Monetary Policy Spillovers Beyond Currency Area*

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Abstract

This paper examines how monetary policy shocks from the European Central Bank (ECB) and the US Federal Reserve (Fed) transmit to economies operating under different exchange rate regimes. Using a dynamic term structure model that allows for nonlinearities around the effective lower bound, I decompose sovereign bond yields for eight economies neighboring the euro area into an expectations component and term premium, and recover shadow short rates during policy-constrained periods. I combine these estimates with high-frequency monetary policy surprises from the ECB and the Fed to identify three transmission channels: aggregate demand, exchange rates, and financial. I find that exchange rate flexibility does not fully insulate recipient economies from foreign monetary policy shocks, as financial markets adjust the expected path of domestic policy rates following both ECB and Fed surprises. The strength and composition of these spillovers vary across exchange rate regimes, maturities, and shock types. These findings highlight the limits of monetary policy insulation in small open economies and provide evidence on the international transmission of conventional and unconventional monetary policy.

Keywords: monetary policy spillovers, term structure, term premia, exchange rate regimes

JEL classification: E43, E52, F33, F4

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1 Introduction

In an interconnected global economy, where macroeconomic activity and asset prices are increasingly synchronized, the conduct of monetary policy by the European Central Bank (ECB) extends far beyond the boundaries of the euro area. The international spillovers of ECB policy decisions to foreign interest rates are sizable and have strengthened over time (Kearns et al., 2023). Nonetheless, the literature on the identification of the specific channels through which these cross-border spillovers operate remains limited and is often confined to transatlantic linkages, i.e. between the euro area and the United States (US), (e.g. Jarociński, 2022), or to global aggregates (e.g. Miranda-Agrippino and Nenova, 2022).

This article contributes to the literature by providing new evidence on the mechanisms through which ECB and Federal Reserve (Fed) monetary policy surprises affect foreign bond yields, focusing on euro area neighboring economies. In particular, I study to what extent flexible exchange rate regimes may insulate from such spillovers. Czechia, Hungary, Poland, Denmark, Sweden, Norway, Switzerland and the United Kingdom constitute an ideal testing ground as they all exhibit a high level of financial and real integration with the euro area, while maintaining varying degrees of monetary independence. Despite the particular position of these economies in the international monetary system, they have received limited attention in the literature as a group.

Identifying spillover channels from origin to destination requires to mobilize several key ingredients that are central to my analysis. First, as for the origin side, I estimate ECB and Fed monetary policy surprises, purged of information effects relying on a high-frequency identification strategy. Second, as for the destination side, I estimate a dynamic term structure model to decompose bond yields into an expectations component and term premia. This approach allows me to disentangle market risk pricing from the expected path of future short-term interest rates, two components that remain otherwise unobserved. Combining these two elements enables a precise identification of the channels through which monetary policy is transmitted across borders.

The results show that monetary policy surprises originating from the ECB and the Fed operate through distinct transmission channels, with the relative importance of these channels depending on the surprise (or shock) type (i.e. target, path, and long-rate) and the exchange rate regime (fixed or flexible). In particular, I find that in pegged economies, the yield curves tend to mimic the reaction of the euro area yield curve, albeit to a lesser magnitude. For ECB *target* surprises, the response of yield curves in fixed exchange rate (pegged) economies is concentrated in the expectations component, whereas the yield curve reaction in flexible exchange rate (floating) economies is less systematic. However, both pegged and floating economies exhibit positive yield responses to ECB *path* surprises, largely driven by expectations, with these effects being the strongest at short-to-medium

maturities and fading toward the long end. Finally, floating economies respond to ECB *long-rate* surprises mainly through higher term premia, while the response of pegged economies is weaker and more concentrated in expectations. Taken together, these results indicate that exchange rate flexibility does not fully insulate my sample of euro area neighboring economies from ECB monetary policy shocks, as markets re-price the path of short-term interest rates. When it comes to Fed monetary policy surprises, I find that *target* surprises generate relatively limited spillovers, while *path* and especially *long-rate* surprises produce more persistent yield responses; for pegged economies, these effects increasingly operate through term premia, whereas floating economies generally display weaker responses.

In addition, I show that ECB *target* surprises exhibit asymmetric spillovers across exchange rate regimes. Pegged economies respond primarily to easing surprises, whereas floating economies respond negatively to tightening surprises. This negative yield response is consistent with an aggregate-demand channel at play. Turning to Fed *long-rate* surprises, pegged economies respond significantly to easing surprises, while floating economies respond significantly to tightening surprises. In both cases, the response is transmitted predominantly through term premia, pointing to a financial transmission channel. By contrast, conditioning on the monetary policy cycle in recipient economies explains only a limited share of the heterogeneity in shock transmission.

These findings have important implications for monetary policy in small open economies. Exchange rate flexibility does not provide full insulation from foreign monetary policy shocks. Even under *de jure* floating regimes, financial markets substantially reprice the expected path of domestic policy rates following foreign monetary policy announcements. This response is qualitatively similar to that observed in pegged economies and is consistent with an active exchange rate channel of international monetary transmission. The results suggest that monetary autonomy under flexible exchange rates may be more limited than implied by the exchange rate regime alone.

Related literature

This article contributes to the growing literature on the international transmission of monetary policy to asset prices. Much of the early research focused on the domestic effects of US monetary policy surprises, and to a lesser extent to ECB monetary policy, on long-term interest rates under both conventional and unconventional policy regimes[1]. Building on this foundation, a more recent strand of research examines the international transmission of monetary policy from major central banks, particularly the Federal Re-

[1]Studies for the US include, among others, Hanson and Stein (2015); Krishnamurthy and Vissing-Jørgensen (2011); Gagnon et al. (2011); Bauer and Neely (2013); Bauer and Rudebusch (2014). For the euro area, related work includes Krishnamurthy et al. (2018), Altavilla et al. (2015) and Odendahl et al. (2024)

serve, to small open economies. Gilchrist et al. (2019) document that US monetary policy surprises significantly affect bond yields in emerging markets. Albagli et al. (2019) identify the channels through which US monetary policy spillovers are transmitted and show that US spillovers have strengthened since the global financial crisis. Their results suggest that spillovers primarily operate through the risk-neutral rate in advanced economies and through term premia in emerging markets, consistent with the presence of foreign exchange intervention. Beyond bond yields, other studies explore the transmission of monetary policy to exchange rates and foreign equity prices (e.g., Kim and Nguyen, 2009, Wongswan, 2006, 2009; Ammer et al., 2010; Brusa et al., 2020; Aizenman et al., 2016). A related body of work investigates the effects of global monetary shocks on macroeconomic outcomes, including output and inflation (e.g. Craine and Martin, 2008; Hausman and Wongswan, 2011; Georgiadis, 2016).

My work extends this literature along several dimensions. First, I identify the effects of monetary policy spillovers across the *entire* yield curve. My analysis is closely related to Albagli et al. (2019) but differs in several important respects. I explicitly compare spillovers originating from the US and the euro area, employ a decomposition that accounts for the effective lower bound (ELB), consider surprises of different natures, and examine a broader range of maturities. In this respect, the paper is also closely related to Kearns et al. (2023). However, by exploiting the yield curve decomposition, I am able to identify the channels through which spillovers operate and uncover new evidence on their transmission mechanisms. Second, I address a gap in the literature by focusing on a set of countries that are highly integrated with the euro area. These results complement those of Corsetti et al. (2026), who find that ECB monetary policy surprises spillover effects do not differ between pegged and floating economies. This regional focus provides a useful laboratory for studying the transmission of both US and euro area monetary policy surprises. Third, I provide novel a decompositions of bond yields and model-implied shadow rates for countries that have received little attention in the literature, including Czechia, Hungary and Poland. These estimates offer new evidence on the term structure dynamics and on the mechanism of monetary policy transmission in Central and Eastern European economies.

2 Through which channels do monetary policy spillovers operate?

In this section, I briefly review the main channels through which monetary policy shocks propagate across borders. To do so, a recipient economy is defined as the economy that receive cross-border monetary policy spillovers, while a originator economy is the economy in which the monetary policy surprise takes place. The conditional response of

the recipient economy's yield curve to an external monetary policy shock is informative about market perceptions of risk and domestic monetary policy reaction. Accordingly, yield curve dynamics can shed light on the relative importance of several transmission mechanisms: the information channel, the aggregate demand channel, the exchange rate regime channel, and the financial channel.

First, comovements in global asset prices around Federal Open Market Committee (FOMC) or ECB Governing Council announcements may reflect financial markets' responses to newly revealed information about US or euro area macroeconomic conditions (Campbell et al., 2012; Nakamura and Steinsson, 2018; Jarociński and Karadi, 2020). As a result, spillovers through the *information channel* may affect the whole yield curve in recipient economies. To the extent that such information is correlated with underlying fundamentals in other economies, yield curves may move in tandem even in the absence of direct causal spillovers (Albagli et al., 2019). Consistent with this interpretation, Jotikasthira et al. (2015) show that comovement in yield curves across advanced economies largely reflects exposure to common global factors.

Second, the *aggregate demand channel* represents a causal mechanism through which monetary policy spillovers derive from real economic integration. A contractionary monetary policy shock in the originator economy reduces domestic consumption and investment, thereby lowering demand for imported goods. This decline in external demand adversely affects exports, output, and inflation in trading partner economies. Anticipating weaker economic conditions, market participants revise their expectations about the future path of monetary policy in the recipient economy, leading to downward adjustments in expected short-term interest rates. As a result, the entire yield curve may shift through changes in expected future policy rates. The magnitude of spillovers through this channel depends on the importance of the originator economy in the recipient's trade structure, in particular on the weight of the originator in its trading partners' overall trade (Ca'Zori et al., 2023).

Third, international transmission may occur through the *exchange rate regime channel*. Monetary authorities in recipient economies may adjust policy rates in response to actions by major foreign central banks in order to mitigate exchange rate fluctuations driven by interest rate differentials. Such policy responses are often motivated by concerns about exchange rate pass-through to inflation or by trade competitiveness considerations. Spillovers are particularly strong under fixed or tightly managed exchange rate regimes. When a recipient economy pegs its currency to that of a larger economy, changes in the originator's policy rate necessitate corresponding adjustments in domestic interest rates to preserve the peg. Even in the absence of immediate policy action, credible and persistent pegs can induce comovements along the yield curve as market expectations align domestic rates with those of the anchor currency.

Finally, the *financial channel* has gained prominence alongside increasing global fi-

nancial integration. Expansionary monetary policy in major economies can induce investors to rebalance their portfolios toward higher-yielding foreign assets, amplifying the cross-border transmission beyond the standard Mundell–Fleming framework through adjustments in risk premia. In integrated financial markets, changes in bond term premia in large economies spill over internationally through portfolio reallocations and global capital flows. This mechanism, also called the *risk-taking channel* is reinforced by the behavior of global financial intermediaries and their balance sheet constraints (Bruno and Shin, 2015; Malamud and Schrimf, 2018). Therefore, spillovers operating through the financial channel become more evident at longer maturities, where movements in term premia play a dominant role.

3 Identification strategy and data

To identify channels of international monetary policy spillovers, I rely on two key ingredients. First, I decompose government bond yields of recipient economies into expectations and term premia components using an arbitrage-free term structure model. Second, I exploit high-frequency monetary policy surprises from the Fed and the ECB that are purged of information effects.

Under standard asset-pricing theory and no-arbitrage assumptions, nominal yields can be decomposed into two latent components: an expectations component, reflecting market expectations of future short-term policy rates, and a term premium, compensating investors for bearing interest rate risk as well as for supply and demand imbalances in bond markets. Formally, the yield on a zero-coupon bond of maturity τ satisfies

$$y_t^\tau = EXP_t^\tau + TP_t^\tau \tag{1}$$

I combine this decomposition with high-frequency monetary policy surprises identified around policy announcements. To *clean* these shocks from information effects, I follow the "poor man's" identification strategy of Jarociński and Karadi (2020), which exploits the joint behavior of interest rates and equity prices. This strategy allows to discard the *information channel* presented in the previous section.

The conditional response of recipient-country yields and of their components to monetary policy surprises originating in the US or the euro area provides a mapping of the transmission channels discussed earlier and summarized in Table 1. Following a contractionary monetary policy surprise, a positive response of the expectations component is consistent with spillovers operating through the exchange rate regime channel, as markets anticipate policy tightening in the recipient economy. In contrast, a negative response of the expectations component points to an adverse aggregate demand channel, reflecting weaker external demand and lower expected future policy rates. Finally, movements in

term premia identify spillovers operating through the financial channel, capturing international portfolio rebalancing and changes in risk compensation.

	Exchange rate	Aggregate demand	Negative Risk-taking	Positive Risk-taking
Expectations component, EXP	+	−	.	.
Term Premia, TP	.	.	+	−

Table 1: Identification strategy

3.1 Fed and ECB monetary policy surprises

In this section, I describe the empirical strategy used to estimate monetary policy surprises in both the United States and the euro area. I follow the approach of Miranda-Agrippino and Nenova (2022), which builds on the long-established methodology introduced by Kuttner (2001) and Gürkaynak et al. (2010), and exploits high-frequency financial market responses around monetary policy announcements. By focusing on a narrow intraday window, this approach ensures that the observed price revisions can be attributed primarily to monetary policy surprises.

Following Miranda-Agrippino and Nenova (2022), I decompose monetary policy surprises into three orthogonal factors that capture the multidimensional nature of ECB and the US Federal Reserve policy actions, using the factor-rotation methodology proposed by Swanson (2021). First, the *target* factor captures surprises that load predominantly on the short-term policy rate. Near the ELB, this factor exhibits low variation. Second, the *path* factor captures surprises that primarily affect market expectations of medium-term interest rates and is naturally associated with forward guidance. As emphasized by Miranda-Agrippino and Nenova (2022), this factor may also incorporate elements of the signaling channel of quantitative easing (Krishnamurthy and Vissing-Jørgensen, 2011). Third, the *long-rate* factor captures movements in long-term interest rates that cannot be explained by changes in shorter maturities; therefore it represents the residual component not explained by the path factor.

High-frequency intraday price changes are obtained from Acosta et al. (2025) for US contracts and from Altavilla et al. (2018) for the euro area. Both datasets include price changes around monetary events over a tight time window[2]. In appendix A.1, I provide

[2]Monetary events include statements and press conferences. For the Fed events, the window length is 100 minutes and spans from 10 minutes before the statement release to 60 minutes after the beginning of the press conference. When no press conference took place, the statement window is used. For the ECB events, the window length is between 110 and 125 minutes long.

	MP1	MP2	ED2	ED3	ED4	UST2Y	UST5Y	UST10Y
Target	1	0.91	0.63	0.50	0.35	0.41	0.30	0.22
Path	0	0.31	0.80	0.93	1	0.97	0.93	0.81
Long-rate	0	-0.26	-0.38	-0.32	-0.24	0.02	0.66	1

Table 2: Loadings of Fed monetary policy factors

Notes: Factors extracted as Swanson (2021). The sample includes 268 FOMC announcements from Feb-1994 to Oct-2025.

	OIS-1M	OIS-3M	OIS-1Y	OIS-2Y	OIS-5Y	OIS-10
Target	1	0.91	0.53	0.35	0.23	0.08
Path	0	0.39	1	1.12	1.11	0.94
Long-rate	0	-0.30	-0.23	0.01	0.46	1

Table 3: Loadings of ECB monetary policy factors

Notes: Factors extracted as Swanson (2021). The sample includes 312 ECB Governing Council announcements from Jan-1999 to Oct-2025.

the procedure that I used to rotate the factors to economically interpretable surprises. Tables 2 and 3 report the factor loadings on the interest rate contracts used in the estimation. The estimated loadings align closely with the theoretical interpretation of each factor: the target factor declines monotonically with maturity; the path factor exhibits a hump-shaped pattern, with its largest loadings at intermediate maturities; and the long-rate factor loads most heavily on long-term contracts. The factors are normalized at these reference maturities to ease interpretation. To achieve identification, I set to zero by construction the loadings of both the path and long-rate factors on the shortest-maturity contracts.

Once the rotated factors are constructed, I further isolate *pure monetary policy* news from *information* effects using the "poor man's" identification of Jarociński and Karadi (2020) [3]. In this way, I am able to distinguish two effects based on the comovement between stock prices and yield curve contracts as predicted by economic theory: a positive correlation points to an information news, while a negative correlation points to a pure monetary policy surprise. The later corresponds to the upper left and lower right panels in Figure 6 and 7. In this "poor man"'s identification, a surprise cannot embed both pure monetary policy news and information news at the same time. Note that surprises are

[3]The existence of a monetary-policy information effect remains debated in the literature. Bauer and Swanson (2023) argue that much of the apparent effect captures the response from the Fed and private agents to the same public information rather than the discoluse of private central-bank information. Hoesch et al. (2023) find that evidence of the information channel is time-varying and has weakened substantially in more recent periods. Overall, the evidence suggests that the information effect may exist, but is neither stable nor as strong as initially thought.

not significantly correlated across jurisdictions (Table 7). I also discard joint monetary policy events that occurred on 13 and 17 September 2001, and on 8 October 2008 as well as those occuring on Sundays. For the Fed, 53% of the monetary policy surprises are pure monetary policy news for the target, 63% for the path, and 50% for the long-rate, against 51%, 57%, and 49%, respectively, for the ECB. This aligns with the results of Miranda-Agrippino and Nenova (2022), for which ECB surprises contain more information news than those of the Fed. Jarociński and Karadi (2020) argue that the more transparent communication strategy adopted by the ECB may be at the origin of this difference.

