Online Appendix to

Monetary Policy, Information and Country Risk Shocks in the Euro Area

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Abstract

This online appendix contains model derivations, details on the data used, and additional results for the paper 'Monetary Policy, Information and Country Risk Shocks in the Euro Area'.

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Contents

A A model of information effects with high and low noise

Let us consider a model in which private agents and the central bank have imperfect information about the state of the economy, and form expectations conditional on private signals clouded by state dependent observational noise. In doing so we extend the model in Miranda-Agrippino and Ricco (2021) to the case where the variance of the noise is not constant.

Agents in the model live in discrete time, with each period t being divided into an opening and a closing stage, i.e. $t \in \{\underline{t}, \bar{t}\}$. The inflation process evolves over time with an AR(1) process:

$$\pi_t = \rho \pi_{t-1} + u_t^\pi \qquad u_t^\pi \sim \mathcal{N}(0, \sigma_\pi^2) \ , \tag{1}$$

with normally distributed innovations, u_t^π, and $|\rho| < 1$.

At the beginning of time t, i.e. $\underline{t}$, private agents (indexed by i) receive a private signal about inflation contaminated by observational noise

$$s_{i,t} = \pi_t + v_{i,t} \qquad v_{i,t} \sim \mathcal{N}(0, \sigma_{v,z}^2), \tag{2}$$

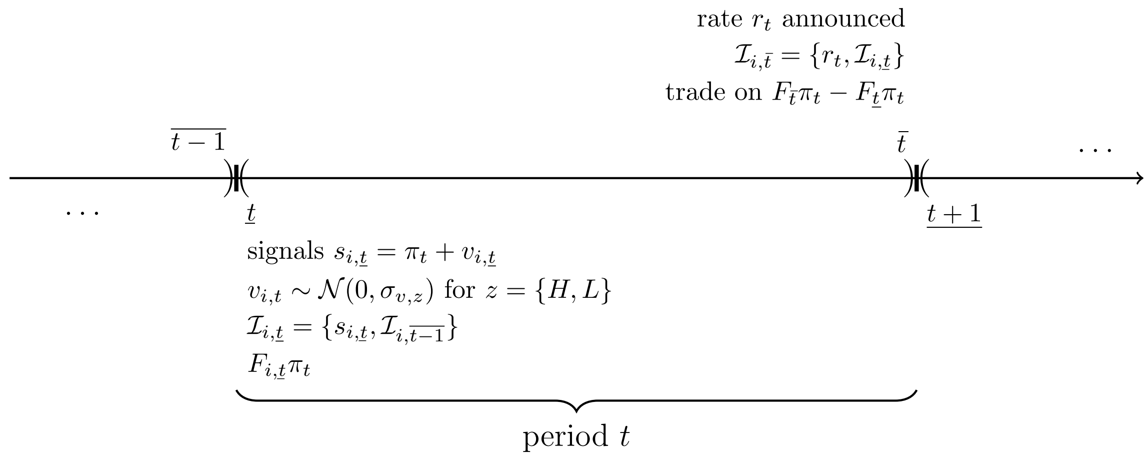
with a state-dependent variance, $\sigma_{v,z}^2$, which is equal across agents and is characterised by the existence of two states, $z \in \{L, H\}$, respectively with high and low noise, i.e. $\sigma_{H,z}^v > \sigma_{L,z}^v$. Agents form and update their expectations about current and future inflation, conditional on the signals observed using a Kalman filter

$$F_{i,\underline{t}}\pi_t = K_{1,\underline{t}} s_{i,\underline{t}} + (1 - K_{1,\underline{t}}) F_{i,\overline{t-1}}\pi_t, \tag{3}$$

$$F_{i,\underline{t}}\pi_{t+h} = \rho F_{i,\underline{t}}\pi_t, \tag{4}$$

where $K_{1,\underline{t}}$ is the Kalman gain. Conditional on their expectations for inflation, agents forecast

Figure A.1: The Information Flow



Note: Each period t has a beginning $\underline{t}$ and an end $\bar{t}$. At $\underline{t}$, agents (both private and central bank) receive a noisy signal $s_{i,\underline{t}}$ about inflation π_t, and update their forecasts $F_{i,\underline{t}}\pi_t$ based on their information set $\mathcal{I}_{i,\underline{t}}$. At $\bar{t}$, the central bank announces the policy rate i_t based on its forecast $F_{cb,\underline{t}}\pi_t$. Agents observe i_t, infer $F_{cb,\underline{t}}\pi_t$, and form $F_{i,\bar{t}}\pi_t$. Trade is a function of the aggregate expectation revision between $\underline{t}$ and $\bar{t}$.

(and trade) the policy rate, that is set by the central bank following a Taylor rule,

$$i_t^{(0)} = r_t = \delta\pi_t + u_t^{mp}, \tag{5}$$

and interest rates at longer horizons, $i_t^{(h)}$ for $h \geq 0$

$$i_{\underline{t}}^{(h)} = \alpha_h F_{\underline{t}}\pi_{t+h} + \xi_t^{(h)}, \tag{6}$$

where $\xi_t^{(h)}$ captures risk premia, $\alpha_0 = \delta$, and $F_{\underline{t}}$ indicates the average expectation over the market.

Let us define $V_{t|\overline{t-1}} \equiv \text{Var}\left(\pi_t - F_{i,\overline{t-1}}\pi_t\right)$, i.e. the variance of the forecast errors for inflation at time t, made at time $\overline{t-1}$. The Kalman gain $K_{1,\underline{t}}$ is given by:

$$K_{1,\underline{t}} = \frac{V_{t|\overline{t-1}}}{V_{t|\overline{t-1}} + \sigma_{v,z}^2}. \tag{7}$$

From the expression for $K_{1,\underline{t}}$, it is clear that, for a given $V_{t|\overline{t-1}}$, the agents will update their forecasts more in states of low noise, as compared to the states of high noise.

The variance of the forecast of π_t made at time $\underline{t}$ will depend on $V_{t|\overline{t-1}}$ as[1]

$$V_{t|\underline{t}} = V_{t|\overline{t-1}} - \frac{(V_{t|\overline{t-1}})^2}{V_{t|\overline{t-1}} + \sigma^2_{v,z}}, \tag{8}$$

$$V_{t|\overline{t-1}} = \rho^2 V_{t-1|\overline{t-1}} + \sigma^2_{\pi}. \tag{9}$$

During period t, the central bank also receives a private signal about the state of the economy, contaminated by a noise of constant volatility, and updates its forecast:

$$s_{cb,t} = \pi_t + v_{cb,t} \qquad v_{cb,t} \sim \mathcal{N}(0, \sigma^2_{v,cb}), \tag{10}$$

$$F_{cb,t}\pi_t = K_{cb,t}s_{cb,t} + (1 - K_{cb,t})F_{cb,t-1}\pi_t. \tag{11}$$

The assumption of constant volatility captures in a stylised manner the fact that the central bank, differently from market operators which have to sample information from prices and data releases, can have a more direct access to data offices and even survey directly financial and economic institutions to take the pulse to the economy. Given the constant noise in the central bank's signal, we can consider the asymptotic value of the Kalman gain, K_{cb}, where we drop the index t.

Conditional on its forecast for π_t, the central bank sets and announces the interest rate for the period:

$$r_t = \delta F_{cb,t}\pi_t + u^{mp}_t. \tag{12}$$

where u^{mp}_t is a monetary policy shock drawn from a normal distribution centred at zero and with variance σ^2_{mp}.

[1]Agents in the model know all the model parameters, including the variance of the signal (either low or high).

At time $\bar{t}$, agents observe the interest rate

$$r_t = \delta \left(K_{cb} s_{cb,t} + (1 - K_{cb}) F_{cb,t-1} \pi_t \right) + u_t^{mp} \tag{13}$$

$$= \delta K_{cb} \pi_t + \delta K_{cb} v_{cb,t} + (1 - K_{cb}) \rho F_{cb,t-1} \pi_{t-1} + u_t^{mp} \tag{14}$$

$$= \delta K_{cb} \pi_t + \delta K_{cb} v_{cb,t} + (1 - K_{cb}) \rho \left(i_{t-1} - u_{t-1}^{mp} \right) + u_t^{mp} \ , \tag{15}$$

which conditional on the past interest rate, is a public signal on the state of the economy:

$$\tilde{s}_{\bar{t}} = \pi_t + \tilde{v}_{cb,\underline{t}} \equiv \pi_t + v_{cb,t} + (\delta K_{cb})^{-1} [u_t^{mp} - (1 - K_{cb}) \rho u_{t-1}^{mp}]. \tag{16}$$

Given this public signal, agents update their expectations[2]

$$F_{i,\bar{t}} \pi_t = K_{2,\bar{t}} \tilde{s}_{cb,\bar{t}} + (1 - K_{2,\bar{t}}) F_{i,\underline{t}} \pi_t,$$

where the gain $K_{2,\bar{t}}$ is:

$$K_{2,\bar{t}} = \frac{V_{t|\underline{t}}}{V_{t|\underline{t}} + \sigma_{\tilde{v}}^2}, \tag{17}$$

and the forecast error variance is such that:

$$V_{t|\bar{t}} = V_{t|\underline{t}} - \frac{(V_{t|\underline{t}})^2}{V_{t|\underline{t}} + \sigma_{\tilde{v}}^2}. \tag{18}$$

Conditional on their updated forecasts, agents revise the price for the rates at longer horizons and trade.

Proposition 1. *The price revisions in interest rates at different maturities triggered by the*

[2]For the sake of simplicity we assume that agents update with a standard Kalman filter without taking into account the structure in the noise of this public signal due to the moving average component in the monetary policy shock.

policy announcement are

$$\Delta i_{\bar{t}}^{(h)} = \alpha_h \rho^h \left(F_{\bar{t}} \pi_t - F_{\underline{t}} \pi_t \right) + \Delta \xi_t^{(h)}, \tag{19}$$

where

$$\begin{aligned} F_{\bar{t}} \pi_t - F_{\underline{t}} \pi_t = {} & (1 - K_{1,\underline{t}}) K_{2,\bar{t}} K^{-1}_{2,\underline{\overline{t-1}}} (1 - K_{2,\overline{t-1}}) [F_{\overline{t-1}} \pi_t - F_{\underline{t-1}} \pi_t] + (K_{2,\bar{t}})(1 - K_{1,\underline{t}}) u_t^{\pi} \\ & + K_{2,\bar{t}} [\nu_{cb,\underline{t}} - (1 - K_{1,\underline{t}}) \rho \nu_{cb,\underline{t-1}}] + K_{2,\bar{t}} (K_{cb} \delta)^{-1} [u_t^{mp} - \rho (2 - K_{cb} - K_{1,\underline{t}}) u_{t-1}^{mp} \\ & + (1 - K_{1,\underline{t}})(1 - K_{cb}) \rho^2 u_{t-2}], \end{aligned} \tag{20}$$

are the average revision in expectations across agents in the market, and $\Delta \xi_t^{(h)}$ *are revisions to risk premia.*

Proof. Eq. (20) follows readily from the same derivations reported in the Online Appendix of Miranda-Agrippino and Ricco (2021), but for $K_{1,\underline{t}}$ and $K_{2,\overline{t-1}}$ time-varying. Eq. (19) is obtained from Eq. (5) and Eq. (6). □

The expression in Eq. (20) shows that, after observing the policy decision, private agents update their expectations towards the view of the central bank, thereby inducing a market wide information effect. The first term in the expression above represents the autocorrelation in revisions of expectations, which is due to the sluggish adjustment of expectations in models of imperfect information. The second term, $(K_{2,\bar{t}})(1 - K_{1,\underline{t}}) u_t^{\pi}$, captures the information channel of monetary policy, that is the fact that the policy announcement delivers information about the shocks hitting the economy. The remaining terms include both monetary policy shocks and central bank noise (another source of policy shock), along with their lags.

We are here interested in understanding how states of low and high variance alters the strength of information effects. Let us first prove that the asymptotic variance of the forecast errors, where one assumes that only one state is realised, is increasing with the variance of the noise, while the Kalman gain is decreasing.

Using the formulae of the Kalman recursion and first substituting Eq. (9), and then Eq. (18), into Eq. (8)

$$
\begin{aligned}
V_{t|\underline{t}} &= V_{t|\overline{t-1}} - \frac{(V_{t|\overline{t-1}})^2}{V_{t|\overline{t-1}} + \sigma_{v,z}^2} \;= \rho^2 V_{t-1|\overline{t-1}} + \sigma_\pi^2 - \frac{(\rho^2 V_{t-1|\overline{t-1}} + \sigma_\pi^2)^2}{\rho^2 V_{t-1|\overline{t-1}} + \sigma_\pi^2 + \sigma_{v,z}^2} \\
&= \frac{(\rho^2 V_{t-1|\overline{t-1}} + \sigma_\pi^2)\sigma_{v,z}^2}{\rho^2 V_{t-1|\overline{t-1}} + \sigma_\pi^2 + \sigma_{v,z}^2} = \frac{(\rho^2 \frac{V_{t-1|\underline{t-1}}\sigma_{\tilde{v}}^2}{V_{t-1|\underline{t-1}} + \sigma_{\tilde{v}}^2} + \sigma_\pi^2)\sigma_{v,z}^2}{\rho^2 \frac{V_{t-1|\underline{t-1}}\sigma_{\tilde{v}}^2}{V_{t-1|\underline{t-1}} + \sigma_{\tilde{v}}^2} + \sigma_\pi^2 + \sigma_{v,z}^2} \\
&= \frac{(\rho^2 (V_{t-1|\underline{t-1}}\sigma_{\tilde{v}}^2) + \sigma_\pi^2 (V_{t-1|\underline{t-1}} + \sigma_{\tilde{v}}^2))\sigma_{v,z}^2}{\rho^2 (V_{t-1|\underline{t-1}}\sigma_{\tilde{v}}^2) + (\sigma_\pi^2 + \sigma_{v,z}^2)(V_{t-1|\underline{t-1}} + \sigma_{\tilde{v}}^2)},
\end{aligned}
\tag{21}
$$

and hence the asymptotic variance, V, of the forecast error, $V_{t|\underline{t}}$, solves the quadratic equation

$$
V = \frac{(\rho^2 V \sigma_{\tilde{v}}^2 + \sigma_\pi^2 (V + \sigma_{\tilde{v}}^2))\sigma_{v,z}^2}{\rho^2 V \sigma_{\tilde{v}}^2 + (\sigma_\pi^2 + \sigma_{v,z}^2)(V + \sigma_{\tilde{v}}^2)},
\tag{22}
$$

which admits only one positive solution:

$$
\begin{aligned}
V =& \frac{-\sigma_\pi^2 \sigma_{\tilde{v}}^2 + \sigma_\pi^2 \sigma_{v,z}^2 - (1-\rho^2)\sigma_{\tilde{v}}^2 \sigma_{v,z}^2}{2\left(\sigma_\pi^2 + \sigma_{\tilde{v}}^2 \rho^2 + \sigma_{v,z}^2\right)} \\
&+ \frac{\sqrt{\left(\sigma_\pi^2 \sigma_{\tilde{v}}^2 - \sigma_\pi^2 \sigma_{v,z}^2 + (1-\rho^2)\sigma_{\tilde{v}}^2 \sigma_{v,z}^2\right)^2 + 4\sigma_\pi^2 \sigma_{\tilde{v}}^2 \sigma_{v,z}^2 \left(\sigma_\pi^2 + \sigma_{\tilde{v}}^2 \rho^2 + \sigma_{v,z}^2\right)}}{2\left(\sigma_\pi^2 + \sigma_{\tilde{v}}^2 \rho^2 + \sigma_{v,z}^2\right)}.
\end{aligned}
\tag{23}
$$

To understand how V depends on the variance of the noise, we can look at the equations defining the asymptotic values of the forecast error variances at different points in time

$$
V = \frac{W \sigma_{v,z}^2}{W + \sigma_{v,z}^2},
\tag{24}
$$

$$
W = \rho^2 U + \sigma_\pi^2,
\tag{25}
$$

$$
U = \frac{V \sigma_{\tilde{v}}^2}{V + \sigma_{\tilde{v}}^2},
\tag{26}
$$

where V, W and U are the asymptotic values of $V_{t|\underline{t}}$, $V_{t|\overline{t-1}}$ and $V_{t-1|\overline{t-1}}$, respectively. In particular, we consider the case where only one value of the observational noise variance is realised and how the asymptotic values of the forecast error variances depend on it. We now prove the following proposition.

Proposition 2. *The asymptotic variances of the forecast errors of the Kalman filter are increasing in the noise in the private signals received by the agents, i.e.*

$$\frac{dV}{d\sigma^2_{v,z}} > 0, \qquad \frac{dW}{d\sigma^2_{v,z}} > 0, \qquad \frac{dU}{d\sigma^2_{v,z}} > 0, \tag{27}$$

and hence

$$V^H > V^L, \qquad W^H > W^L, \qquad U^H > U^L. \tag{28}$$

Proof. Taking derivative w.r.t. $\sigma^2_{v,z}$ one finds:

$$\begin{aligned}
\frac{dV}{d\sigma^2_{v,z}} &= \frac{1}{(W+\sigma^2_{v,z})^2}\left(\left(\frac{dW}{d\sigma^2_{v,z}}\sigma^2_{v,z} + W\right)(W+\sigma^2_{v,z}) - W\sigma^2_{v,z}\left(\frac{dW}{d\sigma^2_{v,z}} + 1\right)\right) \\
&= \frac{1}{(W+\sigma^2_{v,z})^2}\left(W^2 + \sigma^4_{v,z}\frac{dW}{d\sigma^2_{v,z}}\right), &(29)\\
\frac{dW}{d\sigma^2_{v,z}} &= \rho^2\frac{dU}{d\sigma^2_{v,z}}, &(30)\\
\frac{dU}{d\sigma^2_{v,z}} &= \frac{1}{(V+\sigma^2_{\tilde{v}})^2}\left(\frac{dV}{d\sigma^2_{v,z}}\sigma^2_{\tilde{v}}(V+\sigma^2_{\tilde{v}}) - V\sigma^2_{\tilde{v}}\frac{dV}{d\sigma^2_{v,z}}\right) = \frac{\sigma^4_{\tilde{v}}}{(V+\sigma^2_{\tilde{v}})^2}\frac{dV}{d\sigma^2_{v,z}}. &(31)
\end{aligned}$$

Substituting Eq. (31) and Eq. (30) in Eq. (29), one gets:

$$\frac{dV}{d\sigma^2_{v,z}} = \left(1 - \frac{\rho^2\sigma^4_{v,z}}{(W+\sigma^2_{v,z})^2}\frac{\sigma^4_{\tilde{v}}}{(V+\sigma^2_{\tilde{v}})^2}\right)^{-1}\frac{W^2}{(W+\sigma^2_{v,z})^2}. \tag{32}$$

The proposition is obtained by observing that the term in parentheses is greater than zero, and that the signs $dV/d\sigma^2_{v,z}$ determines the sign of $dW/d\sigma^2_{v,z}$ and $dU/d\sigma^2_{v,z}$ due to Eq. (30) and (31). □

This result indicates that when the economy moves from a regime with low noise to a regime of high noise, all the errors at different steps increase, and vice versa. This result will be important in proving how information effects depend on the variance of the noise in the private signals of the agents. Before doing so, we also prove the following propositions.

