Living Up to Expectations: The Effectiveness of Forward Guidance and Inflation Dynamics Post-Global Financial Crisis

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Living Up to Expectations: The Effectiveness of Forward Guidance and Inflation Dynamics Post-Global Financial Crisis*

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Abstract

This paper studies the effectiveness of forward guidance when central banks face private agents with heterogeneous expectations allowing for a degree of bounded rationality. Exploiting unique survey-based measures of expected inflation, output growth, and interest rates, we estimate a small-scale New Keynesian model with forward guidance shocks for the United States and the other G7 countries plus Spain. We find that the share of fully-informed rational expectations (FIRE) agents in aggregate expectations is similar for the U.S., the U.K., Germany, and other major advanced economies (albeit far from one); however, Japan's share is much lower. For each country, the estimate of the share of FIRE agents has declined over time as VAR-based expectations—the heuristic approach assumed under bounded rationality—became more prominent in explaining the more recent data. Forward guidance has correspondingly grown less effective. In a counterfactual analysis, we document that, in the wake of the global financial crisis, inflation would have been significantly higher and the zero lower bound on short-term interest rates much less of a constraint had the public fully incorporated central banks' forward guidance statements as FIRE agents do. Moreover, inflation would have declined more, and somewhat faster, in the wake of the post-COVID-19 inflation surge as well.

Keywords: Forward Guidance, Monetary Policy, Heterogeneous Expectations, Expectations Formation, VAR-based Forecasting.

JEL Classifications: D84, E30, E52, E58, E60, P52.

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1 Introduction

Forward guidance has become a standard component of the modern central bank toolkit. Forward guidance involves providing communication (either explicit or implicit) on the future path of short-term interest rates. Although central banks have used some form of forward guidance for many years, it became particularly popular during the global financial crisis (GFC), when it was deployed in the U.S. and other developed countries as a substitute for conventional rate cuts at the zero lower bound (ZLB). Forward guidance again came to the fore with the onset of the COVID-19 pandemic and the resulting economic instability.

Because forward guidance works by shaping private-sector expectations of the future path of policy, to be effective central bank announcements must be incorporated into the expectations of economic actors. If the public does not believe or directly disregards those forward guidance statements, private-sector expectations of other macroeconomic variables (e.g., output and inflation) will be unaffected by central bank communication, leading to no contemporaneous or anticipated influence of forward guidance on the economy. However, if the public incorporates central bank commitments in their own forecasts, forward guidance ought to anchor private-sector expectations and stimulate the economy in advance of the promised future changes in the path of policy.

Our paper analyzes the effectiveness of forward guidance across both time and countries under a degree of bounded rationality and heterogeneity in the formation of expectations.[1] We also provide intriguing new evidence on how the recent paths of inflation and other aggregate macro variables might have been different over the last several years had central bank announcements been fully incorporated into private expectations by all agents.

We construct a small-scale New Keynesian model based on Curdia et al. (2015) and Cole and Martínez García (2023). In addition to staggered price-setting, the model allows for some explicitly backward-looking elements such as habit formation and price indexation, and features the usual combination of demand and supply shocks. Monetary policy is conducted using an inertial Taylor (1993)–type interest rate rule. The interest rate rule is augmented with a sequence of "news shocks" about future policy following Del Negro et al. (2012) and Cole and Martínez García (2023), which we interpret as forward guidance shocks.

To investigate the effectiveness of forward guidance, we allow for heterogeneous expecta-

[1] Boundedly rational agents are those whose decision-making process is constrained by cognitive limitations, information asymmetry, time constraints, or computational constraints. Unlike fully-informed rational expectations or FIRE agents who can process all available information instantaneously and costlessly, the bounded rationality assumption acknowledges that some agents forecast and make decisions in the real world with only incomplete information and simplified heuristics/econometrics.

tions to recognize that forecasting disagreements occur and can arise in part from differences in the way agents gather and process information to form their expectations. Furthermore, we depart from the full-information rational expectations (FIRE) paradigm introducing a fraction of boundedly rational agents because, as Sargent (1993) argued, an environment populated solely by rational agents attributes to the public much *more* knowledge than sophisticated econometricians are thought to have in reality. In our paper, a fraction of agents form expectations according to rational expectations and, being fully informed, incorporate forward guidance announcements into their decision-making too. The other fraction of agents form expectations as an econometrician, using a backward-looking vector autoregression (VAR) model that *excludes* all announcements about future policy changes. Our heterogeneous beliefs framework is grounded on the axiomatic approach laid out in Branch and McGough (2009). This has the attractive feature that aggregate expectations boil down to a convex combination of FIRE and VAR beliefs.