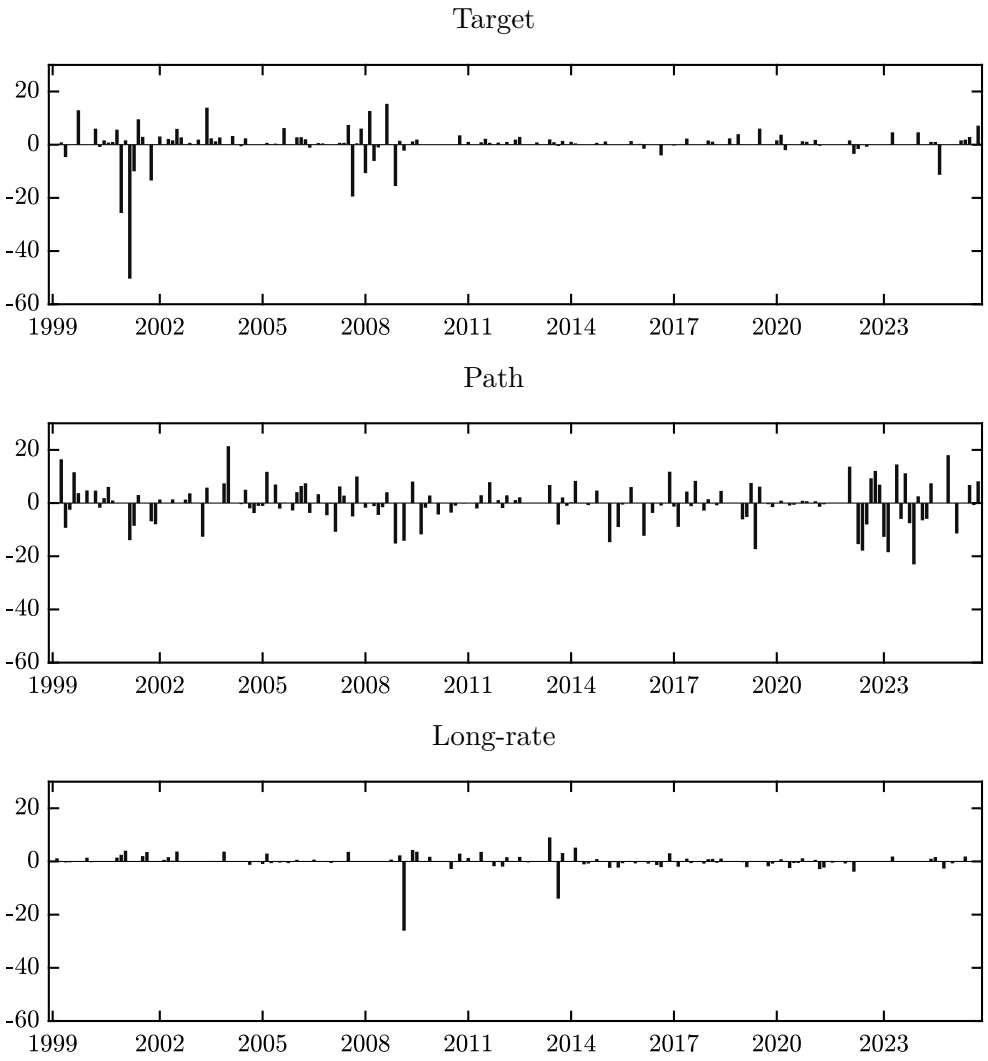


Figure 1: Fed *pure* monetary policy surprises

Figures 1 and 2 display, for each jurisdiction, the time series of the three monetary policy factors purged of information effects. My estimation extends the monetary policy surprises provided by Miranda-Agrippino and Nenova (2022)[4], by including additional

[4]Few methodological elements differ from Miranda-Agrippino and Nenova (2022). First, following Altavilla et al. (2015), I use German government bond yields at the 2-, 5-, and 10-year maturities prior to August 2011. Second, the raw futures-based surprises differ between both papers, as I rely on

years. Since the global financial crisis, Fed target surprises are generally small in magnitude, whereas the path factor gains prominence, particularly from the pandemic onward and during the most recent tightening cycle. The largest surprise I observe over this period occurs at the December 2023 FOMC meeting, which was widely perceived as a dovish pivot following Chair Powell's statement that "rate hikes [were] not the base case anymore". Turning to the euro area, the post-pandemic period features sizable movements in all factors in particular during the 2022 tightening cycle. As such, the October and December 2022 ECB Governing Council meetings stand out as major path surprises in my estimates. At the October meeting, the ECB delivered a 75 basis points rate hike but accompanied it with relatively dovish communication. By contrast, President Lagarde used a hawkish tone in the December meeting despite a smaller rate increase. These examples support the view that the estimated surprises successfully capture key monetary policy events and the associated surprises. Overall, ECB monetary policy surprises are relatively evenly distributed between tightening and easing surprises. Approximately half of target, path and long-rate surprises are positive. For the Federal Reserve, target surprises are predominantly positive: 104 out of 143 observations are classified as tightening surprises. In contrast, path and long-rate surprises are more evenly split, with 88 and 64 positive observations, respectively, corresponding to 52% and 48% of their samples.

Outside scheduled monetary policy meetings, central banks also communicate through speeches and the publication of meeting minutes, both of which may affect financial markets and influence expectations regarding future policy (Altavilla et al., 2026; Istrefi et al., 2026). As a result, part of the information revealed at policy meetings may already be incorporated into asset prices. To assess the robustness of the baseline results, I expand the set of monetary policy events to include additional communication events whenever high-frequency financial data are available. For the United States, Acosta et al. (2025) provide high-frequency asset-price changes around the release of FOMC minutes. I treat these releases as additional monetary policy events and re-estimate the factor model using the augmented sample. Appendix Figure 8 shows that the shocks identified around FOMC minute releases are generally small relative to those observed around scheduled FOMC meetings. For the euro area, I include speeches by the ECB President and members of the Executive Board using the database compiled by Altavilla et al. (2026). I retain only speeches delivered during trading hours and for which all required interest-rate contracts are available. When a speech occurs on the same day as a Governing Council meeting, the meeting is retained and the speech is excluded. I then re-estimate the monetary policy factors using the expanded set of event dates. Figure 9 shows that surprises associated

the updated monetary policy event-window data compiled by Acosta et al. (2025). Consequently, the events included in each of the databases do not entirely overlap. Despite this differences, my estimated monetary policy surprises are largely correlated with those Miranda-Agrippino and Nenova (2022). The correlation reaches 0.995, 0.961, and 0.591 for ECB target, path, and long-rate surprises, respectively. For the United States, the corresponding coefficients are 0.977, 0.926, and 0.894.

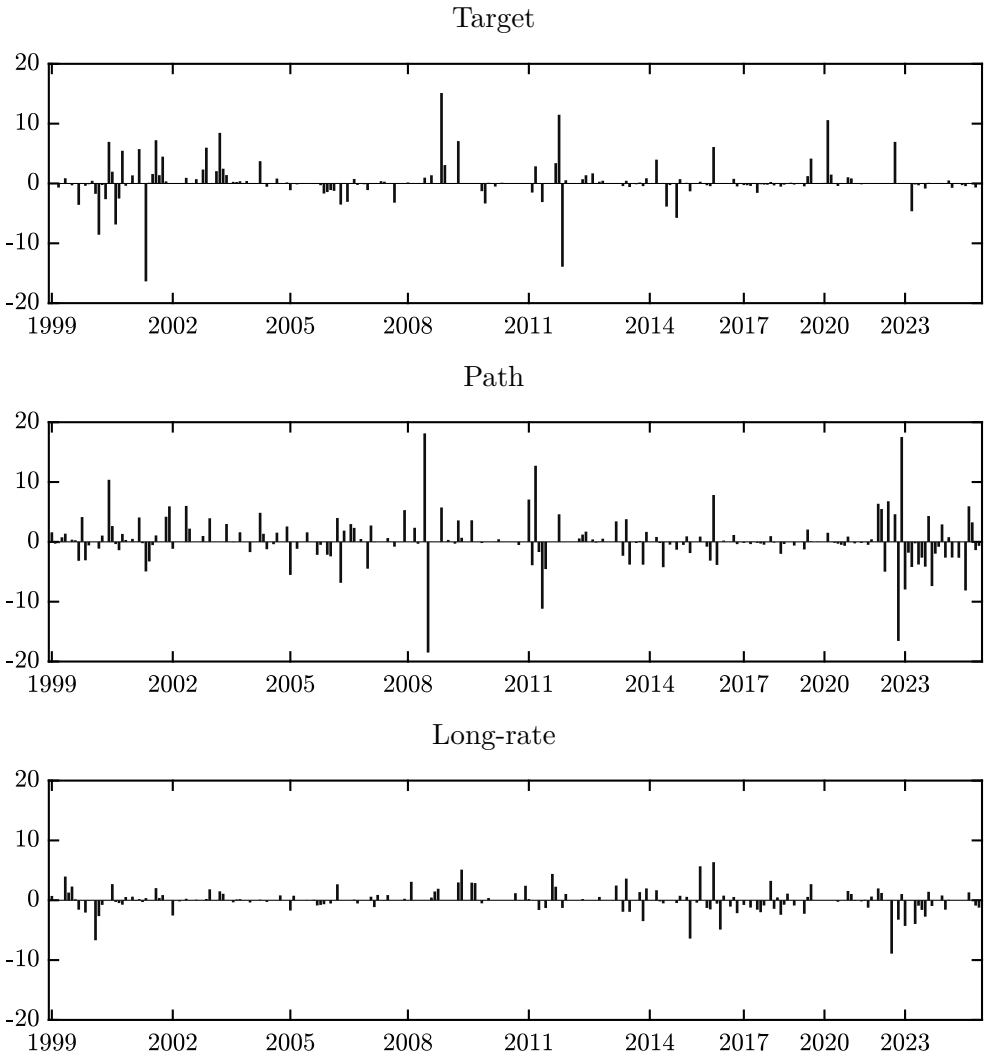


Figure 2: ECB *pure* monetary policy surprises

with unscheduled speeches by the ECB President and Executive Board members can be economically significant and span all three dimensions of monetary policy surprises: target, path and long-rate surprises.

3.2 Decomposing Bond Yields into Expectations and Term Premia

I estimate a shadow-rate term structure model with unspanned risk factors, following the frameworks of Joslin et al. (2014) and Wu and Xia (2016). Under no-arbitrage assumptions, this class of models implies that the cross-section of interest rates reflects expectations of future short rates. Therefore, the model is able to identify the otherwise *unobserved* expectations of the policy rate component, EXP, and to infer term premia, TP, from observed yields. I briefly review here the key aspects of the model.

I assume the existence of risk factors summarized in a K-dimensional state vector

X_t, which represents the new information available to market participants at time t. X_t follows a first-order Gaussian vector autoregression (VAR) under both the physical ($\mathbb{P}$) and risk-neutral measure ($\mathbb{Q}$):

$$X_t = \mu^{\mathbb{P}} + \Phi^{\mathbb{P}} X_{t-1} + \Sigma \varepsilon_t^{\mathbb{P}} \tag{2}$$

$$X_t = \mu^{\mathbb{Q}} + \Phi^{\mathbb{Q}} X_{t-1} + \Sigma \varepsilon_t^{\mathbb{Q}} \tag{3}$$

where $\varepsilon_t^{\mathbb{P}}$ and $\varepsilon_t^{\mathbb{Q}}$ are *i.i.d.* $N(0, I)$ innovations under their respective probability measures. The existence of a risk-neutral probability measure $\mathbb{Q}$ follows from the no-arbitrage assumption, under which $\mathbb{Q}$ prices all traded financial assets. The link between the $\mathbb{P}$ and $\mathbb{Q}$ measures is characterized by the stochastic discount factor (SDF),

$$-\log M_{t+1} = r_t + \frac{1}{2}\lambda_t'\lambda_t + \lambda_t'\varepsilon_{t+1}^{\mathbb{P}} \tag{4}$$

where r_t denotes the observed short rate and λ_t is the market price of risk, capturing the additional expected return required per unit of risk in each of the surprise $\varepsilon_{t+1}^{\mathbb{P}}$. Formally, the parameters governing the physical and risk-neutral dynamics are related as follows:

$$\mu^{\mathbb{Q}} = \mu^{\mathbb{P}} - \Sigma\lambda_0, \quad \Phi^{\mathbb{Q}} = \Phi^{\mathbb{P}} - \Sigma\lambda_1 \tag{5}$$

where the market price of risk is assumed to be affine in the state vector, $\lambda_t = \lambda_0 + \lambda_1 X_t$. I estimate the $\mathbb{P}$-measure dynamics by ordinary least squares and parameterize the $\mathbb{Q}$-measure dynamics following Joslin et al. (2011)[5].

A key feature of the shadow-rate model is that the observed short-term interest rate is given by the maximum of the shadow rate s_t and a lower bound $\underline{r}_t$. Following Black (1995), I assume that

$$r_t = \max\Big(s_t, \underline{r}_t\Big). \tag{6}$$

The lower bound $\underline{r}_t$ is time-varying and depends on the level of the yield curve and survey-based expectations

$$\underline{r}_t = \min\Big(\underline{r}_{t-1}, 0, \mathbf{y}_t, r_{t+3}^{\text{survey}}\Big), \tag{7}$$

where r_{t+3}^{survey} denotes the three-month ahead consensus forecast of the short-term interest rate. The shadow rate is otherwise modeled as an affine function of the state variables X_t,

$$s_t = \delta_0 + \delta_1' X_t. \tag{8}$$

I follow the analytical approximation by Wu and Xia (2016) to price bond yields as

[5]In particular, $\Phi^{\mathbb{Q}}$ is determined by K roots, and I restrict the first and only non-zero element of $\mu^{\mathbb{Q}}$, being the unconditional $\mathbb{Q}$-mean of the short rate.

described in Appendix A.2. Data used for this analysis is detailed in Appendix A.3.

I augment the model with macroeconomic factors Z_t, of dimension $K_Z = 2 < K$, that capture real-economy dynamics relevant for monetary policy. As discussed in Appendix A.4, I motivate the selection of these variables by a Taylor-rule estimation. Specifically, I include one-year-ahead expected inflation, INF, and a linear combination of real activity indicators, denoted GRO.[6] These macroeconomic factors are included as *unspanned* in my model. As such, they are assumed not to contemporaneously affect the cross-section of yields but help predict future yields and, therefore, time variation in term premia. In Appendix A.4, I further examine the interaction between these macroeconomic variables and the yield curve and motivate their inclusion as unspanned factors in the model. I define $\mathcal{P}_t^s$, of dimension $K_\mathcal{P} = 3 < K$, as the first three *shadow* principal components of observed yields, which correspond to the shadow level, slope, and curvature of the yield curve[7]. These factors are *spanned* by yields and capture most of cross-sectional yield variation (Litterman and Scheinkman, 1991).

Following Joslin et al. (2014), under the physical probability measure, the dynamics can be specified jointly as a gaussian VAR

$$\begin{bmatrix} \mathcal{P}_t^s \\ Z_t \end{bmatrix} = \begin{bmatrix} \mu_\mathcal{P}^\mathbb{P} \\ \mu_Z^\mathbb{P} \end{bmatrix} + \begin{bmatrix} \Phi_{\mathcal{P}\mathcal{P}}^\mathbb{P} & \Phi_{\mathcal{P}Z}^\mathbb{P} \\ \Phi_{Z\mathcal{P}}^\mathbb{P} & \Phi_{ZZ}^\mathbb{P} \end{bmatrix} \cdot \begin{bmatrix} \mathcal{P}_{t-1}^s \\ Z_{t-1} \end{bmatrix} + \begin{bmatrix} \varepsilon_{\mathcal{P},t}^\mathbb{P} \\ \varepsilon_{Z,t}^\mathbb{P} \end{bmatrix} \tag{9}$$

while under the risk-neutral measure, the $\mathbb{Q}$ dynamics is

$$\mathcal{P}_t^s = \mu^\mathbb{Q} + \begin{bmatrix} \Phi_{\mathcal{P}\mathcal{P}}^\mathbb{Q} & 0 \end{bmatrix} \cdot \begin{bmatrix} \mathcal{P}_{t-1}^s \\ Z_{t-1} \end{bmatrix} + \varepsilon_{\mathcal{P},t}^\mathbb{Q} \tag{10}$$

Observed yields are fitted with measurement and misspecification errors

$$y_{n,t}^o = y^\mathbb{Q}(X_t, n; \Psi) + \nu_{n,t} \tag{11}$$

where Ψ is a vector of relevant parameters. The model is estimated by maximum likelihood using the factor extraction method by Golinski and Spencer (2024). This method allows to estimate a shadow rate model almost as easily and quickly as simple Gaussian models, while avoiding approximations used in previous approaches (e.g. Bauer and Rudebusch, 2016). The term premia is obtained as the difference between the fitted yields

[6] The activity measure combines output, unemployment growth and gaps, as well as industrial production growth.

[7] In this framework, the vector of risk factors X_t is not directly interpretable. I follow Golinski and Spencer (2024) and Lemke and Vladu (2017) to rotate the latent factors X_t to Gaussian shadow principal components, $\mathcal{P}_t^s$. Defining $\mathcal{P}_t = W' y_{n,t}$ the principal components of yields and $y_{n,t}^G = \bar{a}_n + \bar{b}_n' X_t$ the shadow Gaussian yields - that is the hypothetical yields that would prevail if the lower bound did not exist, I obtain the Gaussian shadow principal components as $\mathcal{P}_t^s = W' y_{n,t}^G$. This rotation transforms the factors into interpretable quantities (Golinski and Spencer, 2024). In practice, the principal components and the shadow principal components are highly correlated.

under the risk-neutral and the physical probability measure

$$\underbrace{\tau_{n,t}}_{\text{TP}} = \underbrace{y^{\mathbb{Q}}_{n,t}}_{\text{Fitted}} - \underbrace{y^{\mathbb{P}}_{n,t}}_{\text{EXP}} \tag{12}$$

I estimate the model separately for each recipient economy using end-of-month zero-coupon yields. Estimated parameters are reported in Table 22.

Overall, the fit is very good. As shown in Table 23, root mean squared errors are generally small, rarely exceeding 10 basis points, with an average slightly above 5 basis points across maturities and countries. Figure 10 compares the observed short rate with the model-implied shadow rate[8]. The two series diverge markedly for several jurisdictions during periods when the policy rate is constrained by the ELB. These economically meaningful differences highlight the relevance of estimating a shadow-rate model for the sample considered. The divergence between observed and shadow rates propagates along the entire yield curve. Table 24 shows that discrepancies between estimates from the standard Gaussian model and the shadow-rate specification are substantially amplified during ELB episodes, supporting the economic relevance of the shadow-rate framework.

I report in Table 4, the variance decomposition of my estimates for 10y maturity. Except for Norway and Poland, term premia account for the majority of yield fluctuations, explaining between 40 and 89 percent of the variation in observed yields. Term premia are negatively correlated with inflation risk and with real activity, while they tend to be positively correlated with inflation expectations. Notable exceptions are Norway, Sweden, and the United Kingdom.

[8] In Appendix Figure 11, I report the sensitivity of the estimated shadow rates to different levels of r_s.

	Variance decomposition			Business cycle correlation	
	$\frac{\text{Var}[EXP_{10}]}{\text{Var}[y_{10}]}$	$\frac{\text{Var}[\text{TP}_{10}]}{\text{Var}[y_{10}]}$	$\frac{2\times\text{Cov}[EXP_{10},\text{TP}_{10}]}{\text{Var}[y_{10}]}$	$\text{Corr}(\text{TP}_{10},\text{GRO})$	$\text{Corr}(\text{TP}_{10},\text{INF})$
CZE	0.04	0.89	0.08	0.29	-0.10
DNK	0.12	0.49	0.39	0.28	-0.11
HUN	0.17	0.52	0.30	0.19	-0.37
NOR	0.33	0.23	0.44	-0.10	-0.07
POL	0.51	0.29	0.22	0.08	-0.28
SWE	0.16	0.40	0.44	-0.02	-0.04
CHE	0.12	0.48	0.39	0.45	0.00
GBR	0.24	0.63	0.12	-0.33	-0.06

Table 4: Variance decomposition and term premium variability

Notes: The table reports the variance decomposition of the 10y yields as well as the correlation of the 10y term premia with macro variables.

Using the monthly parameter estimates, I recover fitted yields at a daily frequency. Alike Lemke and Werner (2017), for any given day, the three principal components, $\mathcal{P}_t$, are constructed as $\mathcal{P}_t = W' y_{n,t}$, where W is a matrix 3×11 obtained from principal component estimation on monthly data over the estimation sample. My model also includes macroeconomic variables, which are linearly interpolated from monthly to daily frequency accounting for the day of macro release set[9]. These daily risk factors are then combined with the model equations to generate daily fitted yields, expectations components, and term premia. Table 25 shows that the transition from monthly to daily frequency introduces only negligible differences in fitted yields. The differences for the term premia are larger, which can be attributable to the indexation of macro variables to the daily information set. Figure 13 presents the daily 10-year yield decomposition for all countries, with dynamics consistent with the variance decompositions reported in Table 4. These daily components help me to identify the channels of transmission of international monetary policy spillovers.

4 Spillovers

This section examines the effects of ECB and Fed monetary policy announcements on the yield curves of euro area neighboring economies at the daily frequency. I formulate

[9]Data are indexed to the week of the typical date of macroeconomic release or survey date. Linear interpolation is used to construct smooth daily series between consecutive observations. This should be viewed as a temporal approximation rather than as implying that the interpolated values were observed in real time; it allows macroeconomic conditions to adjust gradually between successive monthly information dates rather than discretely on release dates.

four testable hypotheses that I empirically test in this section:

Hypothesis 1: Monetary policy surprises around ECB Governing Councils have a larger more effect on the yield curve of pegged economies than on the one of floating economies.

Hypothesis 2: Monetary policy spillovers to euro area neighboring economies are persistent.

Hypothesis 3: The cross-border transmission of monetary policy is symmetric across tightening and easing episodes.

Hypothesis 4: The monetary policy cycles in the recipient economy matter for spillovers.