Proposition 3. *The steady state variances of the forecast errors of the Kalman filter are all increasing in the noise in the public signal delivered by the central bank via the interest rate decisions, which depends on the variance of monetary policy shocks and of the noise in the private signal received by the central bank, i.e.*

$$\frac{dV}{d\sigma^2_{\tilde{v}}} > 0, \qquad \frac{dW}{d\sigma^2_{\tilde{v}}} > 0, \qquad \frac{dU}{d\sigma^2_{\tilde{v}}} > 0. \tag{33}$$

Proof. Following the same steps used in proving Proposition 2, one finds that

$$\frac{dU}{d\sigma^2_{\tilde{v}}} = \left(1 - \frac{\rho^2\sigma^4_{v,z}}{(W+\sigma^2_{v,z})^2}\frac{\sigma^4_{\tilde{v}}}{(V+\sigma^2_{\tilde{v}})^2}\right)^{-1}\frac{V^2}{(V+\sigma^2_{\tilde{v}})^2}, \tag{34}$$

from which follows the statement of the proposition. □

Proposition 4. *The steady state variances of the forecast errors of the Kalman filter are all increasing in the variance of the shock to the inflation process.*

Proof. We can observe that

$$\frac{dW}{d\sigma^2_{\pi}} = \left(1 - \frac{\rho^2\sigma^4_{v,z}}{(W+\sigma^2_{v,z})^2}\frac{\sigma^4_{\tilde{v}}}{(V+\sigma^2_{\tilde{v}})^2}\right)^{-1}. \tag{35}$$

which delivers the result. □

We can now prove the following result.

Proposition 5. *The information channel of monetary policy strengthens with an increase in the noise in the economy, i.e.*

$$\frac{d}{d\sigma^2_{v,z}}(K_{2,\bar{t}}(1-K_{1,\underline{t}})) > 0, \tag{36}$$

and hence

$$K^H_2(1-K^H_1) > K^L_2(1-K^L_1), \tag{37}$$

where K_1^H, K_1^L and K_2^H, K_2^L are the asymptotic values of the Kalman gains in the states of high and low variance, respectively.

Proof. Let us first prove that the Kalman gain $K_{1,\underline{t}}$ is decreasing in the variance of the noise. Let us consider the derivative of $K_{1,\underline{t}}$ in $\sigma_{v,z}^2$:

$$\frac{dK_{1,\underline{t}}}{d\sigma_{v,z}^2} = \frac{1}{(V_{t|\overline{t-1}} + \sigma_{v,z}^2)^2}\left(\sigma_{v,z}^2 \frac{dV_{t|\overline{t-1}}}{d\sigma_{v,z}^2} - V_{t|\overline{t-1}}\right), \tag{38}$$

which shows that asymtotically the sign of $dK_{1,\underline{t}}/d\sigma_{v,z}^2$ depends on the sign of

$$\frac{\sigma_{v,z}^2}{W}\frac{dW}{d\sigma_{v,z}^2} - 1. \tag{39}$$

Let us first express the term of interest as

$$\frac{\sigma_{v,z}^2}{W}\frac{dW}{d\sigma_{v,z}^2} = \frac{\sigma_{v,z}^2}{\rho^2 \frac{V\sigma_{\tilde{v}}^2}{V+\sigma_{\tilde{v}}^2} + \sigma_\pi^2}\frac{dW}{d\sigma_{v,z}^2} \tag{40}$$

$$= \frac{\sigma_{v,z}^2}{\rho^2 \frac{V\sigma_{\tilde{v}}^2}{V+\sigma_{\tilde{v}}^2} + \sigma_\pi^2}\rho^2\frac{dU}{d\sigma_{v,z}^2} \tag{41}$$

$$= \frac{\sigma_{v,z}^2}{\rho^2 \frac{V\sigma_{\tilde{v}}^2}{V+\sigma_{\tilde{v}}^2} + \sigma_\pi^2}\rho^2\frac{\sigma_{\tilde{v}}^4}{(V+\sigma_{\tilde{v}}^2)^2}\frac{dV}{d\sigma_{v,z}^2}, \tag{42}$$

where we first used Eq.s (25-26), and then Eq.s (30-31). We can now observe that for the first factor in the above expression it is true that

$$\frac{\rho^2\sigma_{v,z}^2\sigma_{\tilde{v}}^4}{\left(\rho^2\frac{V\sigma_{\tilde{v}}^2}{V+\sigma_{\tilde{v}}^2} + \sigma_\pi^2\right)(V+\sigma_{\tilde{v}}^2)^2} = \frac{\rho^2\sigma_{v,z}^2\sigma_{\tilde{v}}^4}{(\rho^2 V\sigma_{\tilde{v}}^2 + \sigma_\pi^2(V+\sigma_{\tilde{v}}^2))(V+\sigma_{\tilde{v}}^2)} \tag{43}$$

$$< \frac{\rho^2\sigma_{v,z}^2\sigma_{\tilde{v}}^4}{\rho^2 V\sigma_{\tilde{v}}^2(V+\sigma_{\tilde{v}}^2)} = \frac{\sigma_{v,z}^2\sigma_{\tilde{v}}^2}{V(V+\sigma_{\tilde{v}}^2)} < \frac{\sigma_{v,z}^2}{V}. \tag{44}$$

Hence it holds that if $\frac{\sigma_{v,z}^2}{V}\frac{dV}{d\sigma_{v,z}^2} < 1$, then it is also true that $\frac{\sigma_{v,z}^2}{W}\frac{dW}{d\sigma_{v,z}^2} < 1$. Let us now focus on this simplified problem:

$$
\begin{aligned}
\frac{\sigma_{v,z}^2}{V}\frac{dV}{d\sigma_{v,z}^2} &= \frac{\sigma_{v,z}^2}{V}\left(1-\frac{\rho^2\sigma_{v,z}^4}{(W+\sigma_{v,z}^2)^2}\frac{\sigma_{\tilde{v}}^4}{(V+\sigma_{\tilde{v}}^2)^2}\right)^{-1}\frac{W^2}{(W+\sigma_{v,z}^2)^2} \\
&= \frac{\sigma_{v,z}^2}{V}\left(1-\frac{\rho^2\sigma_{v,z}^4}{(W+\sigma_{v,z}^2)^2}\frac{\sigma_{\tilde{v}}^4}{(V+\sigma_{\tilde{v}}^2)^2}\right)^{-1}\frac{W^2}{(W+\sigma_{v,z}^2)^2} \\
&= \frac{\sigma_{v,z}^2}{\frac{W\sigma_{v,z}^2}{W+\sigma_{v,z}^2}}\left(1-\frac{\rho^2\sigma_{v,z}^4}{(W+\sigma_{v,z}^2)^2}\frac{\sigma_{\tilde{v}}^4}{\left(\frac{W\sigma_{v,z}^2}{W+\sigma_{v,z}^2}+\sigma_{\tilde{v}}^2\right)^2}\right)^{-1}\frac{W^2}{(W+\sigma_{v,z}^2)^2} \\
&= \frac{W}{(W+\sigma_{v,z}^2)}\left(1-\frac{\rho^2\sigma_{v,z}^4}{(W+\sigma_{v,z}^2)^2}\frac{\sigma_{\tilde{v}}^4}{\left(\frac{W\sigma_{v,z}^2}{W+\sigma_{v,z}^2}+\sigma_{\tilde{v}}^2\right)^2}\right)^{-1} \\
&= \frac{W}{(W+\sigma_{v,z}^2)}\left(\frac{(W+\sigma_{v,z}^2)^2\left(\frac{W\sigma_{v,z}^2}{W+\sigma_{v,z}^2}+\sigma_{\tilde{v}}^2\right)^2-\rho^2\sigma_{v,z}^4\sigma_{\tilde{v}}^4}{(W+\sigma_{v,z}^2)^2\left(\frac{W\sigma_{v,z}^2}{W+\sigma_{v,z}^2}+\sigma_{\tilde{v}}^2\right)^2}\right)^{-1} \\
&= W\left(\frac{(W+\sigma_{v,z}^2)\left(\frac{W\sigma_{v,z}^2}{W+\sigma_{v,z}^2}+\sigma_{\tilde{v}}^2\right)^2}{(W+\sigma_{v,z}^2)^2\left(\frac{W\sigma_{v,z}^2}{W+\sigma_{v,z}^2}+\sigma_{\tilde{v}}^2\right)^2-\rho^2\sigma_{v,z}^4\sigma_{\tilde{v}}^4}\right) \\
&= \frac{(W^2+W\sigma_{v,z}^2)\left(\frac{W\sigma_{v,z}^2}{W+\sigma_{v,z}^2}+\sigma_{\tilde{v}}^2\right)^2}{(W^2+W\sigma_{v,z}^2+W\sigma_{v,z}^2+\sigma_{v,z}^4)\left(\frac{W\sigma_{v,z}^2}{W+\sigma_{v,z}^2}+\sigma_{\tilde{v}}^2\right)^2-\rho^2\sigma_{v,z}^4\sigma_{\tilde{v}}^4}.
\end{aligned}
$$

Let us define $\Delta \equiv (W+\sigma_{v,z}^2)\left(\frac{W\sigma_{v,z}^2}{W+\sigma_{v,z}^2}+\sigma_{\tilde{v}}^2\right)^2$. Hence we can write

$$
\begin{aligned}
\frac{\sigma_{v,z}^2}{V}\frac{dV}{d\sigma_{v,z}^2} &= \frac{\Delta}{\Delta+(W\sigma_{v,z}^2+\sigma_{v,z}^4)\left(\frac{W\sigma_{v,z}^2}{W+\sigma_{v,z}^2}+\sigma_{\tilde{v}}^2\right)^2-\rho^2\sigma_{v,z}^4\sigma_{\tilde{v}}^4} \\
&= \frac{\Delta(W+\sigma_{v,z}^2)^2}{\Delta(W+\sigma_{v,z}^2)^2+(W\sigma_{v,z}^2+\sigma_{v,z}^4)\left(W\sigma_{v,z}^2+\left(W+\sigma_{v,z}^2\right)\sigma_{\tilde{v}}^2\right)^2-\rho^2\sigma_{v,z}^4\sigma_{\tilde{v}}^4(W+\sigma_{v,z}^2)^2}.
\end{aligned}
$$

We can now define $\Delta' \equiv \Delta(W+\sigma_{v,z}^2)^2$ to rewrite

$$
\frac{\sigma_{v,z}^2}{V}\frac{dV}{d\sigma_{v,z}^2} = \frac{\Delta'}{\Delta'+\chi_1+\chi_2},
$$

where χ_1 and χ_2 are defined as

$$\chi_1 \equiv (1-\rho^2)\sigma_{v,z}^4\sigma_{\tilde{v}}^4(W+\sigma_{v,z}^2)^2,$$
$$\chi_2 \equiv (W\sigma_{v,z}^2)\left(W^2\sigma_{v,z}^4 + \left(W+\sigma_{v,z}^2\right)^2\sigma_{\tilde{v}}^4 + 2W\sigma_{v,z}^2\left(W+\sigma_{v,z}^2\right)\sigma_{\tilde{v}}^2\right)$$
$$+\sigma_{v,z}^4\left(W^2\sigma_{v,z}^4 + 2W\sigma_{v,z}^2\left(W+\sigma_{v,z}^2\right)\sigma_{\tilde{v}}^2\right).$$

Observing that Δ' is positive, χ_1 is positive since $|\rho|<1$, and χ_2 is the sum of positive terms, it follows that

$$\frac{\sigma_{v,z}^2}{V}\frac{dV}{d\sigma_{v,z}^2} < 1, \tag{45}$$

and hence that the Kalman gain $dK_{1,\underline{t}}$ is decreasing in the private noise, i.e.

$$\frac{dK_{1,\underline{t}}}{d\sigma_{v,z}^2} < 0. \tag{46}$$

We can now observe that

$$\frac{K_{2,\bar{t}}}{d\sigma_{v,z}^2} = \frac{1}{(V_{t|\underline{t}}+\sigma_{\tilde{v}}^2)^2}\sigma_{\tilde{v}}^2\frac{dV_{t|\underline{t}}}{d\sigma_{v,z}^2} > 0, \tag{47}$$

which follows from Eq. (27).

The proposition is then proved observing that $K_{2,\bar{t}}$ is increasing in the variance of the noise of the private signals obtained by the agents, while $K_{1,\underline{t}}$ is decreasing in it. $\square$

B Data

In our empirical analysis, we employ the time series described in Table B.1. All series are at monthly frequency.

Monthly estimates for real GDP and the GDP deflator are obtained using a Kalman filter, following the methodology of Stock and Watson (2010) and Jarociński and Karadi (2020). The list of variables used in the interpolation exercise, along with their sources, is provided in Table B.1.

Subsections B.1 and B.2 discuss the series used for core inflation and industrial production, respectively.

Table B.1: Data Sources

Variable	Series/Dataset	Seas. Adj.	Source
HICP - All-items excluding energy and food	ICP.M.U2.N.XEF000.4.INX		Eurostat
HICP - All-items	ICP.M.U2.N.000000.4.INX		Eurostat
Industrial production for the euro area[1] including construction (2015 = 100)	https://doi.org/10.2908/STS_COPR_M	•	Eurostat
Industrial production for Italy and Germany	STS_INPR_M	•	Eurostat
1-month OIS rate[2]			Datastream
3-month OIS rate[2]			Datastream
1-year OIS rate[2]			Bloomberg
2-year OIS rate[2]			Bloomberg
10-year OIS rate[2]			Datastream
10-year German government bond yield	GTDEM10Y		Bloomberg
10-year Italian government bond yield	GTITL10Y		Bloomberg
10-year ITA-DEU yield spread[3]			Eikon
EUR to USD exchange Rate[4]	https://doi.org/10.2908/ERT_BIL_EUR_M		Eurostat
Recession dates for the euro area[5]	Euro Area business cycle chronology		EABCD Committee[6]
Quarterly forecasts for HICP inflation	440.MPD.Q.U2.HIC.A.XXX.XXXX[7]		ECB MPD
Annual forecasts for HICP inflation	440.MPD.A.U2.HIC.A.XXX.XXXX[7]		ECB MPD
Quarterly forecasts for real GDP growth	440.MPD.Q.U2.YER.P.XXX.XXXX[7]		ECB MPD
Annual forecasts for real GDP growth	440.MPD.A.U2.YER.P.XXX.XXXX[7]		ECB MPD
Quarterly forecasts for HICP inflation	Economic Indicator Polls		Reuters
Annual forecasts for HICP inflation	Economic Indicator Polls		Reuters
Quarterly forecasts for real GDP growth	Economic Indicator Polls		Reuters
Annual forecasts for real GDP growth	Economic Indicator Polls		Reuters
Quarterly forecasts for MRO rate	Central Bank Polls		Reuters
Real GDP			Authors' calculations
GDP deflator			Authors' calculations

[1] The series includes mining and quarrying, manufacturing, electricity, gas, steam and air conditioning supply, and construction sectors.
[2] Last price of the daily series.
[3] Yield spread with respect to 10 year German government bond yield.
[4] Monthly average.
[5] See https://eabcn.org/dbc/peaksandtroughs/chronology-euro-area-business-cycles.
[6] EABCD committee: Euro Area Business Cycle Dating Committee.
[7] The last seven letters vary by forecast season and horizon.
[8] The ECB Macroeconomic Projection Database is available on the ECB website https://data.ecb.europa.eu/data/datasets/MPD.

Table B.1: List of variables used for interpolation

Quarterly indicator	Monthly indicator	Source
Private final consumption		Eurostat
	Retail trade	SDW
	Imports of consumer goods	SDW
Government final consumption		Eurostat
Gross fixed capital formation		Eurostat
	Construction output	Eurostat
Change in business inventories		Eurostat
and acquisitions less disposable values		
	Stocks of finished products	Eurostat
	Volume of stocks	Eurostat
Net exports of goods and services		Eurostat
	Trade balance in goods with rest of world	FRED
	Volume of export order books	Eurostat
	Manufacturing new orders	SDW
GDP deflator		Eurostat
	HICP	SDW
	Domestic PPI	Eurostat

Notes: SDW: Statistical Data Warehouse. FRED: Federal Reserve Economic Data. PPI: Producer price index.

