that the difference of 2 hump-shaped functions is either hump-shaped, U-shaped, or wave-shaped.

The following remark translates this observation into an empirical strategy:

Remark 1. *Empirically, we can identify $dB_{f,t}$ shocks, up to a multiplicative constant, from any default-free rate change in a narrow (high-frequency) interval around communication events such as ECB press conferences; we denote this rate change by $IR_t \propto dB_{f,t}$.*

Moreover, we can identify $dB_{u,t}$ shocks, up to a multiplicative constant, by orthogonalizing high-frequency equity returns with respect to default-free yield changes by ordinary least squares and take the residual: by running $\Delta(\log P_{e,t}) = a + b\ IR_t + \ U_t$, we get $U_t \propto dB_{u,t}$.

D. Model predictions

Our model has a series of implications that characterize the effect of central bank communication on sovereign yields across maturities and across countries. Formally, we run theoretical unconditional multivariate regressions of sovereign yield changes on interest rate and state-of-the-economy shocks in the form

$$\Delta y^{\tau}_{i,t} = \alpha^{\tau}_i + \beta^{\tau}_{i,IR}\ IR_t + \beta^{\tau}_{i,U}\ U_t + \varepsilon^{\tau}_{i,t}, \tag{OA-15}$$

where $\Delta y^{\tau}_{i,t}$ is the change in the τ-year sovereign yield during a small time interval. The following two propositions summarize our results and provide testable implications:

Proposition 2. *There exists $\bar{\gamma}(w_{\lambda,f}, w_{\lambda,u}, \rho\frac{\sigma_u}{\sigma_f}, \kappa_u, \kappa_f, \kappa_\lambda) > 0$ such that the impact of IR shocks, $\beta^{\tau}_{i,IR}$, is positive and hump-shaped if $\gamma_i < \bar{\gamma}$, and wave-shaped otherwise.*

Moreover, for countries i and j, $\beta^{\tau}_{i,IR} - \beta^{\tau}_{j,IR}$ is negative and U-shaped if and only if $(w_{\lambda,f}\sigma_f + \rho w_{\lambda,u}\sigma_u)(\gamma_i - \gamma_j) > 0$.[4]

The second part of Proposition 2 states that as long as monetary policy forward guidance affects the probability of the credit event ($w_{\lambda,f} > 0$), or state-of-the-economy shocks are informative about the probability of the credit event ($w_{\lambda,u} > 0$) and market participants interpret rates staying low for a prolonged period as bad news about the economy (Delphic forward guidance) ($\rho > 0$), and the periphery is weaker, that is, credit-riskier than the core ($\gamma_p > \gamma_c$), interest rate communication shocks have higher impact on core than on peripheral yields. If, however, monetary policy communication does not affect perceived credit risk ($w_{\lambda,f} = \rho w_{\lambda,u} = 0$), or market participants believe there is no difference between core and peripheral losses given the credit event ($\gamma_p = \gamma_c$), the effect is uniform across countries.

Sovereign 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, communication shocks about the future path of monetary policy can affect bond yields via two channels.

A direct effect operates through the expectation channel, and it is uniform across all countries, because they share the same short rate process. Interest rate communication shocks provide information about intended future short rates, so as a response to a negative interest-rate shock, all bond yields decrease. Moreover, the multiplier is hump-shaped across maturities: short-maturity yields are unaffected because IR shocks drive the future path of short rates, and in the long run rates are expected to revert to the constant $\bar{r}$.

[4] Notice that our predictions about regression coefficients describe their shape across all maturities $(0, \infty)$. Given that the data only contains maturities up to 10 years, e.g., a theoretically hump-shaped coefficient curve is consistent with observing an increasing curve in reality.

The second, indirect effect works through the risk premium channel. Innovations to the future path of interest rates can affect the perceived probability of the credit event either directly, or indirectly by revealing information about the Eurozone macroeconomy, du_t. For example, as long as $w_{\lambda,f} > 0$, a negative IR shock, i.e., an announcement that policy rates will be low for longer, increases the probability of a peripheral default. Alternatively, if $\rho > 0$, a negative IR shock, i.e., an announcement that policy rates will be low for longer, is interpreted as a signal of weaker future fundamentals (output, unemployment), which increases future perceived default probabilities. Therefore, in both cases the risk premia investors require to hold credit-risky assets such as long-term sovereign bonds. This risk premium effect is thus negative and U-shaped across maturities.

The heterogeneity in the impact of IR communication shocks on bond yields across countries is driven by the fact that agents expect to suffer larger losses on peripheral long-term bonds than on core ones, $\gamma_p > \gamma_c$, so the risk premium they demand is more sensitive to shocks. Given that the expectation channel is identical for all countries, and the risk premium channel counteracts the expectation channel, core country bonds are more responsive to interest rate shocks than peripheral bonds. Finally, Proposition 2 also suggests that the risk premium channel can be strong enough to dominate the expectation channel and lead to negligible or even negative overall regression coefficients.[5]

Proposition 3. *The impact of U shocks in regression (OA-15), $\beta^{\tau}_{i,U}$, is negative and U-shaped across maturities.*

Moreover, for countries i and j, $\beta^{\tau}_{i,U} - \beta^{\tau}_{j,U} < 0$ if and only if $w_{\lambda,u}(\gamma_i - \gamma_j) > 0$.

Proposition 3 states that if monetary policy communication is informative about the Eurozone economy ($w_{\lambda,u} > 0$) and the periphery is weaker (credit-riskier) than the core ($\gamma_p > \gamma_c$), then state-of-the-economy shocks have a more negative impact on peripheral yields than on core yields. In fact, U shocks do not impact investors' expectations of future short rates, only the risk premium they demand: News about ECB bond purchases that investors interpret optimistically, or positive signals about the economy, $U > 0$, decrease the perceived probability of the credit event and hence the required risk premia; this lowers sovereign yields, especially for peripheral countries. Since state-of-the-economy shocks only affect the risk premia on sovereign bonds and equity, we refer to them as *pure risk premium shocks*.

From Propositions 2 and 3, it is straightforward to determine the impact of shocks on the sovereign yield spread. As the same short rate applies to both core and peripheral countries, the expectation channel is the same and cancels out when considering the spread. However, as long as there is cross-country heterogeneity in the size of the required risk premia, monetary policy communication has non-negligible impact on the yield spread. For example, news about asset purchases that investors deem satisfactory decrease the required risk premia on both core and peripheral countries, but the latter are more sensitive to shocks, thus the peripheral-core yield spread also decreases.

In summary, our model provides a simple framework to characterize how monetary policy communication shocks affect the term structure of risk-free and sovereign yields, and the relationship of yields and equity, and highlights the importance of the risk premium channel. The heuristic

[5]It is interesting to note that if lower future risk-free interest rates were interpreted as good news about the state of the economy ($\rho < 0$), negative IR shocks could decrease both expectations and the required risk premium via the signalling channel. Therefore, risky countries' yields would react more to central bank communication than those of safe countries.

shock identification and the testable Hypotheses 1 and 2 of the main paper are based on Remark 1 and Propositions 2-3.

E. Proofs

Proof of Theorem 1. We solve the model in the slightly more general case that features the equity dividend yield process

$$d\delta_t = \kappa_\delta \left(\bar{\delta} + w_\delta^\top c_t - \delta_t\right) dt + \sigma_\delta dB_{\delta,t} \tag{OA-16}$$

instead of (OA-5), where $c_t \equiv (f_t, u_t)$ and $w_\delta \equiv (w_{\delta,f}, w_{\delta,u})$ vectors. Moreover, we introduce the notation $w_\lambda \equiv (w_{\lambda,f}, w_{\lambda,u})$ to simplify the notation in (OA-4). Setting $w_{\delta,f} = 0$ in the solutions presented here will provide the solution of Section OA-I.

By definition, default-free and defaultable zero-coupon bond prices must satisfy

$$P_t^\tau = \mathrm{E}\left[e^{-\int_t^{t+\tau} r_s ds}\right] \tag{OA-17}$$

and

$$P_{i,t}^\tau = \mathrm{E}\left[e^{-\int_t^{t+\tau} r_s ds - \gamma_i (Z_{t+\tau} - Z_t)}\right]. \tag{OA-18}$$

Moreover, under the risk-neutral measure equity prices equal the expectation of discounted future dividends, which, due to our assumption on the dividend yield process, depend on future prices. Therefore, the equity price solves a fixed-point problem:

$$P_{e,t} = \mathrm{E}\left[\int_t^\infty e^{-\int_t^s r_u du - \gamma_e (Z_s - Z_t)} D_s ds\right] = \mathrm{E}\left[\int_t^\infty e^{-\int_t^s r_u du - \gamma_e (Z_s - Z_t)} \delta_s P_{e,s} ds\right]. \tag{OA-19}$$

Given the affine dynamic for the state variables of the model, we look for a model solution with exponential-affine bond and stock prices in the form (OA-6)-(OA-8). Applying Ito's Lemma to these three, we get the price dynamics

$$\begin{aligned}
\frac{dP_t^\tau}{P_t^\tau} &= \mu_t^\tau dt - B(\tau)\,\sigma_r dB_{r,t} - C(\tau)\,\sigma_f dB_{f,t}, \\
\frac{dP_{i,t}^\tau}{P_{i,t^-}^\tau} &= \left(\mu_{i,t}^\tau - \gamma_i \lambda_t\right) dt - B_i(\tau)\,\sigma_r dB_{r,t} - \left[C_i(\tau)\,\sigma_f + D_i(\tau)\,\sigma_u \rho\right] dB_{f,t} - D_i(\tau)\,\sigma_u \sqrt{1-\rho^2} dB_{u,t} \\
&\quad - E_i(\tau)\,\sigma_\lambda dB_{\lambda,t} - \gamma_i dZ_t, \text{ and} \\
\frac{D_t dt + dP_{e,t}}{P_{e,t^-}} &= \delta_t dt + \frac{dP_{e,t}}{P_{e,t^-}} = \left(\mu_{e,t} - \gamma_e \lambda_t\right) dt - B_e \sigma_r dB_{r,t} - \left(C_e \sigma_f + D_e \sigma_\theta\right) dB_{f,t} - D_e \sigma_u dB_{u,t} \\
&\quad - E_e \sigma_\lambda dB_{\lambda,t} - \gamma_e dZ_t,
\end{aligned}$$

where

$$\mu_t^\tau = A'(\tau) + B'(\tau)\, r_t + C'(\tau)\, f_t - B(\tau)\,\kappa_r \left(\bar{r} + f_t - r_t\right) + C(\tau)\,\kappa_f f_t + \frac{1}{2} B^2(\tau)\,\sigma_r^2 + \frac{1}{2} C^2(\tau)\,\sigma_u^2, \tag{OA-20}$$

$$\mu_{i,t}^{\tau} = A_i'(\tau) + B_i'(\tau) r_t + C_i'(\tau) f_t + D_i'(\tau) u_t + E_i'(\tau) \lambda_t - B_i(\tau) \kappa_r (\bar{r} + f_t - r_t) \quad \text{(OA-21)}$$
$$+ C_i(\tau) \kappa_f f_t + D_i(\tau) \kappa_u u_t - E_i(\tau) \kappa_\lambda \left(\bar{\lambda} - w_\lambda^\top c_t - \lambda_t\right) + \frac{1}{2} B_i^2(\tau) \sigma_r^2 + \frac{1}{2} C_i^2(\tau) \sigma_f^2$$
$$+ C_i(\tau) D_i(\tau) \rho \sigma_f \sigma_u + \frac{1}{2} D_i^2(\tau) \sigma_u^2 + \frac{1}{2} E_i^2(\tau) \sigma_\lambda^2,$$

and

$$\mu_{e,t} = \delta_t + F_e \kappa_\delta \left(\bar{\delta} + w_\delta^\top c_t - \delta_t\right) - A_e - B_e \kappa_r (\bar{r} + f_t - r_t) + C_e \kappa_f f_t + D_e \kappa_u u_t \quad \text{(OA-22)}$$
$$- E_e \kappa_\lambda \left(\bar{\lambda} - w_\lambda^\top c_t - \lambda_t\right) + \frac{1}{2} B_e^2 \sigma_r^2 + \frac{1}{2} C_e^2 \sigma_f^2 + \rho C_e D_e \sigma_f \sigma_u + \frac{1}{2} D_e^2 \sigma_u^2 + \frac{1}{2} E_e^2 \sigma_\lambda^2 + \frac{1}{2} F_e^2 \sigma_\delta^2,$$

where we made use of the processes (OA-1), (OA-2), (OA-3), (OA-4), and (OA-16).