4.1 Transatlantic spillovers

Before turning to the analysis of spillovers to euro area neighboring countries, I first examine how monetary policy surprises are transmitted from the Federal Reserve to the US and the euro area, and from the ECB to the euro area and the US. This exercise provides a benchmark for the remainder of the analysis. I estimate separate regressions for each originator-recipient pair of economies in order to compare spillovers from the shock-originating central bank (the Fed or the ECB) to the US or the euro area[10]. Specifically, I estimate:

$$\Delta y_{n,t,i} = \alpha_{n,i} + \sum_{s=1}^{3} \beta'_{s,n,i,j} \text{MPS}_{s;j,t} + \epsilon_{n,t,i} \tag{13}$$

where $\Delta y_{n,t,i}$ denotes the daily change between dates $t-1$ and t in yields at maturity n in the recipient economy $i \in US, EA$, and $\text{MPS}_{s,j,t}$ refers to the three measures of monetary policy surprises in the originator economy $j \in Fed, ECB$: *target*, *path* and *long-rate*, respectively. I interpret a positive realization of surprises as a monetary policy tightening shock. The surprises are normalized so that a 10 basis points surprise corresponds to an equivalent 10 basis points rate change (in the same monetary policy event window) in the 3-month (3m) contract for *target*, the 1-year (1y) contract for the *path* and the 10-year (10y) contract for *long-rate*. Note that $\hat{\beta}'_{.,n,i,j}$ represents the transition of the intraday surprise to daily frequency. For the US, I use the Treasury yield curve from Gürkaynak et al. (2007), while for the euro area I rely on the overnight index swap (OIS) curve. I report changes in 1y forward rate starting from 1 year from today (1y1y) up to 9y (1y9y). Additional details on the data are provided in the Appendix.

[10]My analysis accounts for time-zone differentials.

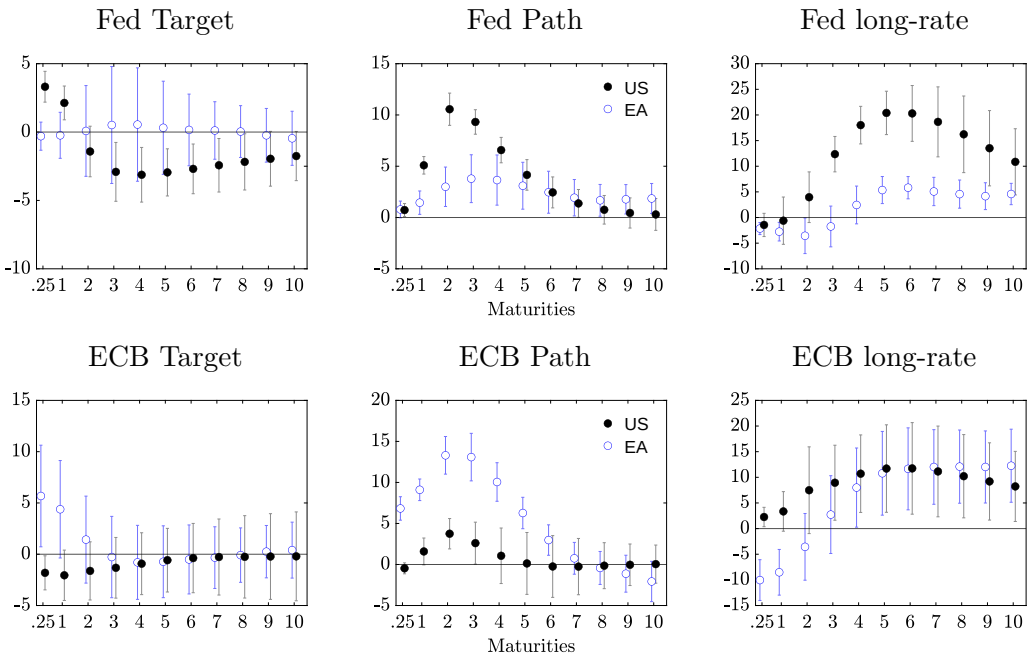


Figure 3: Fed and ECB monetary policy spillovers

Notes: Fed regressions include 202 observations, while 259 observations for ECB. Maturities refers to the 3m and 1y spot rates as well as 1y forward rates in 1 to 9y. Surprises are normalized to 10 basis points. HAC standard errors are reported.

Figure 3 reports the spillover effects on US and euro area forward curves following a Fed monetary policy tightening, distinguishing between *target*, *path*, and *long-rate* surprises. Each data point represents an estimated coefficient and its associated robust standard errors at the 95% confidence interval. Consistent with the identification strategy described in Section 3.1, *target* surprises primarily affect the short end of the US forward curve, *path* surprises exert their strongest influence on the intermediate maturities, and *long-rate* surprises predominantly impact the long end of the curve. Spillovers to the euro area are smaller in magnitude but statistically significant for *path* and *long-rate* surprises. In particular, a 10 basis points *path* surprise is associated with a 10 basis points increase in US 1y1y forward rate against a 3 basis points increase in euro area yields. Effects are stronger at the long end of the curve following a similar magnitude *long-rate* surprise lifting US 1y9y rates to 10 basis points. The euro area curve pivots with a significantly lower short-term rate and a higher long-term rates. This would reflect more expected near-term accommodation, but tighter long-term financial conditions above and beyond what is explained by Fed *target* and *path* surprises.

Turning to ECB surprises, Figure 3 shows a broadly similar pattern of domestic transmission along the euro area forward curve. However, a notable difference emerges in the transatlantic effects of ECB *target* surprises. While ECB *target* surprises do not significantly transmit to the US forward curve, ECB *path* and *long-rate* surprises do. As such, a 10 basis points ECB *path* surprise increase OIS forward rates at 1y1y by 13 basis points against 4 basis points for US forward rates. The sizable response of US yields to

	ECB			Fed		
	EUR/USD	NEER	Stocks	EUR/USD	NEER	Stocks
Effect on Euro Area						
Target	0.01	0.01	-0.17	0.02	-0.01	-0.03
	(0.03)	(0.01)	(0.11)	(0.01)	(0.01)	(0.02)
Path	-0.07**	0.00	-0.01	0.01	-0.02**	-0.01
	(0.01)	(0.01)	(0.03)	(0.01)	(0.00)	(0.02)
long-rate	-0.06	0.02	-0.14*	0.02	-0.04**	-0.05
	(0.06)	(0.02)	(0.07)	(0.01)	(0.01)	(0.03)
R^2	13.56	1.72	9.88	4.48	22.36	2.76
N	234	234	234	174	174	174
Effect on USA						
Target	0.00	0.01	-0.12	-0.01	0.00	-0.06**
	(0.02)	(0.01)	(0.07)	(0.02)	(0.00)	(0.02)
Path	-0.07**	0.00	0.02	0.05**	0.00	-0.06**
	(0.02)	(0.01)	(0.03)	(0.01)	(0.00)	(0.02)
long-rate	-0.04	-0.02	-0.12*	0.08**	0.01	-0.04
	(0.05)	(0.02)	(0.06)	(0.02)	(0.01)	(0.03)
R^2	10.82	0.94	6.79	32.52	1.58	20.38
N	259	259	259	202	202	202

Table 5: Market reactions

Notes: Standard errors are reported in parentheses. ** and * denote significance at the 1% and 5% levels, respectively. N denotes the number of observations.

ECB *long-rate* surprises should be interpreted with caution, as this factor captures residual movements in long-term interest rate expectations associated with ECB Governing Council announcements beyond those explained by changes at shorter maturities.

Table 5 shows the impact of ECB and Fed monetary policy surprises into exchange rates and stock markets. In general, monetary policy surprises appreciate local currency. Namely, a 10 basis points ECB *path* monetary policy surprise appreciates the euro against the US dollar by 7%, while a same magnitude Fed *path* surprise appreciates the dollar by 5%. Beyond bilateral exchange rates, the Fed monetary policy has also an effect on the Euro nominal effective exchange rate (NEER). Stock markets react negatively to monetary policy surprises consistent with the identification strategy of section 3.1, confirming the absence of information effects in these surprises.

	ECB					Fed				
	$h=0$	$h=5$	$h=10$	$h=15$	$h=20$	$h=0$	$h=5$	$h=10$	$h=15$	$h=20$
Effect on euro area										
Target, y^{3m}	0.60**	0.22	-0.12	-0.03	-0.35	0.03	0.09	-0.03	0.04	0.05
	(0.21)	(0.42)	(0.72)	(0.74)	(0.89)	(0.08)	(0.10)	(0.15)	(0.23)	(0.27)
Path, y^{1y1y}	1.35**	1.67**	1.72**	1.44**	1.56**	0.37**	0.49**	0.62**	0.54*	0.33
	(0.09)	(0.36)	(0.35)	(0.33)	(0.36)	(0.08)	(0.14)	(0.21)	(0.23)	(0.30)
long-rate, y^{1y9y}	1.33**	1.53*	1.96*	1.47	1.77	0.47**	0.40	0.02	0.01	0.01
	(0.32)	(0.61)	(0.79)	(0.79)	(0.92)	(0.16)	(0.29)	(0.40)	(0.47)	(0.46)
Effect on US										
Target, y^{3m}	-0.19*	-0.45	-0.82	-0.78	-0.74	0.32**	0.78**	0.67**	0.72**	0.85*
	(0.09)	(0.35)	(0.48)	(0.45)	(0.45)	(0.09)	(0.20)	(0.19)	(0.21)	(0.38)
Path, y^{1y1y}	0.38*	0.71	0.89	0.49	0.31	1.06**	0.76**	0.98**	1.04**	0.78*
	(0.16)	(0.49)	(0.49)	(0.46)	(0.55)	(0.08)	(0.20)	(0.30)	(0.35)	(0.38)
long-rate, y^{1y9y}	0.82*	0.22	0.54	0.60	1.25	1.09**	1.25**	1.19*	1.23*	0.72
	(0.33)	(0.65)	(1.14)	(1.16)	(1.44)	(0.30)	(0.31)	(0.47)	(0.48)	(0.47)

Table 6: Persistence of monetary policy shocks

Notes: The table reports local-projection estimates of the effects of ECB and Fed monetary policy shocks on euro area and US yields at horizons $h = 0, 5, 10, 15, 20$ business days. Each row reports the type of shocks and the response maturity. Newey-West standard errors are reported in parentheses. ** and * denote statistical significance at the 1% and 5% levels, respectively.

I further explore the persistency of these surprises beyond the same day persistence. I estimate

$$y_{n,t+h,i} - y_{n,t-1,i} = \alpha_{n,h,i} + \sum_{s=1}^{3} \beta'_{s,n,h,i,j} \text{MPS}_{s,j,t} + \epsilon_{n,t+h,i} \tag{14}$$

where $y_{n,t+h,i} - y_{n,t-1,i}$ denotes the cumulative change in asset prices over horizon h. The results are reported in Table 6 for the 3-month rate in the case of *target* surprises, the 1y1y forward rate for *path* surprises, and the 1y9y forward rate for *long-rate* surprises. As shown in Figure 3, these shock-tenor combinations are those for which the contemporaneous effects are most pronounced and most closely aligned with the identification of each surprise.

I find that *path* surprises originating from either the Fed or the ECB are highly persistent, affecting domestic interest rates for more than ten days across both short and long maturities. In contrast, spillover effects to foreign bond markets are limited and tend to revert quickly to zero. *Target* surprises display little persistence, either domestically or internationally. Fed *long-rate* surprises exhibit a persistent pivoting effect on the euro area yield curve, with short-term rates declining while long-term rates remain elevated before gradually reverting toward zero. By contrast, ECB *long-rate* surprises have only limited effects on US yields and show little persistence. Within the euro area, *long-rate* surprises also generate a pivoting response of the yield curve, characterized by declining short-term rates and rising long-term rates. These results give me a benchmark to evaluate the extent of international spillovers to non-euro neighboring economies.

Note that these results contrast with those of Miranda-Agrippino and Nenova (2022) that Fed surprises, when significant, have little contemporaneous effect on the euro area yield curve, irrespective of the type of surprise. The authors also find that when the *path* surprises originates from the ECB, US yields respond positively, whereas no significant response is found for ECB *long-rate* surprises, which differs from my results. This discrepancy could arise from differences in the identification of high-frequency *long-rate* monetary policy surprises.

Robustness. Figure 14 confirms that the baseline transatlantic spillover results are robust to a range of alternative specifications. In particular, I consider five robustness exercises. First, I allow for monetary policy surprises on days when both the ECB and the Fed hold policy meetings. Second, I replace the baseline shock measures with empirical surprises constructed directly from intraday changes in contract rates. Specifically, the target factor is given by the intraday change in the shortest-maturity contract (i.e., MP1 for the U.S. and OIS-1M for the euro area), the path factor by the component of the 1y rate change that is orthogonal to the target surprise, and the long-rate factor by the component of the 10y contract rate change that is orthogonal to the first two factors. Third, I augment the surprise series to include Fed minutes and ECB speeches, which

have been shown to contain economically meaningful information for domestic monetary policy (Altavilla et al., 2026; Istrefi et al., 2026). Fourth, I replace the "poor man's" identification strategy with the baseline rotational sign-restriction approach of Jarociński and Karadi (2020). Finally, I additionally control for changes in the VIX.

4.2 Fixed vs. flexible exchange rate regimes

Monetary policy surprises originating from the Federal Reserve and the ECB transmit beyond their respective jurisdictions. To quantify these spillovers and examine the underlying transmission channels, I estimate the following panel regression for euro area neighboring economies:

$$\Delta y_{n,t} = \alpha_n + \beta_{n,j}\text{MPS}_{j,t} + \theta'_{n,j}X_t + \epsilon_{n,t} \tag{15}$$

where X_t includes daily changes in the VIX and in the long-term interest rate of the originator economy. When the shock originates from the Federal Reserve, I orthogonalize the latter with respect to the monetary policy surprise to mitigate collinearity. Miranda-Agrippino and Rey (2020) show that US monetary policy generates financial spillovers to the rest of the world, including economies with floating exchange rates, and is therefore an important driver of the global financial cycle. The control variables are intended to absorb this channel by conditioning on changes in global financial conditions that could otherwise confound the estimated responses. The coefficient of interest, $\beta_{n,j}$, measures the average response of government bond yields in euro area neighboring economies to monetary policy surprises originating in jurisdiction j.

I estimate the specification separately for economies operating under fixed and flexible exchange-rate regimes at the time of the monetary policy announcement. All fixed exchange-rate regimes in my sample are pegged to the euro.. The peg sample includes Denmark throughout the sample period, Hungary until February 2008, Poland until April 2000, and Switzerland and Czechia during selected periods. This classification yields 441 observations around FOMC announcements and 582 observations around ECB Governing Council announcements, corresponding to approximately 32% of the respective samples.

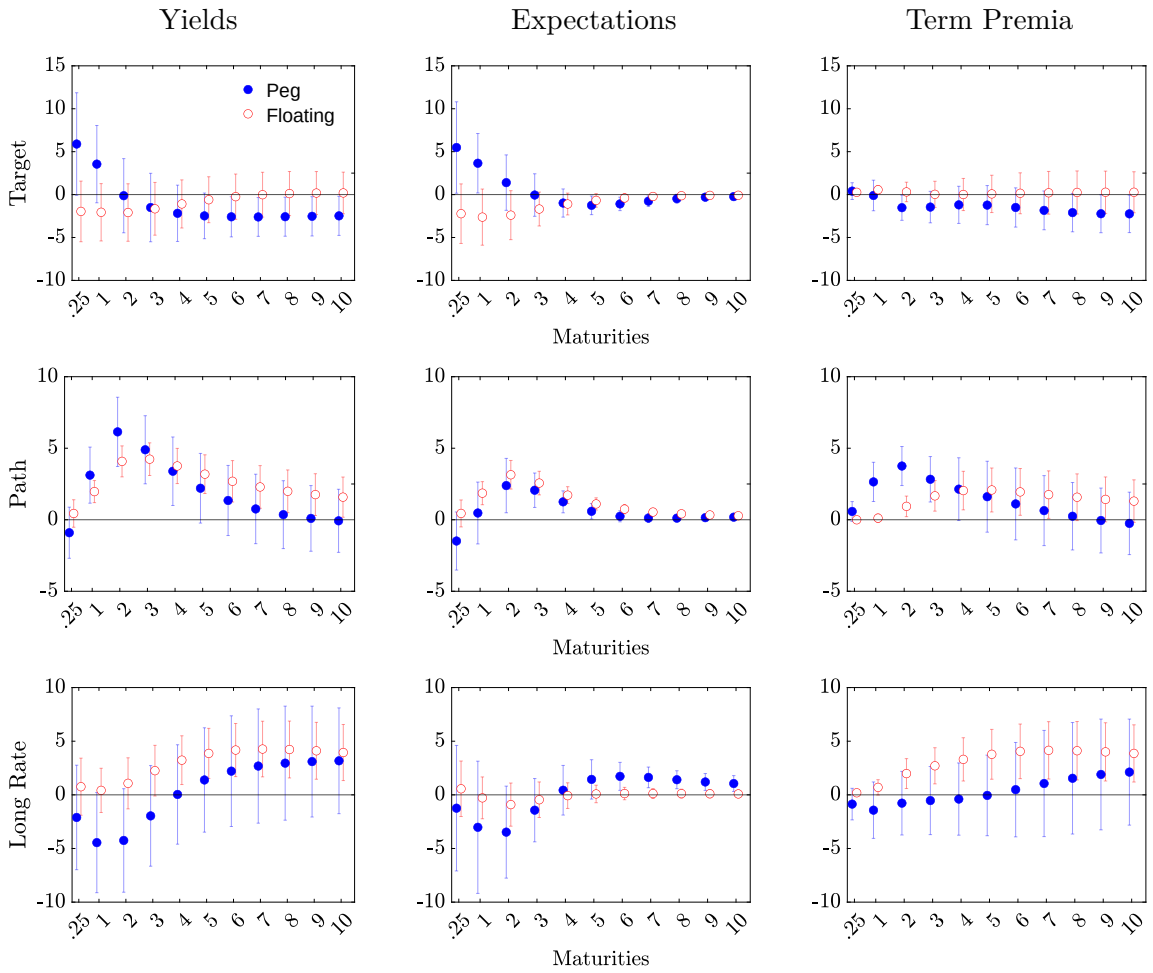


Figure 4: ECB monetary policy spillovers to neighboring countries

Notes: Regressions include 582 observations for pegged-currency economies and 1290 observations for floating-currency economies. Maturities include the 3m and 1y spot rates, as well as 1y forward rates from 1 to 9y ahead. Monetary policy surprises are normalized to 10 basis points. Driscoll-Kraay standard errors are reported.

Figures 4 and 5 report the estimated responses. The left panels show the effects on government bond yields separately for pegged and floating economies. Following ECB *target* surprises, short-term yields increase significantly in pegged economies, whereas the response in floating economies is small and statistically insignificant. This pattern is consistent with the standard *exchange-rate regime channel*: economies maintaining a peg must adjust domestic short rates to monetary policy surprises in the anchor economy.

ECB *path* surprises transmit more broadly. Forward rates increase in both pegged and floating economies, although by substantially less than in the euro area itself. At the relevant maturity, the response is about 13 basis points for the euro area OIS forward curve, compared with approximately 6 basis points in pegged economies and 4 basis points in floating economies. At longer maturities, floating economies display a small but statistically significant response that is absent both for pegged economies and for the euro area forward curve shown in Figure 3. Responses to ECB *long-rate* surprises are

similarly concentrated among floating economies, for which long forward rates increase significantly, while the response in pegged economies is not statistically different from zero. Overall, I cannot reject my first *hypothesis* that ECB monetary policy surprises have a larger effect on the yield curves of pegged economies than on those of economies with floating exchange rates. However, at the longest maturities, and when the surprise reflects either the policy path or long-term interest rates, the effects appear to be weakly stronger for economies with flexible exchange rate regimes.

To identify the mechanisms underlying these yield responses, I exploit the decomposition of yields into the expectations component and term premia described in Section 3.2. I re-estimate equation (15) using each component as the dependent variable. By construction, the sum of the two components equals the model-implied fitted yield, which closely tracks the observed yield. The middle and right panels of Figures 4 and 5 report the responses of the expectations component and term premia, respectively.