B.1 On core inflation

In our baseline specification, we do not report results using either the seasonally adjusted series for core inflation from the ECB or the non-seasonally adjusted series for core inflation from Eurostat. A note on the ECB website explains how in 2015 the German price index for package holidays has changed the seasonal adjustment pattern.[3]

Eurostat has adjusted the series whereas the ECB series still display some distortion especially in 2015 (see Chart C in the ECB article).[4]

Figure B.2 shows that, between September and December 2015, the seasonal pattern of HICP core inflation (Eurostat) exhibits a larger-than-usual peak. Results based on the core measure are very similar, see Figure B.3 and Figure B.4

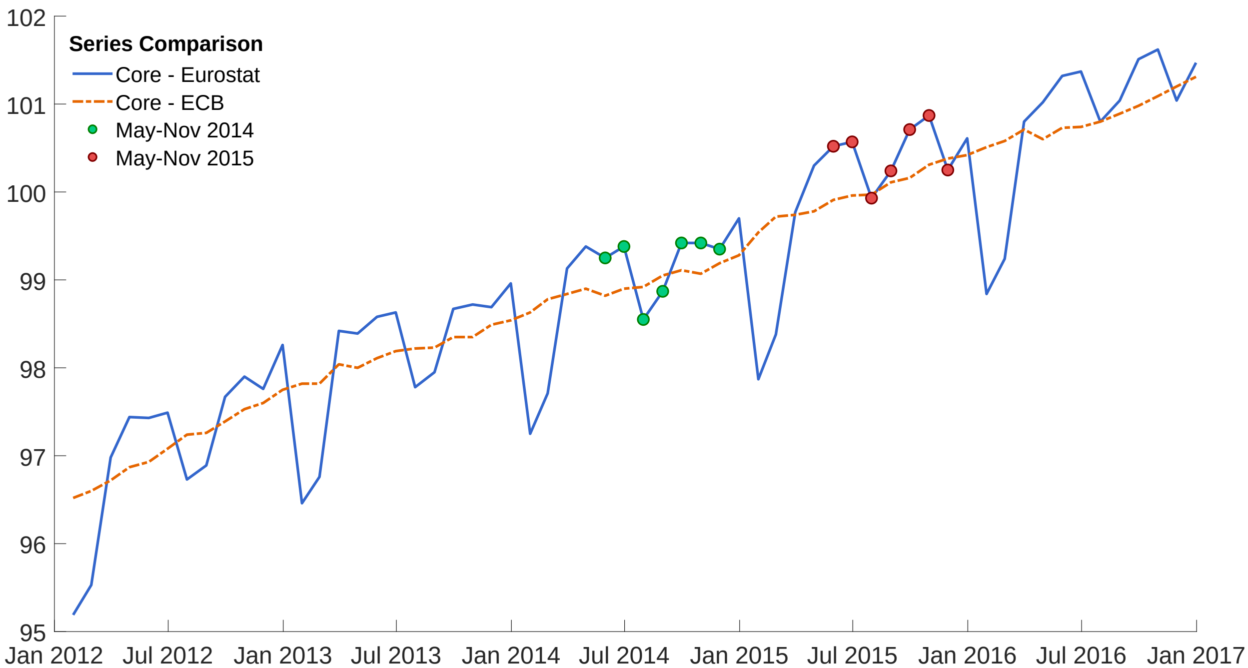
B.2 On industrial production

The series for industrial production we employ, which includes construction, differs slightly from the industrial production series excluding construction. The results in the paper are not affected by the choice of the series. For example, in Figure B.5, we report the IRFs of a 100 basis point tightening identified with the Target factor. We use the measure of industrial production excluding construction from the ECB ('STS.M.I9.Y.PROD.NS0020.4.000').

[3]See 'A new method for the package holiday price index in Germany and its impact on HICP inflation rates' published as part of the ECB Economic Bulletin, Issue 2/2019.

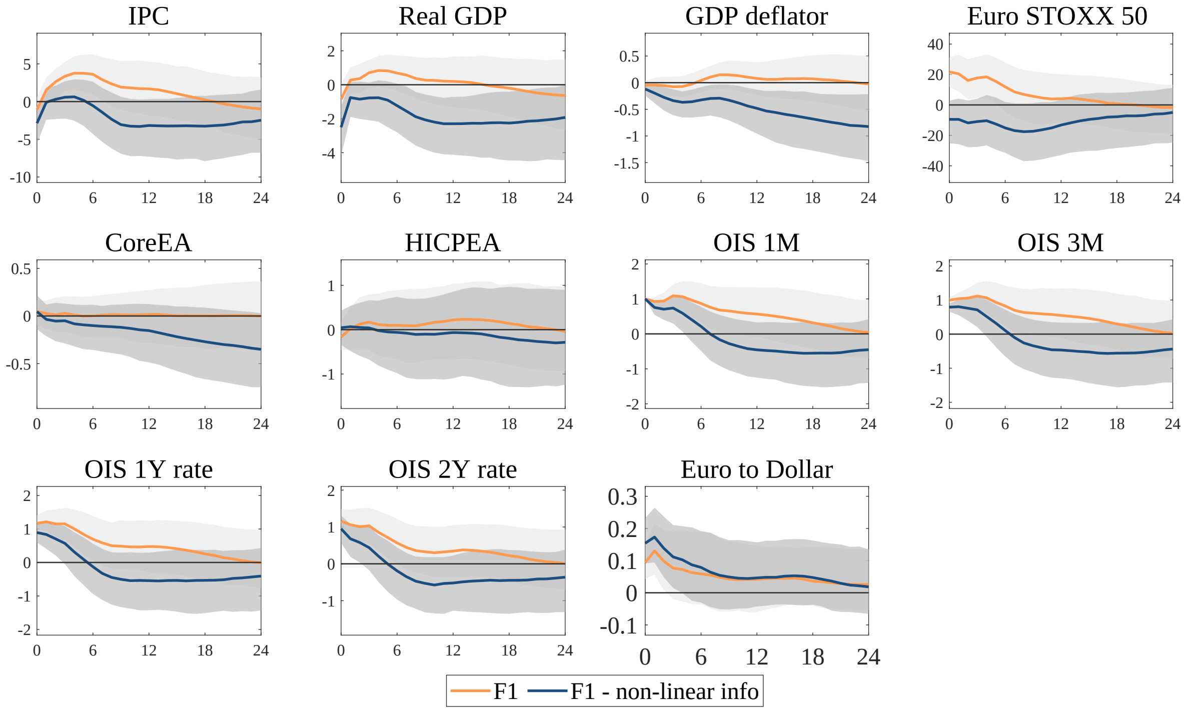
[4]See Eurostat, 'Improved calculation of HICP special aggregates and German package holidays methodological change', February 2019, p. 2 for the description of the changes

Figure B.2: Core inflation in the euro area - ECB and Eurostat measures



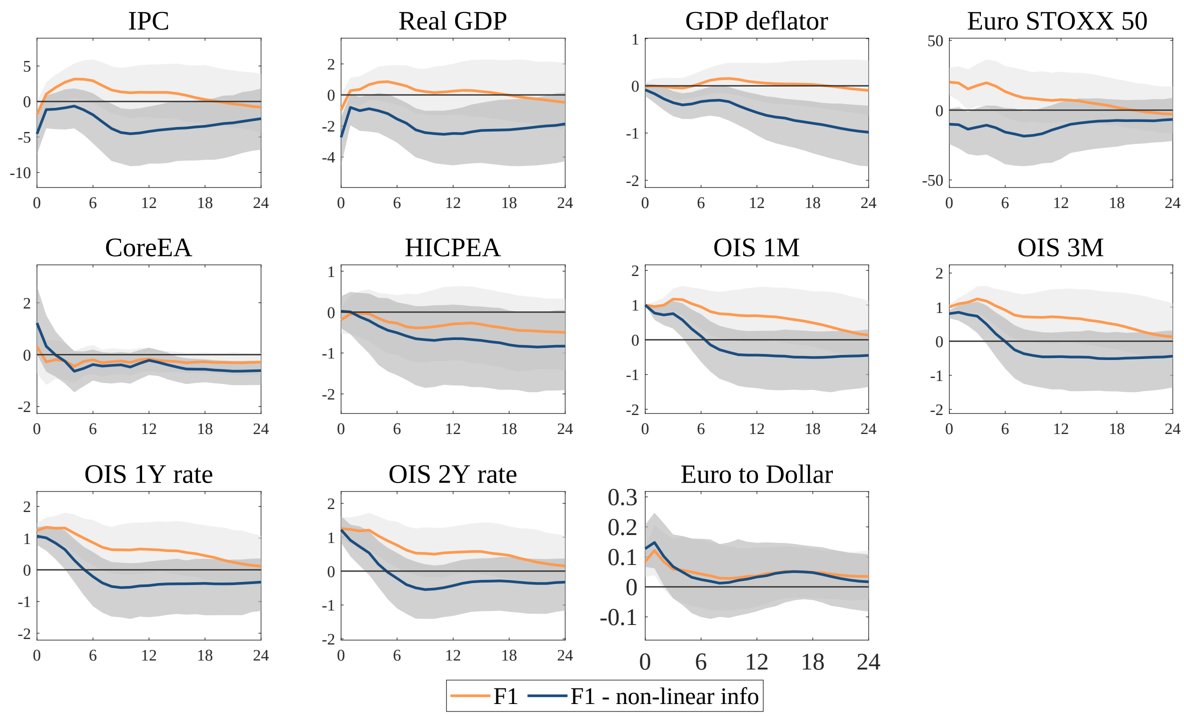
Notes: The figure reports the difference in May-Nov 2015 of the ECB series (in orange) and Eurostat series (in blue). A comparison of the red and green filled circles show how the peak in September 2015 and October 2015 for the Eurostat series were larger than the previous peaks during the same period of the year. This is consistent with Chart C of the ECB note.

Figure B.3: Conventional monetary policy – core inflation (ECB measure)



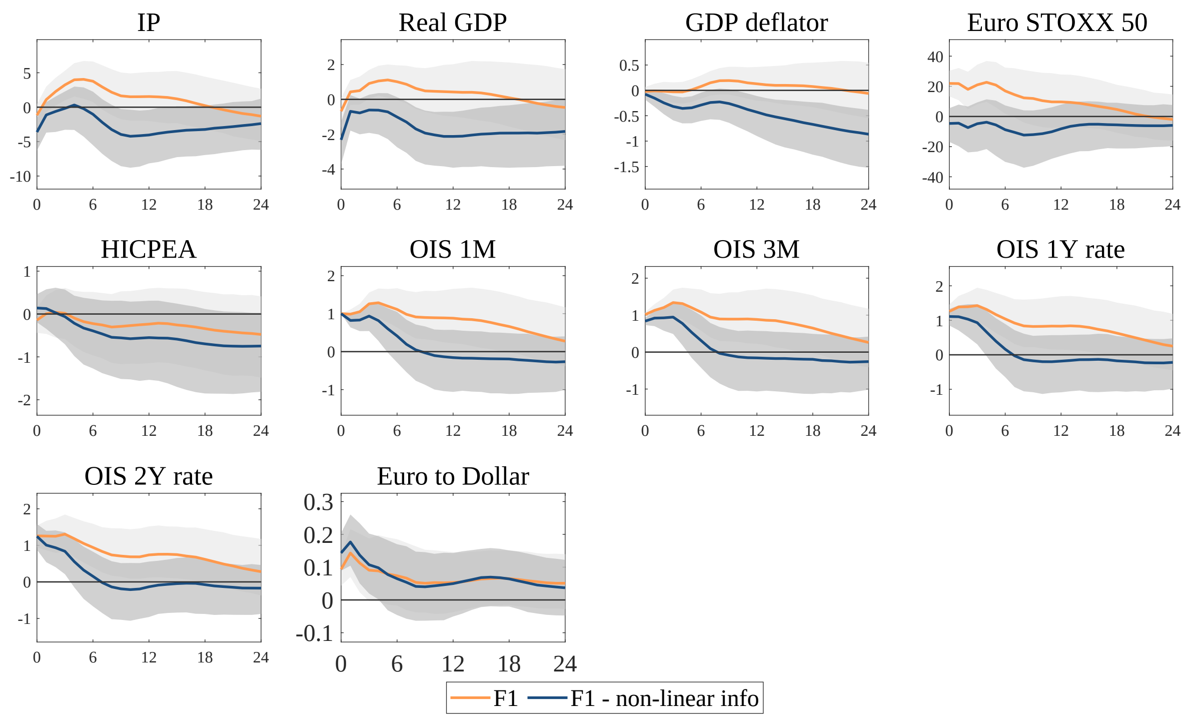
Notes: The figure reports the IRFs to a conventional monetary policy shock, normalised to induce a 100 basis points increase in the 1m-OIS rate. In amber, it reports the responses obtained with the original F1 factor, without any correction for information effects. In blue, it reports the IRFs obtained using the informationally robust F1 factor. The grey shaded areas are 90% coverage bands. The sample considered is 2002m1–2019m12. Core inflation is measured using the ECB core series.

Figure B.4: Conventional monetary policy – core inflation (Eurostat measure)



Notes: The figure reports the IRFs to a conventional monetary policy shock, normalised to induce a 100 basis points increase in the 1m-OIS rate. In amber, it reports the responses obtained with the original F1 factor, without any correction for information effects. In blue, it reports the IRFs obtained using the informationally robust F1 factor. The grey shaded areas are 90% coverage bands. The sample considered is 2002m1–2019m12. Core inflation is measured using the Eurostat core series.

Figure B.5: Conventional monetary policy shock - IP excluding construction



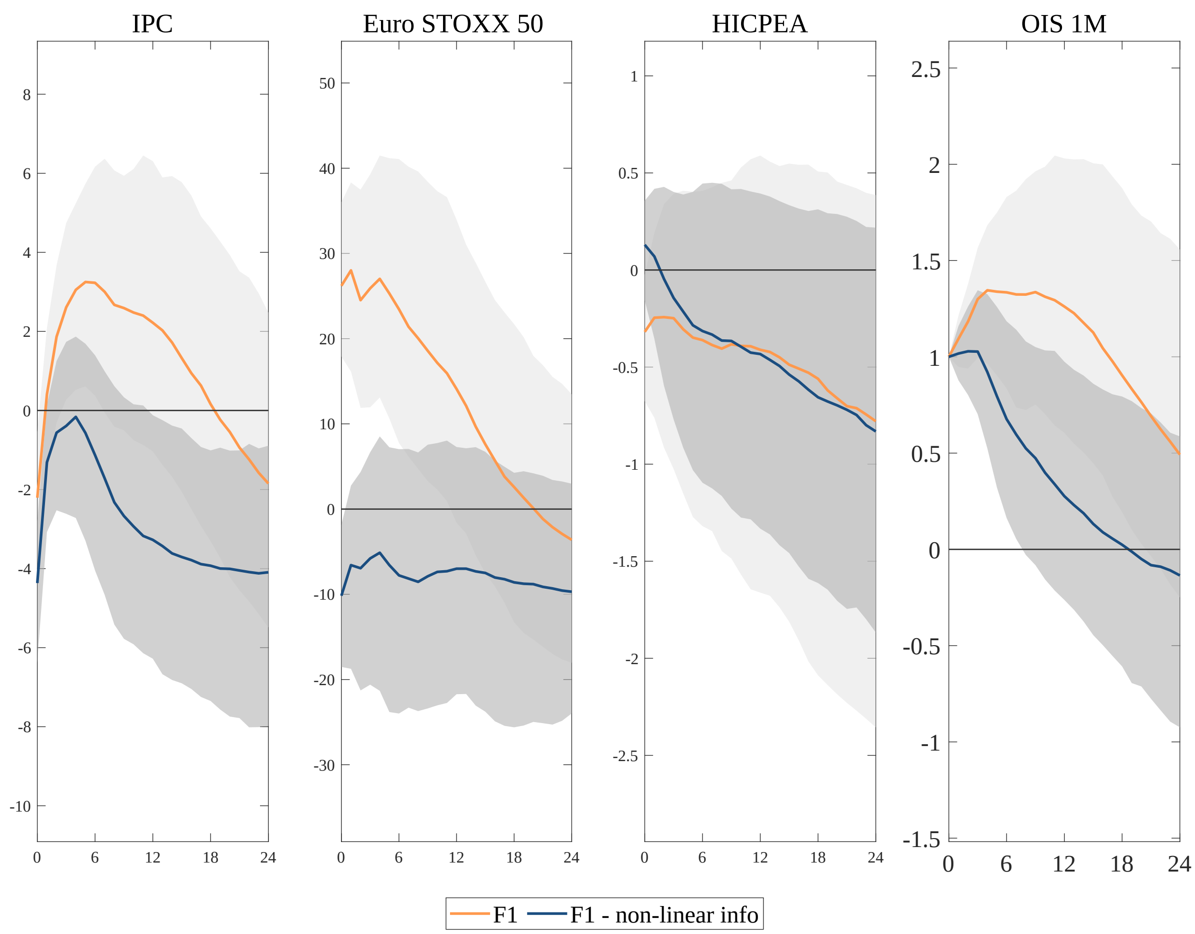
Notes: The figure reports the IRFs to a conventional monetary policy shock, normalised to induce a 100 basis points increase in the 1m-OIS rate. In amber, it reports the responses obtained with the original F1 factor, without any correction for information effects. In blue, it reports the IRFs by using the informationally robust F1 factor. The grey shaded areas are 90% coverage bands. The sample considered is 2002-2019.

B.3 On a small sample VAR

To further assess robustness, we estimate a four-variable VAR including IPC, HICP, 1-month OIS rate, and the stock market index. Figure B.6 shows that, when using the ECB headline inflation series, it yields impulse responses to a conventional monetary policy shock that are qualitatively in line with our baseline results. In contrast, using the Eurostat headline HICP measure in the same VAR delivers a puzzling positive response of inflation (Figure B.7).

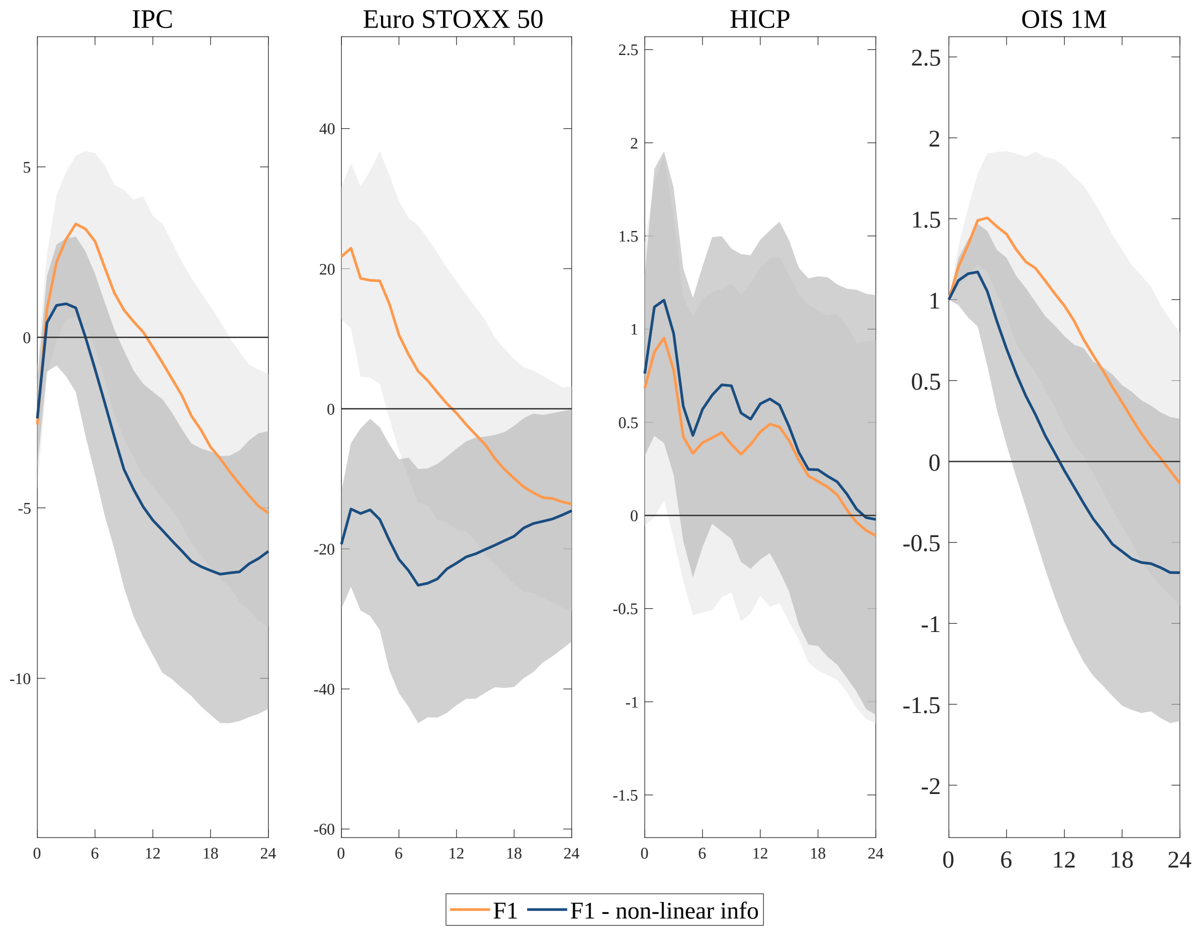
We interpret this as potentially reflecting measurement issues related to the use of non-seasonally adjusted headline inflation series. For this reason, we use the ECB headline inflation series, available at link.