Under the risk-neutral measure asset prices must satisfy

$$\mathrm{E}\left[\frac{dP_t^\tau}{P_t^\tau}\right] = \mathrm{E}\left[\frac{dP_{i,t}^\tau}{P_{i,t^-}^\tau}\right] = \mathrm{E}\left[\frac{D_t dt + dP_{e,t}}{P_{e,t^-}}\right] = r_t,$$

which in turn imply

$$\mu_t^\tau = \mu_{i,t}^\tau - \gamma_i \lambda_t = \mu_{e,t} - \gamma_e \lambda_t = r_t, \quad \text{(OA-23)}$$

Equation (OA-23) shows that expected instantaneous excess returns on all assets must compensate investors for the credit risk they bear. For default-free bonds the risk premium is zero, whereas sovereign bonds and equity have non-zero risk premia that increase in the probability of default λ_t and the losses given a credit event, γ_i and γ_e.

Solving for asset prices requires finding affine equations in r_t, f_t, θ_t, and λ_t. Setting linear terms to zero yields a set of ordinary differential equations (ODEs) in $B(\tau)$, $C(\tau)$, $B_i(\tau)$, $C_i(\tau)$, $D_i(\tau)$, and $E_i(\tau)$, and pins down the constant coefficients $B_e, ..., F_e$. Setting constant terms to zero yields additional ODEs in $A(\tau)$ and $A_i(\tau)$ and pins down the constant coefficient A_e. In particular, substituting (OA-20) into (OA-23) and collecting r_t, f_t, and constant terms, respectively, we obtain the ODEs

$$1 = B'(\tau) + B(\tau) \kappa_r \quad \text{(OA-24)}$$
$$0 = C'(\tau) - B(\tau) \kappa_r + C(\tau) \kappa_f, \text{ and} \quad \text{(OA-25)}$$
$$0 = A'(\tau) - B(\tau) \kappa_r \bar{r} + \frac{1}{2} B^2(\tau) \sigma_r^2 + \frac{1}{2} C^2(\tau) \sigma_u^2. \quad \text{(OA-26)}$$

Together with the boundary conditions $A(0) = B(0) = C(0) = 0$, these yield the $B(\tau)$ and $C(\tau)$ given in (OA-9) and (OA-10), while

$$A(\tau) = \kappa_r \bar{r} \int_0^\tau B(\tau) d\tau - \frac{1}{2} \sigma_r^2 \int_0^\tau B^2(\tau) d\tau - \frac{1}{2} \sigma_f^2 \int_0^\tau C^2(\tau) d\tau. \quad \text{(OA-27)}$$

Substituting (OA-21) into (OA-23) and collecting r_t, f_t, u_t, λ_t, and constant terms, respectively, we obtain the ODEs

$$1 = B_i'(\tau) + B_i(\tau)\kappa_r \tag{OA-28}$$
$$0 = C_i'(\tau) - B_i(\tau)\kappa_r + C_i(\tau)\kappa_f + E_i(\tau)\kappa_\lambda w_{\lambda,f} \tag{OA-29}$$
$$0 = D_i'(\tau) + D_i(\tau)\kappa_u + E_i(\tau)\kappa_\lambda w_{\lambda,u} \tag{OA-30}$$
$$\gamma_i = E_i'(\tau) + E_i(\tau)\kappa_\lambda, \text{ and} \tag{OA-31}$$
$$0 = A_i'(\tau) - B_i(\tau)\kappa_r\bar{r} - E_i(\tau)\kappa_\lambda\bar{\lambda} + \frac{1}{2}B_i^2(\tau)\sigma_r^2 + \frac{1}{2}C_i^2(\tau)\sigma_f^2 + C_i(\tau)D_i(\tau)\rho\sigma_f\sigma_u + \frac{1}{2}D_i^2(\tau)\sigma_u^2 + \frac{1}{2}E_i^2(\tau)\sigma_\lambda^2. \tag{OA-32}$$

Together with the boundary conditions $A_i(0) = B_i(0) = C_i(0) = D_i(0) = E_i(0) = 0$, these yield (OA-9) and (OA-11)-(OA-13), while

$$A_i(\tau) = \kappa_r\bar{r}\int_0^\tau B(\tau)\,d\tau + \kappa_\lambda\bar{\lambda}\int_0^\tau E_i(\tau)\,d\tau - \frac{1}{2}\sigma_r^2\int_0^\tau B^2(\tau)\,d\tau - \frac{1}{2}\sigma_f^2\int_0^\tau C_i^2(\tau)\,d\tau + \rho\sigma_f\sigma_u\int_0^\tau C_i(\tau)D_i(\tau)\,d\tau - \frac{1}{2}\sigma_u^2\int_0^\tau D_i^2(\tau)\,d\tau - \frac{1}{2}\sigma_\lambda^2\int_0^\tau E_i^2(\tau)\,d\tau. \tag{OA-33}$$

Finally, substituting (OA-22) into (OA-23) and collecting r_t, f_t, u_t, λ_t, δ_t, and constant terms, respectively, we obtain

$$B_e = \frac{1}{\kappa_r},\ C_e = \frac{1 - w_{\delta,f} - \gamma_e w_{\lambda,f}}{\kappa_f},\ D_e = -\frac{w_{\delta,u} + \gamma_e w_{\lambda,u}}{\kappa_u},\ E_e = \frac{\gamma_e}{\kappa_\lambda},\ F_e = \frac{1}{\kappa_\delta} \tag{OA-34}$$

and

$$A_e = \bar{\delta} - \bar{r} - \gamma_e\bar{\lambda} + \frac{\sigma_r^2}{2\kappa_r^2} + \frac{\sigma_f^2}{2\kappa_f^2}\left[1 - (w_{\delta,f} + \gamma_e w_{\lambda,f})\right]^2 - \rho\frac{\sigma_f\sigma_u}{\kappa_f\kappa_u}\left[1 - (w_{\delta,f} + \gamma_e w_{\lambda,f})\right](w_{\delta,u} + \gamma_e w_{\lambda,u}) + \frac{\sigma_u^2}{2\kappa_u^2}(w_{\delta,u} + \gamma_e w_{\lambda,u})^2 + \frac{\sigma_\lambda^2}{2\kappa_\lambda^2}\gamma_e^2 + \frac{\sigma_\delta^2}{2\kappa_\delta^2}. \tag{OA-35}$$

Setting $w_{\delta,f} = 0$ in (OA-34) then implies (OA-14). This concludes the Proof of Theorem 1. □

For the Proofs of Propositions 2-3, we make use of the following Lemma:

Lemma 1. *Let us define*

$$X(\tau;\kappa_1,\kappa_2) \equiv \frac{1 - e^{-\kappa_1\tau}}{\kappa_1} + \frac{e^{-\kappa_1\tau} - e^{-\kappa_2\tau}}{\kappa_1 - \kappa_2}$$

where $\tau > 0$ and $\kappa_1, \kappa_2 \in \mathbb{R}$. The function $\frac{X(\tau)}{\tau}$ is positive and hump-shaped across maturities τ for any fixed κ_1 and κ_2, with limits

$$\lim_{\tau\to 0}\frac{X(\tau)}{\tau} = \lim_{\tau\to\infty}\frac{X(\tau)}{\tau} = 0. \tag{OA-36}$$

Proof. Let us define

$$G(x) = \frac{1 - e^{-x}}{x}$$

for all $x > 0$; then simple algebra can confirm

$$\lim_{x \to 0} G(x) = 1 \text{ and } \lim_{x \to \infty} G(x) = 0, \tag{OA-37}$$

which in turn implies (OA-36). Moreover,

$$G'(x) = -\frac{1 - e^{-x} - xe^{-x}}{x^2}, \tag{OA-38}$$

which has the opposite sign as $H(x) \equiv 1 - e^{-x} - xe^{-x}$. But $\lim_{x \to 0} H(x) = 0$ and $H'(x) = e^{-x} + e^{-x}x - e^{-x} = e^{-x}x > 0$ for all $x > 0$. Hence, $H(x) > 0$ for all $x > 0$, which further implies $G'(x) < 0$. Together with (OA-37), we obtain that $G(x)$ is positive and decreasing for all $x > 0$, i.e., $G(x_1) > G(x_2)$ if and only if $x_1 < x_2$. As

$$\frac{X(\tau)}{\tau} = \frac{\kappa_1}{\kappa_2 - \kappa_1} \left(\frac{1 - e^{-\kappa_1 \tau}}{\kappa_1 \tau} - \frac{1 - e^{-\kappa_2 \tau}}{\kappa_2 \tau} \right) = -\kappa_1 \tau \frac{G(\kappa_1 \tau) - G(\kappa_2 \tau)}{\kappa_1 \tau - \kappa_2 \tau}, \tag{OA-39}$$

this implies that $X(\tau)/\tau$ is positive for all $\tau > 0$.

Further, we can study the slopes of the two functions at the short and the long end of the term structure. Differentiating (OA-39) with respect to τ we obtain

$$\frac{d}{d\tau} \frac{X(\tau)}{\tau} = -\frac{\kappa_1}{\kappa_1 - \kappa_2} \left[\kappa_1 G'(\kappa_1 \tau) - \kappa_2 G'(\kappa_2 \tau) \right] = -\frac{\kappa_1}{\tau} \frac{\frac{1 - e^{-\kappa_2 \tau} - \kappa_2 \tau e^{-\kappa_2 \tau}}{\kappa_2 \tau} - \frac{1 - e^{-\kappa_1 \tau} - \kappa_1 \tau e^{-\kappa_1 \tau}}{\kappa_1 \tau}}{\kappa_1 - \kappa_2},$$

therefore

$$\lim_{\tau \to \infty} \frac{d}{d\tau} \frac{X(\tau)}{\tau} = -\kappa_1 \lim_{\tau \to \infty} \frac{e^{-\kappa_1 \tau} - e^{-\kappa_2 \tau}}{(\kappa_1 - \kappa_2)\tau} = 0,$$

and there exists $\bar{\tau} > 0$ such that $\frac{d}{d\tau} \frac{X(\tau)}{\tau} < 0$ for all $\tau > \bar{\tau}$. On the other hand

$$\begin{aligned} \lim_{\tau \to 0} \frac{d}{d\tau} \frac{X(\tau)}{\tau} &= -\frac{\kappa_1}{\kappa_1 - \kappa_2} \lim_{\tau \to 0} \left[\frac{1 - e^{-\kappa_2 \tau} - \kappa_2 \tau e^{-\kappa_2 \tau}}{\kappa_2 \tau^2} - \frac{1 - e^{-\kappa_1 \tau} - \kappa_1 \tau e^{-\kappa_1 \tau}}{\kappa_1 \tau^2} \right] \\ &= -\frac{\kappa_1}{\kappa_1 - \kappa_2} \lim_{\tau \to 0} \left[\frac{\kappa_2 e^{-\kappa_2 \tau}}{2} - \frac{\kappa_1 e^{-\kappa_1 \tau}}{2} \right] = \frac{\kappa_1}{2} > 0, \end{aligned}$$

where the second equality is due to l'Hôspital's rule. Therefore, $X(\tau)/\tau$ is initially increasing from zero, then for large τs it is decreasing and converges to zero. This concludes the proof of the Lemma. □

Proof of Propositions 2-3. To verify Proposition 2, we need to show that:

(i) The impact of an IR shock in regression (OA-15) is given by

$$\beta_{i,IR}^{\tau} = \frac{C_i(\tau)}{\tau} \sigma_f + \frac{D_i(\tau)}{\tau} \sigma_u \rho, \tag{OA-40}$$

(ii) There exists $\bar{\gamma} > 0$ and $\bar{w}_{\lambda,u} > 0$ such that if either $\gamma_i < \bar{\gamma}$ or $w_{\lambda,u} < \bar{w}_{\lambda,u}$, $\beta^{\tau}_{i,IR}$ is positive and hump-shaped across maturities; otherwise $\beta^{\tau}_{i,IR} > 0$ for low τ and $\beta^{\tau}_{i,IR} < 0$ for high τ.