	ECB					Fed				
	USD	EUR	NEER	Stocks	Flows	USD	EUR	NEER	Stocks	Flows
Effects on Peg Economies										
Target	-0.02	0.00	0.00	-0.04	0.62	0.01	-0.00	-0.00	-0.04	0.06
	(0.02)	(0.01)	(0.01)	(0.03)	(0.51)	(0.01)	(0.00)	(0.00)	(0.03)	(0.35)
Path	-0.04*	0.01**	0.00	0.00	-0.27	0.06**	0.01*	-0.02**	-0.01	0.01
	(0.02)	(0.00)	(0.00)	(0.01)	(0.18)	(0.01)	(0.00)	(0.00)	(0.02)	(0.10)
long-rate	-0.12**	-0.01	0.01	-0.06	0.74	0.10**	0.00	-0.02*	-0.05*	0.24
	(0.04)	(0.01)	(0.01)	(0.04)	(0.74)	(0.02)	(0.01)	(0.01)	(0.03)	(0.22)
R^2	15.37	6.47	2.81	26.88	1.45	33.53	3.97	10.00	20.18	0.77
N	649	649	649	649	373	514	514	514	514	351
Effects on Float Economies										
Target	0.00	0.00	-0.01	-0.05	0.16	0.01	-0.01	0.00	-0.01	-0.78
	(0.02)	(0.01)	(0.01)	(0.04)	(0.50)	(0.01)	(0.00)	(0.00)	(0.02)	(0.95)
Path	-0.02	0.03**	-0.00	-0.00	-0.38	0.06**	0.01**	-0.02**	-0.02	0.38
	(0.01)	(0.01)	(0.00)	(0.02)	(0.53)	(0.01)	(0.00)	(0.00)	(0.01)	(0.43)
long-rate	-0.09*	-0.00	0.03*	-0.01	1.30*	0.11**	0.02	-0.04**	-0.12**	-0.29
	(0.03)	(0.02)	(0.01)	(0.05)	(0.65)	(0.02)	(0.01)	(0.01)	(0.02)	(0.55)
R^2	14.28	10.76	5.28	28.49	0.62	33.63	3.62	10.62	26.60	0.67
N	1423	1423	1423	1423	667	1102	1102	1102	1102	633

Table 7: Market reactions

Notes: The table reports estimates on LC/USD, LC/EUR, NEER, domestic stock market index and portfolio flows proxied by EPFR data. Standard errors are reported in parentheses. ** and * denote significance at the 1% and 5% levels, respectively. The number of observations is reported in the row labeled N.

The decomposition provides strong evidence of an *exchange rate regime channel* following ECB *target* surprises in pegged economies. The increase in short-term yields is

almost entirely explained by the expectations component, while term premia do not respond significantly. The modest response at longer maturities is accompanied by a small decline in term premia. This pattern is difficult to reconcile with a demand channel operating through higher term premia; instead, it is more consistent with a combination of expected monetary policy adjustment and, at longer maturities, a risk-taking mechanism.

ECB *path* surprises also operate importantly through expectations. Expected future short rates rise in both pegged and floating economies. The latter result is particularly informative. Even in economies that are formally floating, financial markets revise upward the expected *path* of domestic short rates following an ECB *path* surprise. Thus, *de jure* exchange-rate flexibility does not eliminate monetary policy comovement: conditional on an ECB surprise, markets price a domestic monetary policy response in the same direction. This provides evidence of an exchange-rate-related transmission channel even outside formal pegs.

Nevertheless, term premia contribute to the adjustment. In pegged economies, part of the response at the short end of the curve reflects higher term premia. By contrast, in floating economies, the term-premium response is more pronounced at longer maturities and accounts for part of the increase in long forward rates. ECB *long-rate* surprises provide the clearest evidence of this second channel: the increase in long-term rates in floating economies is driven primarily by term premia, consistent with a risk-taking channel.

The response of other asset prices to ECB surprises is consistent with the evidence from forward rates. Table 7 shows that the currencies of euro area neighboring economies appreciate against both the US dollar and the euro following ECB *path* and *long-rate* surprises. In contrast, local equity prices display no statistically significant response. These results suggest that the transmission documented in the yield curve is accompanied by an exchange-rate adjustment, rather than by a broad repricing of domestic risky assets.

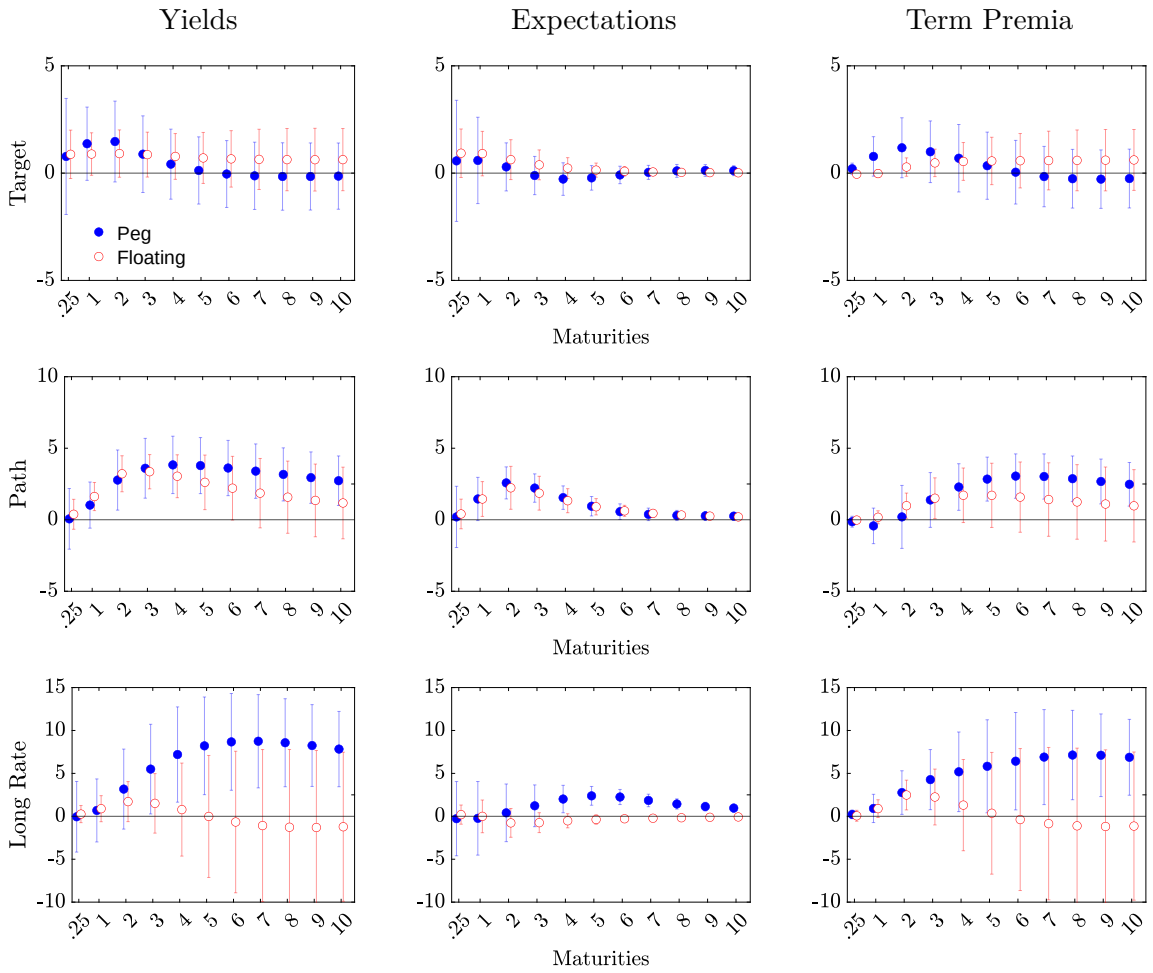


Figure 5: Fed monetary policy spillovers

Notes: Regressions include 441 observations for pegged-currency economies and 951 observations for floating-currency economies. Maturities include the 3m and 1y spot rates, as well as 1y forward rates from 1 to 9y ahead. Monetary policy surprises are normalized to 10 basis points. Driscoll-Kraay standard errors are reported.

Figure 5 shows that the distinction between pegged and floating economies is less pronounced following FOMC surprises. *Target* and *path* shocks generate broadly similar yield responses in both exchange rate regimes. As for ECB *path* surprises, Fed *path* shocks transmit partly through the expectations component, indicating that markets revise the expected *path* of monetary policy in recipient economies following changes in the expected *path* of US policy rates.

The main difference appears for Fed *long-rate* surprises. The response of yields in pegged economies is considerably larger and is concentrated at longer maturities. Both expectations and term premia contribute, but term premia account for the larger share of the adjustment. The magnitude is comparable to the response of the euro area yield curve: the euro area 1y9y forward rate increases by roughly 5 basis points and about 6 basis points in neighboring economies operating under a peg.

	ECB					Fed				
	$h=0$	$h=5$	$h=10$	$h=15$	$h=20$	$h=0$	$h=5$	$h=10$	$h=15$	$h=20$
Peg										
Target, y^{3m}	0.63*	0.62	0.26	0.38	0.09	0.10	-0.08	-0.13	-0.11	-0.04
	(0.25)	(0.44)	(0.54)	(0.57)	(0.70)	(0.12)	(0.09)	(0.13)	(0.16)	(0.19)
Path, y^{1y1y}	0.50**	1.46*	1.95**	1.26	1.38	0.44**	0.60*	0.56	0.16	0.05
	(0.13)	(0.66)	(0.60)	(0.86)	(1.33)	(0.10)	(0.29)	(0.38)	(0.48)	(0.57)
long-rate, y^{1y9y}	0.39	1.09	1.73	1.76	1.19	0.71**	0.45	-0.16	0.06	0.06
	(0.27)	(0.85)	(1.10)	(1.26)	(1.20)	(0.20)	(0.49)	(0.46)	(0.65)	(0.73)
Float										
Target, y^{3m}	-0.24	-0.78	-1.16*	-1.40	-2.08	0.08	0.10	-0.04	-0.10	0.01
	(0.15)	(0.43)	(0.47)	(0.81)	(1.14)	(0.04)	(0.06)	(0.10)	(0.15)	(0.12)
Path, y^{1y1y}	0.46**	1.28**	1.48**	1.04**	1.32*	0.39**	0.60**	0.75**	0.61*	0.43
	(0.08)	(0.27)	(0.32)	(0.35)	(0.55)	(0.07)	(0.16)	(0.20)	(0.28)	(0.30)
long-rate, y^{1y9y}	0.38*	0.88	1.43	1.48	1.07	-0.17	-0.34	-0.62	-0.26	-0.15
	(0.15)	(0.48)	(0.77)	(0.91)	(0.85)	(0.44)	(0.57)	(0.48)	(0.38)	(0.40)

Table 8: Monetary Policy Spillovers by Exchange Rate Regime

Notes: The table reports local-projection estimates of the effects of ECB and Fed monetary policy shocks on euro area and US yields at horizons $h = 0, 5, 10, 15, 20$ business days. Each row reports the type of shocks and the response maturity. Driscoll-Kraay standard errors are reported in parentheses. ** and * denote statistical significance at the 1% and 5% levels, respectively.

The persistence of these surprises is summarized in Table 8. Overall, the results indicate that *path* shocks are the most persistent across exchange rate regimes, with a somewhat greater persistence in economies with floating exchange rates. In contrast, *target* and *long-rate* surprises are relatively short-lived leading to rejection of my second *hypothesis*.

Beyond forward rates, I show in Table 7 that exchange rates respond significantly to Fed surprises, with local currencies depreciating against both the US dollar and in nominal effective terms. While equity prices ar considerably less responsive to *target* and *path* surprises, they decline following *long-rate* surprises, consistent with the stronger term-premium response documented at longer maturities. Across these asset-price responses, there is little systematic evidence of differences between pegged and floating economies.

Overall, the results point to two complementary transmission mechanisms. First, monetary policy surprises induce revisions in expected future short rates even in economies classified as floating. Therefore, exchange-rate flexibility is relative rather than absolute: financial markets price a systematic domestic monetary policy response to foreign monetary policy surprises. Second, term-premium responses, particularly following *long-rate* surprises, indicate an additional risk-taking or portfolio-rebalancing channel. Consistent with this interpretation, the yield curves of neighboring economies operating under a peg respond in a manner similar to that of the anchor economy, while floating economies remain exposed to foreign monetary policy through both expected policy rates and global term-premium movements.

Robustness. The baseline results are robust to a range of alternative specifications (see Figure 15). I conduct the same robustness checks as in Section 4.1, supplemented by three additional exercises. First, I exclude events in which a global monetary policy surprise occurs on the same day as a domestic monetary policy decision. Second, I remove the control for the global financial cycle, proxied by US long-term interest rates. Third, I estimate the panel specification with country fixed effects to account for time-invariant country-specific heterogeneity. Across these exercises, the qualitative pattern of the results remains unchanged, with the estimated effects pointing in the same direction as in the baseline specification. Figure 16 further assesses the sensitivity of the panel estimates to the country composition of the sample. Specifically, I re-estimate the spillover effects while excluding one country at a time. The estimates remain remarkably stable across these leave-one-out specifications, indicating that the baseline results are not driven by any single country.

	DNK	CZE	NOR	GBR	SWE	POL	HUN	CHE
Target								
y_t^{3m}	0.63**	0.15	-0.63	-0.23	-0.04	-0.67	1.04	-0.10
	(0.18)	(0.13)	(0.44)	(0.19)	(0.11)	(0.37)	(0.59)	(0.25)
Proportion EXP	90%	91%	−98%	−96%	−90%	−95%	72%	−97%
Proportion TP	−10%	9%	−2%	4%	−10%	5%	28%	−3%
Path								
y_t^{1y1y}	0.98**	0.65**	0.62**	0.59**	0.51**	0.46**	0.05	0.02
	(0.18)	(0.13)	(0.09)	(0.12)	(0.17)	(0.12)	(0.27)	(0.09)
Proportion EXP	27%	59%	69%	51%	81%	42%	97%	95%
Proportion TP	73%	41%	31%	49%	19%	58%	3%	−5%
Long-rate								
y_t^{1y9y}	1.53**	-0.16	0.40	0.54**	1.24**	1.29**	-0.16	0.14
	(0.39)	(0.48)	(0.34)	(0.19)	(0.37)	(0.48)	(0.95)	(0.33)
Proportion EXP	28%	12%	4%	3%	−0%	2%	0%	−21%
Proportion TP	72%	−88%	96%	97%	100%	98%	−100%	79%

Table 9: ECB monetary policy spillovers

Notes: The table reports country-specific OLS estimates of spillover specifications. Standard errors are reported in parentheses. ** and * denote significance at the 1% and 5% levels, respectively. The rows labeled Proportion EXP and Proportion TP report the share of the total yield response accounted for by each component. Signed contributions of the expectations component and term premia are reported.

4.3 Country-specific reactions

Moving beyond *de jure* exchange rate classifications, I examine the spillover estimates country by country. Table 9 confirms the results presented in the previous section but highlights substantial heterogeneity across countries and maturities.

As expected, Denmark's short-term yield responds significantly and in the same direction as the ECB monetary policy surprise. A 10 basis point *target* surprise translates into a 6.3 basis point increase in Danish three-month yield. This magnitude is roughly aligned with the reaction of the euro area OIS short rate. This result is consistent with Denmark's long-standing exchange rate peg to the euro and its corresponding limited degree of monetary autonomy. At longer maturities, the transmission mechanism becomes more nuanced. While the response of the 1y1y forward rates is also close to one-for-one with an ECB *path* surprise, more than 70% of the adjustment operates through the term premia. This finding points to an important role of the financial channel in addition to the exchange-rate channel though potential portfolio rebalancing channels. These results are consistent with the high degree of substitutability between euro area and Danish government bonds, with investors reallocating toward euro area bonds following an ECB

tightening surprise or toward Danish bonds following an ECB easing surprise. The response of the 1y9y forward rate to *long-rate* surprise is similarly strong, exceeding the unity and remaining broadly consistent with movements along the euro area OIS yield curve.

More generally, the results reveal substantial heterogeneity in the response of neighboring European bond markets to ECB surprises. Czechia, Norway, the United Kingdom, Sweden, and Poland all exhibit positive responses to *path* surprises at the three-year maturity, with a transmission ranging from around 4.6 to 6.5 basis points. By contrast, Hungary and Switzerland show little evidence of a significant response, despite both countries having experienced periods of relatively close exchange-rate alignment with the euro. Interestingly, their yield curves are substantially more responsive to US monetary policy shocks, as shown in Table 10.

For ECB *path* surprises, the transmission in most countries operates primarily through the expectations component. This pattern is particularly pronounced in Sweden, despite its floating exchange rate regime. At longer maturities, ECB surprises are transmitted to the United Kingdom, Sweden, and Poland predominantly through term premia, consistent with the financial channel. Taken together, these results indicate that *de jure* exchange rate classifications provide only a partial account of international monetary spillovers. The relative importance of expectations and term premia varies systematically across countries and maturities, pointing to a broader role for financial integration, asset substitutability, and portfolio adjustment in shaping cross-border transmission.

The response to Fed monetary policy surprises, reported in Table 10, is likewise highly heterogeneous across countries. The magnitude and composition of the response vary substantially with both the type of monetary policy surprise and the maturity considered.

4.4 Asymmetric spillovers

Adrian et al. (2024) document a pronounced asymmetry in the international transmission of the Fed monetary policy. The baseline results point to substantial heterogeneity in the transmission of foreign monetary policy shocks. I now investigate two potential sources of asymmetry. First, I examine whether spillovers depend on the sign of the monetary policy surprise in the originator economy, distinguishing between tightening and easing surprises. Second, I assess whether the response depends on the monetary policy cycle of the recipient economy at the time of the shock.

Tightening vs. easing *surprises*

I first split monetary policy surprises according to their sign and report results in Table 11. For ECB surprises, the response of forward rates in pegged economies is stronger

	DNK	CZE	NOR	GBR	SWE	POL	HUN	CHE
Target								
y_t^{3m}	0.21	-0.02	0.03	0.11*	0.00	-0.04	0.11	0.33*
	(0.26)	(0.07)	(0.14)	(0.05)	(0.07)	(0.14)	(0.10)	(0.13)
Proportion EXP	93%	−61%	93%	99%	−12%	−84%	92%	98%
Proportion TP	7%	−39%	−7%	−1%	88%	16%	−8%	−2%
Path								
y_t^{1y1y}	0.33*	0.14	0.25*	0.47**	0.40**	0.18	0.71**	0.30**
	(0.13)	(0.12)	(0.11)	(0.11)	(0.12)	(0.10)	(0.20)	(0.07)
Proportion EXP	47%	76%	54%	30%	63%	75%	40%	46%
Proportion TP	53%	−24%	46%	70%	37%	−25%	60%	54%
long-rate								
y_t^{1y9y}	0.51**	-0.54	0.52**	0.41	0.59**	0.46	-1.97	0.37
	(0.11)	(0.54)	(0.16)	(0.21)	(0.17)	(0.74)	(1.98)	(0.20)
Proportion EXP	31%	0%	0%	5%	−8%	−1%	−0%	3%
Proportion TP	69%	−100%	100%	95%	92%	99%	−100%	97%

Table 10: Fed monetary policy spillovers

Notes: The table reports country-specific OLS estimates of spillover specifications. Standard errors are reported in parentheses. ** and * denote significance at the 1% and 5% levels, respectively. The rows labeled Proportion EXP and Proportion TP report the share of the total yield response accounted for by each component. Signed contributions of the expectations component and term premia are reported.

following easing *target* surprises, with the adjustment operating primarily through the expectations component. By contrast, *path* surprises transmit more symmetrically across tightening and easing episodes, with both expectations and term premia contributing to the response.