Figure B.6: Conventional monetary policy – small VAR with ECB headline HICP



Notes: The figure reports the IRFs to a conventional monetary policy shock, normalised to induce a 100 basis points increase in the 1m-OIS rate. The VAR includes IPC, HICP, OIS1M, and the stock market index. In amber, it reports the responses obtained with the original F1 factor, without any correction for information effects. In blue, it reports the IRFs obtained using the informationally robust F1 factor. The grey shaded areas are 90% coverage bands. The sample considered is 2002m1–2019m12. Headline inflation is measured using the ECB series.

Figure B.7: Conventional monetary policy – small VAR with Eurostat headline HICP



Notes: The figure reports the IRFs to a conventional monetary policy shock, normalised to induce a 100 basis points increase in the 1m-OIS rate. The VAR includes IPC, HICP, OIS1M, and the stock market index. In amber, it reports the responses obtained with the original F1 factor, without any correction for information effects. In blue, it reports the IRFs obtained using the informationally robust F1 factor. The grey shaded areas are 90% coverage bands. The sample considered is 2002m1–2019m12. Headline inflation is measured using the Eurostat series.

C Factor extraction

We employ high-frequency price changes for 14 variables, as reported in the Euro Area Monetary Policy Database (EA-MPD): 1-month OIS, 3-month OIS, 6-month OIS, 1-year OIS, 2-year OIS, 5-year OIS, 10-year OIS, 2-year SPREAD, 5-year SPREAD, 10-year SPREAD, EUR/GBP, EUR/JPY, EUR/USD, and STOXX50. We include price changes observed during both the press release and press conference windows. Unlike Altavilla et al. (2019), we do not remove any observations over this period.

The factor structure is:

$$Y = F\Lambda + \epsilon, \tag{48}$$

where Y is a $T \times 14$ matrix of surprises with T representing the number of ECB governing council meetings from 2002 to 2019. We extract four factors from these surprises. F represents the matrix of factors which, in our case, is $T \times 4$ and Λ is the loading matrix (4×14).

The factor structure is not unique. Consider an orthonormal matrix U (4×4) such that $UU' = I$:

$$Y = \tilde{F}\tilde{\Lambda} + \epsilon, \tag{49}$$

where $\tilde{F} = FU$ and $\tilde{\Lambda} = U'\Lambda$, which defines new matrices $\tilde{F}$ and $\tilde{\Lambda}$ consistent with the factor structure. Given the existence of 4 factors, 16 restrictions are needed to identify U, up to a sign.

Suppose $X_{.,j}$ is the j^{th} column of matrix X and $X_{i,.}$ is the i^{th} row of matrix X. The orthogonality of the columns provides 6 restrictions:

$$U'_{.,1}U_{.,2} = 0, U'_{.,1}U_{.,3} = 0, U'_{.,1}U_{.,4} = 0,$$
$$U'_{.,2}U_{.,3} = 0, U'_{.,2}U_{.,4} = 0, U'_{.,3}U_{.,4} = 0$$

The normalisation of the columns delivers 4 additional restrictions:

$$U'_{.,1}U_{.,1} = 1, U'_{.,2}U_{.,2} = 1, U'_{.,3}U_{.,3} = 1, U'_{.,4}U_{.,4} = 1$$

Thus, one has to define 6 additional restrictions to uniquely identify U (up to sign).

Following Gürkaynak et al. (2005) and Altavilla et al. (2019), we impose that all the factors apart from the target factor have zero effect on the 1-month OIS. This provides three additional restrictions:

$$U'_{.,2}\Lambda_{.,1} = 0, U'_{.,3}\Lambda_{.,1} = 0, U'_{.,4}\Lambda_{.,1} = 0$$

Following Swanson (2021) and Altavilla et al. (2019), we impose that the QE/QT factor has minimal variance in the pre-crisis period (January 2002-7 August 2008).[5]

We finally impose two restrictions on the fourth factor. First, we impose that it has zero effect on 10-year OIS to capture a factor that mainly influence sovereign yield:

$$U'_{.,4}\Lambda_{.,7} = 0$$

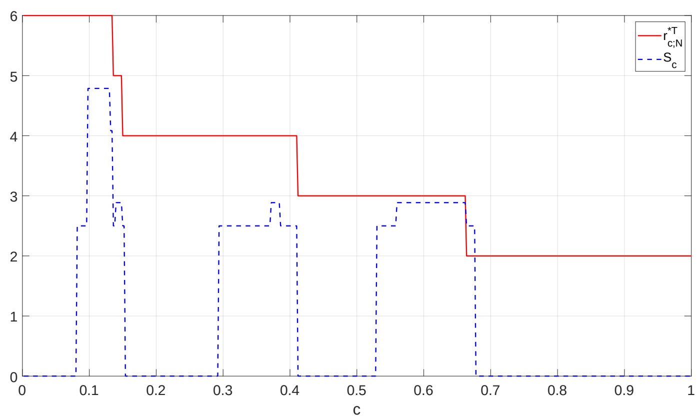
Second, we impose that country risk factor has the smallest variance in the pre-crisis period (January 2002-7 August 2008), as done for the QE/QT factor. This restriction is similar to what is imposed in Motto and Özen, 2022.

[5] Note that the uniqueness is up to a sign, so we have four scale normalisation. Altavilla et al. (2019) imposes that the three factors Target, Forward Guidance and Quantitative Easing are positively correlated with OIS 1 month, OIS 2 years and OIS 10 years, respectively. We do the same and we impose that the fourth factor, country risk factor, is positively correlated with 10-year Spread.

D Alessi et al. (2010)'s test

In Figure D.8, we report the result of the test of Alessi et al. (2010). The number of factors is determined by the second stability interval, i.e. the smallest value of c for which $r^{*T}_{c,N}$ is a constant function of the interval. Following Alessi et al. (2010), we have a stability interval when S_c is equal to zero. Thus, the second stability interval corresponds to a value of $r^{*T}_{c,N}$ equal to four, which indicates the existence of four statistically significant factors.

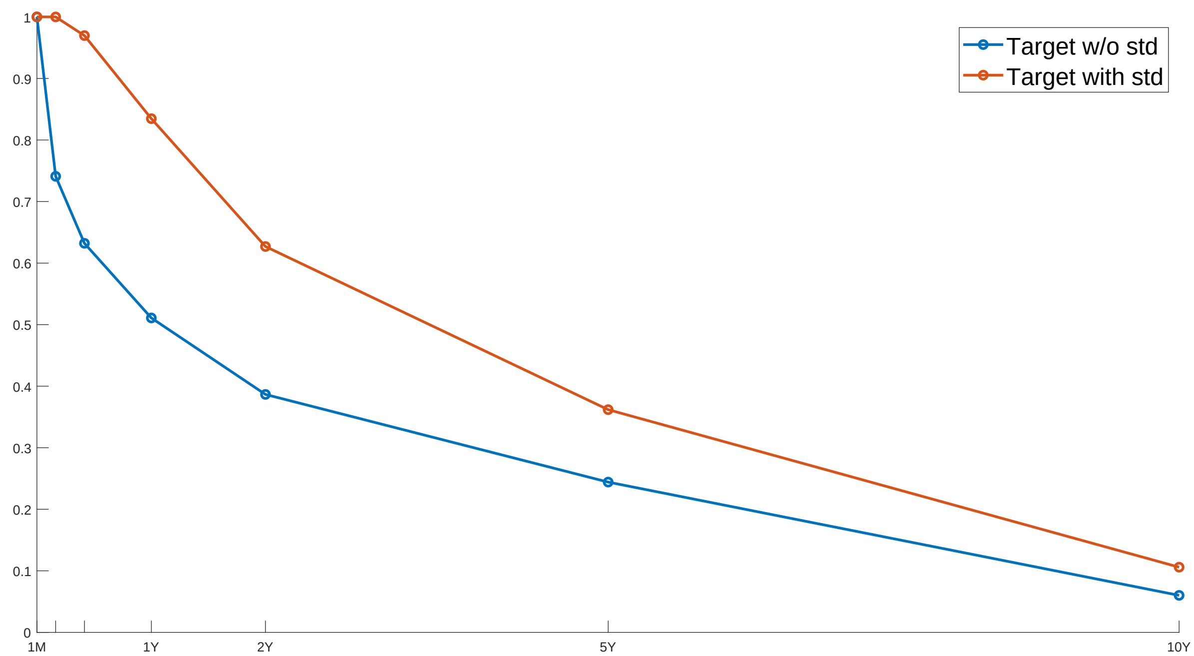
Figure D.8: Alessi et al. (2010) test for the number of factors



Notes: The figure reports the test proposed by Alessi et al. (2010). It plots $r^{*T}_{c,N}$ as a function of the parameter c, the penalisation term for the information criterion to evaluate the number of factors. The second stability interval for which S_c is equal to zero corresponds to $r^{*T}_{c,N} = 4$.

E Target factor loadings

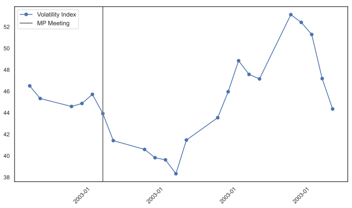
Figure E.9: Press release window



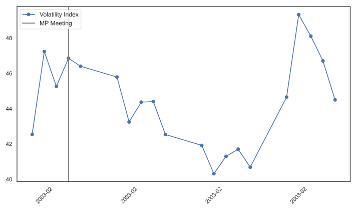
Notes: The figure compares the loadings of the Target factor as in Altavilla et al. (2019) (in blue) with the loading of the same factor extracted after standardising market surprises.

F VSTOXX in periods of high volatility

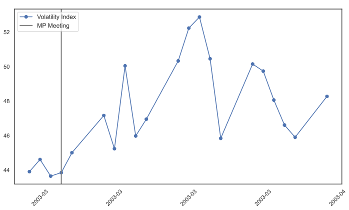
Figure F.10: Euro Stoxx Volatility Index for MP Meeting Dates 2003-2009



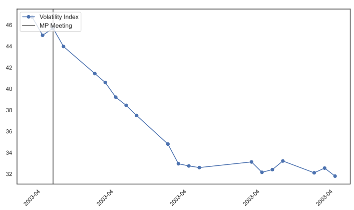
(a) MP Meeting Date: 2003-01-09



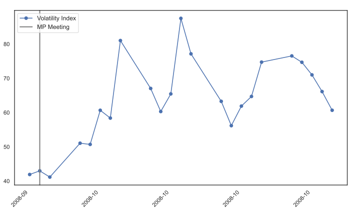
(b) MP Meeting Date: 2003-02-06



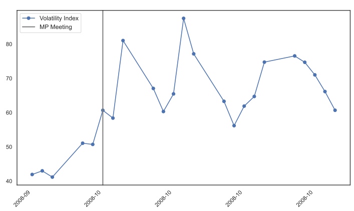
(c) MP Meeting Date: 2003-03-06



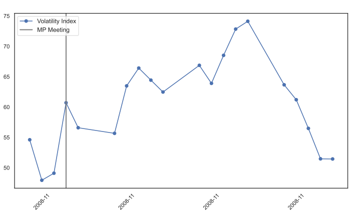
(d) MP Meeting Date: 2003-04-03



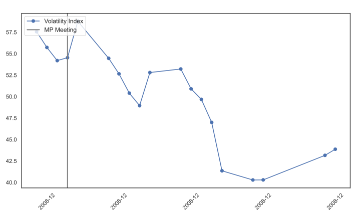
(e) MP Meeting Date: 2008-10-02



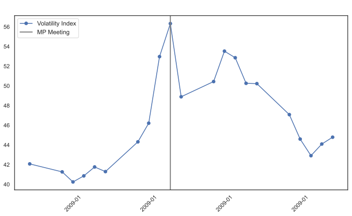
(f) MP Meeting Date: 2008-10-08



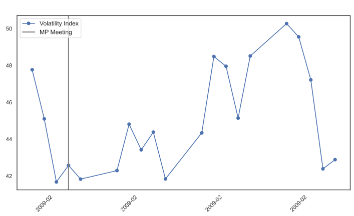
(g) MP Meeting Date: 2008-11-06



(h) MP Meeting Date: 2008-12-04



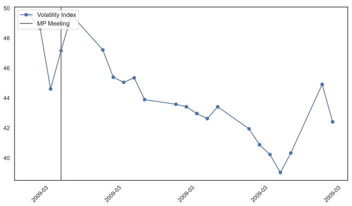
(i) MP Meeting Date: 2009-01-15



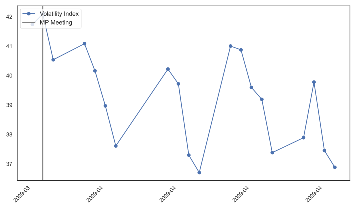
(j) MP Meeting Date: 2009-02-05

Notes: The figure displays the Euro Stoxx Volatility Index dynamics for the specified monetary policy meeting dates. Each subplot reports the volatility for the month of the MP meeting.

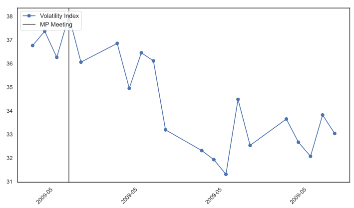
Figure F.11: Euro Stoxx Volatility Index for MP Meeting Dates 2009-2011



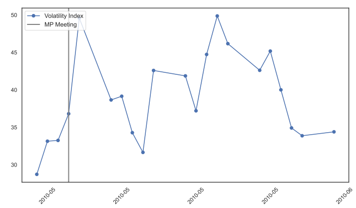
(a) MP Meeting Date: 2009-03-05



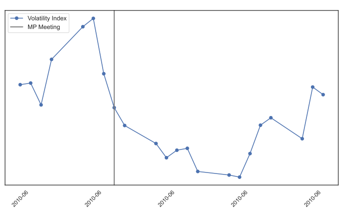
(b) MP Meeting Date: 2009-04-02



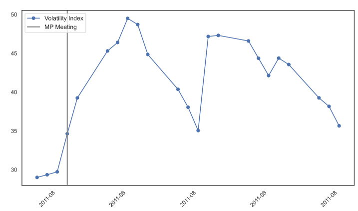
(c) MP Meeting Date: 2009-05-07



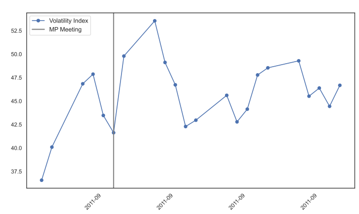
(d) MP Meeting Date: 2010-05-06



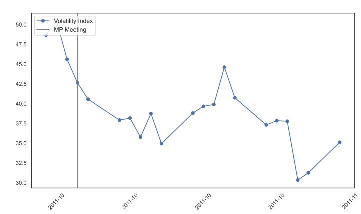
(e) MP Meeting Date: 2010-06-10



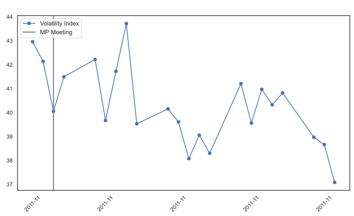
(f) MP Meeting Date: 2011-08-04



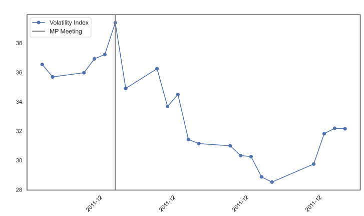
(g) MP Meeting Date: 2011-09-08



(h) MP Meeting Date: 2011-10-06



(i) MP Meeting Date: 2011-11-03



(j) MP Meeting Date: 2011-12-08

Notes: The figure displays the Euro Stoxx Volatility Index dynamics for the specified monetary policy meeting dates. Each subplot reports the volatility for the month of the MP meeting.