(iii) If $\rho w_{\lambda,u} (\gamma_i - \gamma_j) = 0$ for countries i and j, then $\beta^{\tau}_{i,IR} = \beta^{\tau}_{j,IR}$ for all $\tau > 0$. If $\rho w_{\lambda,u} > 0$ and $\gamma_i > \gamma_j$, then $\beta^{\tau}_{i,IR} < \beta^{\tau}_{j,IR}$ for all $\tau > 0$.

To verify Proposition 3, we need to show that:

(iv) The impact of state-of-the-world shocks in regression (OA-15) is given by

$$\beta^{\tau}_{i,U} = \frac{D_i(\tau)}{\tau} \sigma_u \sqrt{1-\rho^2}. \tag{OA-41}$$

(v) If $w_{\lambda,u}\gamma_i \neq 0$, $\beta^{\tau}_{i,U}$ is negative and U-shaped across maturities.

(vi) If $w_{\lambda,u} > 0$, and $\gamma_i = \gamma_j$ for countries i and j, $\beta^{\tau}_{i,U} = \beta^{\tau}_{j,U} < 0$. If $w_{\lambda,u} > 0$ and $\gamma_i > \gamma_j > 0$, we have $\beta^{\tau}_{i,U} < \beta^{\tau}_{j,U} < 0$.

To verify (i) and (iv), notice that (OA-18) implies that sovereign yields are given in the form

$$dy^{\tau}_{i,t} = \frac{A_i(\tau) + B_i(\tau) r_t + C_i(\tau) f_t + D_i(\tau) u_t + E_i(\tau) \lambda_t + \gamma_i Z_t}{\tau}. \tag{OA-42}$$

From (OA-2), (OA-3), and (OA-42), regressing changes in yields on $dB_{f,t}$ and $dB_{u,t}$ shocks yields the coefficients (OA-40) and (OA-41). Then, Lemma 1 and the assumptions on the signs and magnitudes of the relevant parameters together imply that all the statements (ii)-(iii) and (v)-(vi) are straightforward. In particular, we obtain that $\frac{C(\tau)}{\tau}$ and $\frac{C_i(\tau)}{\tau}$ are positive and hump-shaped across maturities, $\frac{D_i(\tau)}{\tau}$ is negative and U-shaped across maturities, and thus $\beta^{\tau}_{i,f} = \frac{C_i(\tau)}{\tau}\sigma_f + \frac{D_i(\tau)}{\tau}\sigma_u\rho$ is the sum of a hump-shaped and a U-shaped function. As long as the multiplicative coefficient of the U-shaped component is small, overall $\beta^{\tau}_{i,f}$ also remains hump-shaped. □

OA-II. Supplementary results and omitted tables

A. *Exclusion dates*

Table I summarizes all announcement dates that were excluded from the analysis.

[Insert Table I here]

B. *Construction of risk premium shocks*

To construct risk premium shocks, we regress the log return of the most liquid Eurostoxx 50 futures contract during the communication window on principal components of default-free interest rate changes and take the residual. We study two specifications: we either use only the first principal component, which is our IR shock, or the first five principal components. Formally, we run the regression

$$EQ_t = a + b^\top PC_t + \varepsilon_t, \tag{OA-43}$$

where PC_t equals PC_1 ($= IR$) for the univariate specification or the vector of PC_1 to PC_5 in the multivariate case. Table II reports estimates for both cases. The full sample runs from January 2001 to December 2014, the pre-crisis period is from January 2001 through November 2009, and the crisis period runs from December 2009 through December 2014. These dates are guided by both economic reason and by formal break tests discussed in the following subsection. Principal components are computed within each subsample so the right-hand-side variables in the multivariate specifications are orthogonal. As our results are essentially the same in the two specifications, except for the regression R^2, in the main analysis we use the residuals from the univariate regression as risk premium shocks.

[Insert Table II here]

In our main analysis, we orthogonalize equity shocks with respect to the interest rate shock using the full sample period; however, our results remain the same if we orthogonalize with respect to the different periods. Thus, we obtain the pure *risk premium shocks* by

$$U_t \equiv EQ_t - \hat{a} - \hat{b}\ IR_t, \tag{OA-44}$$

where $\hat{a}$ and $\hat{b}$ are the OLS point estimates from the univariate specification of (OA-43).

C. *Break points*

We follow the standard framework of Bai (1997) and Bai and Perron (1998, 2003) (henceforth, BP) for testing structural break models in which some of the regression parameters are allowed to break at m possible break points, thus and corresponding to $m + 1$ regimes. The framework is based on least squares principles, where the dependent variable is projected on a linear combination of regressors with both time-invariant coefficients and time varying coefficients. This method allows us to detect the presence of up to m unknown number of breaks in the following regression equation:

$$\Delta\left(y^{\tau}_{p,t} - y^{\tau}_{c,t}\right) = a^{\tau}_{j} + b^{\tau}_{j} IR_t + c^{\tau}_{j} U_t + \epsilon^{\tau}_{i,t} \quad , \quad t = T_{j-1}+1, \ldots, T_j \qquad \text{(OA-45)}$$

for $j = 1, 2, \ldots, m+1$, where m is the number of breaks, T_j is the period in which the j'th break occurs ($T_0 \equiv 0$ and $T_{m+1} \equiv T$), and $\Delta\left(y^{\tau}_{p,t} - y^{\tau}_{c,t}\right)$ is the periphery-core yield spread change for maturity τ on date t.

We apply the BP procedure to two-year and ten-year yield spreads by considering the possibility that a pre-specified number of breaks occur in the b^{τ} and c^{τ} coefficients at any point in the sample between January 2001 and December 2018. We test the null of no break versus a fixed number of up to $m = 3$ breaks using the supF type test. For the two-year yield we reject 0 versus 1 or 2 breaks at the 1% level, and 0 versus 3 breaks at the 5% level. The results for the ten-year spread are very similar.

We also investigate the number of breaks without pre-specifying a particular number m on which to fix inference. BP introduced the so-called double maximum tests $UD\max$ and $WD\max$ of the null hypothesis of no structural break against an unknown number of breaks given some upper bound. Further, we follow BP and allow for heteroskedasticity and autocorrelation in residuals using the method proposed by Andrews (1991) that selects an automatic bandwidth. Using the critical values provided by BP for an upper bound $M = 3$, we obtain $UD\max$ and $WD\max$ values that are significant at the 5% and 1% level, respectively. These findings provide strong evidence that there are at least two structural breaks in the relationship between yield spreads and policy shocks in our sample.

Considering a break number up to $m = 3$, we obtain that the first break happens on 3 December, 2009 (8 October, 2009) for the two-year (10-year) spread. We confirm late 2009 as the first break date using a Chow-type test via a search of where the test statistic attains its maximum value, which for both two-year and ten-year spreads is between October and December 2009. The p-value of the Chow test statistic is virtually zero when estimated on either spread when the break date is specified as occurring in the fourth quarter of 2009. The second break test picks 5 July, 2012 (8 March, 2012) for the two-year (ten-year) spread, while the third break is identified as 15 April, 2015 (4 September, 2014) for the two-year (ten-year) spread.

Based on these results, we choose the first date in our crisis sample as 3 December, 2009. This date also coincides with the first ECB meeting in which the Greek crisis was mentioned during the Q&A. More specifically, a press correspondent asked: "and my second question was, quite simply, how worried are you about the situation in Greece and the risk of a possible default?". We choose 4 December, 2014 as the final date in our crisis sample, which is close to the mid point of the final suggested break for the two-year and ten-year spreads. Moreover, since January 2015, the ECB (i) introduced the PSPP programme and (ii) changed its communication strategy by releasing some information about unconventional policies together with the release of its monetary policy decision at 13:45 CET. These results together suggest that ending the crisis period in December 2014 is both statistically and economically warranted.

Between the 1st and 3rd breaks (December 2009 to $\sim$ December 2014), the estimated b^{τ} and c^{τ} coefficients are strongly significantly negative, while they are not statistically different from zero from January 2001 to November 2009, and while they are significant from January 2015 through December 2018, they are an order of magnitude smaller compared to the crisis period.

This confirms that our selection of break dates is appropriate.

D. Individual countries

In this section we provide results for the sensitivity of individual country bond yields to our shocks. We run regressions of τ-period zero coupon yield changes $\Delta y^{\tau}_{i,t}$ for $i =$ Germany, France, Italy and Spain for the pre-crisis and crisis periods separately, in the form of

$$\Delta y^{\tau}_{i,t} = a^{\tau}_i + b^{\tau}_i IR_t + c^{\tau}_i U_t + \epsilon^{\tau}_{i,t} \tag{OA-46}$$

for maturities $\tau = 3, \ldots, 120$ months. Table III summarizes the results for the pre-crisis period country by country, whereas Table IV contains the crisis period estimates.

[Insert Tables III and IV here]

E. Controlling for macroeconomic news

In a recent paper, Bauer and Swanson (2020) argue that because the Federal Reserve and the market pay attention to the same news, news consists an omitted variable and drives out the so-called "Fed information effect" documented in Nakamura and Steinsson (2018). It is reasonable to assume that similar mechanisms are at work in the Euro area and that many different news items arrive before the monetary policy announcement that affect the ECB's reaction function as well as the market's forecast about future economic activity. We use the change in Now-casting GDP forecasts as a proxy for macroeconomic news. The Now-casting model combine a large set of economic indicators for the Euro area to forecast GDP growth. We therefore control for economic news released between two ECB meetings by including the change in Now-casting GDP forecasts in the regression specification:

$$\Delta y^{\tau}_{i,t} = a^{\tau}_i + b^{\tau}_i IR_t + c^{\tau}_i U_t + d^{\tau}_i NEWS_t + \epsilon^{\tau}_{i,t}, \tag{OA-47}$$

where $NEWS_t$ is the change in Now-casting forecasts. Table V presents the results for the crisis period. The coefficients on IR and U shocks are virtually unchanged with respect to our baseline specification.