More generally, the results suggest that financial markets respond more strongly to tightening than to easing surprises, although this pattern varies across surprises and exchange-rate regimes. The asymmetry is particularly pronounced for *target* surprises in floating economies. Tightening surprises are associated with a decline in yields, driven mainly by the expectations component. This response differs from the standard monetary-policy transmission mechanism and is consistent with an aggregate-demand interpretation, whereby a tighter ECB surprise leads markets to revise downward the expected *path* of domestic short rates in recipient economies.

For *path* surprises, tightening surprises generally generate larger yield responses than easing surprises, both in pegged and floating economies. The adjustment again reflects changes in expected future short rates as well as, at some maturities, term premia. This reinforces the baseline result that foreign *path* surprises affect not only global discount rates but also market expectations about the future stance of monetary policy in recipient

economies.

The corresponding results for Fed surprises are broadly similar, with a few notable exceptions. *Path* tightening surprises produce stronger responses than easing surprises, in line with the ECB evidence. For *long-rate* surprises, however, the asymmetry depends on the exchange-rate regime: pegged economies respond more strongly to easing surprises, whereas floating economies display a larger response to tightening surprises.

Taken together, these results indicate that the international transmission of monetary policy is nonlinear in the sign of the originating shock. In particular, tightening surprises tend to trigger larger revisions in expected policy rates, while the response to *long-rate* surprises depends more strongly on the exchange-rate regime. This suggests that the relative importance of the exchange-rate and financial channels varies with both the nature and the direction of the monetary policy surprises.

	ECB						Fed					
	Target$^+$	Path$^+$	long-rate$^+$	Target$^-$	Path$^-$	long-rate$^-$	Target$^+$	Path$^+$	long-rate$^+$	Target$^-$	Path$^-$	long-rate$^-$
Peg												
Observed yield	0.67	0.76**	0.05	0.51**	0.60**	0.57	0.02	0.53**	0.48	0.10	0.22	1.08**
Standard error	(0.51)	(0.24)	(0.49)	(0.12)	(0.10)	(0.38)	(0.12)	(0.07)	(0.31)	(0.18)	(0.20)	(0.33)
EXP	81%	50%	62%	93%	30%	20%	−39%	59%	5%	91%	78%	14%
TP	19%	50%	−38%	−7%	70%	80%	61%	41%	95%	9%	−22%	86%
Floating												
Observed yield	-0.46*	0.55**	0.51*	0.15	0.35**	0.45**	0.16	0.52**	1.06**	0.09	0.30**	-0.38
Standard error	(0.21)	(0.09)	(0.23)	(0.13)	(0.07)	(0.15)	(0.12)	(0.08)	(0.39)	(0.06)	(0.09)	(0.37)
EXP	−95%	67%	2%	75%	88%	4%	93%	73%	1%	94%	57%	−2%
TP	5%	33%	98%	25%	12%	96%	−7%	27%	99%	−6%	43%	−98%

Table 11: Monetary policy spillovers by shock sign and exchange rate regime

Notes: The table reports the response of forward yields in euro area neighboring economies to positive (+) and negative (−) ECB and Fed monetary policy surprises. Results are reported separately for pegged and floating exchange-rate regimes. *Target* surprise is evaluated on 3m rate response, *path* surprise to the 1y1y rate, and *long-rate* surprise to the 1y9y rate. Standard errors are reported below the observed-yield coefficients. ** and * denote statistical significance at the 1% and 5% levels, respectively. EXP and TP report the shares of the yield response associated with expectations and the term premium. The shares are calculated relative to the sum of the absolute responses of the expectations and term-premium components.

Tightening vs. easing *cycles*

I next examine whether spillovers depend on the monetary policy stance of the recipient economy. Table 12 reports the corresponding estimates. A foreign monetary policy surprise may induce a different repricing of the domestic yield curve depending on whether the recipient central bank is itself tightening or easing. I therefore split the sample according to whether the recipient economy is in a tightening or easing phase at the time of the foreign monetary policy announcement.

For ECB surprises, the response of pegged economies is concentrated in tightening phases. In particular, *path* surprises generate a larger and more statistically significant repricing of forward rates when the recipient economy is tightening, whereas there is little evidence of systematic differences across cycles for the other ECB surprises.

The asymmetry is more pronounced among floating economies. ECB *path* surprises transmit more strongly during tightening phases than during easing phases. By contrast, *long-rate* surprises generate larger responses during easing phases. This pattern suggests that the transmission channel varies over the domestic monetary policy cycle: *path* surprises interact more strongly with expectations about domestic policy when the recipient central bank is already tightening, whereas *long-rate* surprises appear to operate more through longer-term discount-rate or term-premium adjustments during easing episodes.

The pattern differs somewhat for Federal Reserve surprises. For both pegged and floating economies, *path* and *long-rate* surprises tend to generate larger yield responses during easing phases. Thus, the sensitivity of recipient yield curves to Fed surprises appears to increase when domestic monetary policy is accommodative, particularly at intermediate and longer maturities.

Overall, the results show that international monetary policy spillovers depend not only on the exchange-rate regime and the type of surprise, but also on the direction of the foreign surprise and the domestic monetary policy cycle. The transmission of *path* surprises is especially state dependent, consistent with foreign monetary policy news affecting expectations about the future domestic policy *path*. *Long-rate* surprises display a different form of asymmetry, with their transmission varying more strongly across exchange-rate regimes and domestic policy phases. These results lead me to nor reject *hypotheses* three and four.

	ECB						Fed					
	Tightening cycle			Easing cycle			Tightening cycle			Easing cycle		
	Target	Path	long-rate	Target	Path	long-rate	Target	Path	long-rate	Target	Path	long-rate
Peg												
Observed yield	0.97	0.61**	0.56	0.29	0.35	0.02	-0.11	0.23	0.69*	0.26	0.39**	0.74*
Standard error	(0.63)	(0.12)	(0.35)	(0.18)	(0.27)	(0.42)	(0.08)	(0.21)	(0.33)	(0.27)	(0.07)	(0.30)
EXP	89%	34%	17%	98%	33%	54%	−82%	48%	17%	97%	81%	10%
TP	11%	66%	83%	2%	67%	−46%	18%	52%	83%	3%	19%	90%
Floating												
Observed yield	-0.11	0.44**	0.38*	-0.23	0.34**	0.45*	0.17	0.27*	0.98	0.04	0.35**	-0.11
Standard error	(0.15)	(0.08)	(0.18)	(0.26)	(0.11)	(0.20)	(0.12)	(0.12)	(0.52)	(0.04)	(0.07)	(0.48)
EXP	−86%	80%	−9%	−90%	67%	8%	99%	59%	1%	87%	77%	−9%
TP	14%	20%	91%	10%	33%	92%	1%	41%	99%	−13%	23%	−91%

Table 12: Monetary policy spillovers by exchange rate regime and recipient policy cycle

Notes: The table reports the response of forward yields in euro area neighboring economies to ECB and Federal Reserve monetary policy surprises, separately according to whether the recipient economy is in a tightening or easing cycle. Results are reported separately for pegged and floating exchange-rate regimes. *Target* surprise is evaluated on 3m rate response, *path* surprise to the 1y1y rate, and *long-rate* surprise to the 1y9y rate. Standard errors are reported below the observed-yield coefficients. ** and * denote statistical significance at the 1% and 5% levels, respectively. EXP and TP report the shares of the yield response associated with expectations and the term premium. The shares are calculated relative to the sum of the absolute responses of the expectations and term-premium components.

4.5 Country heterogeneity

The preceding sections show that the exchange rate regime alone is insufficient to account for differences in monetary policy spillovers. The country-by-country analysis instead reveals substantial heterogeneity in both the magnitude and composition of the responses. This section discusses several potential sources of this cross-country variation. Table 13 summarizes heterogeneity along four dimensions: trade linkages, currency invoicing, banking exposure, and the composition of the investor base.

Trade openess. Trade linkages with the euro area are substantial but vary considerably across countries. Czechia and Hungary exhibit the strongest trade exposure to the euro area, with 85% and 77% of total GDP, respectively, whereas Norway and the United Kingdom are the least exposed countries in the sample. By comparison, trade exposure to the United States is generally more limited. Switzerland is a notable exception, with a trade openness with the US of roughly 10% of total GDP. These differences suggest that monetary policy shocks in the originator economy could transmit more strongly to highly exposed economies through trade linkages, for example through changes in external demand associated with tighter or looser financial conditions. This mechanism would be consistent with an *aggregate demand channel*. The empirical responses, however, provide limited support for this interpretation. Despite their strong trade integration with the euro area, short-term interest rates in Czechia and Hungary generally do not respond significantly to ECB monetary policy shocks, with the exception of the response of Czech rates to ECB path shocks (Table 9). Similarly, Swiss forward rates respond to US monetary policy shocks, but the direction and composition of these responses are difficult to reconcile with a simple aggregate-demand channel.

Currency invoicing. A second dimension is the currency composition of trade invoicing. Recent work by Zhang (2022) emphasizes that the currency in which international trade is invoiced can shape the international transmission of monetary policy. Greater exposure to euro- or US dollar-denominated invoicing may strengthen the exchange-rate channel if market participants expect the recipient-economy central bank to adjust its policy stance in response to exchange-rate pressures. Consistent with geographic and economic integration, imports in economies neighboring the euro area are predominantly invoiced in euros, while the US dollar generally accounts for a smaller share. There is, however, meaningful cross-country heterogeneity. The United Kingdom stands out, with close to 40% of imports invoiced in US dollars, compared with about 34% invoiced in euros. Although this pattern should not be interpreted causally, the United Kingdom is also one of the few countries in the sample in which short-term interest rates respond positively to Federal Reserve target shocks through the expectations component, apart

from Switzerland (Table 10).

Banking exposure. Miranda-Agrippino and Rey (2020) show that the global financial cycle induced by US monetary policy is transmitted in part through the deleveraging of global banks and increases in aggregate risk aversion. This risk-taking channel, as emphasized by Borio and Zhu (2012) and Bruno and Shin (2015), may generate corrections in bond markets of economies neighboring the euro area through retrenchment in international credit flows. Table 13 reports cross-border claims of banks located in the euro area and the United States. These measures capture the exposure of residents in the recipient economies to banks located in the two originator economies. Czechia, Poland, and Hungary display particularly strong exposure to euro area banks. Exposure to US-located banks is generally more limited, with the United Kingdom standing out at roughly 16% of total cross-border claims. This pattern is consistent with the relatively strong response of UK term premia to US monetary policy shocks. As shown in Table 10, approximately 70% of the response of the UK 1y1y yield is accounted for by the term-premium component, the largest share among the countries considered. While this evidence is descriptive, it is consistent with a transmission mechanism operating through international banking and portfolio-balance channels.

Investor base. Finally, I report in Table 13 the foreign-investor share in domestic bond markets and, where available, the share held by relatively price-sensitive private investors rather than banks or official institutions. A larger foreign-investor base may increase the sensitivity of domestic bond prices to changes in US or euro area monetary conditions by strengthening the role of international portfolio rebalancing. Norway and Denmark, in particular, exhibit relatively high levels of foreign participation in their domestic bond markets.

	DNK	CZE	NOR	GBR	SWE	POL	HUN	CHE
Euro area								
Trade openness	25.7	85.4	22.4	14.6	29.7	47.4	77.4	35.7
Share EUR in imports	48.9	68.0	35.3	33.9	61.0	55.7	75.3	45.6
Share residents exposed to EA banks	64.6	93.1	–	57.6	46.7	78.2	67.7	38.2
United States								
Trade openness	3.9	3.1	2.7	4.0	4.1	2.8	3.7	10.6
Share USD in imports	27.8	20.0	24.1	39.8	30.0	27.3	16.6	33.7
Share residents exposed to US banks	1.5	–	12.1	16.4	8.8	0.5	0.6	2.7
Global								
Share price-sensitive investors	44.3	25.0	67.8	31.5	19.2	27.1	35.5	12.9
Share foreign non-bank investors	8.1	59.2	64.5	43.2	1.4	54.0	71.7	23.5

Table 13: Cross-country heterogeneity

Notes: "Trade openness" denotes the share of total imports and exports of the country relative to real GDP expressed in USD on 2024. "Share EUR (USD) in imports" denotes the share of imports invoiced in euros or US dollars as of 2018. "Share residents exposed to EA (US) banks" represents the cross-border claims of banks located in the euro area or the US on the country's residents on Q4 2025. The table also includes data on the share of domestic and foreign non-bank investors in total public debt and the share of foreign non-bank investors in total foreign investors as of Q4 2024. All entries are expressed as percentages. Darker cells indicate larger values, with the shading scale ranging from white at 0 to medium gray at 100. A dash denotes unavailable data.

Taken together, these patterns provide useful context for the cross-country heterogeneity documented in the preceding results. Countries differ substantially in their trade exposure, invoicing currencies, banking linkages, and foreign participation in domestic bond markets, each of which provides a plausible channel for the international transmission of monetary policy. The evidence in Table 13, however, is descriptive and should not be interpreted as establishing a causal link between these characteristics and the estimated spillovers. Assessing whether these dimensions account systematically for cross-country differences in monetary policy transmission would require a separate empirical analysis that directly relates bilateral exposures and market structure to the magnitude and composition of the estimated responses.

5 Conclusion

This article examines the international transmission of ECB and Fed monetary policy surprises, around FOMC and Governing Councils events, to the sovereign yield curves of neighboring euro area economies. Using a term structure model to decompose yield responses into expectations and term premia, and combining these estimates with high-frequency identified monetary policy surprises, I show that exchange rate flexibility does not fully insulate recipient economies from external monetary policy surprises. In particular, following ECB announcements, floating economies exhibit same-direction adjust-

ments in short-term interest rates, indicating that monetary policy expectations respond even in the absence of a formal exchange rate peg. This result complements Corsetti et al. (2026), who show that the spillovers from euro area monetary policy are not systematically weaker under floating exchange rate regimes. More broadly, the findings indicate that the strength and composition of international monetary policy spillovers depend on both the nature of the originating shock and the characteristics of the recipient economy.

The analysis also highlights the importance of distinguishing among different types of monetary policy surprises. Target, path, and long-rate surprises do not necessarily propagate through the same channels, and their effects may be reflected differently in expected short rates and term premia. This distinction is particularly relevant for understanding the international transmission of unconventional monetary policy, for which movements in longer-term rates may operate primarily through financial rather than expectations channels. The results therefore suggest that assessments of monetary policy spillovers should account not only for the exchange rate regime, but also for the type of policy surprise and the segment of the yield curve through which it is transmitted.

Several limitations should be kept in mind. First, the analysis does not explicitly account for model uncertainty. To mitigate this concern, the interpretation of the decomposition is restricted to cases in which observed yields, or model-implied forward rates constructed from accurately fitted spot rates, display statistically significant responses. Second, the term structure model deliberately abstracts from credit and currency risk. The objective is to retain a parsimonious framework, while allowing for nonlinearities around the ELB, in order to isolate the transmission of monetary policy surprises through expectations and term premia. Finally, the monetary policy surprises are constructed from factors estimated over the full sample. Although the results are robust to using empirical surprises based on changes in specific maturities, an alternative approach would be to rely on event-specific functional shocks, as in Inoue and Rossi (2021), which may be better suited to capturing time variation in the structure of monetary policy surprises.

These limitations point to several directions for future research. A natural extension would be to test empirically the role of real and financial bilateral exposure of my sample of countries in propagating shocks.

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Appendix A Appendix

A.1 Monetary policy surprises

Swanson's factors extraction. The factor structure for the monetary policy window surprise is given by

$$X = F\Lambda + \epsilon \tag{16}$$

where F is the matrix whose rows contain the unobserved factors for each policy event, and Λ is the matrix of loadings. In order to interpret the latent factors, I need to rotate Λ so that the first factor corresponds to the target factor, the second the path factor and the third the long-rate factor. As such, I apply the following transformation using a maitrx U of size (3×3) that satisfies $UU' = I$.

$$X = \tilde{F}\tilde{\Lambda} + \epsilon \tag{17}$$

where $\tilde{F} = FU$, and $\tilde{\Lambda} = U'\Lambda$. As Swanson (2021), I impose economic restrictions to identify a unique matrix U^* such that the rotated factors $F^* = FU^*$ can be interpreted as orthogonal surprises, each describing the three dimension of monetary policy. Orthogonality gives six restrictions on the elements of U. Three restrictions comes from the columns of U having unit length:

$$U'_{.1}U_{.1} = 1, U'_{.2}U_{.2} = 1, U'_{.3}U_{.3} = 1 \tag{18}$$

and three from the columns of U being orthogonal

$$U'_{.1}U_{.2} = 0, U'_{.1}U_{.3} = 0, U'_{.2}U_{.3} = 0 \tag{19}$$

To identify the monetary policy factors, we need to impose three additional restrictions on the elements of U. Requiring that the second and third factors do not load on the shortest horizon price (one-month OIS for EA and the next contract fed funds, $MP1$, for the US).

$$U'_{.2}\Lambda_{.1} = 0, U'_{.3}\Lambda_{.1} = 0 \tag{20}$$

The third and final additional restriction comes from requiring that the rotated third factor has minimum variance in the pre-crisis period (until August 2008 for both jurisdictions). In other words, among all the orthonormal matrices satisfying the above restrictions, I want to pick the one giving a rotated third factor with the lowest variance in the pre-crisis period. Indeed, the long-rate factor should have minimum variance before the crisis as in Swanson (2021). Let F^{pre} denote the factor matrix for all the pre-crisis monetary policy events. The third factor is $F^{\text{pre}}U_{3.}$ with variance $\sum_{t=1}^{T}(F_t^{\text{pre}}U_{3.}^2)/T$, where T is the number of pre-crisis policy events. The rotation matrix u_{ij} can thus be obtained

by solving the following optimization problem.

$$U^* = \arg\min_{u_{ij}} \frac{1}{T} \sum_{t=1}^{T} (F_t^{\text{pre}} U_{3.})^2 \tag{21}$$

subject to

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

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

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

As matrix U^* is unique up to a sign normalization. I normalize it such that the target factor has a loading of 1 on the shortest-maturity contract, the path factor has a loading of 1 on 1-year rate and the long-rate factor has loading of 1 on the 10-year rate.

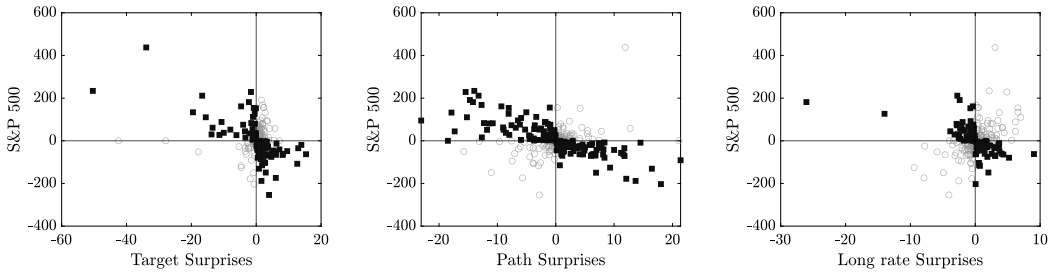


Figure 6: Fed monetary policy surprises

Notes: Intraday reactions of monetary policy surprises and the stock market (S&P500) around FOMC announcements. Pure monetary policy surprises are identified in black while information surprises in gray.

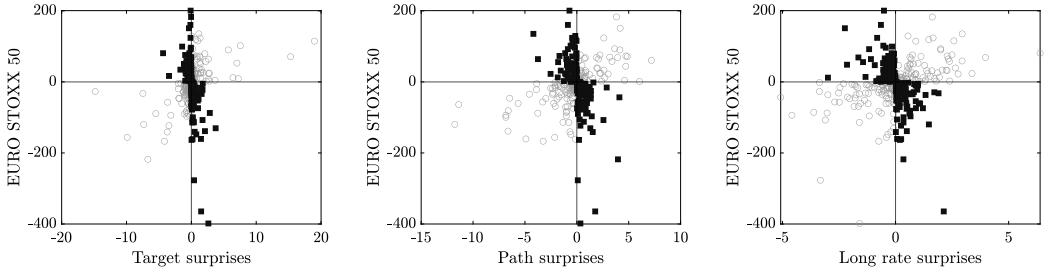


Figure 7: ECB monetary policy surprises

Notes: Intraday reactions of monetary policy surprises and the stock market (STOXX50) around ECB Governing Council announcements. Pure monetary policy surprises are identified in black while information surprises in gray.