G Information effects – Additional tables

Table G.11: Projection of yield curve surprises on forecasts - Linear specification

	(1) 1m-OIS	(2) 3m-OIS	(3) 6m-OIS	(4) 1y-OIS	(5) 2y-OIS	(6) 5y-OIS	(7) 10y-OIS
$MRO_{q=0}$	0.064	0.248	0.292	0.287	0.352	0.606	0.540**
	(0.200)	(0.279)	(0.339)	(0.423)	(0.448)	(0.416)	(0.249)
$\Delta MRO_{q=0}$	-4.292**	-5.866*	-5.492	-4.354	-4.423	-0.677	1.332
	(2.008)	(3.083)	(3.551)	(3.807)	(4.435)	(3.224)	(1.697)
$HICP_{q=1}$	-0.723	-0.348	-0.732	-1.702	-2.605	-2.625*	-1.677*
	(0.774)	(1.115)	(1.359)	(1.686)	(1.763)	(1.458)	(1.005)
$GDP_{q=0}$	-1.507	-2.257	-1.022	-0.632	-1.067	0.400	0.740
	(1.759)	(2.142)	(2.592)	(3.158)	(3.495)	(3.046)	(2.085)
$GDP_{q=1}$	-0.500	2.924	1.751	1.594	3.738	2.065	-0.643
	(2.627)	(3.255)	(4.135)	(5.294)	(5.967)	(4.992)	(3.238)
$GDP_{q=2}$	3.342	0.447	-0.759	-2.371	-4.668	-3.769	-3.436
	(2.187)	(2.558)	(3.412)	(4.701)	(5.429)	(4.240)	(2.941)
$GDP_{y=0}$	0.287	0.206	0.339	0.381	0.282	0.151	0.155
	(0.313)	(0.320)	(0.332)	(0.335)	(0.421)	(0.370)	(0.279)
$HICP_{y=0}$	0.676	0.560	0.402	0.820	1.248	1.161	0.916
	(0.767)	(1.027)	(1.189)	(1.428)	(1.527)	(1.268)	(0.831)
$HICP_{y=1}$	-1.727	-2.970	-2.587	-2.287	-1.915	-2.780	-2.960
	(1.360)	(1.870)	(2.161)	(2.557)	(2.852)	(2.487)	(1.838)
$\Delta HICP_{y=0}$	2.420	2.647	3.779	4.835	4.792	4.917	6.311**
	(1.676)	(1.840)	(2.356)	(3.148)	(3.426)	(3.322)	(2.492)
$HICP^{ECB}_{q=0}$	0.645	0.359	0.164	1.015	2.537	3.919**	3.360**
	(0.886)	(1.212)	(1.559)	(2.062)	(2.239)	(1.946)	(1.337)
$\Delta HICP^{ECB}_{q=0}$	-0.616	-0.078	-0.601	-0.372	-0.306	0.681	0.801
	(0.824)	(1.174)	(1.519)	(2.083)	(2.211)	(1.966)	(1.256)
$GDP^{ECB}_{y=0}$	0.214	0.333	0.399	0.365	-0.022	-0.354	-0.417
	(0.336)	(0.390)	(0.489)	(0.610)	(0.726)	(0.581)	(0.423)
$HICP^{ECB}_{y=0}$	-0.607	-0.023	0.425	-0.188	-1.675	-3.278	-3.132**
	(1.018)	(1.436)	(1.841)	(2.411)	(2.610)	(2.225)	(1.468)
$GDP^{ECB}_{q=0}$	-1.668	-1.709	-2.116	-1.193	0.237	1.657	3.295*
	(1.866)	(2.236)	(2.552)	(3.140)	(3.425)	(2.831)	(1.914)
$Constant$	2.004	3.293	3.689	4.275	4.615	5.954**	6.106***
	(1.767)	(2.281)	(2.571)	(3.004)	(3.353)	(2.910)	(2.254)
$\mathcal{R}^2_{adj}$	0.048	0.067	0.037	0.015	0.011	0.019	0.087
N	197	197	197	197	197	197	197

Notes: The table reports regression results for a test of linear information effects along the yield curve surprises. The sample period considered is 2002-2019. Robust standard errors are in parentheses.

Table G.11: Projection of spreads, exchange rates and stock market surprises on forecasts - Linear specification

	(1) 2y-Spread	(2) 5y-Spread	(3) 10y-Spread	(4) EURGBP	(5) EURJPY	(6) EURUSD	(7) STOXX50
$MRO_{q=0}$	0.252	-0.558	-0.454	0.052	0.051	0.077	0.003
	(0.592)	(0.628)	(0.649)	(0.036)	(0.043)	(0.048)	(0.069)
$\Delta MRO_{q=0}$	-2.088	-7.555**	-6.030	0.028	0.185	0.147	1.112***
	(3.095)	(3.712)	(3.774)	(0.154)	(0.176)	(0.193)	(0.380)
$HICP_{q=1}$	1.164	1.970	1.772	-0.120	-0.115	-0.144	0.040
	(1.156)	(1.345)	(1.375)	(0.166)	(0.180)	(0.218)	(0.270)
$GDP_{q=0}$	-2.061	-1.066	-3.608	-0.190	0.178	-0.097	0.723
	(3.050)	(3.773)	(3.288)	(0.280)	(0.310)	(0.343)	(0.533)
$GDP_{q=1}$	0.055	-2.184	0.245	-0.058	-0.081	0.029	-0.500
	(3.549)	(5.773)	(4.287)	(0.322)	(0.415)	(0.423)	(0.655)
$GDP_{q=2}$	-1.902	2.640	1.916	0.185	-0.154	0.094	-0.029
	(3.485)	(4.203)	(4.197)	(0.334)	(0.377)	(0.434)	(0.623)
$GDP_{y=0}$	0.309	-0.243	-0.050	-0.015	-0.012	-0.015	0.040
	(0.323)	(0.372)	(0.369)	(0.035)	(0.048)	(0.039)	(0.076)
$HICP_{y=0}$	-0.212	-1.346	-1.468	-0.004	0.115	0.050	-0.048
	(1.173)	(1.189)	(1.137)	(0.127)	(0.141)	(0.167)	(0.237)
$HICP_{y=1}$	-0.275	3.224	3.213	0.007	-0.380	-0.238	-0.181
	(2.646)	(2.522)	(2.579)	(0.289)	(0.316)	(0.365)	(0.530)
$\Delta HICP_{y=0}$	-0.357	-0.431	-2.252	0.579**	0.838**	0.929***	-0.295
	(2.371)	(2.872)	(2.518)	(0.286)	(0.354)	(0.331)	(0.328)
$HICP^{ECB}_{q=0}$	-0.079	-0.341	-1.759	0.051	0.169	0.135	-0.140
	(2.132)	(2.401)	(2.276)	(0.205)	(0.236)	(0.249)	(0.321)
$\Delta HICP^{ECB}_{q=0}$	1.056	2.459	2.664*	0.052	-0.109	-0.108	-0.072
	(1.540)	(2.096)	(1.587)	(0.177)	(0.230)	(0.221)	(0.269)
$GDP^{ECB}_{y=0}$	-0.522	0.439	0.074	-0.035	0.010	0.039	-0.028
	(0.442)	(0.690)	(0.516)	(0.064)	(0.057)	(0.046)	(0.080)
$HICP^{ECB}_{y=0}$	-0.280	0.173	1.380	-0.041	-0.129	-0.101	0.201
	(2.651)	(2.676)	(2.434)	(0.218)	(0.249)	(0.275)	(0.357)
$GDP^{ECB}_{q=0}$	2.642	-1.675	0.774	0.347	0.228	0.057	-0.191
	(3.065)	(4.349)	(3.238)	(0.270)	(0.290)	(0.327)	(0.449)
Constant	-0.541	-5.464	-4.894	0.098	0.530	0.347	0.158
	(3.723)	(3.629)	(4.056)	(0.362)	(0.418)	(0.481)	(0.724)
$\mathcal{R}^2_{adj}$	-0.022	0.025	0.005	0.002	0.013	0.004	0.032
N	197	197	197	197	197	197	197

Notes: The table reports regression results for a test of linear information effects in spreads, exchange rates, and stock market surprises. The sample period considered is 2002-2019. Robust standard errors are in parentheses.

Table G.11: Projection of spreads, exchange rates and stock market surprises on forecasts - Non-linear specification

	(1) 2y-Spread	(2) 5y-Spread	(3) 10y-Spread	(4) EURGBP	(5) EURJPY	(6) EURUSD	(7) STOXX50
$MRO_{q=0}$	0.231	-0.299	-0.331	0.063	0.040	0.071	-0.031
	(0.521)	(0.562)	(0.530)	(0.040)	(0.047)	(0.053)	(0.075)
$\Delta MRO_{q=0}$	-10.562**	-15.764**	-14.159*	0.148	0.213	0.212	1.150
	(5.270)	(7.736)	(8.195)	(0.259)	(0.289)	(0.328)	(0.733)
$HICP_{q=1}$	0.437	0.716	0.495	-0.109	-0.088	-0.113	0.172
	(1.398)	(1.718)	(1.495)	(0.193)	(0.210)	(0.258)	(0.315)
$GDP_{q=0}$	-4.794	-5.101	-7.296	-0.225	0.240	-0.053	0.830
	(4.057)	(4.866)	(5.181)	(0.345)	(0.395)	(0.436)	(0.643)
$GDP_{q=1}$	1.143	-3.563	-1.903	-0.193	-0.208	-0.034	-0.357
	(4.175)	(7.386)	(5.887)	(0.339)	(0.467)	(0.471)	(0.722)
$GDP_{q=2}$	-0.445	3.985	4.693	0.032	-0.192	0.041	0.328
	(3.929)	(4.957)	(5.380)	(0.390)	(0.433)	(0.498)	(0.601)
$GDP_{y=0}$	0.373	0.145	0.123	0.022	0.010	0.005	0.015
	(0.320)	(0.413)	(0.341)	(0.039)	(0.054)	(0.043)	(0.086)
$HICP_{y=0}$	0.342	-0.256	-0.705	-0.039	0.114	0.031	-0.084
	(1.647)	(1.821)	(1.743)	(0.169)	(0.191)	(0.231)	(0.324)
$HICP_{y=1}$	0.169	3.044	4.584	-0.025	-0.394	-0.208	-0.224
	(2.700)	(3.076)	(3.188)	(0.308)	(0.346)	(0.388)	(0.610)
$\Delta HICP_{y=0}$	2.303	1.459	-0.917	0.636*	0.821**	0.833**	-0.429
	(2.366)	(3.003)	(2.718)	(0.339)	(0.413)	(0.400)	(0.377)
$HICP^{ECB}_{q=0}$	1.305	-0.227	-0.877	0.142	0.322	0.236	-0.334
	(2.204)	(2.749)	(2.537)	(0.233)	(0.288)	(0.316)	(0.371)
$\Delta HICP^{ECB}_{q=0}$	2.149	4.026*	4.774**	-0.102	-0.172	-0.147	-0.009
	(1.996)	(2.380)	(2.074)	(0.203)	(0.292)	(0.288)	(0.326)
$GDP^{ECB}_{y=0}$	-1.010**	-0.104	-0.436	-0.060	-0.027	0.002	-0.023
	(0.466)	(0.750)	(0.563)	(0.065)	(0.064)	(0.051)	(0.092)
$HICP^{ECB}_{y=0}$	-2.450	-0.890	-0.621	-0.099	-0.279	-0.192	0.438
	(2.840)	(3.195)	(2.872)	(0.255)	(0.306)	(0.352)	(0.425)
$GDP^{ECB}_{q=0}$	7.243*	4.464	7.256	0.308	0.286	0.114	-0.276
	(4.084)	(5.597)	(5.452)	(0.334)	(0.383)	(0.444)	(0.600)
$I(index) * MRO_{q=0}$	2.161	-0.153	-1.218*	0.021	0.091	-0.156	-0.019
	(1.848)	(1.005)	(0.694)	(0.135)	(0.142)	(0.111)	(0.190)
$I(index) * \Delta MRO_{q=0}$	15.809***	10.898	11.433	-0.161	-0.227	-0.331	0.417
	(5.916)	(8.154)	(7.956)	(0.386)	(0.360)	(0.356)	(0.843)
$I(index) * HICP_{q=1}$	20.511**	22.377***	3.133	0.720	0.331	0.721	-1.497
	(9.319)	(6.784)	(4.852)	(0.720)	(0.841)	(0.593)	(1.122)
$I(index) * GDP_{q=0}$	25.892**	34.597***	15.753**	-1.019	-1.354	-1.139	0.934
	(12.639)	(6.826)	(6.181)	(0.833)	(0.862)	(0.765)	(1.274)
$I(index) * GDP_{q=1}$	-44.072*	-31.956**	-1.032	1.506	1.850	1.391	-2.890
	(24.288)	(13.165)	(8.366)	(1.409)	(1.812)	(1.528)	(2.975)
$I(index) * GDP_{q=2}$	13.212	-0.650	-13.662	1.105	0.196	1.385	2.889
	(18.939)	(12.136)	(8.578)	(1.656)	(1.632)	(1.312)	(4.473)
$I(index) * GDP_{y=0}$	-4.245	-6.198***	-0.359	-0.401	-0.183	-0.433**	0.038
	(2.751)	(1.894)	(1.304)	(0.257)	(0.267)	(0.192)	(0.258)
$I(index) * HICP_{y=0}$	-11.988**	-13.747***	-4.138	0.158	-0.085	0.124	1.363**
	(5.140)	(3.777)	(2.762)	(0.421)	(0.378)	(0.338)	(0.627)
$I(index) * HICP_{y=1}$	-5.295	-1.592	4.562	-1.123	-0.505	-0.897*	-0.306
	(7.569)	(5.252)	(3.396)	(0.783)	(0.704)	(0.503)	(1.213)
$I(index) * \Delta HICP_{y=0}$	-9.512	-6.841	-5.222	-0.660	-0.020	-0.092	-0.994
	(9.347)	(7.661)	(5.067)	(0.901)	(0.877)	(0.608)	(1.398)
$I(index) * HICP^{ECB}_{q=0}$	-1.499	-0.968	-4.360	0.025	-0.797	-0.901*	1.904*
	(6.018)	(4.765)	(3.672)	(0.721)	(0.543)	(0.526)	(0.989)
$I(index) * \Delta HICP^{ECB}_{q=0}$	-18.878***	-15.061***	-4.461	0.286	0.858*	0.841	-3.214**
	(5.810)	(3.763)	(2.842)	(0.792)	(0.469)	(0.615)	(1.485)
$I(index) * GDP^{ECB}_{y=0}$	7.230***	6.768***	0.960	0.685**	0.384*	0.447*	0.199
	(2.252)	(1.856)	(1.297)	(0.327)	(0.201)	(0.246)	(0.464)
$I(index) * HICP^{ECB}_{y=0}$	0.055	0.680	6.502	-0.345	0.743	0.806	-2.476**
	(6.720)	(5.293)	(4.224)	(0.837)	(0.588)	(0.602)	(1.109)
$I(index) * GDP^{ECB}_{q=0}$	-9.567	-19.269**	-14.736**	-0.980	-1.092**	-1.628***	1.514
	(7.591)	(8.131)	(7.280)	(0.713)	(0.494)	(0.517)	(1.344)
Constant	-1.139	-4.451	-5.736	0.251	0.550	0.296	-0.081
	(3.580)	(4.164)	(4.284)	(0.397)	(0.451)	(0.508)	(0.818)
$\mathcal{R}^2_{adj}$	0.062	0.080	0.022	-0.020	-0.037	-0.042	0.009
N	197	197	197	197	197	197	197

Notes: The table reports regression results for a test of non-linear information effects in spreads, exchange rates, and stock market surprises. The sample period considered is 2002-2019. Robust standard errors are in parentheses.

Table G.11: Projection of yield curve surprises on forecasts - Lasso over larger set of forecasts

	(1) 1m-OIS	(2) 3m-OIS	(3) 6m-OIS	(4) 1y-OIS	(5) 2y-OIS	(6) 5y-OIS	(7) 10y-OIS
$\Delta HICP^{ECB}_{q=4}$	-2.623**	-1.869	-2.471	-3.024			
	(1.064)	(1.663)	(1.778)	(2.277)			
$\Delta MRO_{q=1}$	-3.135**						
	(1.518)						
$\Delta HICP_{q=4}$	-3.565						
	(2.200)						
$\Delta MRO_{q=0}$		-2.740	-2.992*	-4.637*	-3.150		
		(1.787)	(1.770)	(2.461)	(2.504)		
$\Delta GDP_{q=4}$		-6.221					
		(3.880)					
$\Delta GDP^{ECB}_{q=4}$			-7.481	-13.089**	-8.300		
			(4.930)	(6.575)	(5.606)		
$HICP^{ECB}_{y=0}$			0.530*				
			(0.318)				
$HICP^{ECB}_{q=4}$				1.123***	1.126**	1.013**	0.722***
				(0.431)	(0.449)	(0.423)	(0.415)
$\Delta HICP^{ECB}_{y=0}$				2.325**			
				(1.010)			
$\Delta MRO_{q=3}$				3.790			
				(2.527)			
$\Delta HICP_{q=0}$				-0.439	-0.751	-0.827	
				(0.430)	(0.574)	(0.505)	
$GDP_{q=4}$					-1.665		
					(3.019)		
$\Delta GDP^{ECB}_{q=0}$							3.641**
							(1.824)
$\Delta HICP^{ECB}_{q=3}$						1.999	1.421
						(1.219)	(1.003)
$\Delta HICP_{q=2}$							1.843*
							(1.052)
$GDP_{q=2}$							-6.593**
							(3.298)
$HICP_{y=1}$							-1.134
							(0.731)
Constant	0.007	-0.023	-0.299	0.133	1.136	0.697	1.390
	(0.189)	(0.194)	(0.262)	(0.641)	(1.277)	(0.808)	(1.238)
$\mathcal{R}^2_{adj}$	0.124	0.081	0.090	0.097	0.063	0.056	0.111
N	197	197	197	197	197	197	197

Notes: The table reports regression results for a test of linear information effects along yield curve surprises when we use LASSO over a larger set of forecasts with respect to the baseline. Specifically, we include forecast for longer horizons (up to four quarters for quarterly forecasts and two years for yearly forecasts). By including a larger set of forecasts, especially those at longer horizons, we are able to capture more than 11% of the variability of the 10y-OIS rate and larger variability for longer maturities of the yield curve. The sample period considered is 2002-2019. Robust standard errors are in parentheses.