[Insert Table V here]

OA-III. Survey expectations

We use survey data from Consensus Economics to document the sensitivity of survey forecasts to our ECB communication shocks. We estimate the following regression model:

$$f_{i,t+1} - f_{i,t-1} = a_i + b_i IR_t + c_i U_t + d_i NEWS_t + \epsilon^{\tau}_{i,t},$$

where $f_{i,t}$ is the median of survey expectations of GDP growth over the next year for core and peripheral countries at time t; $NEWS_t$ is the change in the Now-casts between monetary policy meetings. ECB monetary policy meetings and survey collection for time t happen roughly at the same time. For this reason, we take the change in survey expectations from time $t-1$ to time $t+1$ and regress it on shocks at time t. Table VI shows the results for the ECB communication shocks for the crisis period. The results show that the effects have the expected sign: positive IR and U shocks both increase survey expectations about future GDP growth during the crisis period; the coefficients are larger for peripheral countries than for core countries. However, the coefficients are not precisely estimated: the coefficients for U shocks are statistically significant for core but not for periphery; the coefficients for IR shocks are only significant for peripheral countries. We would then interpret these results cautiously as the uncertainty related to the estimation is high.

[Insert Table VI here]

OA-IV. Robustness

We perform a host of robustness checks to our main result. First, we study the effect of other macroeconomic announcements on our results. Second, we explore the impact of varying the high-frequency window length to identify our monetary shocks. Third, we use high frequency changes in bond yields instead of daily changes in our sovereign regressions. Fourth, we reconstruct our monetary policy communication shocks separately in the two relevant subsamples and check whether they alter our results. Finally we estimate our sovereign regression using bootstrapped standard errors to take into account the extra sampling variation due to the construction of our shocks.

A. Other macroeconomic announcements

The high frequency identification of monetary policy shocks is designed to ensure that movements in asset prices during the specified time window are exclusively attributable to ECB monetary policy. In our sample, there are no other Eurozone macroeconomic news released within the time frame spanned by our monetary policy windows. That being said, there is still a potential risk of contamination from other shocks outside the Eurozone. More specifically, we find that two other major events often occur around or contemporaneously with the ECB monetary press conference: (i) the announcement of the Bank of England monetary policy decision; and (ii) the release of the US Initial Jobless Claims.

Bank of England monetary policy shocks. The Bank of England (BoE) currently sets and announces its policy decision eight times a year (roughly once every six weeks) on Thursdays. Before September 2016, the meetings were held monthly also on Thursdays. The BoE releases its rate decision at 12:00 UK time (13:00 CET). At a quarterly frequency the rate decision is accompanied by the inflation report and by a press conference starting at 12:30 UK time (13:30 CET).[6] We estimate monetary policy shocks for the Bank of England using the same identification strategy we use for our ECB shocks. To this end, we use UK swap rates with maturities ranging from one month to ten years, and estimate the variation in rates from five minutes before the rate decision to 100 minutes afterwards. We then use a PCA analysis in the same fashion as described in Section III of the main paper and extract the first two principal components.

[6] The press conference in the past was held 12:45 UK time (13:45 CET); the time change is not going to affect our identification as our time window spans both the previous and the current press-conference timing.

US Initial Jobless Claims. Data on US Initial Jobless Claims are announced every Thursday at 8:30 Eastern Standard Time, which coincides with the start of the ECB press conference. To study any potential impact on our results, we also estimate shocks due to macroeconomic surprises in jobless claims data. Bloomberg collects surveys of forecasts for most macroeconomic variables and we use the median of initial jobless claims forecasts as a proxy for market expectations. We then compute the surprise component as the difference between the actual release and market expectations and divide this variable by its overall standard deviation.

To test whether our results are robust to the contamination from these additional shocks we re-estimate our baseline regression but additionally control for the BoE monetary policy shocks and the US Initial Jobless Claim macroeconomic news:

$$\Delta y_{i,t}^{\tau} = a_i^{\tau} + b_i^{\tau} IR_t + c_i^{\tau} U_t + d_i^{\tau}\ BoE\ PC1_t + e_i^{\tau}\ BoE\ PC2_t + f_i^{\tau} JC_t + \epsilon_{i,t}^{\tau}, \qquad \text{(OA-48)}$$

where $\Delta y_{i,t}^{\tau}$ are daily zero-coupon yield changes for $i = c, p$ with maturities $\tau = 3, \ldots, 120$ months. IR and U are the usual ECB interest rate and risk premium shocks, $BoE\ PC1$ and $BoE\ PC2$ are respectively the first and second principal component extracted from the Bank of England monetary policy window, and JC is the US Initial Jobless Claim surprise.

Table VII presents the results for the crisis period. We find that while surprises in US Jobless Claims are statistically insignificant for both core and peripheral yields, Bank of England interest rate shocks seems to affect the periphery-core spread. Most importantly, however, our results on the effect of ECB monetary policy remain robust: results for ECB IR and U shocks are broadly unchanged. We therefore conclude that our results are not contaminated by other macroeconomic announcements released contemporaneously with the ECB monetary press conference.

[Insert Table VII here]

B. Window length

Our main results are based on shocks estimated using a window that starts at 14:25 and ends at 16:10 CET, i.e., is 105 minutes long. In order to check if using a different window length would affect our results, we estimated ECB IR and U shocks using window length ranging from 100 minutes to 150 minutes. Table VIII reports estimated coefficients for the regression of ten-year periphery-core spreads on shocks when we vary the window length. We find that estimated coefficients are remarkably stable across different window sizes and are virtually the same as our main results. Therefore, the exact window size does not have a material impact on our results.

[Insert Table VIII here]

C. High-frequency bond yields

Our main regression results use daily changes for the sovereign yields. One might wonder how the results would look like if we used high-frequency changes instead. To this end, we sample high-frequency sovereign yields using various windows ranging from 100 to 150 minutes, and re-run our main regression for the crisis period. The results, gathered in Table IX, are again very similar to those reported in the main paper. We therefore conclude that our results are not due to using daily instead of high-frequency yields changes.

[Insert Table IX here]

D. Static vs dynamic principal components

One might be worried that estimating our communication shocks over the full 14-year window is not taking into account the fact that the nature of communication has changed over time. To see whether this assumption has any impact on our results, we re-run regression our baseline regression after estimating the IR and U shock series separately for the pre-crisis and crisis windows. That is, for each subsample we separately estimate the principal components of swap changes, and then orthogonalize equity returns of the specific time period with respect to the first PC. To save space, Table X reports the estimated results for the crisis period only. We note that the results are virtually the same as those reported in the main paper.

[Insert Table X here]

E. Bootstrapped standard errors

One might be worried that the standard errors do not take into account the extra sampling variability associated with the computation of the IR and U shocks. To see whether this may have impact on our results, we follow Bauer and Swanson (2020) and compute standard errors using 10,000 bootstrap replications. Table XI shows in bracket the 95% confidence bands estimated via the bootstrap procedure. To save space, Table XI reports the estimated results for the crisis period only. We note that taking into account the extra sampling variation, has no effect on the significance of our results.

[Insert Table XI here]

OA-V. Relation to Altavilla, Brugnolini, Gürkaynak, Motto, and Ragusa (2019)

In a recent working paper Altavilla, Brugnolini, Gürkaynak, Motto, and Ragusa (2019) (henceforth, ABGMR) construct ECB monetary policy shocks and study their effect on sovereign bond yields similarly to us. In the following, we outline in detail the differences between their approach and ours in (i) how we construct monetary policy communication shocks and (ii) how our findings relate to theirs.

In our paper, we back out two communication shocks: one extracted from OIS and longer-maturity swap rates (a forward guidance shock, IR) and one extracted from equity returns (a risk premium shock, U).[7] In contrast, ABGMR identify four different monetary policy factors that are estimated using OIS swap rates. They label these factors `target`, `timing`, `forward guidance`,

[7] We do not report the impact of target shocks on sovereign yields, because, except for a few outliers, they are significantly smaller than communication shocks, and their contribution to explain sovereign yield movements is small.

and `quantitative easing` (QE). One major difference between our approach and the authors' is that they define monetary policy only via movements in the term structure of risk-free interest rates *alone*. We instead also estimate a risk premium shocks. To make our results comparable to theirs, we drop any discussion around U shocks and only focus on IR shocks.

A. *Comparison of shocks*

As a first exploration, we compare our IR shock to the timing, forward guidance, and quantitative easing shocks in ABGMR. The upper panel in Table XII presents correlations between our IR shock and the three shocks. We find that our communication shock is a linear combination of the ABGMR shocks as our shock is strongly correlated with their FG shocks in the pre-crisis (January 2002 - November 2009) as well as the crisis sample (December 2009 - December 2014). In the 2015 - 2018 period, however, it is instead mostly correlated with the QE shocks.

[Insert Table XII here]

B. *Comparison of main results*

An important finding of our paper is to show that communication shocks in the crisis period on ECB regular announcement dates contributed to a widening of the spread between peripheral and core yields. This is the result of a muted response of peripheral yields with respect to communication shocks in our sample.

While the authors study the effect of their shocks on the cross-section of sovereign bond yields, they never look at the spread itself. In the following, we therefore re-estimate our main regressions using their shocks both with daily and high frequency data. Figure 1 shows the reaction of core yields, peripheral yields and the periphery-core spread to ABGMR Forward Guidance shocks using daily bond yields. Notice that the results are consistent with our main findings in our paper as the patterns look virtually the same. We noticeably see that peripheral bonds' sensitivity falls in the crisis sample. The lower right panel also confirms that estimated coefficients from regressing the periphery-core spread on FG are statistically significant. The results hold even if we use high-frequency data as left-hand side variables; see Figure 2. Tables XIII and XIV collect detailed regression results for the crisis sample for daily and high-frequency data, respectively. While the overall patterns are strikingly similar to our findings, we notice a sharp drop in R^2s when using our shocks compared to ABGMR. For example, in the crisis period, we find that IR and U shocks explain more than 20% of the variation of peripheral bond yields at the ten-year maturity while the equivalent number in ABGMR forward guidance and timing shocks explain a mere 1%. As we argue in our paper, the high R^2 is solely due to risk premium shocks that explain the majority of the variation of peripheral bond yields during this period.

[Insert Tables XIII and XIV here]

To conclude, we believe that the results in ABGMR are consistent with our main findings and, make our results robust to a different shock specification.

[Insert Figures 1 and 2 here]

Tables

date	Type of announcement
4 January, 2001	No press conference
18 January, 2001	No press conference
15 February, 2001	No press conference
15 March, 2001	No press conference
29 March, 2001	No press conference
26 April, 2001	No press conference
23 May, 2001	No press conference
2 August, 2001	No press conference
17 September, 2001	Unscheduled, no press conference
27 September, 2001	No press conference
25 October, 2001	No press conference
1 August, 2002	No press conference
31 July, 2003	No press conference
5 August, 2004	No press conference
4 August, 2005	No press conference
2 August, 2007	No press conference
8 October, 2008	Coordinated rate cut of 50bps with other central banks
6 November, 2008	BoE 150bp cut

Table I. Excluded ECB announcement days

This table lists ECB announcement dates which are excluded from our main analysis. Excluded dates either include announcements that were not followed by a press conference, unscheduled meetings, or days with coordinated measures with other central banks.

	const	PC_1	PC_2	PC_3	PC_4	PC_5	$\overline{R}^2$
Full Sample	-16.40	1.53					-0.16
	(−3.23)	(0.65)					
	-15.22	1.53	-0.25	8.00	1.36	-2.05	9.46
	(−3.08)	(0.77)	(−1.46)	(2.68)	(2.05)	(−2.74)	
Pre-crisis	-14.97	2.46					0.57
	(−2.67)	(0.75)					
	-15.12	2.46	-0.42	-0.10	2.42	2.96	1.16
	(−2.54)	(0.81)	(−0.66)	(−0.08)	(0.53)	(2.36)	
Crisis	-18.66	-0.25					-1.53
	(−1.96)	(−0.08)					
	-14.41	-0.25	0.37	19.96	-7.10	0.21	23.30
	(−1.76)	(−0.07)	(1.45)	(4.37)	(−1.76)	(0.17)	

Table II. Equity returns regressed on PCs of swap rate changes

This table reports estimates of regressions from equity returns on the principal components of swap rate changes computed around ECB press conferences. Univariate and multivariate specifications are reported for three samples: The full sample runs from January 2001 to December 2014; the pre-crisis period runs from January 2001 to November 2009, and the crisis period runs from December 2009 to December 2014. Principal components are computed within each sub-sample so the right-hand variables in the multivariate specifications are orthogonal. The R^2s reported are adjusted for degrees of freedom.