In our framework, the fraction of FIRE private agents is represented by the parameter $\tau \in [0, 1]$. When $\tau \to 1$, all agents exhibit homogeneous, full-information, and rational expectations, as typically assumed in the workhorse New Keynesian model (e.g., Del Negro et al. (2012) with forward guidance shocks). When $\tau \to 0$, aggregate expectations are also homogeneous, but reduced to a backward-looking VAR forecasting model. Consequently, when τ is larger, forward guidance announcements are quite effective at steering inflation and output from the moment of the announcement onward (and anticipation effects are stronger) as the share of FIRE agents dominates. When τ is instead close to zero, forward guidance becomes largely ineffective.

The parameter τ governs the convex combination of two different types of expectations (or forecasting models) between private agents, making its identification dependent on the heterogeneity of beliefs within the economy. Although τ determines the share of FIRE agents in the economy, it can also be understood as a (reduced-form) measure of the imperfect credibility of forward guidance, as described by Yellen (2006). To be precise, what that entails is simply that deviations from FIRE violate the Yellen (2006)'s notion of full credibility under which "market participants correctly anticipate the actions that the [central bank] will make in response to economic news and shocks [including forward guidance]. This alignment of the [central bank's] actions and the public's expectations strengthens the monetary policy transmission mechanism and shortens policy lags. In contrast, in the absence of [full] credibility, policymakers and the public [or part of the public] may work at cross-purposes, and monetary policy must act to overcome and dislodge expectations that hinder the achievement of [the central bank's] goals."[2]

The majority of our empirical analysis focuses on four countries: the U.S., the U.K., Germany, and Japan. However, we also present results that extend our analysis to other major advanced economies of the G7+ group (Canada, France, Italy, and Spain).[3] Our data sample extends from the third quarter 1990 (third quarter 1994 for Spain) through the third quarter 2022, including the most recent COVID-19 episode. For each country, we estimate the model parameters and recover smoothed shocks using Bayesian methods.

The data feature not only typical macro aggregates but also survey-based expectations from Consensus Economics, which collects responses on the values of future macroeconomic variables from the world's leading forecasters for all of the countries we consider. The expectations data series includes forecasts of one- and two-period-ahead real GDP growth and one-period-ahead headline CPI inflation. To identify forward guidance shocks, we exploit interest rate expectations up to 5 quarters ahead from the same source.[4]

The results of the full sample show that the estimates of the major countries of τ lie close to 0.5 over the full sample, except Japan's. The U.S. is estimated to be the highest, followed by the U.K. and Germany. Japan is estimated to be the lowest, with a notably lower estimate than the other countries. However, these estimates mask interesting time series heterogeneity. For all four countries, we find larger τ estimates for the earlier great moderation period (1990–2007) and substantially smaller estimates for the most recent period of (mostly) low interest rates (2005–2022).

We find similar results for Canada, France, Italy, and Spain that tend to be close in magnitude to what we find for the U.S., the U.K., and Germany, but not Japan. We also perform a rolling estimation exercise, reestimating the model over successive 69-quarter samples. For each country, we find approximately monotonic decreases in the mean estimate of τ. These estimated declines in τ coincide with smaller estimated effects of a hypothetical forward guidance shock in the model.

Taking the U.S. as an example, we estimate that a stimulative forward guidance shock

[2] Strictly speaking, τ measures the fraction of FIRE agents who react to forward guidance announcements, not the fraction of agents who believe central bank announcements about the future path of policy to be credible. However, because agents who use a backward-looking VAR for forecasting do not incorporate forward guidance announcements, we think it appropriate, with caveats, to refer to τ also as an implicit indicator of the misalignment between the forward guidance of the central bank and the public expectations of the policy path, as in Yellen (2006).

[3] See Martínez García (2018) for further details on the common business cycle patterns of the G7+ countries.

[4] As a robustness check, we also use longer-dated interest rate forecasts, extending them up to 8 quarters ahead, and find similar results. More details about the data can be found in Appendix A.

was approximately two-thirds as effective at raising output and inflation at the end of the sample period as at the beginning. Put differently, forward guidance effectiveness seems to have declined during the period in which forward guidance was used most prominently as nominal short-term rates became stuck at the ZLB for extended periods.

The economic significance of a declining τ is then investigated with a counterfactual exercise. Specifically, we explore the question: What would the path of aggregate macro variables have looked like had each central bank been interacting solely with FIRE agents (i.e., $\tau = 1$) under exactly the same forward guidance shocks recovered from our baseline estimation? In other words, what would the effect of forward guidance have been had it been deployed when it was most potent? For the U.S., the U.K., and Germany, inflation would have been higher and the ZLB on short-term nominal interest rates less of an issue in the wake of the GFC.