	ECB Target	ECB Path	ECB LR	ECB Target (MP)	ECB Path (MP)	ECB LR (MP)
ECB Target	-0.148*	-0.129	0.004			
ECB Path	-0.044	0.016	0.039			
ECB LR	-0.007	-0.020	0.003			
ECB Target (MP)				0.071	0.081	0.085
ECB Path (MP)				-0.023	-0.007	0.037
ECB LR (MP)				0.015	0.039	0.043

Table 14: Cross-country correlation in monetary policy factors

Notes: Pairwise correlation coefficients. ** and * denote significance at the 1% and 5% levels, respectively.

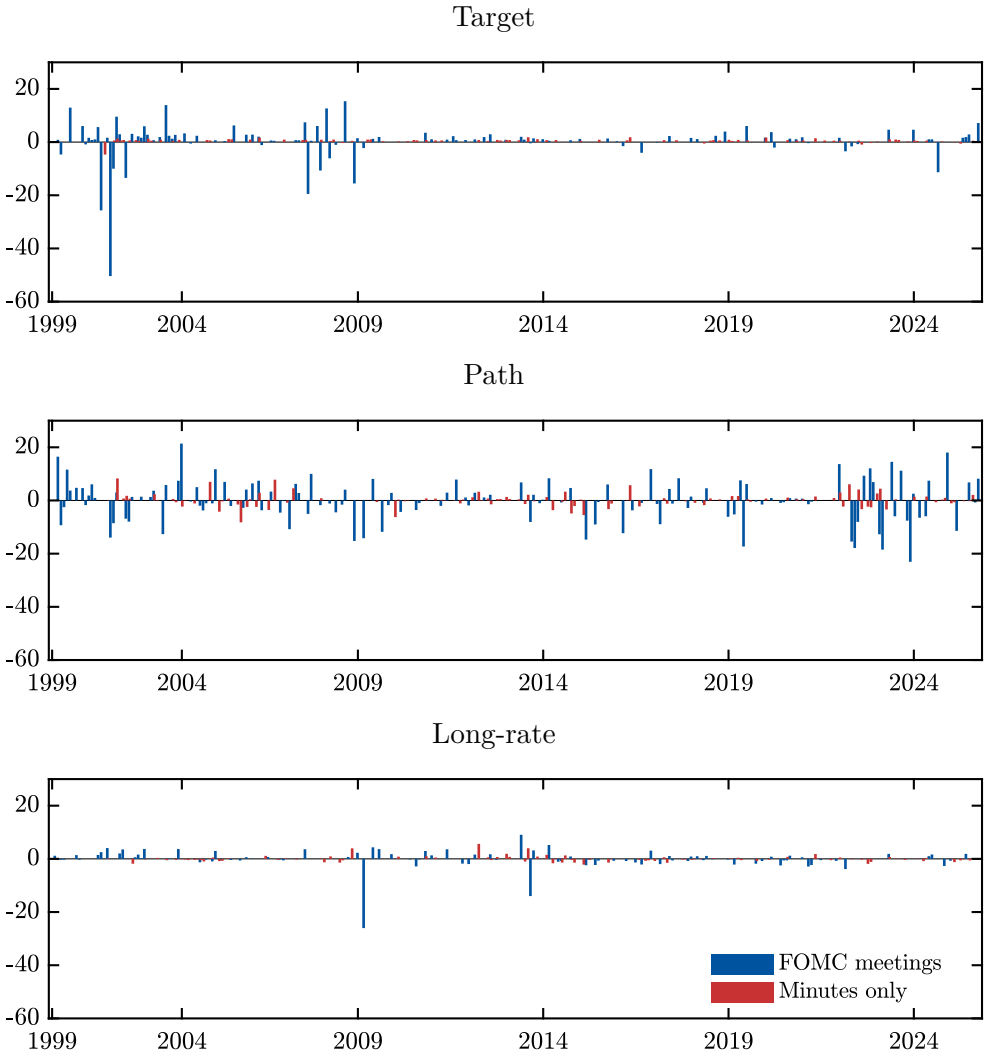


Figure 8: Fed *pure* monetary policy surprises including minutes

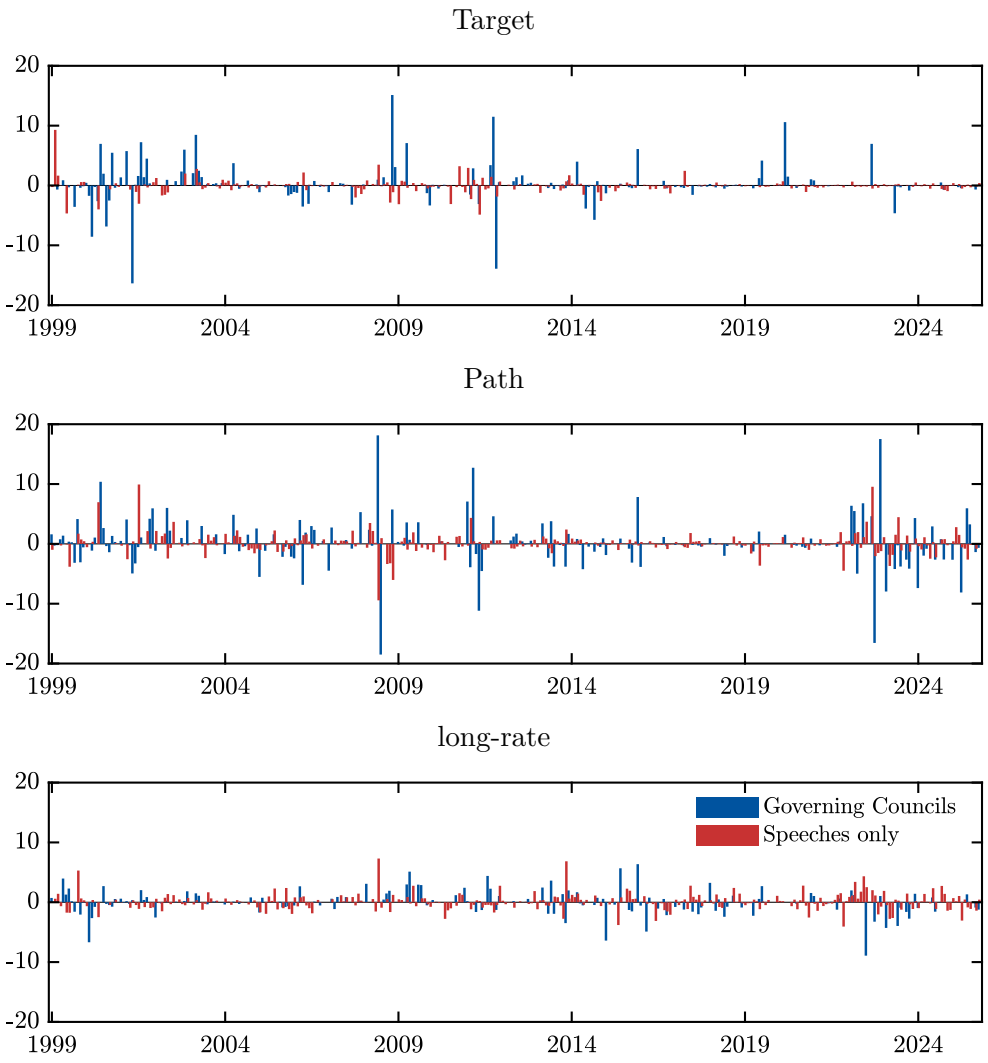


Figure 9: ECB *pure* monetary policy surprises including speeches

A.2 A shadow rate term structure model with macro factors

Pricing bond yields using Wu and Xia (2016) approximation.

Define $f_{n,n+1,t}$ as the forward rate at time t for a bond starting at $t+n$ and maturing at $t+n+1$,

$$f_{n,n+1,t} = (n+1)y_{n+1,t} - ny_{n,t} \tag{22}$$

which is a linear function of yields on risk-free n and $n+1$ period pure discount bonds. The forward rate in the shadow rate term structure can be approximated with

$$f^G_{n,n+1,t} = \underline{r}_t + \sigma^{\mathbb{Q}}_n g\left(\frac{a_n + b'_n X_t - \underline{r}_t}{\sigma^{\mathbb{Q}}_n}\right) \tag{23}$$

where $(\sigma^{\mathbb{Q}}_n)^2 = \text{Var}^{\mathbb{Q}}_t(s_{t+n})$ and g being a function that consists of a normal cumulative distribution function and a normal probability density function such that $g(z) \equiv \Phi(z) +$

$\phi(z)$. Spot yields, $y_{n,t}^G$, are the average of the first n one-period forwards

A.3 Additional Information on the Data

Yield curve data. Zero-coupon yield curve data come from diverse sources (see Table 15). I prioritize national official yield curve data and complement them with market-based data when official series are unavailable. For Bloomberg data, I rely on the IYC database at the beginning of the sample and on BVAL data toward the end of the sample. When two datasets are spliced, I carefully verify that neither GovC nor FOMC meetings occurred within one week before or one week after the splicing date.

	Yield curves		Short rates	
	Starting date	Source	Instrument	Source
EUR	Jan. 1999	Bloomberg, LSEG Datastream	3m OIS	LSEG Datastream
USA	Jan. 1999	Gürkaynak et al. (2007)	3m T-bill	LSEG Datastream
CZE	Jan. 2001	Bloomberg	3m ZC rate	Bloomberg
DNK	Jan. 1999	Bloomberg	3m T-bill	LSEG Datastream
HUN	Apr. 2001	Bloomberg	3m T-bill	LSEG Datastream
NOR	Jan. 1999	Norges Bank, Bloomberg	6m T-bill	LSEG Datastream
POL	Jan. 1999	Bloomberg	3m ZC rate	Bloomberg
SWE	Jan. 1999	Bloomberg	3m T-bill	LSEG Datastream
CHE	Jan. 1999	Swiss National Bank	3m T-bill	LSEG Datastream
GBR	Jan. 1999	Bank of England	3m T-bill	LSEG Datastream

Table 15: Interest rates data descriptions

Notes: ZC stands for zero-coupon.

Macroeconomic data. I use monthly OECD data for the unemployment rate and industrial production. Gross domestic product (GDP) is available at a quarterly frequency in constant prices and is obtained from national sources. Growth rates of unemployment, output, and industrial production are computed as year-on-year percentage changes. The unemployment gap and the output gap are constructed using a Hodrick–Prescott filter, with smoothing parameter $\lambda = 129{,}600$ for monthly data and $\lambda = 1{,}600$ for quarterly data. Inflation data come from national sources for Switzerland and the United Kingdom, and from Eurostat for all other countries. I use survey forecasts from Consensus Economics for inflation and short-term interest rates at horizons of 3 and 12 months. The 12-month-ahead inflation forecast is computed as a weighted average of the current-year and next-year survey forecasts.

A.4 Macroeconomic information and the yield curve

To provide insight into the economic forces driving changes in interest rates, the finance literature has developed macro-finance term structure models (MTSMs) that incorporate both yield curve variables and macroeconomic signals. In these models, the short-term interest rate is represented as an affine function of risk factors that include these macroeconomic indicators (Bauer and Rudebusch, 2017). This section motivates the use of such indicators as relevant variables interacting with the yield curve. First, I demonstrate that my selected variables are significantly correlated with both the policy rate and short-term market interest rates. Second, I analyze how these variables load on the different pricing factors of the yield curve, namely level, slope, and curvature. Third, I discuss the spanning hypothesis - an implied feature of most MTSMs - and show that, although it is clear that these macroeconomic signals are unspanned by the yield curve, modeling them as unspanned in an MTSM yields economically equivalent results. I argue that it is more convenient for a practical point of view to estimate the model with unspanned macro variables as it implies fewer parameters to estimates.

Taylor rule. The selection of macroeconomic variables is motivated by their relevance to the central bank's reaction function, given that the short end of the yield curve closely reflects monetary policy. Incorporating these variables into the VAR dynamics under the physical dynamics of the MTSM aids in calibrating the expectations component.

	INF		GRO					
	EInf	RInf	OGap	OGro	IPGro	UGap	UGro	PC
CZE	100%	100%	100%	100%	75%	0%	100%	100%
DNK	100%	100%	25%	25%	100%	0%	100%	100%
HUN	100%	50%	100%	0%	0%	100%	25%	100%
NOR	58.3%	50%	100%	100%	0%	100%	100%	100%
POL	66.7%	100%	75%	100%	100%	0%	0%	100%
SWE	100%	100%	75%	100%	75%	0%	75%	75%
CHE	91.7%	66.7%	0%	25%	100%	0%	100%	75%
GBR	100%	75%	0%	0%	50%	0%	0%	0%

Table 16: Frequency of coefficient significance across pairwise specifications

Notes: The table reports results from OLS regressions using 309 observations by countries. Coefficients are classified as statistically significant when the p-value is below 5%. For each jurisdiction, 24 regressions are estimated: 12 regressions with the policy rate as the dependent variable and 12 regressions with the short-term interest rate (3-month Treasury bill). Each inflation (INF) variable appears in 12 regressions, whereas each growth (GRO) variable appears in 4 regressions. The first cell indicates that expected inflation is statistically significant in 100% of the pairwise regression specifications. EInf denotes expected inflation; RInf realized inflation; OGap the output gap; OGro year-over-year output growth; IPGro year-over-year industrial production growth; UGap the unemployment gap; UGro year-over-year unemployment growth; and PC the principal component of GRO variables.

I estimate a simple Taylor rule at a monthly frequency for each country. I consider a set of macroeconomic variables. On the price side, I include two measures of price growth: expected inflation and realized inflation. On the activity side, I consider five variables: output and unemployment gaps and growth rates, as well as industrial production growth. Growth rates are defined as year-on-year changes. In addition, I construct a principal component of the activity variables that summarizes their common co-movements.

I regress both the policy rate set by the central bank and the market short rate (the short end of the yield curve) on a price growth variable, INF, an activity variable, GRO, and the lag of the dependent variable. Table 16 reports the frequency with which coefficients are statistically significant across pairwise specifications. The first cell of the table indicates that expected inflation is always significant, regardless of which activity variable is included. Overall, I find that price growth variables are more likely to be significant across specifications. For activity variables, there is substantial heterogeneity across countries. However, when I replace individual activity indicators with the principal component, PC, I observe a high frequency of statistical significance. I therefore select expected inflation and the principal component as the baseline macroeconomic variables in the Taylor rule specification.

	CZE	DNK	HUN	NOR	POL	SWE	CHE	GBR
Dependent variable: Policy rate, i_t								
Constant	-0.096**	-0.146**	-0.066	-0.066	-0.025	-0.065**	-0.018	-0.117**
	(0.031)	(0.028)	(0.063)	(0.043)	(0.029)	(0.015)	(0.016)	(0.026)
i_{t-1}	0.941**	0.975**	0.947**	0.980**	0.976**	0.977**	0.964**	0.994**
	(0.011)	(0.010)	(0.016)	(0.008)	(0.009)	(0.009)	(0.015)	(0.006)
INF	0.075**	0.096**	0.079*	0.051*	0.036**	0.056**	0.048*	0.055**
	(0.019)	(0.019)	(0.033)	(0.020)	(0.010)	(0.009)	(0.009)	(0.012)
GRO	0.025**	0.019*	0.039**	0.045**	0.082**	0.023**	0.018*	0.010
	(0.007)	(0.008)	(0.015)	(0.010)	(0.014)	(0.009)	(0.009)	(0.012)
R^2	0.993	0.992	0.989	0.991	0.995	0.988	0.979	0.995
Dependent variable: Market short rate, $y_t^{(3m)}$								
Constant	-0.084**	-0.146**	-0.056	-0.025	-0.016	-0.055**	-0.020	-0.105**
	(0.031)	(0.028)	(0.078)	(0.049)	(0.034)	(0.017)	(0.017)	(0.028)
$y_{t-1}^{(3m)}$	0.937**	0.974**	0.951**	0.983**	0.980**	0.980**	0.967**	0.993**
	(0.013)	(0.010)	(0.014)	(0.009)	(0.010)	(0.009)	(0.013)	(0.007)
INF	0.071**	0.098**	0.069*	0.031	0.026*	0.047**	0.044*	0.051**
	(0.018)	(0.018)	(0.032)	(0.024)	(0.013)	(0.009)	(0.020)	(0.012)
GRO	0.030**	0.020*	0.043**	0.043**	0.085**	0.021	0.017**	0.011
	(0.009)	(0.009)	(0.015)	(0.011)	(0.021)	(0.011)	(0.006)	(0.010)
R^2	0.987	0.991	0.981	0.989	0.995	0.991	0.982	0.994

Table 17: Taylor rule estimates

Notes: The table reports OLS estimates using 309 country-level observations. Standard errors are reported in parentheses. ** and * denote statistical significance at the 1% and 5% levels, respectively. INF denotes expected inflation. GRO denotes the principal component extracted from growth-related variables.

Table 14 reports the selected regression for each dependent variable. The results confirm the policy relevance of the two selected macroeconomic variables. Central banks tend to increase policy rates in response to higher expected inflation and stronger economic activity. I note some exceptions, such as the activity variable for the United Kingdom. This suggests that the Bank of England responds primarily to expected inflation, consistent with its mandate. Accordingly, I focus on this activity measure alongside expected inflation in the subsequent analysis.

Going beyond simple correlations between macroeconomic indicators and short rates, I examine information from the entire yield curve. Table 18 reports, for each country, the correlations between the two macroeconomic variables of interest and the first three principal components that characterize yield curve dynamics: the level, slope, and curvature. The results indicate that INF is generally more strongly correlated with the

joint dynamics of the three principal components than is *GRO*. This finding is consistent with the inflation-targeting mandates of the central banks in the sample. Interestingly, the activity variable exhibits relatively higher correlations in Denmark and Switzerland, both of which maintain exchange rate pegs to the euro. Moreover, while INF loads more heavily on the level factor of the yield curve, I do not observe a clear pattern for *GRO*.

	Joint	Level	Slope	Curvature	N
INF					
Czechia	0.68	0.41	0.27	0.01	286
Denmark	0.33	0.25	0.03	0.05	309
Hungary	0.70	0.37	0.30	0.04	283
Norway	0.34	0.04	0.27	0.03	309
Poland	0.38	0.37	0.01	0.00	309
Sweden	0.50	0.03	0.36	0.10	309
Switzerland	0.42	0.34	0.09	0.00	309
United Kingdom	0.01	0.00	0.01	0.00	309
GRO					
Czechia	0.18	0.01	0.04	0.12	286
Denmark	0.21	0.01	0.15	0.05	309
Hungary	0.08	0.01	0.01	0.06	283
Norway	0.11	0.03	0.01	0.07	309
Poland	0.12	0.04	0.02	0.05	309
Sweden	0.17	0.02	0.07	0.07	309
Switzerland	0.26	0.07	0.18	0.02	309
United Kingdom	0.08	0.07	0.01	0.00	309

Table 18: Unspanned macro variation

Notes: The table reports R^2 that indicate whether yields span macro variables. Each macro variable are regressed one at a time on the level, slope, curvature and all factors jointly. INF denotes expected inflation. *GRO* denotes the principal component extracted from growth-related variables. N displays the number of observations.

Spanning hypothesis. How should macroeconomic factors and the yield curve interact within a term structure model? This question has been central to the macro–finance literature and has been extensively discussed by Bauer and Rudebusch (2017). In this section, I examine both statistical and economic evidence on this relationship. The initial results provide preliminary insights into the extent to which macroeconomic variables are spanned by the yield curve. To motivate the modeling choice for yield dynamics in this set of countries, I study the relationship between realized excess bond returns, which is used as a proxy for risk premia, and macroeconomic factors. Under the spanning hypothesis, the current yield curve contains all information necessary to forecast future interest rates and bond returns. In other words, additional macro-financial variables should not significantly improve the forecasting performance of the yield curve. This implies that the yield

curve spans all relevant information for predicting future yields and returns, rendering other variables redundant. While this hypothesis provides a natural benchmark in the macro–finance literature, existing evidence suggests that its validity is case-dependent (Bauer and Hamilton, 2018).