	3	6	12	24	36	48	60	72	84	96	108	120
						Germany						
IR	0.43	0.88	1.38	1.66	1.55	1.45	1.33	1.20	1.06	0.92	0.78	0.74
	(3.81)	(5.75)	(13.74)	(18.33)	(16.81)	(14.86)	(12.77)	(11.88)	(11.10)	(9.69)	(8.15)	(7.92)
$U(\times 10^{-2})$	0.21	0.34	-0.57	-0.80	-0.56	-0.55	-0.42	-0.26	-0.15	-0.06	-0.00	-0.07
	(0.44)	(0.60)	(-0.88)	(-1.19)	(-0.84)	(-0.80)	(-0.57)	(-0.36)	(-0.21)	(-0.08)	(-0.01)	(-0.09)
$\overline{R}^2$	20.62	48.55	62.34	61.42	57.44	51.39	46.12	41.25	35.82	29.38	22.43	21.14
ΔR^2	-1.41	-0.76	-0.36	-0.23	-0.57	-0.69	-0.91	-1.11	-1.27	-1.42	-1.57	-1.59
						France						
IR	0.61	0.84	1.27	1.66	1.57	1.47	1.36	1.23	1.08	0.92	0.80	0.72
	(4.09)	(7.76)	(11.14)	(18.09)	(16.81)	(14.58)	(12.50)	(11.64)	(10.69)	(9.11)	(8.23)	(7.41)
$U(\times 10^{-2})$	0.77	-0.45	-0.31	-0.69	-0.63	-0.65	-0.51	-0.40	-0.28	-0.23	-0.10	-0.13
	(1.19)	(-0.69)	(-0.42)	(-1.01)	(-0.97)	(-0.96)	(-0.70)	(-0.56)	(-0.38)	(-0.30)	(-0.13)	(-0.16)
$\overline{R}^2$	15.17	31.92	50.79	61.64	57.04	53.21	48.02	44.13	37.79	29.73	24.15	20.34
ΔR^2	-0.92	-1.00	-0.88	-0.36	-0.51	-0.54	-0.79	-0.94	-1.16	-1.35	-1.52	-1.58
						Italy						
IR	0.48	0.95	1.46	1.58	1.52	1.38	1.30	1.14	0.97	0.86	0.80	0.72
	(4.73)	(9.07)	(12.02)	(14.20)	(12.73)	(11.09)	(9.98)	(9.64)	(9.01)	(8.07)	(7.39)	(6.76)
$U(\times 10^{-2})$	-0.16	-0.03	-0.26	-0.59	-0.76	-0.47	-0.36	-0.30	-0.23	-0.20	0.13	0.22
	(-0.24)	(-0.06)	(-0.35)	(-0.87)	(-1.21)	(-0.71)	(-0.57)	(-0.49)	(-0.36)	(-0.33)	(0.18)	(0.31)
$\overline{R}^2$	13.69	43.10	61.97	58.99	57.21	51.86	47.36	41.31	31.99	29.33	26.22	21.42
ΔR^2	-1.68	-1.15	-0.69	-0.51	-0.30	-0.74	-0.92	-1.07	-1.30	-1.36	-1.46	-1.50
						Spain						
IR	0.31	0.47	0.65	1.60	1.57	1.41	1.38	1.28	1.10	0.95	0.86	0.82
	(1.92)	(3.71)	(3.34)	(16.32)	(15.73)	(11.89)	(11.97)	(11.35)	(9.17)	(7.86)	(7.01)	(6.77)
$U(\times 10^{-2})$	-0.69	-0.69	-0.74	-0.47	-0.74	-0.58	-0.60	-0.40	-0.36	-0.23	-0.23	-0.25
	(-1.26)	(-1.23)	(-0.78)	(-0.73)	(-1.20)	(-0.86)	(-0.89)	(-0.62)	(-0.53)	(-0.33)	(-0.32)	(-0.33)
$\overline{R}^2$	8.03	15.35	11.78	61.67	59.64	51.42	49.72	45.26	37.14	30.21	25.29	23.32
ΔR^2	-0.50	-0.50	-1.12	-0.56	-0.30	-0.65	-0.65	-0.93	-1.11	-1.34	-1.43	-1.46

Table III. Sovereign yield reactions to communication shocks pre-crisis

This table reports the results of multivariate regressions of zero-coupon one-day changes in European sovereign yields of different maturities (months) on interest rate and pure risk premium communication shocks:

$$\Delta y^{\tau}_{i,t} = a^{\tau}_i + b^{\tau}_i IR_t + c^{\tau}_i U_t + \epsilon^{\tau}_{i,t}, \quad \tau = 3, \ldots, 120 \text{ months.}$$

t-statistics reported in parenthesis are calculated using HAC standard errors with 2 lags. ΔR^2 is the change in the adjusted R^2 when adding U shocks to a univariate regression on IR shocks. Data run from January 2001 to November 2009.

	3	6	12	24	36	48	60	72	84	96	108	120
						Germany						
IR	0.73	1.01	1.27	1.61	1.62	1.65	1.59	1.50	1.39	1.27	1.19	1.16
	(4.39)	(3.15)	(6.23)	(7.72)	(8.71)	(9.20)	(8.54)	(8.73)	(8.57)	(8.15)	(7.84)	(7.69)
$U(\times 10^{-2})$	1.65	-0.87	0.40	0.56	0.98	1.24	1.60	1.86	2.09	2.32	2.54	2.54
	(2.03)	(-1.26)	(0.91)	(1.08)	(1.60)	(1.77)	(2.01)	(2.28)	(2.55)	(2.79)	(2.99)	(3.00)
$\overline{R}^2$	8.03	10.46	56.47	57.92	59.66	59.83	54.72	54.05	53.20	51.63	50.17	50.00
ΔR^2	0.12	-2.32	-1.01	-0.84	0.36	1.29	2.72	4.68	7.10	10.05	12.80	13.25
						France						
IR	0.54	0.97	1.19	1.43	1.42	1.29	1.25	1.11	0.99	0.89	0.79	0.71
	(5.27)	(7.41)	(7.94)	(7.09)	(8.04)	(6.78)	(6.35)	(5.72)	(5.31)	(4.85)	(4.45)	(4.07)
$U(\times 10^{-2})$	0.09	0.20	0.27	-0.20	0.07	-0.18	-0.25	-0.11	-0.04	0.11	0.12	-0.00
	(0.50)	(0.82)	(0.82)	(-0.33)	(0.10)	(-0.20)	(-0.24)	(-0.11)	(-0.04)	(0.12)	(0.12)	(-0.00)
$\overline{R}^2$	31.77	54.32	58.72	53.25	48.21	38.93	32.67	29.02	24.96	21.35	17.71	14.24
ΔR^2	-2.21	-1.35	-1.15	-1.48	-1.72	-1.98	-2.14	-2.34	-2.50	-2.59	-2.71	-2.86
						Italy						
IR	0.31	0.26	0.51	-0.30	-0.17	-0.21	-0.18	-0.20	-0.21	-0.18	-0.18	-0.18
	(1.12)	(0.90)	(1.49)	(-0.67)	(-0.43)	(-0.52)	(-0.49)	(-0.57)	(-0.67)	(-0.63)	(-0.63)	(-0.65)
$U(\times 10^{-2})$	-0.19	-2.10	-4.53	-6.89	-7.49	-7.49	-8.05	-7.79	-7.56	-7.04	-7.47	-7.68
	(-0.11)	(-2.90)	(-3.65)	(-3.59)	(-3.77)	(-3.88)	(-3.91)	(-3.88)	(-3.72)	(-3.67)	(-3.49)	(-3.47)
$\overline{R}^2$	6.70	11.14	11.66	14.48	15.90	16.72	19.15	19.36	19.23	19.60	22.61	24.26
ΔR^2	-3.06	3.28	7.25	13.54	15.43	16.58	19.11	19.35	19.21	19.59	22.45	23.95
						Spain						
IR	0.94	1.00	0.86	-0.22	-0.23	-0.31	-0.37	-0.39	-0.44	-0.39	-0.40	-0.39
	(1.40)	(1.31)	(1.35)	(-0.52)	(-0.56)	(-0.77)	(-0.95)	(-1.01)	(-1.17)	(-1.05)	(-1.12)	(-1.09)
$U(\times 10^{-2})$	0.61	0.99	-0.64	-7.59	-9.28	-9.65	-9.63	-9.49	-10.44	-10.14	-10.15	-9.96
	(0.56)	(0.69)	(-0.38)	(-3.31)	(-4.31)	(-4.11)	(-4.23)	(-4.05)	(-3.50)	(-3.31)	(-3.21)	(-3.38)
$\overline{R}^2$	17.91	13.54	0.82	16.08	21.93	26.46	27.24	29.17	33.91	32.65	33.17	33.07
ΔR^2	-2.21	-2.00	-3.14	16.07	21.92	26.38	27.14	29.01	33.25	31.65	32.11	31.94

Table IV. Sovereign yield reactions to communication shocks during the crisis

This table reports the results of multivariate regressions of zero-coupon one-day changes in European sovereign yields of different maturities (months) on interest rate and pure risk premium communication shocks:

$$\Delta y^{\tau}_{i,t} = a^{\tau}_i + b^{\tau}_i IR_t + c^{\tau}_i U_t + \epsilon^{\tau}_{i,t}, \quad \tau = 3, \ldots, 120 \text{ months.}$$

t-statistics reported in parenthesis are calculated using HAC standard errors with 2 lags. ΔR^2 is the change in the adjusted R^2 when adding U shocks to a univariate regression on IR shocks. Data run from December 2009 to December 2014.