Concretely, our analysis suggests that at least some of the "missing inflation" post-GFC that has puzzled the earlier literature could be due to issues related to the potency of the anticipatory effects of forward guidance predicted under FIRE. Japan is somewhat of an outlier in the counterfactual analysis in part because Japan reached the ZLB in the early 1990s: While we estimate that the ZLB would have been less of a constraint, the differences in Japan's path of inflation post-GFC would not have been as stark as they were for the other three major countries. The evidence for Canada, France, Italy, and Spain is largely consistent with that for the U.S., the U.K., and Germany.

We next employ our counterfactual exercise to study the inflation surge that occurred in the aftermath of the short-lived COVID-19 recession. For the U.S., the U.K., and Germany, our analysis reveals that inflation would have started to decline faster, and somewhat sooner, in 2022 had central banks been interacting solely with FIRE agents. This suggests that forward guidance was likely appropriate to bring down inflation but may have been calibrated under the assumption of greater alignment with the FIRE paradigm. The evidence is largely consistent when we look at the experiences of Canada, France, Italy, and Spain. In turn, Japan is again an outlier.

Our paper contributes to a large literature that studies forward guidance and the so-called forward guidance puzzle. The paper shows that heterogeneous expectations—and the bounded rationality of some agents—dampen the implausibly strong anticipation effects of forward guidance found in dynamic stochastic general equilibrium (DSGE) models with only FIRE agents (see, e.g., Del Negro et al. (2012) and the more recent work of Cole and Martínez García (2023)). The finding of Kohlhas and Walther (2021) that survey-based measures of expectations are incompatible with standard ways of modeling rational expectations also underscores the need to incorporate heterogeneous expectations into macroeconomic models, as we do here.[5]

Tetlow (2022) examines expectations formation, credibility, and policy communication relative to determinants of the sacrifice ratio. Our work considers aggregate outcomes in a related manner, exploring through counterfactuals the role of heterogeneous expectations and bounded rationality on the post-GFC missing inflation puzzle and on the post-COVID-19 inflation surge. Our paper also builds on a growing literature that relies on survey-based forecasts to discipline the identification of news shocks (Martínez García (2021); Angeletos and Huo (2021); Milani (2023)). The novel contribution of our paper is studying empirically how expectations formation and its implications for the effectiveness of forward guidance vary across both time and space. Our counterfactual analyses also offer some potential insights into the role of central bank announcements in the recent behavior of inflation.

The remainder of the paper is organized as follows: Section 2 introduces the baseline model with forward guidance, heterogeneous forecasts, and bounded rationality, exploring its properties and the role of the key parameter τ. Section 3 outlines the dataset and Bayesian estimation strategy. Section 4 presents the main findings on the effectiveness of forward guidance across time and space, including counterfactual analyses and robustness checks, extending the analysis to all G7+ countries. Section 5 concludes. Appendix A details the data sources, and Appendix B provides additional tables and figures.

2 Model

We employ a standard New Keynesian model that follows from the workhorse framework laid out by Woodford (2003), Giannoni and Woodford (2004), Milani (2007), Curdia et al. (2015), Cole and Milani (2017) and, more recently, Cole and Martínez García (2023). The log-linear approximation that we take to the data is derived from the optimizing behavior of households and firms as shown in Cole and Martínez García (2023). The model incorporates habit formation in consumption, price stickiness, and price indexation.

Monetary policy is characterized by an inertial Taylor (1993) interest rate feedback rule

[5] Caballero and Simsek (2022) characterize forecasting heterogeneity as "mistakes" when central bank interest rate decisions are misaligned with private expectations. Their work focuses on differences in expectations between markets and the central bank rather than among private agents themselves, in contrast to our model. According to Park (2018), monetary authorities typically employ macroeconomic models constructed under FIRE to forecast future economic activity, the future path of inflation, and the policy rate—that is, central banks tend to use models lacking the sort of heterogeneity in expectations that is central to our model and, therefore, tend to misjudge the effects to be expected from forward guidance.

that describes the response of monetary policy to economic conditions. We augment this policy rule in one important dimension by explicitly distinguishing between unanticipated (surprise) and anticipated (forward guidance) shocks to monetary policy—a distinction that allows us to investigate a reduced-form representation of central bank's forward guidance announcements in a general equilibrium framework. We describe the monetary policy rule in greater detail in Subsection 2.2 below.

Here, we depart from the FIRE, homogeneous-beliefs paradigm embedded in most of the DSGE literature. Private agents are modeled as heterogeneous-beliefs household-firm pairs that form expectations in different ways. The differences in beliefs imply that not all private actors end up incorporating the central bank's forward guidance in their outlooks (forecasts) and decision-making processes.