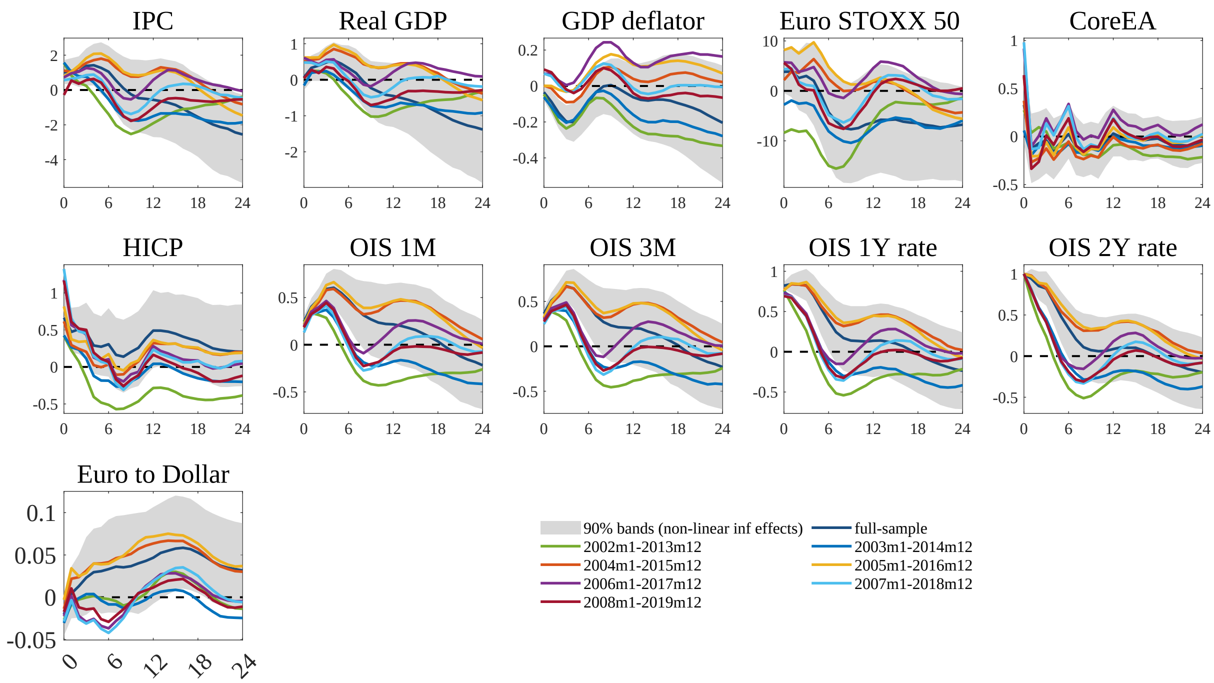
Table G.11: Projection of spreads, exchange rates and stock market surprises on forecasts - Lasso over larger set of forecasts

	(1) 2y-Spread b/(se)	(2) 5y-Spread b/(se)	(3) 10y-Spread b/(se)	(4) EURGBP b/(se)	(5) EURJPY b/(se)	(6) EURUSD b/(se)	(7) STOXX50 b/(se)
$HICP_{q=0}$	0.861***						
	(0.286)						
$\Delta GDP^{ECB}_{q=3}$		-8.520					
		(7.622)					
$\Delta HICP^{ECB}_{q=3}$		3.354**					
		(1.633)					
$\Delta MRO_{q=0}$		-3.258*	-4.143*				0.657***
		(1.823)	(2.127)				(0.215)
$\Delta MRO_{q=4}$		-1.213					
		(1.496)					
$GDP_{q=1}$		-1.947					
		(2.387)					
$\Delta GDP_{q=3}$		-9.544					
		(8.812)					
$HICP_{q=1}$		1.166***					
		(0.432)					
$\Delta GDP^{ECB}_{q=0}$				0.719***			
				(0.247)			
$\Delta HICP_{q=2}$						0.371***	
						(0.136)	
$\Delta MRO_{q=2}$							0.341*
							(0.194)
Constant	-1.667***	-1.540*	-0.090	-0.004	-0.015	-0.031	-0.093**
	(0.461)	(0.816)	(0.310)	(0.026)	(0.033)	(0.034)	(0.046)
$\mathcal{R}^2_{adj}$	0.025	0.077	0.021	0.050	0.000	0.024	0.060
N	197	197	197	197	197	197	197

Notes: The table reports regression results for a test of linear information effects in spreads, exchange rates, and stock market surprises when we use LASSO over a larger set of forecasts with respect to the baseline. Specifically, we include forecast for longer horizons (up to four quarters for quarterly forecasts and two years for yearly forecasts). The sample period considered is 2002-2019. Robust standard errors are in parentheses.

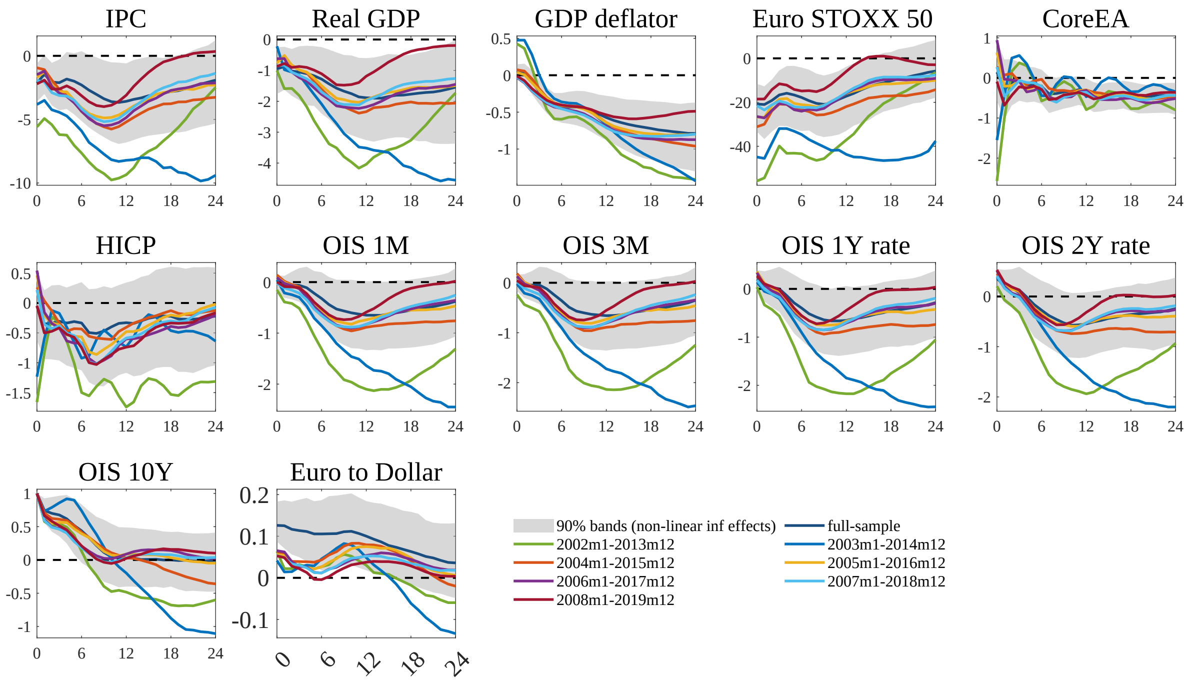
H Rolling subsamples for IRFs

Figure H.12: Forward Guidance factor – rolling sample



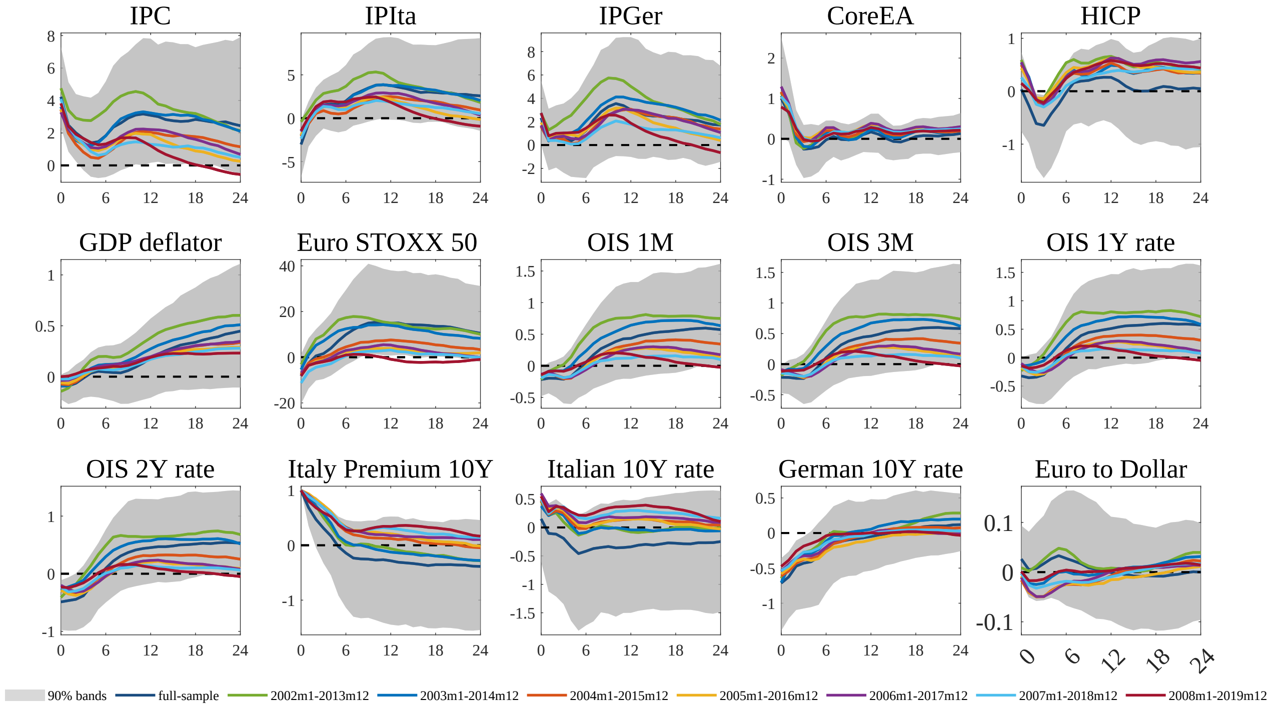
Notes: The figure reports the IRFs to a forward guidance shock on the baseline sample and on a set of rolling subsamples. The shock is identified with the informationally robust forward guidance factor, corrected for non-linear information effects, and normalised to induce a 100 basis points increase in the 2y-OIS rate. The grey shaded areas are 90% coverage bands of the baseline specification.

Figure H.13: QE factor – rolling sample



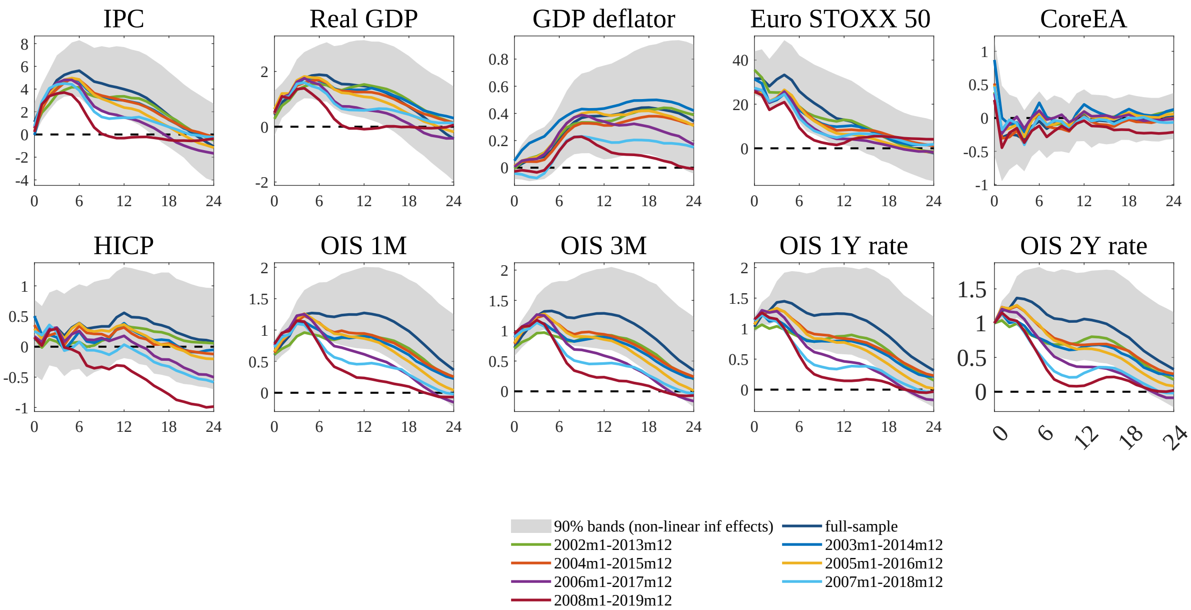
Notes: The figure reports the IRFs to a quantitative tightening shock on the baseline sample and on a set of rolling subsamples. The shock is identified with the QE/QT factor, corrected for non-linear information effects, and normalised to induce a 100 basis points increase in the 10y-OIS rate. The grey shaded areas are 90% coverage bands of the baseline specification.

Figure H.14: Asymmetric country risk factor – rolling sample



Notes: The figure reports the IRFs to a asymmetric country risk shock on the baseline sample and on a set of rolling subsamples. The shock is identified with the asymmetric country risk factor, corrected for non-linear information effects, and normalised to induce a 100 basis points increase in the spread between the 10y Italian government bond yield and the 10y German government bond yield. The grey shaded areas are 90% coverage bands of the baseline specification.

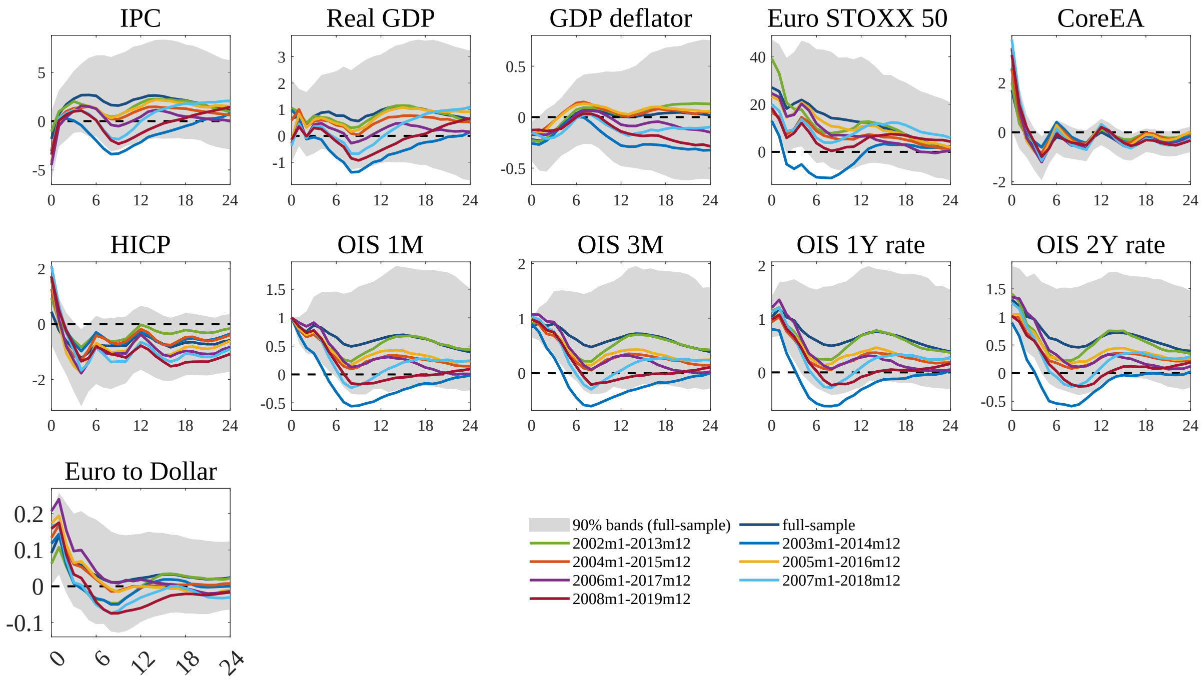
Figure H.15: INFORMATION FACTOR – ROLLING SAMPLE



Notes: The figure reports the IRFs to an 'information surprise' on the baseline sample and on a set of rolling subsamples. The shock is identified with an information factor defined as the sum of the first two principal components of the fitted values of the non-linear information effects regressions, and normalised to induce a 100 basis points increase in the 2y-OIS rate. The grey shaded areas are 90% coverage bands of the baseline specification.

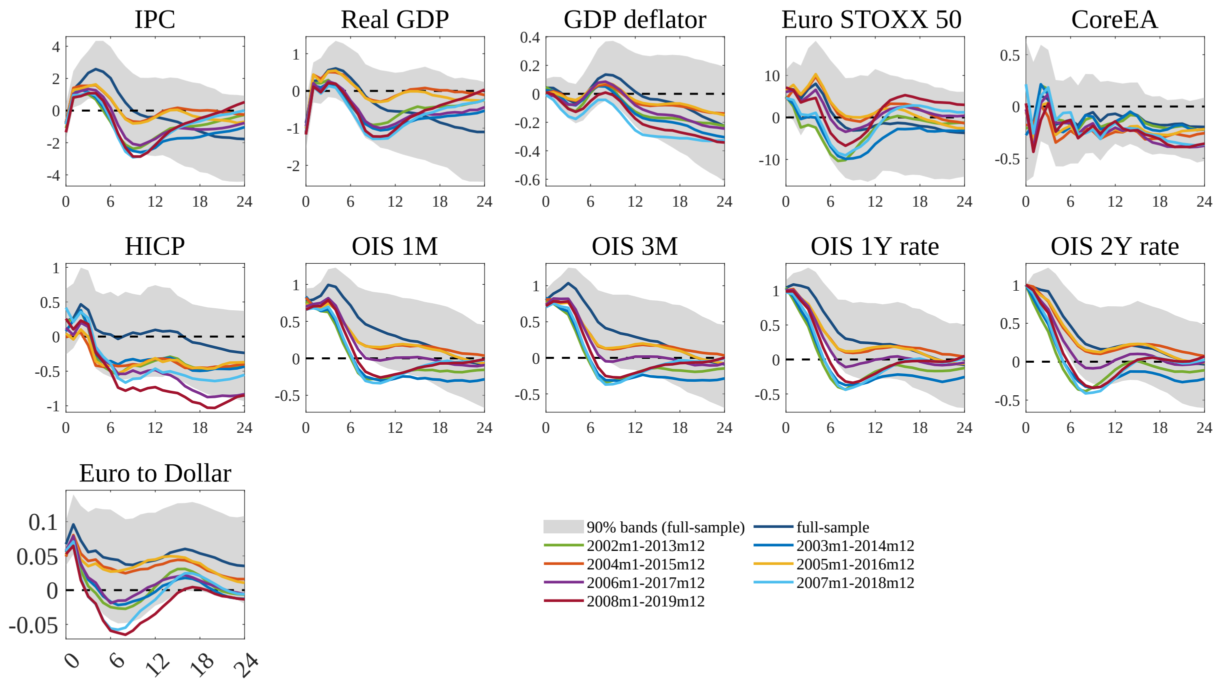
I Rolling subsamples for IRFs Altavilla et al. (2019)

Figure I.16: Target factor Altavilla et al. (2019) – rolling sample



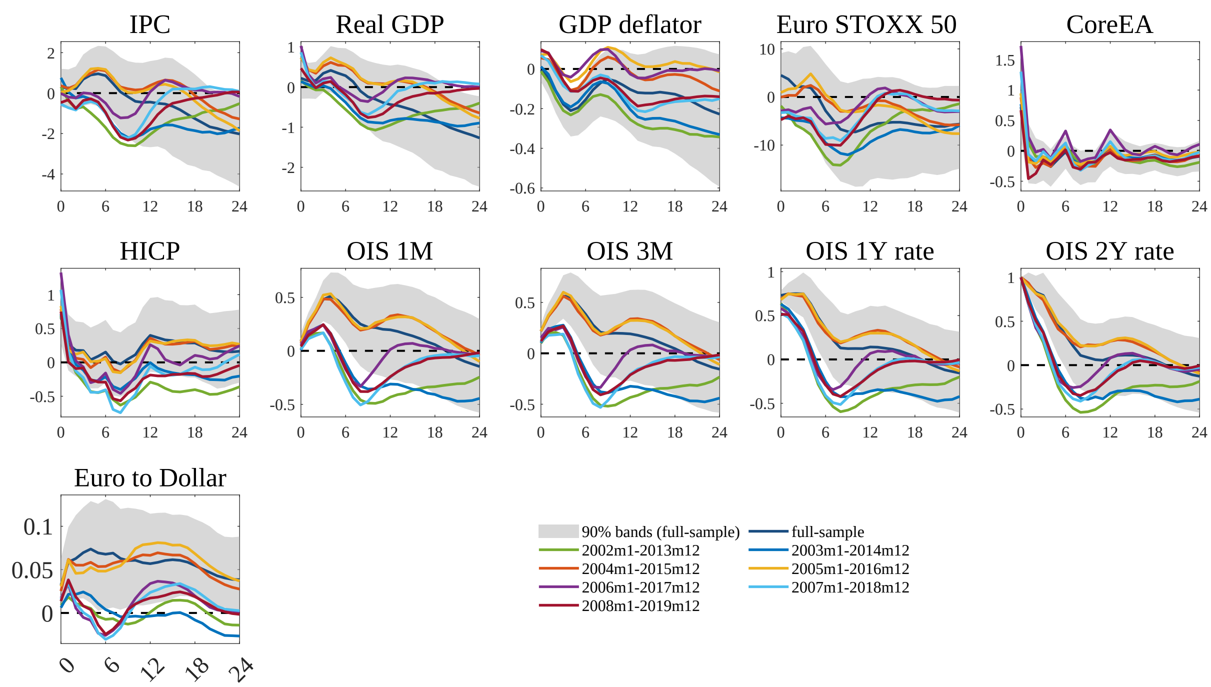
Notes: The figure reports the IRFs to a conventional monetary policy shock on the baseline sample and on a set of rolling subsamples. The shock is identified with the Target factor of Altavilla et al. (2019), and normalised to induce a 100 basis points increase in the 1m-OIS rate. The grey shaded areas are 90% coverage bands of the sample 2002-2019.