	3	6	12	24	36	48	60	72	84	96	108	120
						Core						
IR	0.64	0.99	1.24	1.53	1.53	1.47	1.42	1.31	1.19	1.08	0.99	0.94
	(5.47)	(5.63)	(7.50)	(8.69)	(9.36)	(8.31)	(7.49)	(7.00)	(6.58)	(6.10)	(5.71)	(5.54)
$U(\times 10^{-2})$	0.82	-0.34	0.29	0.13	0.49	0.52	0.67	0.88	1.03	1.22	1.34	1.27
	(2.05)	(-0.85)	(0.81)	(0.25)	(0.80)	(0.76)	(0.88)	(1.23)	(1.49)	(1.83)	(1.99)	(1.92)
$NEWS$	-4.50	-0.11	-4.14	-3.91	-2.95	-1.03	-0.44	-0.08	0.49	0.55	0.50	0.10
	(-1.92)	(-0.02)	(-1.68)	(-1.32)	(-0.98)	(-0.31)	(-0.12)	(-0.02)	(0.14)	(0.15)	(0.14)	(0.03)
$\overline{R}^2$	17.89	25.88	63.94	60.22	58.76	53.66	47.18	46.02	43.68	40.92	37.68	35.18
						Periphery						
IR	0.62	0.64	0.68	-0.26	-0.20	-0.26	-0.27	-0.29	-0.32	-0.28	-0.29	-0.28
	(2.19)	(1.55)	(1.81)	(-0.63)	(-0.48)	(-0.64)	(-0.68)	(-0.76)	(-0.89)	(-0.86)	(-0.91)	(-0.88)
$U(\times 10^{-2})$	0.23	-0.61	-2.57	-7.20	-8.40	-8.59	-8.87	-8.68	-9.05	-8.63	-8.84	-8.85
	(0.30)	(-0.58)	(-1.44)	(-2.50)	(-3.10)	(-3.43)	(-3.69)	(-3.85)	(-4.04)	(-4.05)	(-4.01)	(-4.03)
$NEWS$	2.05	-4.38	1.18	3.18	-0.94	-1.45	-2.44	-3.14	-3.86	-3.06	-2.53	-2.85
	(0.58)	(-0.98)	(0.13)	(0.28)	(-0.08)	(-0.13)	(-0.21)	(-0.28)	(-0.34)	(-0.28)	(-0.24)	(-0.28)
$\overline{R}^2$	20.95	14.81	4.29	14.80	18.80	21.44	23.32	24.33	27.00	26.54	28.22	28.96
						Periphery−Core Spread						
IR	-0.02	-0.35	-0.55	-1.79	-1.73	-1.73	-1.69	-1.60	-1.51	-1.36	-1.28	-1.22
	(-0.10)	(-0.69)	(-1.50)	(-4.73)	(-4.47)	(-4.22)	(-3.86)	(-3.71)	(-3.60)	(-3.49)	(-3.34)	(-3.20)
$U(\times 10^{-2})$	-0.58	-0.27	-2.86	-7.33	-8.89	-9.10	-9.54	-9.56	-10.08	-9.85	-10.18	-10.12
	(-0.67)	(-0.24)	(-1.62)	(-2.71)	(-3.57)	(-4.01)	(-4.33)	(-4.48)	(-4.49)	(-4.40)	(-4.24)	(-4.30)
$NEWS$	6.55	-4.28	5.32	7.08	2.01	-0.41	-1.00	-3.06	-4.35	-3.61	-3.03	-2.95
	(1.81)	(-0.62)	(0.53)	(0.61)	(0.16)	(-0.04)	(-0.17)	(-0.27)	(-0.39)	(-0.33)	(-0.28)	(-0.29)
$\overline{R}^2$	5.84	-0.48	1.68	23.76	26.80	29.41	31.07	32.56	34.95	34.89	36.02	36.24

Table V. Controlling for macroeconomic news

This table reports the results of multivariate regressions of zero-coupon one-day changes in core yields versus peripheral yields of different maturities (months) on IR and U communication shocks and NEWS:

$$\Delta y_{i,t}^{\tau} = a_i^{\tau} + b_i^{\tau} IR_t + c_i^{\tau} U_t + d_i^{\tau} NEWS_t + \epsilon_{i,t}^{\tau}, \quad \tau = 3, \ldots, 120 \text{ months.}$$

t-statistics reported in parenthesis are calculated using HAC standard errors with 2 lag. Core yields are defined as the average of Germany and France and Peripheral yields defined as the average of Italy and Spain. ΔR^2 is the change in the adjusted R^2 when adding U shocks to a univariate regression that uses only IR shocks. Data run from December 2009 to December 2014.

	Core	Periphery
IR	1.20	1.38
	(1.08)	(1.90)
$U(\times 10^{-2})$	6.67	10.49
	(1.94)	(1.61)
$\overline{R}^2$	6.31	10.27

Table VI. Consensus Economics survey reactions to communication shocks
This table reports the response of core and peripheral countries' GDP forecasts to ECB communication shocks controlling for other macroeconomic news:

$$f_{i,t+1} - f_{i,t-1} = a_i + b_i IR_t + c_i U_t + d_i NEWS_t + \epsilon^{\tau}_{i,t}.$$

t-statistics reported in parenthesis are calculated using HAC standard errors with 2 lag. Core forecasts are defined as the average of Germany and France and Peripheral forecasts defined as the average of Italy and Spain. The table only report coefficients for IR and U shocks. Data run from December 2009 to December 2014.

	3	6	12	24	36	48	60	72	84	96	108	120
IR	0.01	-0.56	-0.73	-2.07	-2.03	-1.99	-1.93	-1.81	-1.69	-1.51	-1.41	-1.35
	(0.04)	(-0.90)	(-1.58)	(-4.16)	(-3.94)	(-3.61)	(-3.41)	(-3.28)	(-3.34)	(-3.26)	(-3.16)	(-3.06)
$U(\times 10^{-2})$	-0.88	0.01	-2.84	-7.20	-8.50	-8.60	-8.95	-8.92	-9.29	-9.07	-9.39	-9.35
	(-1.28)	(0.02)	(-2.34)	(-4.24)	(-4.67)	(-4.31)	(-4.18)	(-4.07)	(-3.82)	(-3.64)	(-3.52)	(-3.62)
BoE PC1	-1.76	-1.18	-2.40	-1.66	-0.14	1.43	2.56	3.09	4.71	4.94	5.35	5.26
	(-1.15)	(-0.72)	(-1.29)	(-0.56)	(-0.06)	(0.65)	(1.25)	(1.59)	(2.06)	(2.10)	(2.06)	(2.08)
BoE PC2	0.37	0.70	0.90	0.40	0.08	-0.30	-0.61	-0.70	-0.96	-0.98	-1.04	-1.01
	(0.91)	(1.72)	(2.30)	(0.75)	(0.18)	(-0.76)	(-1.51)	(-1.71)	(-1.88)	(-1.81)	(-1.71)	(-1.68)
US J.C.	0.16	-1.37	-1.47	-3.60	-3.71	-3.06	-2.81	-2.45	-1.77	-1.33	-0.97	-0.91
	(0.22)	(-0.92)	(-0.85)	(-1.72)	(-1.69)	(-1.42)	(-1.27)	(-1.13)	(-0.84)	(-0.68)	(-0.52)	(-0.50)
$\overline{R}^2$	2.74	0.17	0.95	23.83	27.21	29.57	31.60	33.28	36.71	36.85	38.29	38.45

Table VII. Controlling for other macroeconomic announcements

This table reports the results of multivariate regressions of zero-coupon one-day changes in periphery minus core yield spread of different maturities (months) on IR and U communication shocks, BoE interest rate shocks, and the US Initial Jobless Claims shock:

$$\Delta\left(y^{\tau}_{p,t} - y^{\tau}_{c,t}\right) = a^{\tau} + b^{\tau} IR_t + c^{\tau} U_t + d^{\tau} BoE\ PC1_t + e^{\tau} BoE\ PC2_t + f^{\tau} JC_t + \epsilon^{\tau}_t, \quad \tau = 3, \ldots, 120 \text{ months.}$$

Core yields are defined as the average of Germany and France, peripheral yields are defined as the average of Italy and Spain. t-statistics reported in parenthesis are calculated using HAC standard errors with 2 lags. Data run from December 2009 to December 2014.

	100	110	120	130	140	150
IR	-1.22	-1.08	-1.29	-1.36	-1.30	-1.46
	(-3.24)	(-3.06)	(-3.47)	(-3.87)	(-3.31)	(-3.21)
$U(\times 10^{-2})$	-10.09	-8.99	-8.99	-8.59	-8.47	-8.00
	(-3.34)	(-3.08)	(-3.23)	(-3.14)	(-3.20)	(-3.35)
$\overline{R}^2$	37.27	33.08	36.39	36.29	36.51	39.88

Table VIII. Varying the press conference window length

This table reports the results of multivariate regressions of zero-coupon changes in periphery minus core ten-year (120 months) yield spread on IR and U communication shocks:

$$\Delta\left(y_{p,t}^{120} - y_{c,t}^{120}\right) = a^{120} + b^{120} IR_t + c^{120} U_t + \epsilon_t^{120},$$

where each column indicates the number of minutes since the start of the ECB press conference. Core yields are defined as the average of Germany and France and Peripheral yields defined as the average of Italy and Spain. t-statistics reported in parenthesis are calculated using HAC standard errors with 2 lag. Data run from December 2009 to December 2014.

	100	110	120	130	140	150
			Core			
IR	0.69	0.72	0.80	0.76	0.83	0.80
	(4.69)	(4.85)	(5.98)	(5.24)	(5.78)	(5.82)
$U(\times 10^{-2})$	0.56	0.69	0.57	0.56	0.64	0.74
	(1.68)	(2.00)	(1.30)	(1.18)	(1.38)	(1.46)
$\overline{R}^2$	54.74	55.68	55.11	49.84	56.11	53.12
$\Delta\overline{R}^2$	1.30	2.45	0.71	0.52	1.14	1.97
			Periphery			
IR_t	0.13	0.17	0.16	0.15	0.17	0.13
	(0.89)	(1.18)	(1.09)	(0.86)	(0.93)	(0.73)
$U(\times 10^{-2})$	-5.56	-5.54	-5.58	-6.05	-6.16	-6.63
	(-2.95)	(-2.94)	(-3.26)	(-3.36)	(-3.52)	(-3.55)
$\overline{R}^2$	41.92	42.70	46.43	47.46	48.49	49.70
$\Delta\overline{R}^2$	38.68	38.86	42.15	41.95	42.42	44.05
			Periphery−Core Spread			
IR_t	-0.57	-0.55	-0.65	-0.61	-0.66	-0.66
	(-3.51)	(-3.10)	(-4.22)	(-3.87)	(-4.42)	(-4.38)
$U(\times 10^{-2})$	-6.12	-6.23	-6.15	-6.61	-6.79	-7.37
	(-2.96)	(-3.01)	(-3.20)	(-3.21)	(-3.40)	(-3.42)
$\overline{R}^2$	45.46	47.00	49.96	50.06	51.52	52.63
$\Delta\overline{R}^2$	40.62	42.04	43.56	43.29	43.65	45.07

Table IX. High-frequency sovereign yield reaction to communication shocks
This table reports the results of multivariate regressions of changes in periphery minus core ten-year (120 months) yield spreads on IR and U communication shocks:

$$\Delta\left(y_{p,t}^{120} - y_{c,t}^{120}\right) = a^{120} + b^{120} IR_t + c^{120} U_t + \epsilon_t^{120},$$

where each column indicates the number of minutes (i.e. the length of the window) to construct the high frequency change in yields. Core yields are defined as the average of Germany and France and Peripheral yields defined as the average of Italy and Spain. t-statistics reported in parenthesis are calculated using HAC standard errors with 2 lag. Data run from December 2009 to December 2014.

	3	6	12	24	36	48	60	72	84	96	108	120
IR	-0.03	-0.32	-0.43	-1.58	-1.58	-1.56	-1.52	-1.41	-1.32	-1.19	-1.10	-1.05
	(-0.14)	(-0.62)	(-1.06)	(-4.03)	(-4.12)	(-4.02)	(-3.79)	(-3.53)	(-3.50)	(-3.34)	(-3.14)	(-3.05)
$U(\times 10^{-2})$	-0.21	-0.49	-2.78	-7.68	-9.29	-9.56	-9.94	-9.77	-10.55	-10.37	-10.76	-10.44
	(-0.32)	(-0.41)	(-2.09)	(-3.85)	(-4.63)	(-4.29)	(-4.07)	(-4.02)	(-3.54)	(-3.46)	(-3.28)	(-3.30)
$\overline{R}^2$	0.84	-0.66	2.13	24.60	29.11	31.63	32.99	34.00	37.19	37.39	38.09	37.35
ΔR^2	-3.23	-3.09	0.83	15.09	20.56	22.88	24.79	26.27	30.28	31.25	32.79	32.26

Table X. Core versus peripheral yield reactions: Dynamic PCs

This table reports the results of multivariate regressions of zero-coupon one-day changes in peripheral and core yield spreads of different maturities (months) on IR and U communication shocks during ECB announcement days:

$$\Delta\left(y_{p,t}^{\tau} - y_{c,t}^{\tau}\right) = a^{\tau} + b^{\tau} IR_t + c^{\tau} U_t + \epsilon_t^{\tau}, \quad \tau = 3, \ldots, 120 \text{ months.}$$

IR and U shock series separately for the pre-crisis and crisis windows. Core yields are defined as the average of Germany and France and Peripheral yields defined as the average of Italy and Spain. t-statistics reported in parenthesis are calculated using HAC standard errors with 2 lag. ΔR^2 is the change in the adjusted R^2 when adding U shocks to a univariate regression on IR shocks. Data run from December 2009 to December 2014.