I then regress excess bond returns on yield curve principal components and macroeconomic variables. To obtain robust inference on the spanning relationship between domestic bond yields and macroeconomic factors, I employ the parametric bootstrap procedure of Bauer and Hamilton (2018). To this end, I first compute realized excess bond returns from observed yields. The h-period (overlapping) return on a bond with maturity n in excess of the risk-free rate is

$$rx_{t+h}^{n} = p_{t+h}^{n-1} - p_t^{(n)} - y_t^{(1)} = -(n-1)y_{t+h}^{(n-1)} + ny_t^{(n)} - y_t^{(1)} \tag{24}$$

where $p_t^{(n)}$ denotes the log-price of a zero-coupon bond and $y_t^{(n)}$ the corresponding yield of maturity n. The key question of is whether the current yield curve contains *all* of the information relevant for predicting future returns, that is, whether the spanning hypothesis holds. To answer this question, I estimate the following equation:

$$rx_{t+h} = \beta_1' x_{1t} + \beta_2' x_{2t} + u_{t+h} \tag{25}$$

where the depend variable is the excess return on long-term bond, x_{1t} and x_{2t} are vectors containing K_1 and K_2 predictors, respectively, and u_{t+h} is a forecast error. The predictors x_{1t} contain a constant and the information in the yield curve captured by the first three principal components that is the level, slope and curvature. These three components summarized 88% of the Hungarian yield curve variation. The null hypothesis of interest is

$$H_0 : \beta_2 = 0$$

which says that the relevant predictive information is spanned by the information in the domestic yield curve and that x_{2t} has no additional predictive power. In my application $x_{1t} = (PC1_t, PC2_t, PC3_t)'$ and $x_{2t} = (\text{GRO}_t, \text{INF}_t)'$ I test whether β_2 deviates significantly from zero, i.e. that x_{2t} brings predictive power to forecast future domestic yields.

Turning to the analysis of individual coefficients (Table 19), I find no evidence of an unspanned relationship between macroeconomic factors and the yield curve. These results are robust to small-sample p-values. This finding can be rationalized by the fact that the countries in the sample operate under inflation-targeting regimes, and that inflation expectations, as well as measures of economic activity, are strongly significant in the Taylor rule. As a result, this information is already embedded in the yield curve and does not improve the out-of-sample prediction of excess bond returns. This inter-

	PC1	PC2	PC3	GRO	INF	Wald
Czechia						
Coefficient	0.474	1.243	5.839	-0.857	0.114	
HAC p-value	0.013	0.113	0.112	0.531	0.842	0.820
BC bootstrap p-value				0.732	0.902	0.938
Denmark						
Coefficient	0.193	1.390	2.078	-0.125	-0.719	
HAC p-value	0.063	**0.011**	0.067	0.758	0.230	0.472
BC bootstrap p-value				0.864	0.425	0.763
Hungary						
Coefficient	0.162	1.749	3.426	-0.332	-1.009	
HAC p-value	0.488	**0.038**	0.185	0.889	0.256	0.509
BC bootstrap p-value				0.949	0.490	0.821
Norway						
Coefficient	0.118	1.332	4.128	-0.250	-0.042	
HAC p-value	0.295	**0.010**	**0.018**	0.511	0.914	0.784
BC bootstrap p-value				0.680	0.944	0.905
Poland						
Coefficient	0.134	2.354	0.439	-0.212	-2.063	
HAC p-value	0.471	**0.003**	0.852	0.843	0.061	0.160
BC bootstrap p-value				0.908	0.219	0.511
Sweden						
Coefficient	0.178	1.910	3.481	0.915	-0.083	
HAC p-value	0.051	**0.000**	0.067	0.098	0.865	0.248
BC bootstrap p-value				0.364	0.911	0.631
Switzerland						
Coefficient	0.240	0.843	3.495	0.105	-0.113	
HAC p-value	0.055	0.057	**0.019**	0.812	0.814	0.957
BC bootstrap p-value				0.890	0.889	0.986
United Kingdom						
Coefficient	0.073	2.001	2.095	-1.160	0.329	
HAC p-value	0.507	**0.000**	0.291	**0.015**	0.468	**0.036**
BC bootstrap p-value				0.213	0.654	0.372

Table 19: Statistical inference in excess return regressions

Notes: Predictive regressions for annual excess bond returns, averaged over two- through ten-year bond maturities, using yield PCs and two macro variables that are described in the text. HAC statistics and p-values are calculated using Newey-West standard errors with 18 lags. The column "Wald" reports results for the χ^2 test that GRO and INF have no predictive power; the other columns report results for individual t -tests.We obtain bootstrap distributions of the test statistics under the null hypothesis that GRO and INF have no predictive power—the text describes the design of the simple and bias-corrected (BC) bootstraps. Critical values (c.v.'s) are the 95th percentile of the bootstrap distribution of the test statistics, and p-values are the frequency of bootstrap replications in which the test statistics are at least as large as in the data. Under Size I report estimates of the size of the tests, based on simulations from the simple bootstrap under the null hypothesis. I report power estimates using a bootstrap under the alternative hypothesis, as described in the text. p-values below 5% are emphasized with bold face.

pretation is consistent with Bauer and Rudebusch (2017), who argue that the monetary policy reaction function can provide a systematic link between macroeconomic variables and interest rates. Policy-relevant macroeconomic variables—those that materially influence monetary policy—exhibit little evidence of unspanned variation and are therefore largely spanned by the yield curve. Overall, I cannot reject the spanning hypothesis that macroeconomic factors are spanned by the yield curve. These results suggest that this relationship should be incorporated into the DTSM, with the short rate specified as

$$r_t = \delta_0 + \delta_1 X_t + \delta_2 M_t.$$

Knife edge test. I conduct likelihood ratio tests as described by Bauer and Rudebusch (2017) to formally test for the validity of this results. Here, I perform direct hypothesis tests of the knife-edge unspanned macro restrictions that underlie the model. Under the spanning hypothesis, the macro factors are not directly linked to contemporaneous yields such that

$$Y_t = A + B\mathcal{P}_t + 0_{M\times M} M_t \tag{26}$$

which is a direct consequence of the "knife-edge restrictions" that impose that $\rho_M = 0$ and $\Phi^Q = 0$. I formally test this restrictions following Bauer and Rudebusch (2017). Results are displayed in Table 20. The battery of tests is unambiguous: I cannot reject the hypothesis of a spanned relationship between yields and macroeconomic factors.

Nonetheless, the economic differences between models estimated under the spanning and unspanning assumptions are quantitatively small. Table 21 reports the means, standard deviations, and correlations of outputs from the yield-only model, the spanned macro–finance model, and the unspanned specification. Although the models exhibit distinct features in terms of levels and volatilities, the implied term premia are nearly identical across specifications. In particular, the correlation between spanned and unspanned term premia is essentially one for the 10-year maturity and ranges from 0.93 to 1 for the 2-year maturity.

These results indicate that, despite the strong statistical rejection of the spanning hypothesis, its economic relevance is negligible. Differences in in-sample fit are effectively zero, and discrepancies in both the expectations component and term premia are economically small. In light of these findings, I model macroeconomic factors as unspanned. This choice has the benefit to reduce the number of parameters to be estimated while producing quantitatively similar results. I therefore adopt the unspanned macro–finance (USM) specification to preserve parsimony. This advantage is particularly useful for the shadow rate model, for which estimation is computationally time consuming.

	Cross section	Time series	Total
Czechia			
LLK SM(3,2)	13757	3879	17636
LLK USM(3,2)	13431	3858	17290
Likelihood-ratio statistic			693
Denmark			
LLK SM(3,2)	15414	4232	19646
LLK USM(3,2)	15294	4229	19523
Likelihood-ratio statistic			246
Hungary			
LLK SM(3,2)	12175	3186	15362
LLK USM(3,2)	11620	3188	14808
Likelihood-ratio statistic			1107
Norway			
LLK SM(3,2)	15811	3897	19708
LLK USM(3,2)	15238	3895	19134
Likelihood-ratio statistic			1149
Poland			
LLK SM(3,2)	13462	3881	17343
LLK USM(3,2)	13396	3872	17267
Likelihood-ratio statistic			151
Sweden			
LLK SM(3,2)	15856	4372	20228
LLK USM(3,2)	15681	4330	20011
Likelihood-ratio statistic			434
Switzerland			
LLK SM(3,2)	15605	4468	20073
LLK USM(3,2)	15155	4441	19596
Likelihood-ratio statistic			952
United Kingdom			
LLK SM(3,2)	16064	4192	20256
LLK USM(3,2)	15543	4145	19688
Likelihood-ratio statistic			1137

Table 20: Tests of knife-edge restrictions in MTSMs

Notes: The table displays the log-likelihood values for spanned and unspanned MTSMs (denoted SM(3, 2) and USM(3, 2), respectively), as well as the likelihood-ratio statistic that USM(3, 2) is an acceptable restricted version of SM(3, 2). The first two columns report the contribution to the log-likelihood of the cross-sectional fitting errors and the VAR forecast errors. The 5% (0.1%) critical value for a χ-distributed random variable is 67.5 (86.7).

	Mean			Std. dev.			Correlations	
	YM	SM	USM	YM	SM	USM	SM,YM	SM,USM
10y term premia								
Czechia	2.36	1.89	2.07	1.51	1.56	1.58	0.97	1
Denmark	1.97	2.17	1.91	1.11	1.11	1.15	0.99	1
Hungary	3.72	3.47	3.33	1.15	1.92	1.64	0.90	1
Norway	1.72	1.73	1.71	0.67	0.70	0.69	0.97	1
Poland	4.16	4.81	5.13	1.43	1.16	1.18	0.29	1
Sweden	2.05	1.72	1.98	1.01	0.99	0.99	0.99	1
Switzerland	1.39	1.57	1.48	0.77	0.85	0.88	0.98	1
United Kingdom	2.6	1.75	2.54	1.2	1.25	1.26	0.91	1
2y term premia								
Czechia	0.40	0.36	0.42	0.58	0.77	0.83	0.71	1
Denmark	0.25	0.41	0.25	0.40	0.47	0.53	0.80	1
Hungary	0.64	0.90	0.71	0.49	1.89	1.18	0.71	0.98
Norway	0.18	0.20	0.18	0.19	0.28	0.27	0.67	0.93
Poland	0.40	0.4	0.43	0.68	0.96	0.99	0.46	1
Sweden	0.35	0.30	0.35	0.47	0.54	0.55	0.92	1
Switzerland	0.27	0.35	0.28	0.24	0.28	0.33	0.71	0.99
United Kingdom	0.06	0.01	0.08	0.44	0.55	0.62	0.75	1

Table 21: Term premia estimates across models

Notes: YM stands for yield only model; SM stands for spanned macro factor mode; USM stands for unspanned macro factor model.

A.5 Additional model output

	eig1	eig2	eig3	ϕ	ϕ	ϕ	ϕ	ϕ	ϕ	ϕ
				$\times 1,000$						
CZE	1.00	0.96	0.96	0.16	7.93	1.28	-0.64	3.57	-0.14	1.63
DNK	0.99	0.98	0.87	0.43	8.79	-0.86	1.88	3.25	-0.00	1.99
HUN	0.99	0.97	0.97	1.96	31.45	-13.58	1.56	7.85	0.97	3.50
NOR	1.00	0.95	0.95	0.14	6.57	-1.40	0.53	3.02	0.19	1.51
POL	0.98	1.00	0.92	1.29	10.88	-3.80	0.54	4.30	0.09	2.28
SWE	1.00	0.94	0.94	0.07	6.28	-1.25	0.54	2.35	0.44	1.44
CHE	1.00	0.95	0.94	0.19	5.78	-1.87	-0.15	2.49	-0.01	1.63
GBR	0.98	0.98	0.92	0.66	8.44	-2.39	1.18	2.78	0.03	1.49

Table 22: Estimated model parameters

	3m	1y	2y	3y	4y	5y	6y	7y	8y	9y	10y
CZE	7	10	5	5	5	5	6	5	4	4	5
DNK	3	7	5	3	4	4	4	2	2	3	5
HUN	19	22	15	6	7	8	8	6	6	7	11
NOR	6	9	4	3	3	3	3	2	2	2	5
POL	7	12	9	5	7	13	7	10	6	7	12
SWE	4	7	4	3	3	3	2	2	1	2	3
CHE	6	10	4	4	4	4	3	3	2	3	5
GBR	5	8	3	3	3	3	3	2	1	2	4

Table 23: Root mean square errors by maturities (in bps)

Notes: RMSE computed at monthly frequency.

	CZE		DNK		HUN		NOR		POL		SWE		CHE		GBR	
	H	L	H	L	H	L	H	L	H	L	H	L	H	L	H	L
3m	1	4	3	9	4	7	1	1	0	3	1	5	1	4	2	5
1y	5	10	19	21	8	20	3	7	4	13	8	12	4	10	8	13
2y	7	14	31	28	11	28	4	11	9	25	16	18	8	15	12	18
3y	11	15	34	31	14	30	5	14	13	34	20	21	12	18	15	22
4y	14	15	33	34	17	29	6	16	17	40	20	23	14	19	17	24
5y	16	14	30	36	20	27	6	17	20	45	17	24	15	20	18	25
6y	18	13	28	38	21	25	7	19	23	48	15	25	15	21	18	25
7y	18	13	26	39	22	24	7	20	24	51	14	26	15	22	18	26
8y	17	14	24	39	22	23	7	20	25	52	14	26	15	22	18	26
9y	16	14	23	39	23	22	7	20	26	54	14	26	15	23	18	26
10y	16	14	23	38	23	22	7	19	27	55	14	27	16	25	17	27

Table 24: Shadow-rate versus non-shadow-rate specification

	3m	1y	2y	3y	4y	5y	6y	7y	8y	9y	10y
Fitted yields											
CZE	0.11	0.13	0.08	0.02	0.05	0.07	0.06	0.03	0.01	0.04	0.08
DNK	0.11	0.24	0.06	0.08	0.12	0.12	0.08	0.04	0.03	0.08	0.13
HUN	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NOR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
POL	0.01	0.02	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.01	0.01
SWE	0.08	0.12	0.05	0.04	0.06	0.06	0.04	0.01	0.02	0.04	0.06
CHE	0.07	0.12	0.06	0.03	0.06	0.07	0.05	0.02	0.02	0.04	0.07
GBR	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.01
Term premia											
CZE	0.83	3.03	4.69	5.09	4.69	3.97	3.24	2.64	2.21	1.93	1.75
DNK	0.86	3.38	5.11	5.63	5.48	4.98	4.37	3.83	3.40	3.08	2.85
HUN	1.26	5.09	7.50	8.09	7.77	7.09	6.34	5.62	5.00	4.47	4.02
NOR	0.16	0.92	1.46	1.58	1.50	1.37	1.25	1.15	1.06	0.98	0.92
POL	1.24	6.35	10.38	11.99	12.29	11.92	11.23	10.42	9.58	8.79	8.06
SWE	0.48	2.37	3.61	3.68	3.15	2.60	2.25	2.08	1.99	1.93	1.85
CHE	0.36	1.32	2.02	2.26	2.27	2.16	2.00	1.84	1.69	1.55	1.43
GBR	0.24	1.24	2.27	2.99	3.40	3.55	3.51	3.36	3.14	2.90	2.66

Table 25: Average monthly–daily differences in fitted yields and term premia (bps)

Notes: This table reports average differences between monthly and daily estimates. The first block shows the difference between monthly fitted yields and end-of-month daily fitted yields. The second block shows end-of-month differences between term premia from the monthly fitted model and those from the daily filtered model.