Figure I.17: TIMING FACTOR ALTAVILLA ET AL. (2019) – ROLLING SAMPLE



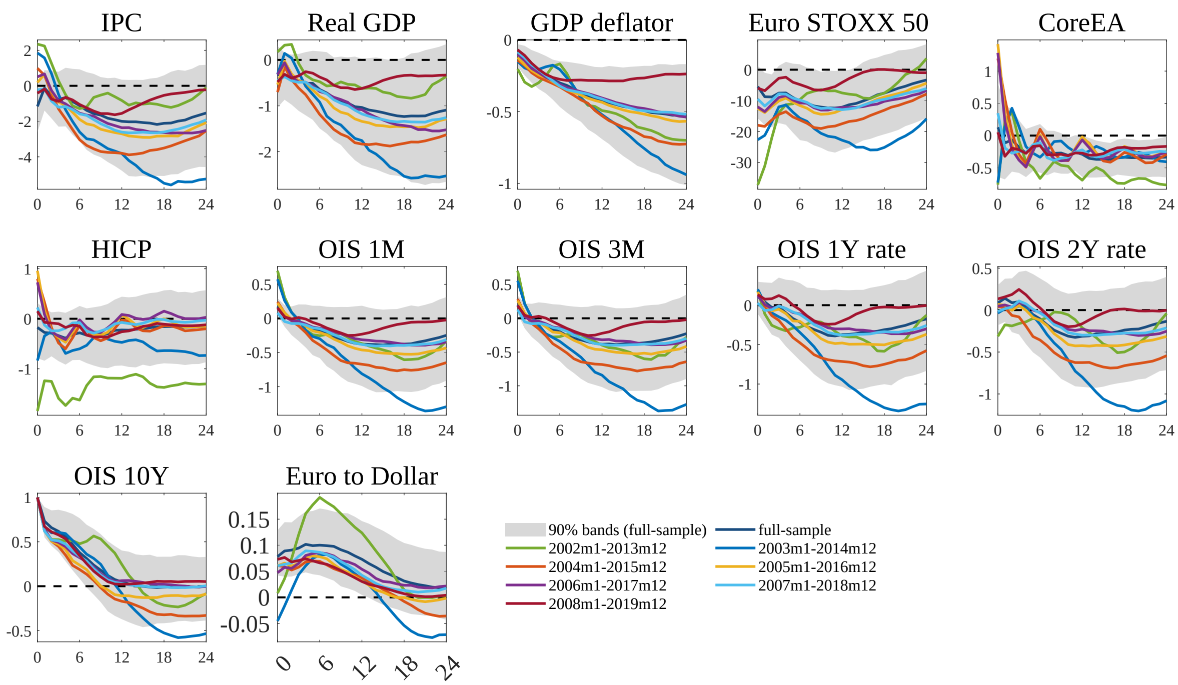
Notes: The figure reports the IRFs to a timing shock on the baseline sample and on a set of rolling subsamples. The shock is identified with the Timing factor of Altavilla et al. (2019), and normalised to induce a 100 basis points increase in the 2y-OIS rate. The grey shaded areas are 90% coverage bands of the sample 2002-2019.

Figure I.18: Forward guidance factor Altavilla et al. (2019) – rolling sample



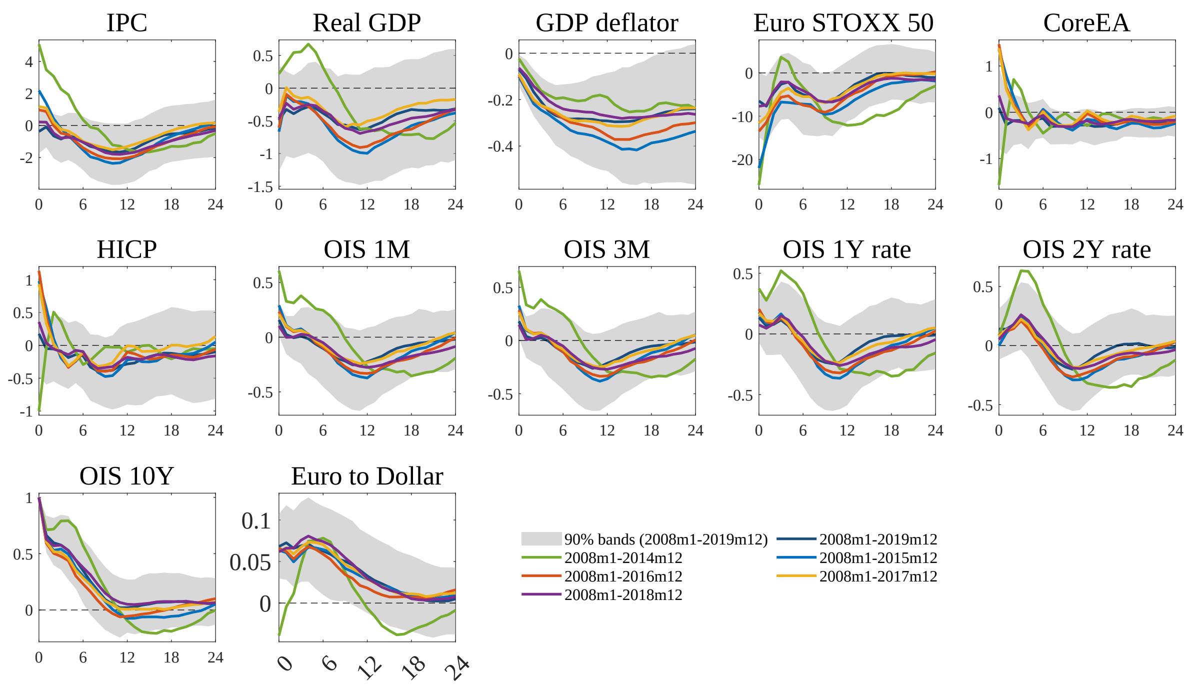
Notes: The figure reports the IRFs to a forward guidance shock on the baseline sample and on a set of rolling subsamples. The shock is identified with the Forward Guidance factor of Altavilla et al. (2019), and normalised to induce a 100 basis points increase in the 2y-OIS rate. The grey shaded areas are 90% coverage bands of the sample 2002-2019.

Figure I.19: Quantitative easing/tightening factor Altavilla et al. (2019) – rolling sample



Notes: The figure reports the IRFs to a quantitative tightening shock on the baseline sample and on a set of rolling subsamples. The shock is identified with the QE/QT factor of Altavilla et al. (2019), and normalised to induce a 100 basis points increase in the 10y-OIS rate. The grey shaded areas are 90% coverage bands of the sample 2002-2019.

Figure I.20: Quantitative easing/tightening (Altavilla et al. (2019) factor) – extending samples



Notes: The figure reports the IRFs to a quantitative tightening shock on a set of subsamples starting from 2008. The shock is identified with the QE/QT factor of Altavilla et al. (2019), and normalised to induce a 100 basis points increase in the 10y-OIS rate. The grey shaded areas are 90% coverage bands of the sample 2008-2019.

J Variance decomposition – Additional tables

Table J.20: Variance Decomposition at a short run horizon

Variables	*Target*	*Forward Guidance*	*QE*	*Asymmetric Country Risk*	*Information*
IP	5.67	14.55	5.46	9.78	13.33
	(3.67, 8.23)	(8.43, 20.51)	(2.73, 9.14)	(5.88, 13.86)	(8.60, 18.90)
Real GDP	5.54	14.24	6.83	–	7.86
	(3.48, 8.65)	(3.34, 11.44)	(1.59, 15.35)	–	(4.48, 11.81)
Stock Market	4.49	9.88	11.38	5.69	37.77
	(2.86, 6.70)	(5.66, 13.97)	(7.43, 15.59)	(2.55, 8.50)	(28.96, 45.40)
HICP	3.02	7.01	2.63	3.28	3.95
	(1.73, 4.79)	(4.56, 9.73)	(1.36, 4.18)	(1.77, 5.26)	(1.90, 6.33)
1m-OIS	16.92	20.19	5.24	8.61	26.24
	(11.69, 22.26)	(13.08, 27.78)	(1.86, 10.10)	(3.67, 13.87)	(19.14, 34.27)
1y-OIS	12.23	39.40	5.12	8.12	31.62
	(8.29, 16.12)	(29.46, 46.90)	(2.10, 8.86)	(3.80, 12.13)	(23.48, 39.60)
2y-OIS	8.87	43.14	5.71	8.06	27.16
	(5.93, 12.40)	(33.53, 50.45)	(2.77, 9.32)	(4.07, 12.41)	(19.29, 34.25)
10y-OIS	–	–	17.86	–	–
	–	–	(12.72, 22.87)	–	–
Spead 10y	–	–	–	10.32	–
	–	–	–	(6.65, 15.65)	–
IP Italy	–	–	–	5.61	–
	–	–	–	(3.07, 8.45)	–
IP Germany	–	–	–	4.26	–
	–	–	–	(2.36, 6.69)	–

Notes: The table reports the percentage share of the variance of each variable attributable to each monetary policy shock, in the range of short-term frequencies (i.e. 2 and 16 months), following the approach of Forni et al. (2022). 68% confidence bands are reported in parentheses.

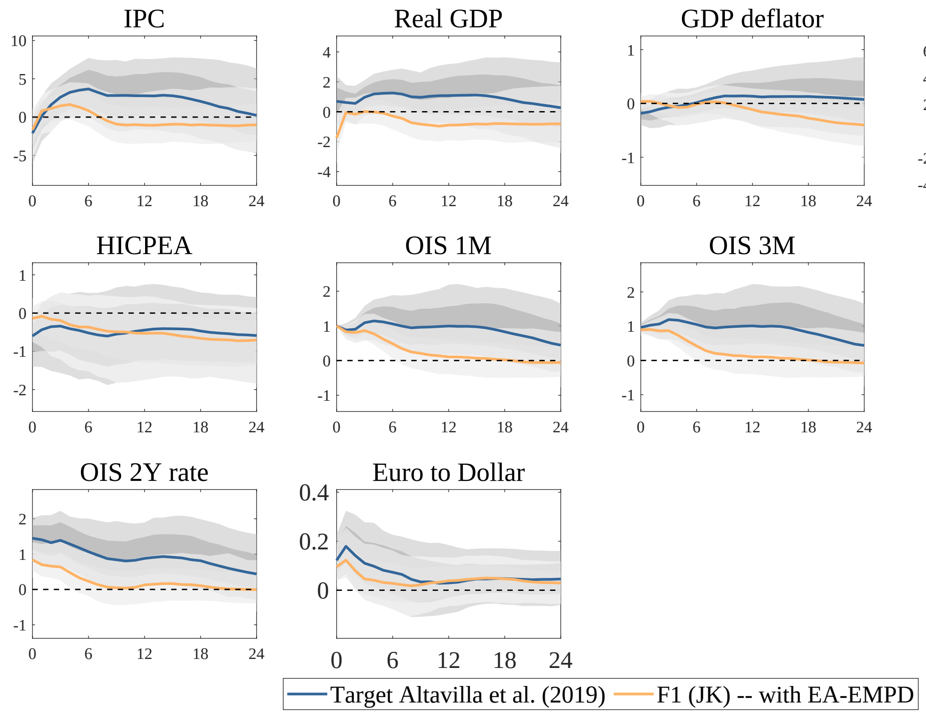
Table J.20: Variance Decomposition – overall variance

Variables	*Target*	*Forward Guidance*	*QE*	*Asymmetric Country Risk*	*Information*
IP	3.16	7.36	9.45	7.52	23.99
	(1.25, 6.73)	(3.39, 12.90)	(3.89, 16.99)	(2.84, 13.38)	(15.70, 34.66)
Real GDP	4.71	9.29	13.79	–	14.82
	(1.56, 9.40)	(3.81, 16.06)	(6.60, 21.80)	–	(8.35, 23.02)
Stock Market	3.35	6.50	14.86	6.79	32.19
	(1.31, 6.78)	(2.45, 11.97)	(7.42, 22.44)	(2.70, 12.74)	(21.33, 43.89)
HICP	4.10	6.59	3.23	2.50	5.05
	(1.21, 8.66)	(3.41, 12.03)	(1.19, 7.70)	(1.23, 4.67)	(1.94, 11.82)
1m-OIS	4.72	8.62	7.12	5.24	44.42
	(2.70, 7.86)	(5.36, 12.90)	(1.89, 14.46)	(1.45, 10.21)	(32.89, 56.13)
1y-OIS	3.91	12.58	6.25	5.70	42.85
	(2.11, 6.70)	(8.47, 17.03)	(1.87, 12.63)	(1.80, 10.45)	(31.24, 54.25)
2y-OIS	3.58	15.10	5.38	5.61	40.21
	(1.78, 6.00)	(10.46, 19.55)	(1.99, 10.57)	(2.25, 10.22)	(29.20, 51.23)
10y-OIS	–	–	10.83	–	–
	–	–	(6.41, 15.72)	–	–
Spread 10y	–	–	–	3.85	–
	–	–	–	(1.79, 7.01)	–
IP Italy	–	–	–	5.51	–
	–	–	–	(2.16, 10.95)	–
IP Germany	–	–	–	3.66	–
	–	–	–	(1.32, 8.34)	–

Notes: The table reports the percentage share of the overall variance (i.e. 2+ months) of each variable attributable to each monetary policy shock following the approach of Forni et al. (2022). 68% confidence bands are reported in parentheses.

K Info à la Jarociński and Karadi (2020)

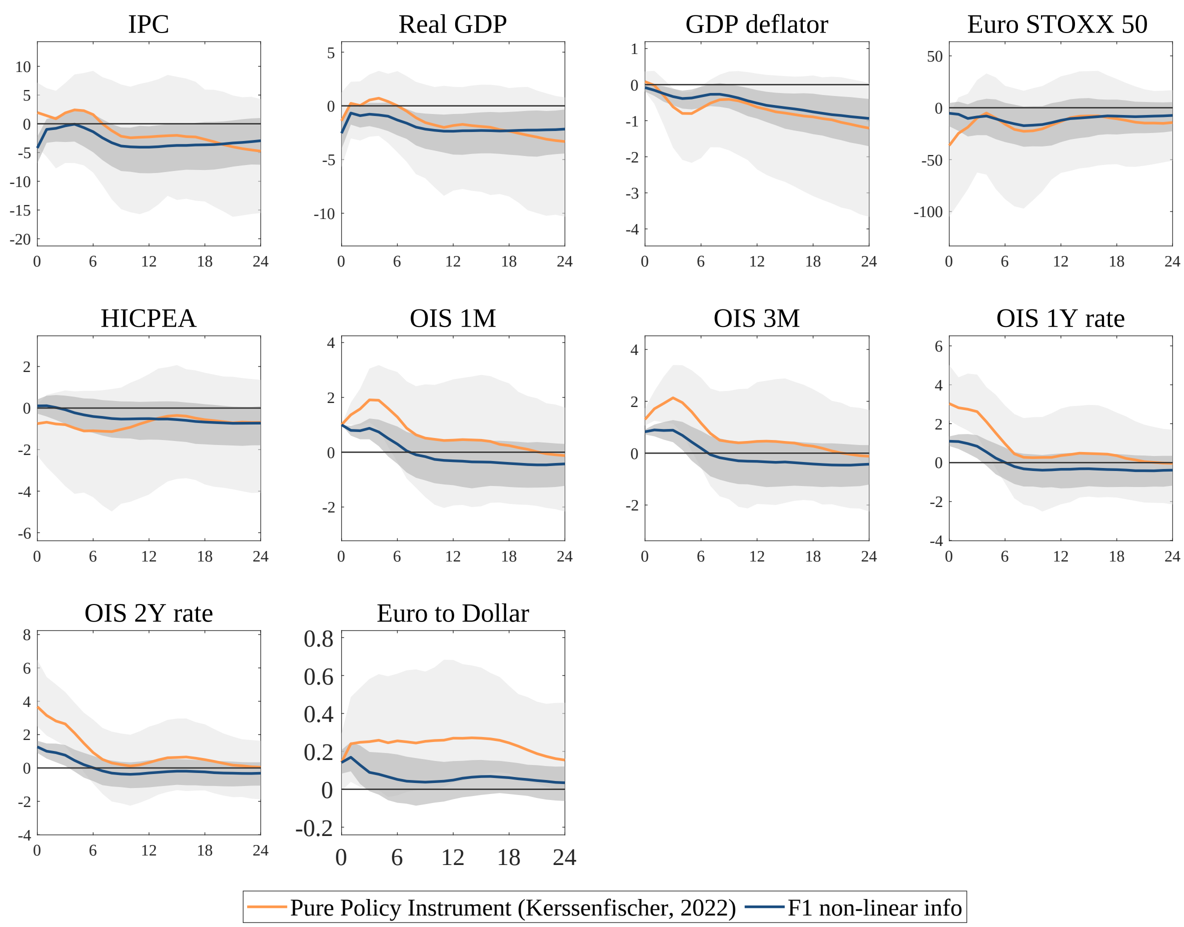
Figure K.21: Conventional monetary policy shock – Altavilla et al. Target vs JK approach



Notes: The figure reports the IRFs to a conventional monetary policy shock, normalised to induce a 100 basis points increase in the 1m-OIS rate. In blue, it reports the responses obtained using the Target factor constructed following Altavilla et al. (2019). In blue, it reports the responses obtained using the EA-EMPD-based Target factor after correcting for information effects following Jarociński and Karadi (2020). The grey shaded areas are 90% coverage bands.