	3	6	12	24	36	48	60	72	84	96	108	120
						Core						
IR	0.64	0.99	1.23	1.52	1.52	1.47	1.42	1.31	1.19	1.08	0.99	0.94
	[0.24:0.82]	[0.64:1.49]	[0.68:1.47]	[0.99:1.82]	[1.12:1.83]	[1.12:1.85]	[1.07:1.85]	[0.97:1.74]	[0.87:1.63]	[0.77:1.52]	[0.69:1.44]	[0.64:1.38]
$U(\times 10^{-2})$	0.87	-0.34	0.33	0.18	0.53	0.53	0.67	0.88	1.03	1.22	1.33	1.27
	[0.17:1.86]	[-1.27:0.57]	[-0.39:1.06]	[-0.89:1.27]	[-0.69:1.79]	[-0.85:1.92]	[-0.86:2.21]	[-0.55:2.34]	[-0.35:2.42]	[-0.10:2.57]	[0.03:2.67]	[-0.01:2.57]
$\overline{R}^2$	17.40	27.16	63.07	60.08	59.00	54.40	48.09	46.95	44.63	41.91	38.74	36.30
ΔR^2	-0.09	-2.18	-0.87	-1.26	-0.82	-0.97	-0.88	-0.10	0.76	2.17	3.23	2.93
						Periphery						
IR	0.60	0.66	0.74	-0.21	-0.25	-0.29	-0.31	-0.31	-0.35	-0.33	-0.34	-0.34
	[-0.14:1.10]	[-0.35:1.37]	[-0.35:1.45]	[-1.48:0.76]	[-1.57:0.71]	[-1.56:0.60]	[-1.60:0.55]	[-1.53:0.50]	[-1.50:0.42]	[-1.40:0.42]	[-1.39:0.42]	[-1.38:0.40]
$U(\times 10^{-2})$	0.66	-0.83	-2.45	-7.50	-8.77	-9.04	-9.27	-8.90	-9.53	-9.15	-9.43	-9.17
	[-0.77:2.08]	[-3.57:1.68]	[-6.45:1.14]	[-13.57:-1.86]	[-14.26:-3.24]	[-14.09:-3.59]	[-14.04:-3.74]	[-13.39:-3.62]	[-13.65:-3.86]	[-13.14:-3.75]	[-13.65:-3.82]	[-13.22:-3.77]
$\overline{R}^2$	15.93	12.48	5.60	16.43	20.92	23.65	25.14	25.49	29.25	28.91	30.22	29.79
ΔR^2	-1.59	-1.79	0.31	16.41	20.91	23.61	25.09	25.41	28.85	28.30	29.41	28.90
						Periphery−Core spread						
IR	-0.04	-0.33	-0.49	-1.74	-1.77	-1.77	-1.73	-1.62	-1.55	-1.41	-1.34	-1.27
	[-0.55:0.39]	[-1.59:0.55]	[-1.39:0.33]	[-2.85:-0.74]	[-2.98:-0.84]	[-3.06:-0.93]	[-3.10:-0.93]	[-2.96:-0.84]	[-2.83:-0.79]	[-2.62:-0.68]	[-2.55:-0.60]	[-2.47:-0.55]
$U(\times 10^{-2})$	-0.21	-0.49	-2.78	-7.68	-9.29	-9.57	-9.95	-9.78	-10.55	-10.37	-10.76	-10.44
	[-1.83:1.12]	[-3.26:2.04]	[-6.71:0.59]	[-13.27:-2.39]	[-14.29:-4.21]	[-14.12:-4.51]	[-14.28:-4.74]	[-13.90:-4.71]	[-14.80:-4.99]	[-14.60:-4.97]	[-15.44:-5.05]	[-14.94:-4.92]
$\overline{R}^2$	0.85	-0.59	2.18	24.67	29.21	31.74	33.11	34.12	37.30	37.50	38.18	37.44
ΔR^2	-3.23	-3.09	0.84	15.12	20.59	22.90	24.82	26.30	30.31	31.28	32.81	32.29

Table XI. Core versus peripheral yield reactions: Bootstrapped standard errors

This table reports the results of multivariate regressions of zero-coupon one-day changes in core yields versus peripheral yields of different maturities (months) on IR and U communication shocks:

$$\Delta y_{i,t}^{\tau} = a_i^{\tau} + b_i^{\tau} IR_t + c_i^{\tau} U_t + \epsilon_{i,t}^{\tau}, \quad \tau = 3, \ldots, 120 \text{ months.}$$

Core yields are defined as the average of Germany and France and peripheral yields defined as the average of Italy and Spain. 95% confidence intervals based on bootstrapped standard errors are presented in brackets. ΔR^2 is the change in the adjusted R^2 when adding U shocks to a univariate regression that uses only the IR shocks. Data run from December 2009 to December 2014.

	Jan2002-Sep2018	Jan2002 - Nov2009	Dec2009 - Dec2014	Jan2015-Sep2018
	Panel A: Correlations			
Timing	0.45	0.36	0.60	0.34
FG	0.83	0.88	0.75	0.75
QE	0.22	0.09	0.20	0.82
	Panel B: Regression			
Timing	0.83	0.88	0.79	0.30
	(25.07)	(17.81)	(31.40)	(1.03)
FG	0.62	0.64	0.58	0.61
	(43.07)	(37.41)	(36.60)	(7.21)
QE	0.35	0.28	0.37	0.50
	(7.63)	(3.34)	(6.01)	(5.08)
$\overline{R}^2$	93.89	94.01	95.44	89.22

Table XII. Comparison of shocks

Panel A reports correlations between our IR communication shock and ABGMR's `Timing`, `forward guidance` (`FG`), and `quantitative easing` (`QE`) shocks for different sub-samples. Panel B reports the results of multivariate regressions of the IR shocks on `Timing`, `FG`, and `QE` for different sub-samples:

$$IR_t = a + b\, \texttt{Timing}_t + c\, \texttt{FG}_t + +d\, \texttt{QE}_t + \epsilon_t.$$

t-statistics reported in parenthesis are calculated using HAC standard errors with 2 lag.

	3	6	12	24	36	48	60	72	84	96	108	120
	Core											
Ti_t	0.93	0.73	1.06	1.11	1.07	0.99	0.93	0.83	0.74	0.66	0.60	0.56
	(4.88)	(5.06)	(14.70)	(7.15)	(5.72)	(3.89)	(3.25)	(3.10)	(2.97)	(2.85)	(2.82)	(2.81)
FG_t	0.20	0.63	0.80	1.04	1.00	0.94	0.88	0.79	0.71	0.62	0.56	0.53
	(1.28)	(5.91)	(10.58)	(11.11)	(10.65)	(9.66)	(8.73)	(8.32)	(7.72)	(6.86)	(6.16)	(5.84)
$\overline{R}^2$	21.08	26.33	72.34	66.40	60.22	51.36	42.44	39.15	34.99	30.00	25.55	23.86
	Periphery											
Ti_t	1.12	1.33	1.30	0.03	0.14	0.11	0.15	0.14	0.13	0.10	0.06	0.04
	(4.71)	(3.05)	(3.96)	(0.07)	(0.31)	(0.28)	(0.40)	(0.42)	(0.37)	(0.30)	(0.19)	(0.13)
FG_t	0.16	0.07	0.01	-0.50	-0.58	-0.59	-0.61	-0.62	-0.59	-0.52	-0.49	-0.46
	(1.64)	(0.39)	(0.02)	(−0.91)	(−1.04)	(−1.14)	(−1.22)	(−1.33)	(−1.33)	(−1.26)	(−1.18)	(−1.13)
$\overline{R}^2$	26.20	22.67	4.37	0.07	2.20	2.34	3.27	3.64	4.59	4.06	3.59	3.50
	Periphery−Core Spread											
Ti_t	0.18	0.64	0.29	-0.97	-0.82	-0.77	-0.68	-0.58	-0.54	-0.49	-0.48	-0.46
	(0.70)	(1.26)	(1.28)	(−1.86)	(−1.58)	(−1.93)	(−1.87)	(−1.76)	(−1.61)	(−1.47)	(−1.40)	(−1.37)
FG_t	-0.04	-0.50	-0.62	-1.16	-1.12	-1.07	-1.01	-0.95	-0.83	-0.71	-0.63	-0.58
	(−0.17)	(−2.74)	(−3.68)	(−2.78)	(−2.57)	(−2.74)	(−2.67)	(−2.70)	(−2.55)	(−2.38)	(−2.10)	(−2.01)
$\overline{R}^2$	1.14	6.59	1.50	7.93	5.68	5.21	4.08	3.66	2.28	1.35	0.44	0.20

Table XIII. Core versus peripheral yield reactions to AGBMR shocks: daily data

This table reports the response of core and peripheral countries' bond yields as well as the periphery-core spread at different maturities for Timing and Forward Guidance shocks around ECB press conferences:

$$\Delta y^{\tau}_{i,t} = a^{\tau}_i + b^{\tau}_i \, \texttt{Timing}_t + c^{\tau}_i \, \texttt{FG}_t + \epsilon^{\tau}_{i,t}, \quad \tau = 3, \ldots, 120 \text{ months.}$$

Data run from December 2009 to December 2014. t-statistics reported in parenthesis are calculated using HAC standard errors with 2 lag.