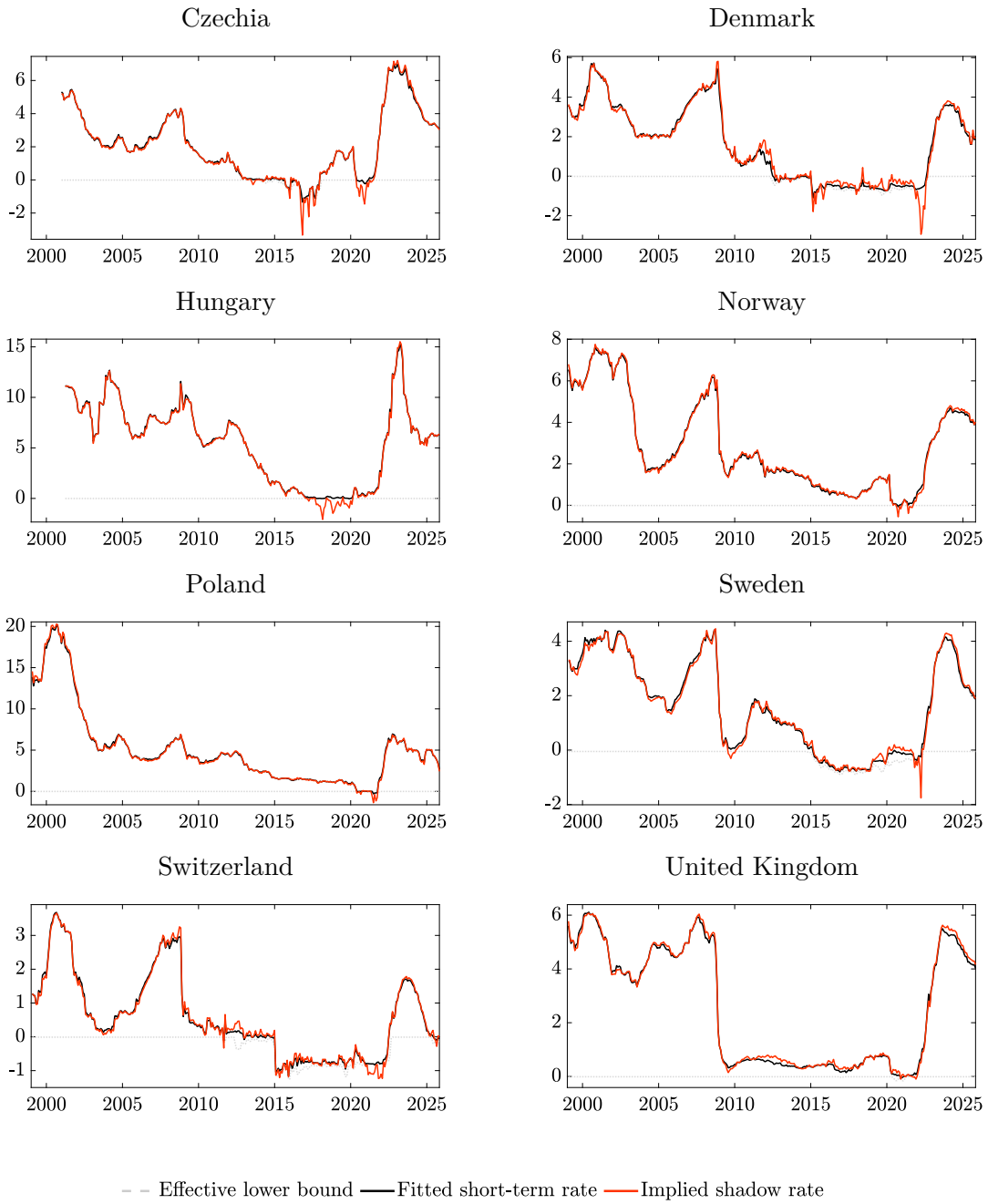


Figure 10: Shadow rates

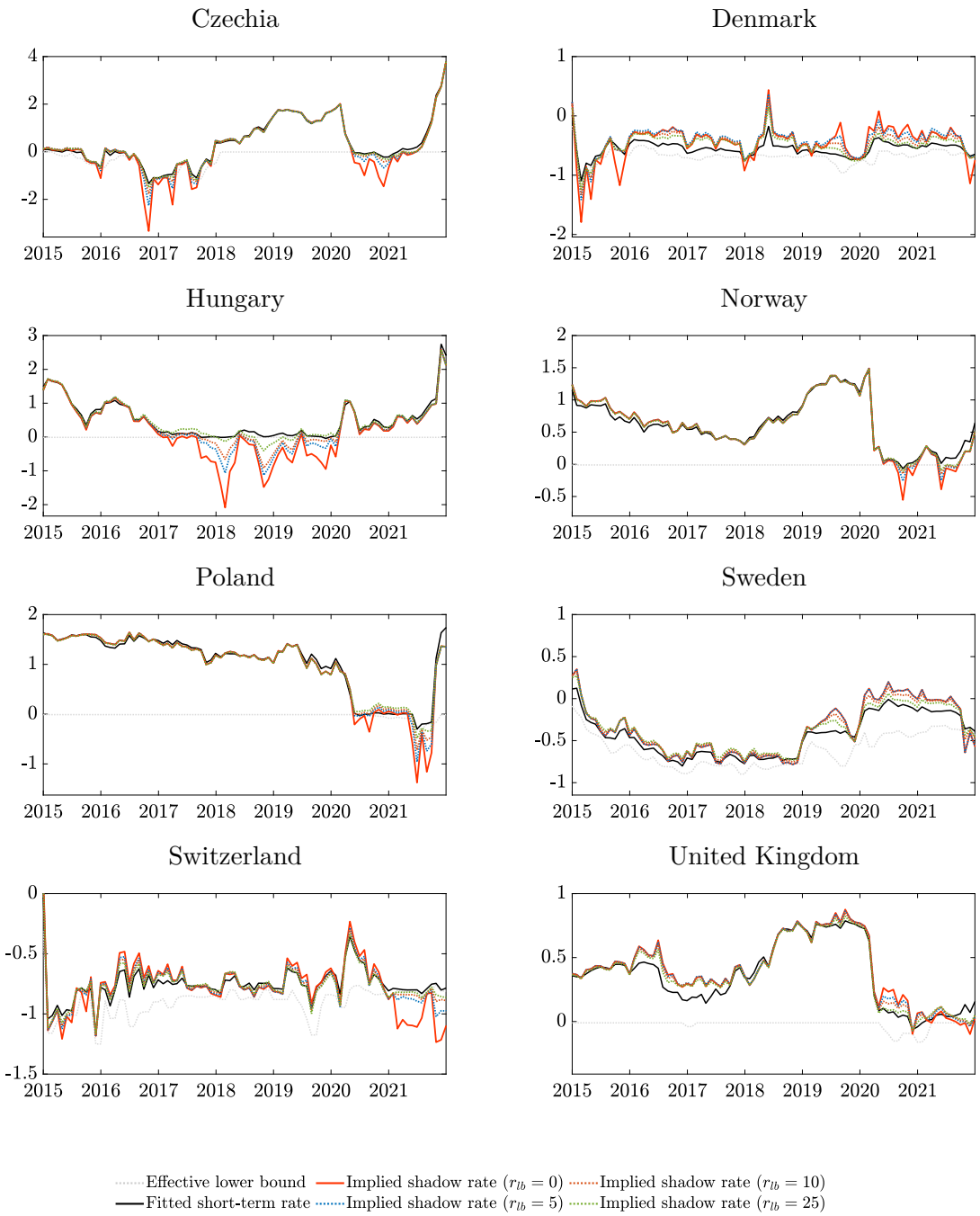


Figure 11: Sensitivity of shadow rates to r_s

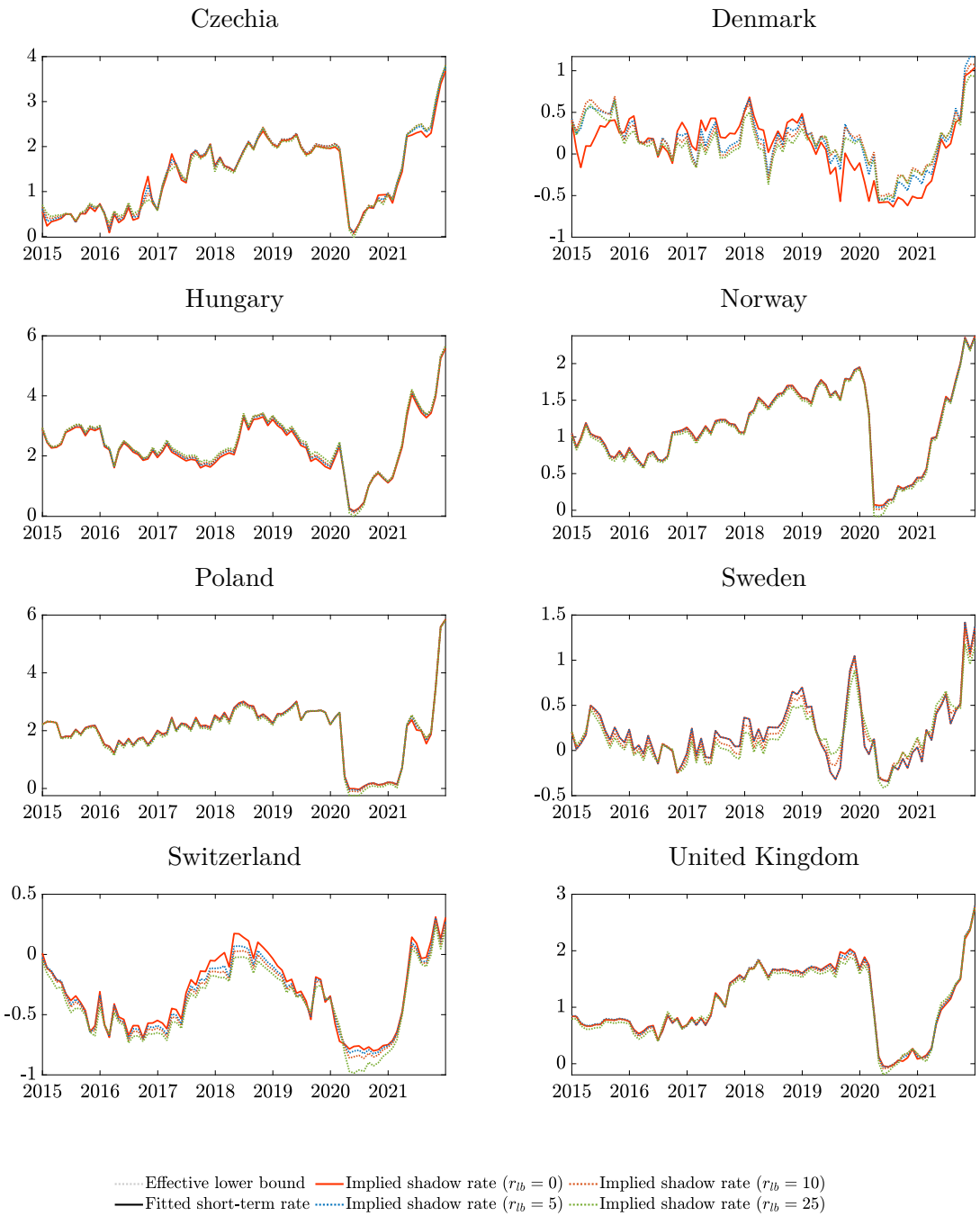


Figure 12: Sensibility of expectations components to r_s

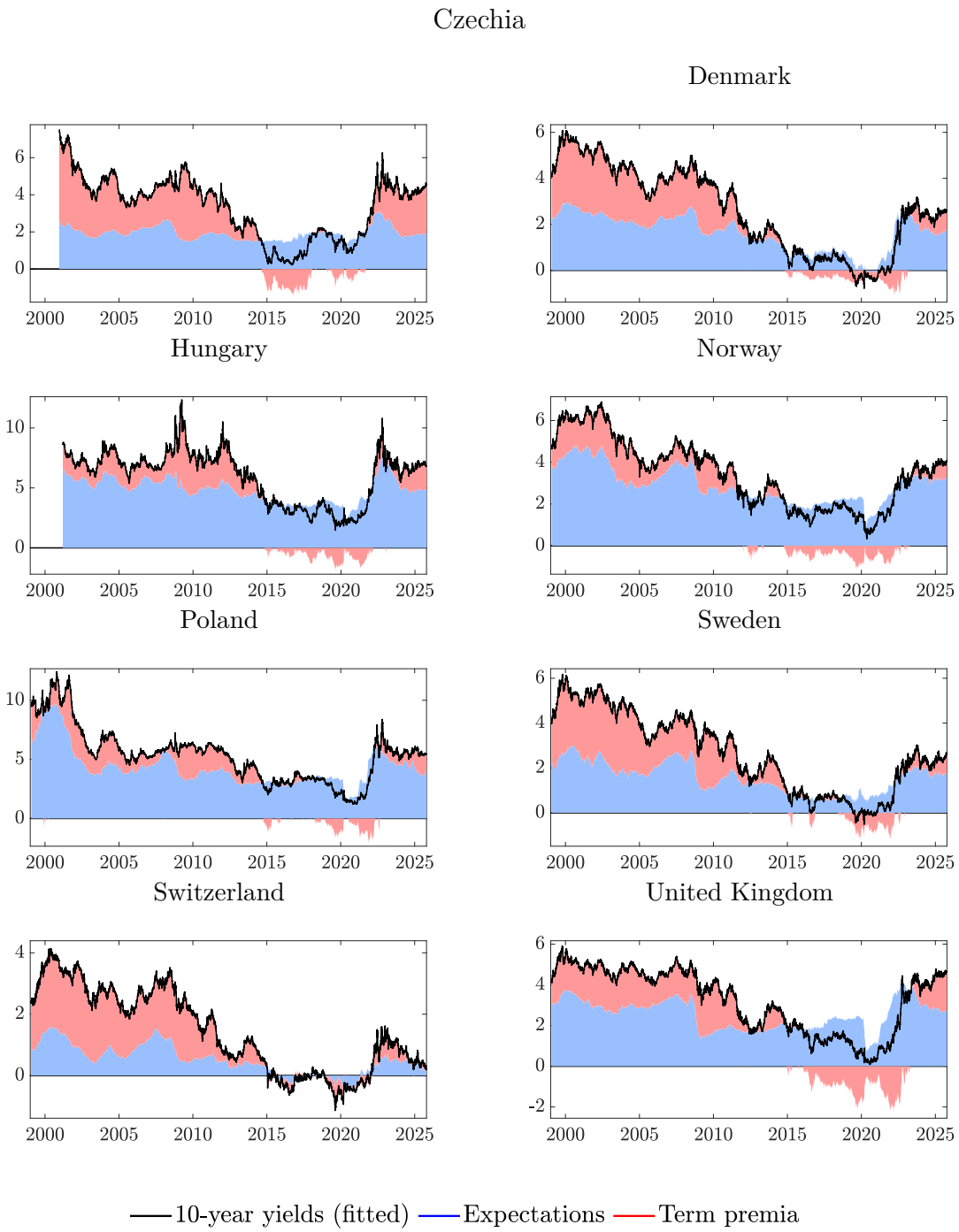


Figure 13: Decomposition of 10-year bond yields into expectations and term premia

A.6 Additional robustness

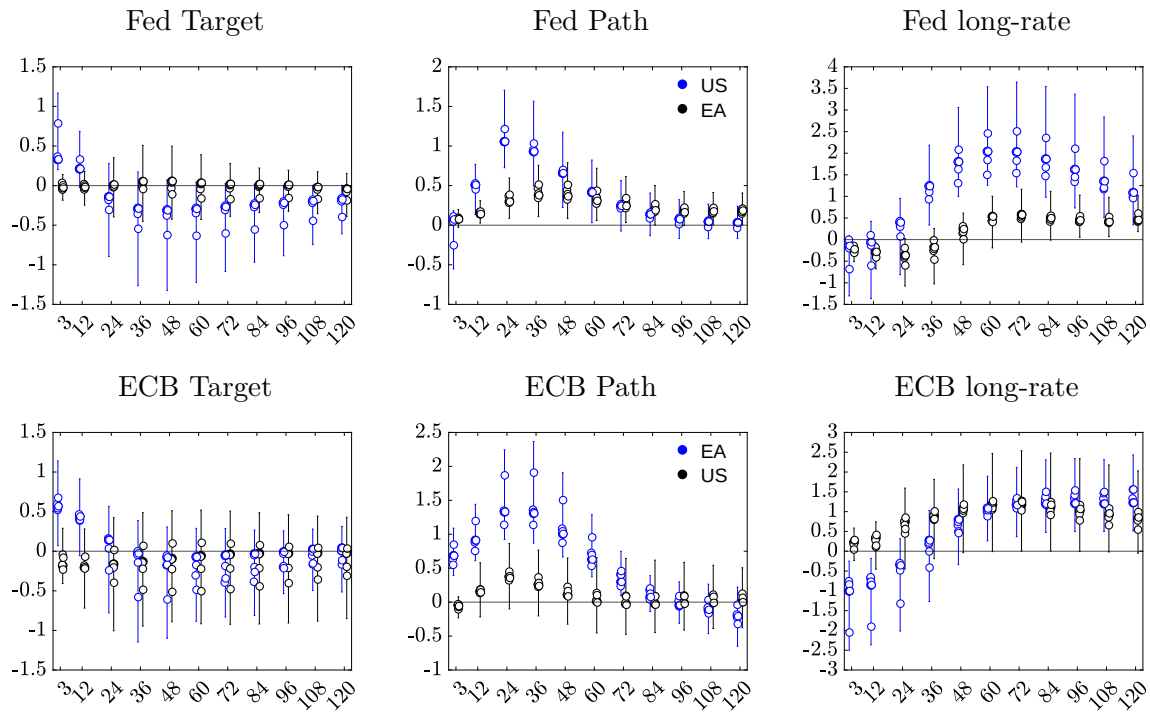


Figure 14: Fed and ECB monetary policy spillovers robustness

Notes: Regressions for the Fed are based on 202 observations, while regressions for the ECB are based on 259 observations. HAC standard errors are reported.

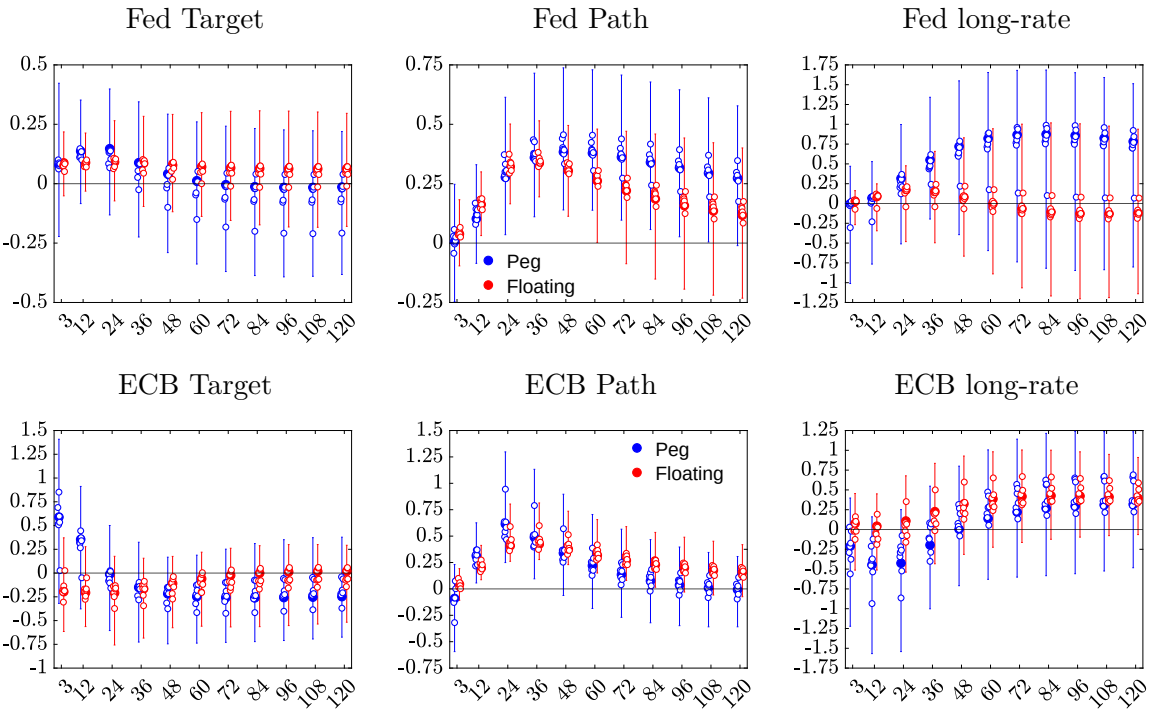


Figure 15: Fed and ECB monetary policy spillovers - leave out

Notes: Maturities refers to the 3m and 1y spot rates as well as 1-year forward rates in 1 to 9 years. Surprises are normalized to 10 basis points. HAC standard errors are reported.

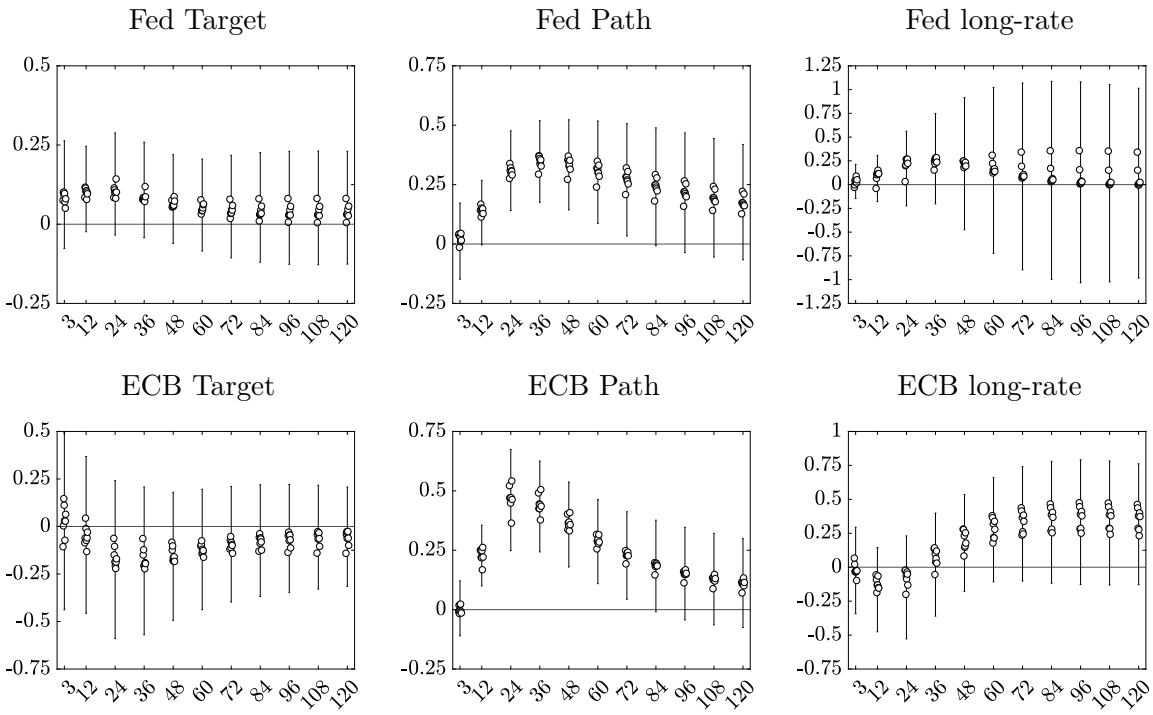


Figure 16: Fed and ECB monetary policy spillovers - leave out

Notes: Maturities include the 3m and 1y spot rates, as well as 1y forward rates from 1 to 9y ahead. Monetary policy surprises are nor normalized. Driscoll-Kraay standard errors are reported.