L A comparison with Kerssenfischer (2022)

Figure L.22: Conventional monetary policy shock – comparison with Kerssenfischer (2022)



Notes: The figure reports the IRFs to a conventional monetary policy shock, normalised to induce a 100 basis points increase in the 1m-OIS rate. In amber, it reports the responses obtained with the pure policy instrument identified by Kerssenfischer (2022). In blue, it reports the IRFs by using the informationally robust F1 factor. The grey shaded areas are 90% coverage bands. The sample considered is 2002m3-2019m12.

M List of 10 largest surprises in identified factor series

The tables below report the largest surprises in the four identified factors. In each table, the surprises are listed in chronological order. Specifically:

- Column 2 of each table records the magnitude of the surprise on the particular date.
- Column 3 contains any changes in the key interest rates of the ECB: the Main Refinancing Operations (MRO) rate, the Marginal Lending Facility (MLF) rate and the Deposit Facility (EDF) rate. Prior to the Global Financial Crisis, in the event of a change in the policy rate, all three rates moved by the same magnitude. After October 2008, this was not always the case. On such dates, we specify the rates which were changed.
- Column 4 provides the authors' summary of the economic analysis discussed in the Introductory Statement of the ECB president during the press conference held after the policy decision.[6] The economic analysis typically contains details about real GDP growth and inflation, as well as their outlook.
- Column 5 provides additional notes on the events. These combine insights from high frequency surprise data in OIS rates and sovereign bond yields on policy announcement dates, the median expected MRO forecast data[7], and the transcripts of the Q&A session held with journalists after the ECB president's Introductory Statement.

[6] The transcripts of the ECB's monetary policy decisions can be found on the ECB website. They contain the Introductory Statement delivered by the ECB president and the Q&A session held with journalists.

[7] Reuters conducts polls for the median expected MRO multiple times for a specific quarter. We create a h quarter(s) ahead fixed event forecast from these polls.

M.1 Target factor

Table M.22: Ten largest surprises in the target factor

Date	Surprise	Rate Change	Introductory Statement	Notes
Nov 2002	1.85	0	Lower than expected real GDP growth in Q3:2002 due to heightened uncertainty from "geopolitical tensions, evolution of oil prices and developments in stock markets." Inflation was close to 2% target.	Forecasters expected ECB to reduce rates due to subdued economic growth. A journalist commented, "Mr. Duisenberg, I think it is fair to say that you, the ECB, disappointed a lot of people today by not cutting interest rates."
Mar 2003	2.34	-25bps	Economic growth remained sluggish in previous months. Further, modest growth was expected in 2003 owing to geopolitical tensions and rise in oil prices. Inflation is likely to be on target in the medium term.	OIS yields rose at the short end of the yield curve. A journalist commented, "the markets have reacted somewhat badly to this rate decision and there seems to be some suspicion that it was a rather unhealthy compromise, possibly between those that wanted to cut by 50 basis points and those who maybe wanted to cut by 25 basis points or leave rates unchanged."
Jun 2008	1.63	0	Real GDP growth in the first half of the year was above expectations. Inflation was above 3% for several months and there were elevated risks to price stability over the medium term due to energy and food prices.	In the press conference, a journalist commented: "Markets are now, after your comments, pricing in a 65% chance of an increase in July, next month."
Oct 2008	-5.61	-100bps MLF -50bps MRO with fixed tender	Collapse of large banks in the U.S. led to heightened uncertainty about real GDP growth and inflation.	Policy response to the turmoil in financial markets.
Nov 2008	5.16	-50bps	Financial market tensions caused a break in economic growth momentum. Prices and wages were expected moderate in light of weak domestic and global economy.	The ECB decision followed in the wake of larger rate cuts by the Federal Reserve and the Bank of England.
Aug 2011	-2.89	0	ECB concerned about deceleration in real GDP growth amidst heightened uncertainty. Inflation in the short term was a concern with upside risks to its medium term outlook.	Announcement of monetary easing measures such as the Long-term Refinancing Operations at 3 months and 6 months maturity, and continuing MROs at fixed rate until Jan 2012.
Oct 2011	4.69	0	Lacklustre economic growth due to slowing global demand, falling business confidence and deteriorating conditions in sovereign debt markets. Elevated inflation in previous months along with lacklustre growth.	OIS yields rose despite announcement of various policy measures such as Longer-term Refinancing Operations (LTRO) and Covered Bonds Purchase Programme (CBPP2). The median MRO forecast indicated an expectation of 25bps rate cut, but there was no change in the policy rate.
Nov 2011	-3.45	-25bps	Expectation of low real GDP growth due to sovereign debt crisis and slower global economic growth. Inflation is expected to decline from 3% in October to below 2% in 2012.	During the Q&A, the ECB president talked about the euro area "heading towards a mild recession by the end of the year."
Jul 2012	-2.79	-25bps	Real GDP growth remained weak. Risks of higher inflation subsided due to a cooling in futures price of oil.	The ECB president pointed out that risks surrounding the economic outlook continue to be on the downside.
Sep 2014	-1.73	-20bps	Real GDP growth saw a modest expansion but was weaker than expected. Inflation remained lower than the medium-term target.	The ECB announced a reduction in policy rates, and purchases of non-financial private sector bonds and covered bonds.

M.2 Forward guidance factor

Table M.22: Ten largest surprises in the forward guidance factor

Date	Surprise	Rate Change	Introductory Statement	Notes
Mar 2003	-1.85	-25bps	Economic growth remained sluggish in previous months. Further, modest growth was expected in 2003 owing to geopolitical tensions and rise in oil prices. Inflation was expected to be on target in the medium term.	ECB president revealed new set of forecasts where economic growth figures were revised downwards.
Jun 2003	-2.98	-50bps	Economic growth remained very modest. Inflation expected to decline below the 2% target due to sluggish demand and exchange rate appreciation.	Downgrade of real GDP growth forecast for 2003 prompted the ECB to provide a monetary stimulus.
Jul 2005	1.65	0	Economic growth remained subdued. Rising oil prices seem to be hampering demand and confidence. However, several indicators, such as favourable financial conditions and corporate earnings, point to a gradual recovery. Prices are stable around the 2% target.	
Jun 2008	2.64	0	Real GDP growth in the first half of the year was above expectations. Inflation was above 3% for several months and there were elevated risks to price stability over the medium term due to energy and food prices.	In the press conference, a journalist remarked: "Markets are now, after your comments, pricing in a 65% chance of an increase in July, next month."
Jul 2008	-2.62	25bps	Real GDP growth expected to slow down in coming quarters. Inflation reached 4% in Jun 2008, well above the 2% target. High energy and food prices present an upside risk to price stability over the medium term.	In the press conference, the ECB president did not commit to future increase in the policy rate while markets had priced in a series of rate hikes.
Aug 2008	-2.21	0	Real GDP growth expected to be weaker in Q2:2008. Inflation remained well above the target with upside risks to price stability over the medium term.	The ECB's concern about economic growth prevented it from further increasing the policy rate. During the Q&A, a journalist asked, "Just a quick question. After this press conference investors will have certainly priced out any possibility of a rate increase this year and early next year. Are you comfortable with that?"
Mar 2011	1.84	0	Positive momentum in real GDP growth, although uncertainty was elevated. ECB flagged upside risks to price outlook.	ECB staff projections for Mar 2011 signalled an uptick in HICP inflation relative to Dec 2010. The central bank signalled that rates could increase soon if the incoming data suggests that inflation will remain high.
May 2011	-1.47	0	Economic growth was on a positive trajectory since Q4:2010. Inflation rate was above target and under upward pressure from higher than expected fuel prices.	The ECB left the policy rate unchanged due to which markets reversed their bets on an aggressive tightening cycle.
Aug 2011	-1.44	0	ECB concerned about deceleration in real GDP growth. Inflation in the short term was a concern with risks to its medium term outlook on the upside.	Liquidity measures announced in the form of supplementary LTROs with 3 months and 6 months maturity. Additionally, MRO to be conducted at fixed rate until Jan 2012.
Dec 2016	1.84	0	Economic growth continued into Q4:2016. It was further expected to expand at a "moderate but firming pace." Inflation still below 2% target and will see a gradual recovery towards the 2% target.	Reduced pace of APP from 80 billion until Mar 2017 to 60 billion until the end of Dec 2017 or beyond, if necessary.

M.3 Quantitative easing factor

Table M.22: Ten largest surprises in the quantitative easing/tightening factor

Date	Surprise	Rate Change	Introductory Statement	Notes
May 2003	1.41	0	A review of monetary policy and communication.	N/A
May 2009	1.76	-25bps MRO -50bps MLF	Global economic growth was expected to remain subdued. Inflation was low primarily due to global commodity prices, but the ECB confident of maintaining medium-term price stability.	ECB president termed covered bond purchases as "enhanced credit support" and ruled out quantitative easing. This signalled that the ECB did not intend to target long term OIS yields with this programme.
Jan 2011	1.23	0	ECB worried about negative spillover of financial sector into the real economy. There was short-term pressure on inflation, but price stability expected to be maintained over the medium-term.	ECB president warned about upside risks to inflation and that rates may be raised despite ongoing economic conditions, reminding journalists about 2008 where the ECB raised rates during the economic slowdown. This hawkish tone raised medium and long-term OIS rates.
Aug 2012	-1.35	0	Real GDP growth remained flat and was expected to remain weak. Inflation was expected to decline below the 2% target well into 2013. ECB additionally commented on irreversibility of the euro.	The ECB committed to undertaking further non-standard measures for repairing monetary policy transmission in the Euro Area.
Feb 2013	-1.34	0	QoQ EA real GDP growth contracting since H2:2012 and likely to stay weak. Loan growth to non-financial sectors also remained negative. Prices were hovering around 2% target.	
Jan 2015	-1.76	0	Lacklustre economic growth accompanied by low credit growth. In addition, weak inflation dynamics due to fall in energy prices.	ECB announced Extended Asset Purchase Programme (APP). Targeted LTRO pricing to be reduced by removing spread over MRO.
Oct 2015	-1.43	0	Real GDP growth continued its recovery in 2015, but was likely to decline owing to weaker foreign demand. Inflation remained near zero, but was expected to rise due to base effects.	ECB credited asset purchases with reducing cost of borrowing for firms and households in the Euro Area. Reaffirmation of APP to run till Sep 2016.
Dec 2015	3.44	-10bps EDF	ECB,"Today's decisions were taken in order to secure a return of inflation rates towards levels that are below, but close to, 2% and thereby to anchor medium-term inflation expectations."	APP extended till Mar 2017. Journalist asked in the Q&A,"You've just explained your reasoning, but nevertheless, financial markets appear to be disappointed."
Dec 2016	-1.24	0	Economic growth continued into Q4:2016. It was further expected to expand at a "moderate but firming pace."	Reduced pace of APP from €80 billion until Mar 2017 to €60 billion until the end of Dec 2017 or beyond, if necessary. However, the ECB committed to increasing the pace if the outlook became less favourable, or if financial conditions became inconsistent.
Jun 2018	-1.42	0	Slow, but broad based real GDP growth. Inflation expected to remain below 2%, but expected to increase towards the end of the year.	Pace of APP to continue at €30bn. The ECB provided a roadmap for reducing pace of asset purchases. Further, it provided date and state dependent forward guidance on policy rates.

M.4 Asymmetric country risk factor

Table M.22: Ten largest surprises in asymmetric country risk factor

Date	Surprise	Rate Change	Introductory Statement	Notes
Aug 2011	1.97	0	ECB concerned about deceleration in real GDP growth. Short-term inflation was a concern with risks to its medium-term outlook on the upside.	Longer-term refinance operations (LTRO) with three and six months maturity. MRO to continue to be conducted at fixed rate with full allotment until Jan 2012. However, none of these announcements reduced sovereign spreads that were already high since the EU summit on Jul 21.
Dec 2011	3.14	-25bps	Dampened economic growth as well as outlook due to financial market tensions. Going forward, downward revision in 2012 real GDP growth.	Introduced liquidity enhancing measures to improve financial conditions. These included a three year LTRO, reducing the rating threshold for certain asset-backed securities (ABS) and reducing the reserve ratio. Despite these assurances, yield spreads increased.
Jul 2012	3.28	-25bps	Real GDP growth remained weak. Risks to higher inflation were subsiding.	ECB president pointed to tensions in some euro area sovereign debt markets. However, no additional measures were discussed by the Governing Council to tackle fragmentation in financial markets.
Aug 2012	6.21	0	Real GDP growth remained flat and was expected to remain weak. Inflation was expected to decline below the 2% target well into 2013. ECB additionally commented on the irreversibility of the Euro, "Risk premia that are related to fears of the reversibility of the euro are unacceptable, and they need to be addressed in a fundamental manner. The euro is irreversible."	Italian and Spanish yields jumped higher during the press conference while German yields declined.
Sep 2012	-3.18	0	Economic growth remained weak, inflation above 2%, but likely to subside in the medium term. Heightened uncertainty in financial markets.	The ECB introduced Outright Monetary Transactions (OMT) for secondary bonds, "OMTs will enable us to address severe distortions in government bond markets which originate from, in particular, unfounded fears on the part of investors of the reversibility of the euro." This announcement was effective in reducing sovereign bond spreads.
Jan 2013	-1.74	0	Economic weakness in the euro area was expected to continue well into 2013. Inflation declined from summer of 2012, owing to a cooling of oil prices.	ECB highlighted that accommodative monetary policy will further reduce fragmentation. Moreover, it was "not thinking about an exit" for non-standard policies that were introduced to reduce fragmentation in the euro area financial markets.
Jul 2013	-3.10	0	Economic growth, labour market, and credit expansion remained subdued. There was an emergence of a few green shoots of economic growth. Inflation is likely to remain below 2%.	ECB focussed on improving transmission of monetary policy by further reducing fragmentation of Euro Area credit markets.
Dec 2015	2.17	-10bps EDF	ECB, "Today's decisions were taken in order to secure a return of inflation rates towards levels that are below, but close to, 2% and thereby to anchor medium-term inflation expectations."	A journalist in the Q&A asked, "You've just explained your reasoning, but nevertheless, financial markets appear to be disappointed." Sell-off in bond markets, with Italian and Spanish yields increasing more than the German yields.
Jun 2018	-2.41	0	Slow, but broad based real GDP growth. Inflation likely to remain below 2%, but expected to increase towards the end of the year.	The ECB stressed that the situation in sovereign bonds was localised and not as extreme as the 2011 episode associated with redenomination risk. Sovereign yields of Italy declined more than all other major member countries.
Sep 2019	-1.98	-10bps	Inflation remained far from the 2% target. Outlook for real GDP growth and inflation revised downwards.	ECB restarted the Asset Purchase Programme (APP). Italian and Spanish yields declined while French and German yields increased.

N Non-conventional monetary policy in the euro area

Since the Global financial crisis, the ECB has adopted a number of non-conventional monetary policy measures.

Long-term refinancing operations (LTROs) aimed at providing liquidity to the financial system have been carried out more frequently, including very longer-term refinancing operations (VLTROs), with maturities of up to three years, conducted from December 2011 to February 2012.

Since September 2014, the ECB has conducted three series of targeted longer-term refinancing operations (TLTROs), designed to stimulate bank lending to the real economy. During the COVID-19 pandemic, the pandemic emergency longer-term refinancing operations (PELTROs) provided emergency liquidity to the money markets.

The Outright Monetary Transactions (OMT) is a programme allowing for conditional purchases of sovereign bonds in secondary markets, introduced in line with President Draghi's July 2012 commitment to do 'whatever it takes' to preserve the euro. It was never activated but provided a backstop to countries under market pressures.

The ECB's first explicitly defined quantitative easing programme with a price stability goal, the asset purchase programme (APP), was launched in March 2015. Additional ECB asset purchase programs initiated in 2014 include (i) the corporate sector purchase programme (CSPP), (ii) the public sector purchase programme (PSPP), (iii) the asset-backed securities purchase programme (ABSPP), (iv) the third covered bond purchase programme (CBPP3), and (v) the pandemic emergency purchase programme (PEPP). Further details are available on the ECB website.

The ECB has adopted different types of conditional forward guidance, providing at different points in time guidance about the path of the policy rates or of the asset purchases. The ECB's first instance of forward guidance was in July 2013, when the Governing Council said that it expected 'interest rates to remain low for an extended period of time'.

In June 2014, the ECB became the first major central bank to adopt a negative interest rate policy (NIRP), setting one of its key rates below zero. NIRP was maintained until September 2022.

The Transmission Protection Instrument (TPI), approved in July 2022, is an additional instrument in the ECB toolkit, that can be activated 'to counter unwarranted, disorderly market dynamics that pose a serious threat to the transmission of monetary policy across the euro area'. In the event of market tensions causing some countries to experience sharp deteriorations in financing conditions, 'not warranted by country-specific fundamentals', the ECB can make targeted secondary market purchases of securities of those countries.

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