	3	6	12	24	36	48	60	72	84	96	108	120
						Core						
TI_t	0.62	0.96	0.90	0.99	0.82	0.71	0.60	0.49	0.49	0.39	0.30	0.24
	(11.42)	(13.33)	(10.29)	(22.10)	(11.60)	(8.04)	(7.77)	(4.76)	(6.79)	(6.33)	(4.56)	(3.13)
FG_t	0.32	0.51	0.51	0.87	0.81	0.78	0.66	0.66	0.55	0.50	0.42	0.41
	(5.57)	(11.83)	(5.04)	(18.57)	(12.56)	(8.92)	(5.64)	(7.30)	(6.53)	(6.17)	(5.34)	(5.01)
$\overline{R}^2$	26.67	85.54	85.93	84.40	81.38	70.94	55.85	55.63	49.30	44.70	36.40	32.81
						Periphery						
TI_t	0.44	0.95	1.14	0.51	0.58	0.41	0.37	0.21	0.24	0.14	0.14	0.08
	(3.51)	(7.44)	(4.36)	(1.89)	(1.95)	(1.38)	(1.23)	(0.72)	(0.86)	(0.53)	(0.56)	(0.29)
FG_t	-0.03	0.27	0.09	0.31	0.25	0.17	0.11	0.10	0.11	0.07	0.07	0.08
	(−0.26)	(2.03)	(0.30)	(1.41)	(1.03)	(0.68)	(0.44)	(0.45)	(0.48)	(0.32)	(0.35)	(0.36)
$\overline{R}^2$	7.89	28.61	28.90	2.49	1.38	0.17	-0.09	-0.36	0.96	0.48	0.14	0.79
						Periphery−Core Spread						
TI_t	-0.18	0.04	0.34	-0.45	-0.23	-0.26	-0.20	-0.24	-0.23	-0.22	-0.13	-0.13
	(−1.45)	(0.24)	(2.65)	(−1.70)	(−0.82)	(−0.94)	(−0.64)	(−0.81)	(−0.84)	(−0.77)	(−0.48)	(−0.48)
FG_t	-0.31	-0.15	-0.26	-0.45	-0.45	-0.47	-0.40	-0.41	-0.29	-0.28	-0.20	-0.18
	(−2.84)	(−1.39)	(−1.21)	(−3.63)	(−3.24)	(−3.09)	(−2.32)	(−2.93)	(−2.26)	(−2.22)	(−1.65)	(−1.55)
$\overline{R}^2$	8.70	-1.29	3.66	5.04	2.84	2.92	2.12	2.19	0.85	0.39	-0.34	-0.33

Table XIV. Core versus peripheral yield reactions to AGBMR shocks: high-frequency data

This table reports the high-frequency response of core and peripheral countries' bond yields as well as the periphery-core spread at different maturities for Timing and Forward Guidance shocks around ECB press conferences:

$$\Delta y^{\tau}_{i,t} = a^{\tau}_i + b^{\tau}_i \, \texttt{Timing}_t + c^{\tau}_i \, \texttt{FG}_t + \epsilon^{\tau}_{i,t}, \quad \tau = 3, \ldots, 120 \text{ months.}$$

t-statistics reported in parenthesis are calculated using HAC standard errors with 2 lag. Data run from December 2009 to December 2014.

Figures

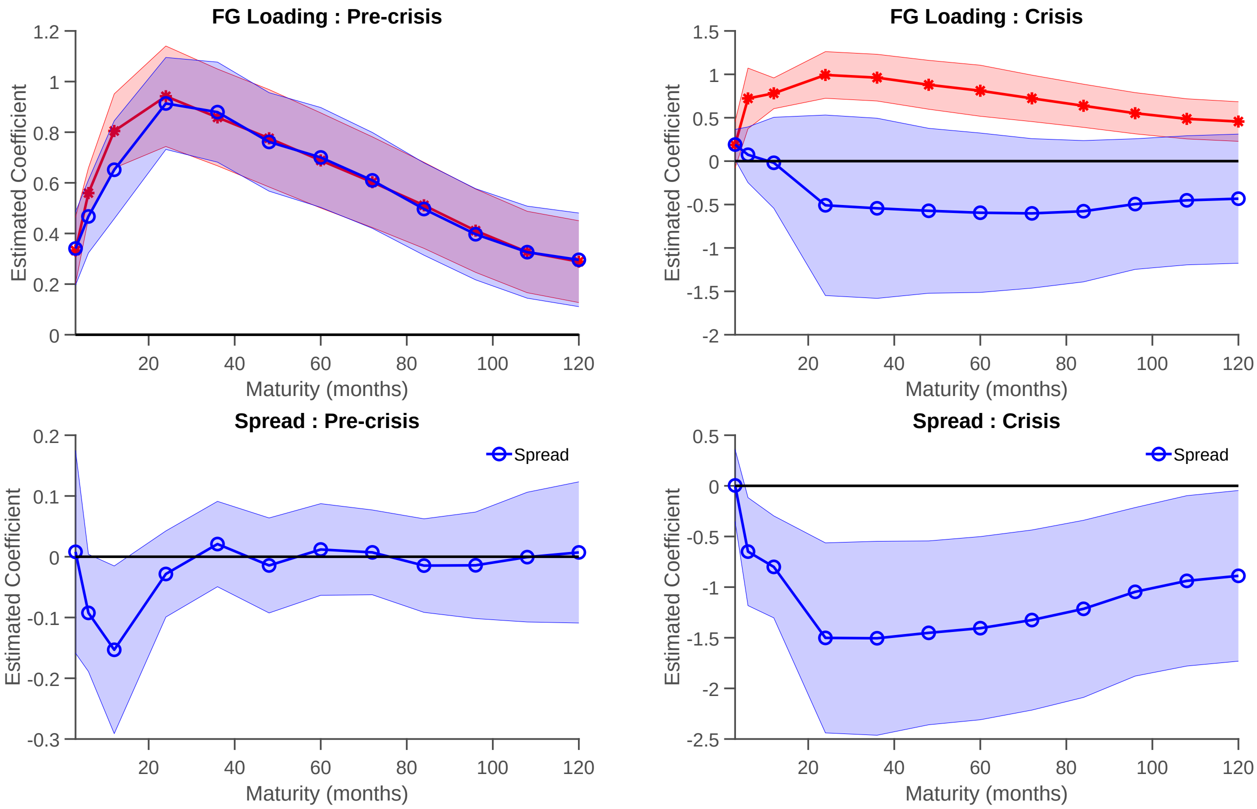

Figure 1. Core versus peripheral yield reactions to AGBMR shocks: daily data
This figure plots the response of core and peripheral countries' bond yields as well as the periphery-core spread at different maturities for Timing and Forward Guidance shocks around ECB press conferences:

$$\Delta y_{i,t}^{\tau} = a_i^{\tau} + b_i^{\tau}\,\texttt{Timing}_t + c_i^{\tau}\,\texttt{FG}_t + \epsilon_{i,t}^{\tau}, \quad \tau = 3, \ldots, 120 \text{ months.}$$

Data run from January 2001 to November 2009 on the left panels and from December 2009 to December 2014 on the right panels. Bands display 95% confidence intervals computed HAC standard errors with 2 lag.

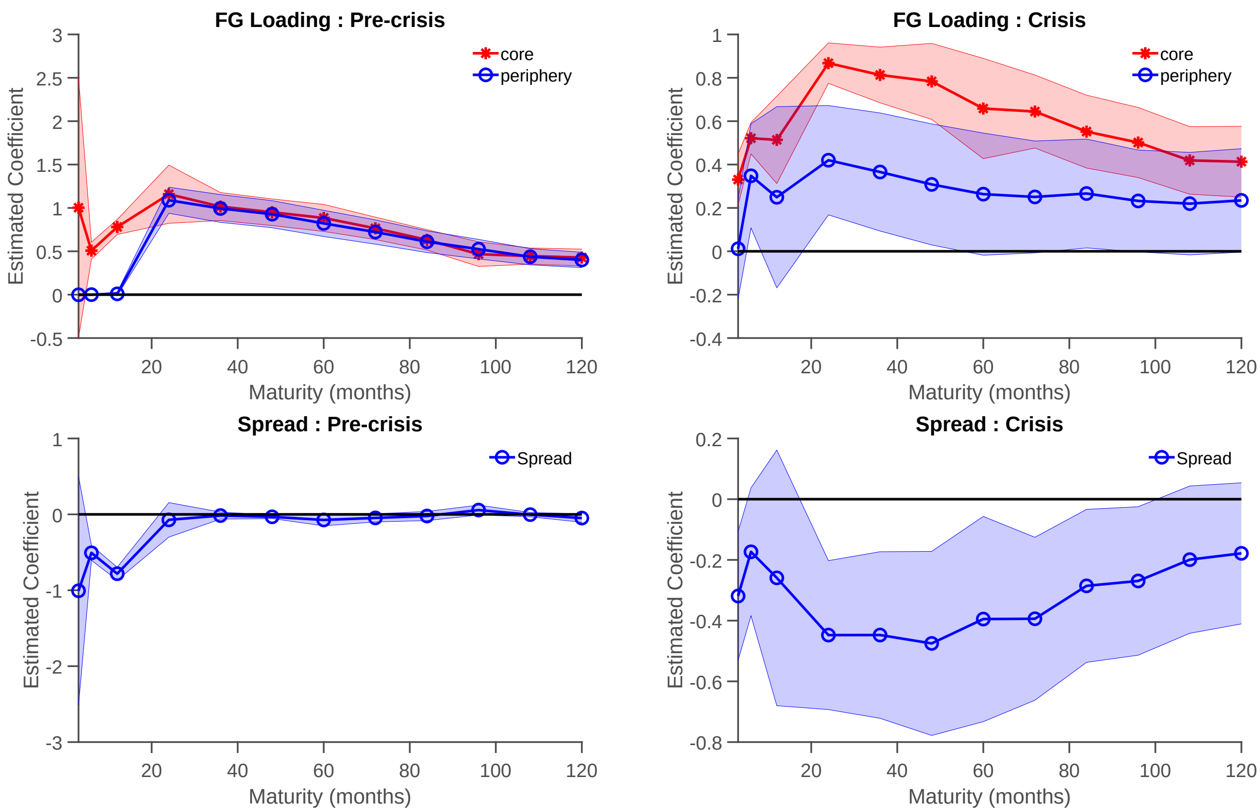

Figure 2. Core versus peripheral yield reactions to AGBMR shocks: high-frequency data
This figure plots the high-frequency response of core and peripheral countries' bond yields as well as the periphery-core spread at different maturities for Forward Guidance shocks around ECB press conferences based on the regression:

$$\Delta y^{\tau}_{i,t} = a^{\tau}_i + b^{\tau}_i \, \texttt{Timing}_t + c^{\tau}_i \, \texttt{FG}_t + \epsilon^{\tau}_{i,t}, \quad \tau = 3, \ldots, 120 \text{ months.}$$

Data run from January 2001 to November 2009 on the left panels and from December 2009 to December 2014 on the right panels. Bands display 95% confidence intervals computed using HAC standard errors with 2 lag.

References

Altavilla, Carlo, Luca Brugnolini, Refet S. Gürkaynak, Roberto Motto, and Giuseppe Ragusa, 2019, Measuring euro area monetary policy, *Journal of Monetary Economics* 108, 162–179.

Andrade, Philippe, and Filippo Ferroni, 2019, Delphic and odyssean monetary policy shocks: Evidence from the euro area, Working Paper, Boston Federal Reserve Bank.

Andrews, Donald WK, 1991, Heteroskedasticity and autocorrelation consistent covariance matrix estimation, *Econometrica* pp. 817–858.

Bai, Jushan, 1997, Estimation of a change point in multiple regression models, *Review of Economics and Statistics* 79, 551–563.

——— , and Pierre Perron, 1998, Estimating and testing linear models with multiple structural changes, *Econometrica* 66, 47–78.

——— , 2003, Computation and analysis of multiple structural change models, *Journal of Applied Econometrics* 18, 1–22.

Bauer, Michael D., and Eric T. Swanson, 2020, The fed's response to economic news explains the 'fed information effect', Working Paper, Federal Reserve Bank of San Francisco.

Campbell, Jeffrey R., Jonas D. M. Fisher, Alejandro Justiniano, and Leonardo Melosi, 2016, Forward guidance and macroeconomic outcomes since the financial crisis, in Inc. National Bureau of Economic Research, ed.: *NBER Macroeconomics Annual 2016* vol. 31.

Du, Songzi, and Haoxiang Zhu, 2017, Are cds auctions biased and inefficient?, *Journal of Finance* 72, 2589–2628.

Markit, 2010, Credit event auction primer, `http://www.creditfixings.com/information/affiliations/fixings/auctions/docs/credit_event_auction_primer.pdf`.

Merton, Robert C., 1974, On the pricing of corporate debt: The risk structure of interest rates, *Journal of Finance* 29, 449–470.

Nakamura, Emi, and Jón Steinsson, 2018, High frequency identification of monetary non-neutrality, *Quarterly Journal of Economics* 133, 1283–1330.

Romer, Christina D., and David H. Romer, 2000, Federal reserve information and the behavior of interest rates, *American Economic Review* 90, 429–457.