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– Not for Publication –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*

$$P_t^\tau = e^{-[A(\tau)+B(\tau)r_t+C(\tau)f_t]}, \tag{OA-6}$$
$$P_{i,t}^\tau = e^{-[A_i(\tau)+B_i(\tau)r_t+C_i(\tau)f_t+D_i(\tau)u_t+E_i(\tau)\lambda_t+\gamma_i Z_t]}, \text{ and} \tag{OA-7}$$
$$P_{e,t} = e^{F_e\delta_t-A_et-B_er_t-C_ef_t-D_eu_t-E_e\lambda_t-\gamma_eZ_t}, \tag{OA-8}$$

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

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

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

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

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

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

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

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

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

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. $\square$

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:

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

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 $\Delta y_{i,t}^{\tau}$ for $i =$ Germany, France, Italy and Spain for the pre-crisis and crisis periods separately, in the form of

$$\Delta y_{i,t}^{\tau} = a_i^{\tau} + b_i^{\tau} IR_t + c_i^{\tau} U_t + \epsilon_{i,t}^{\tau} \tag{OA-46}$$

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:

$$\Delta y_{i,t}^{\tau} = a_i^{\tau} + b_i^{\tau} IR_t + c_i^{\tau} U_t + d_i^{\tau} NEWS_t + \epsilon_{i,t}^{\tau}, \tag{OA-47}$$

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:

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

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:

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

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:

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

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:

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

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:

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

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:

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

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:

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

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

Figures

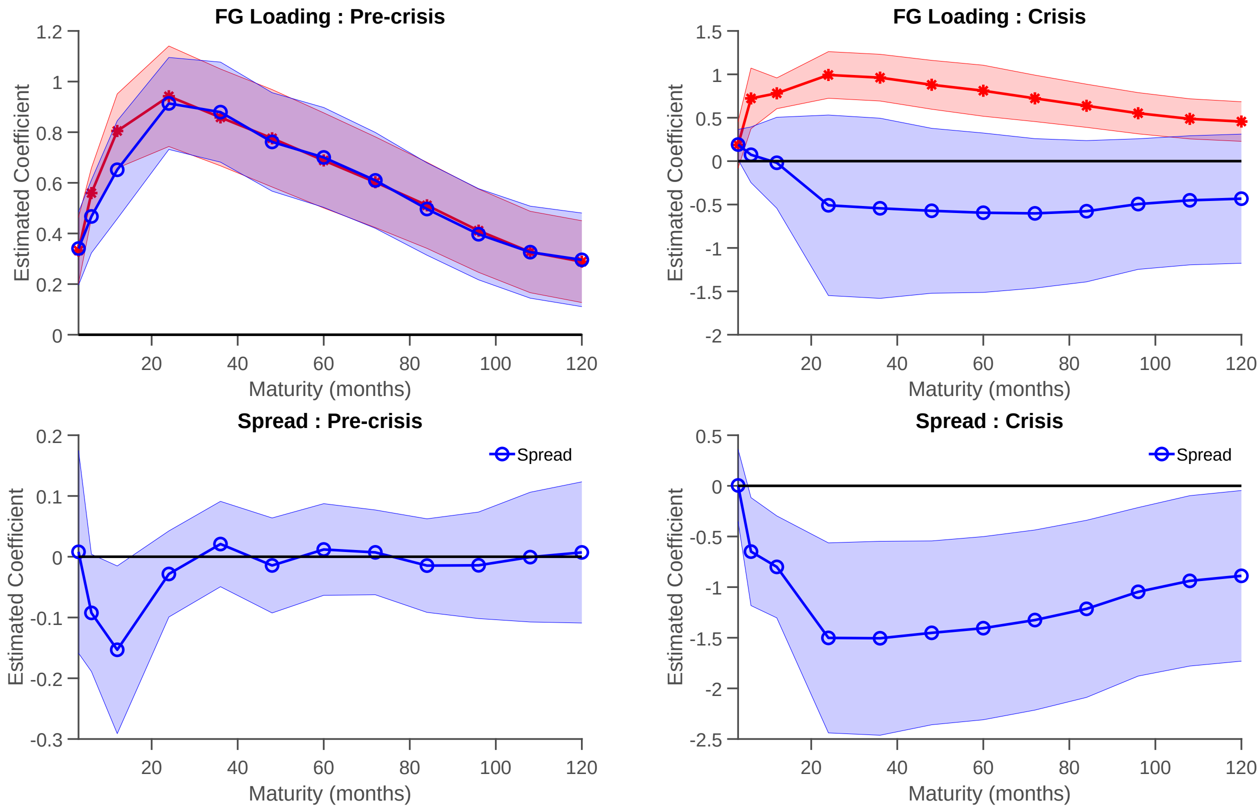

Figure 1. Core versus peripheral yield reactions to AGBMR shocks: daily data
This figure plots the response of core and peripheral countries' bond yields as well as the periphery-core spread at different maturities for Timing and Forward Guidance shocks around ECB press conferences:

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

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.

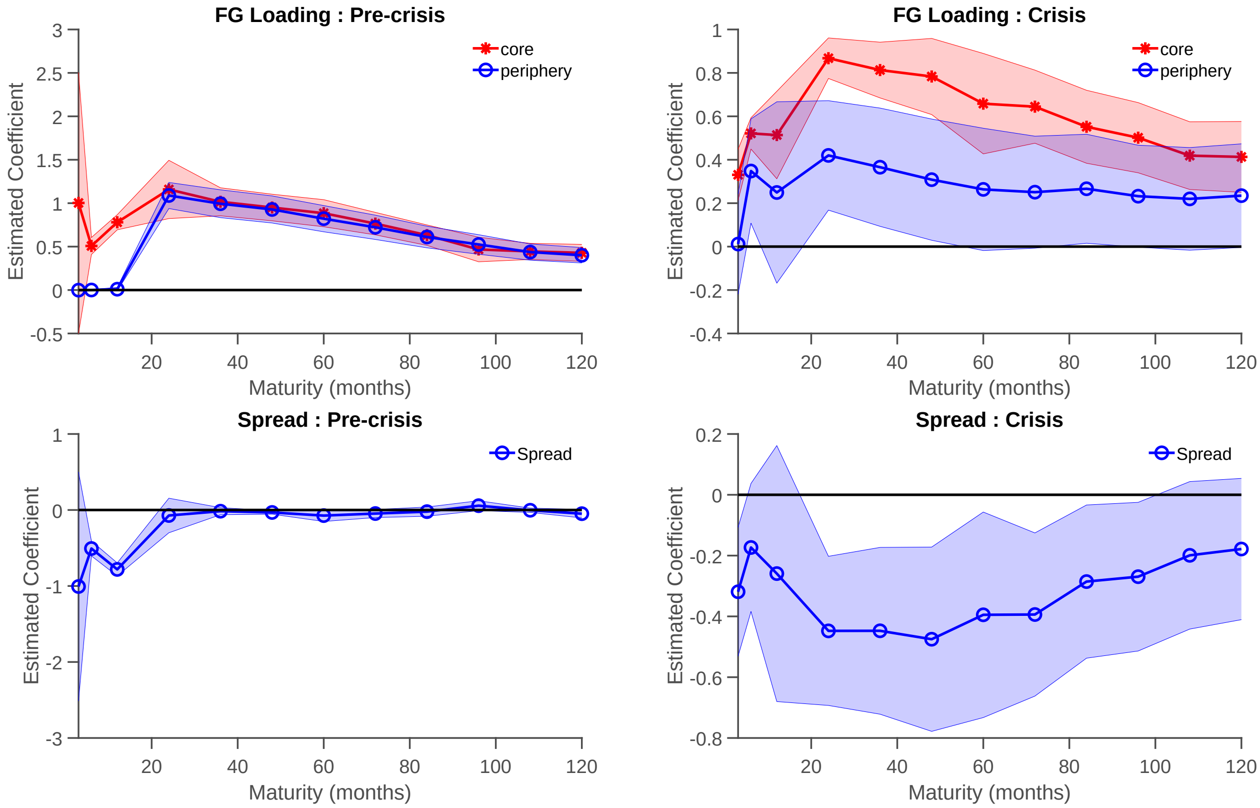

Figure 2. Core versus peripheral yield reactions to AGBMR shocks: high-frequency data This figure plots the high-frequency response of core and peripheral countries' bond yields as well as the periphery-core spread at different maturities for Forward Guidance shocks around ECB press conferences based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

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

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 using HAC standard errors with 2 lag.

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