In FIRE models, central bank announcements are fully incorporated. In models in which some agents have limited information and processing capabilities and form expectations based on standard VAR techniques to fit the observed data, such announcements are ruled out in practice. VAR techniques are relatively straightforward to implement but do not directly capture the central bank's efforts to shape expectations through forward guidance, as they rely solely on realized macroeconomic variables. Nonetheless, if a sufficient number of FIRE agents respond to these announcements, influencing aggregate outcomes, the VAR model implicitly adjusts to approximate the resulting changes in the macro dynamics.[6]

2.1 Main Structural Relationships

As in Curdia et al. (2015) and Cole and Martínez García (2023), the workhorse New Keynesian model can be described with the following pair of log-linearized equations, the dynamic investment–savings (IS) equation and the New Keynesian Phillips curve (NKPC), respectively:

$$\tilde{x}_t = \mathbb{E}_t(\tilde{x}_{t+1}) - (1-\beta\eta)(1-\eta)\left(i_t - \mathbb{E}_t(\pi_{t+1}) - r_t^n\right), \tag{1}$$

$$\tilde{\pi}_t = \beta\mathbb{E}_t(\tilde{\pi}_{t+1}) + \xi_p\left(\omega x_t + \left((1-\beta\eta)(1-\eta)\right)^{-1}\tilde{x}_t\right) + \mu_t, \tag{2}$$

[6] A VAR model serves as a reduced-form representation of the solution to a forward-looking (log-linearized) DSGE model (Martínez García (2020)), offering flexibility and ease of use for forecasting. This flexibility enables private agents to form expectations based solely on observed macroeconomic outcomes, without relying on knowledge of the policy rule or the economy's structure. While a finite-order VAR can replicate the solution of a workhorse model with homogeneous FIRE agents under general conditions and without forward guidance shocks, this breaks down in the presence of forward guidance or news shocks, distinguishing it from the learning literature reviewed by Evans and Honkapohja (2001).

where

$$\tilde{y}_t \equiv y_t - \eta y_{t-1} - \beta\eta\mathbb{E}_t\left(y_{t+1} - \eta y_t\right), \tag{3}$$

$$\tilde{y}_t^n \equiv y_t^n - \eta y_{t-1}^n - \beta\eta\mathbb{E}_t\left(y_{t+1}^n - \eta y_t^n\right), \tag{4}$$

$$\tilde{x}_t \equiv \tilde{y}_t - \tilde{y}_t^n = x_t - \eta x_{t-1} - \beta\eta\mathbb{E}_t\left(x_{t+1} - \eta x_t\right), \tag{5}$$

$$\tilde{\pi}_t \equiv \pi_t - \iota_p \pi_{t-1}. \tag{6}$$

The one-period nominal interest rate (i_t) is the nominal short-term rate, inflation ($\pi_t \equiv \Delta p_t$) is the first difference on the consumption price level in logs p_t, and the output gap (x_t) is defined as $x_t \equiv y_t - y_t^n$, i.e., the log deviation of actual output (y_t) from its potential counterpart absent all frictions (y_t^n). Here, we denote the aggregate expectations operator as $\mathbb{E}_t(\cdot)$. We describe how this aggregate expectations operator incorporates heterogeneous beliefs in Subsection 2.3 below.

The intertemporal rate of substitution is set to unity, while the parameter $\omega > 0$ describes the inverse of the Frisch elasticity of labor supply. We introduce habit formation in consumption with the parameter $0 \leq \eta \leq 1$. The intertemporal discount factor is $0 < \beta < 1$, and in the spirit of Calvo (1983), a fraction of firms, given by the parameter $0 \leq \theta \leq 1$, is unable to adjust their prices every period, while the remaining fraction $(1-\theta)$ of firms can. Hence, the composite coefficient ξ_p defined as $\frac{(1-\theta\beta)(1-\theta)}{\theta}$ scales the slope of the NKPC. Furthermore, as in Yun (1996), non-reoptimizing firms index their prices to past inflation with the degree of indexation determined by the parameter $0 \leq \iota_p \leq 1$.

We use equation (5) to re-express the system of equations given by (1)–(2) and describe the dynamics of the economy in terms of actual output (y_t) and potential output (y_t^n). Using the actual and potential output transformations in equations (3)–(4), along with (6), straightforward algebra allows us to further rewrite the system of equations (1)–(2) (i.e., the dynamic IS and NKPC equations above) in terms of three observable endogenous macro variables: the output level in logs (y_t) or, alternatively, output growth ($g_t \equiv \Delta y_t$, the first difference of y_t), inflation ($\pi_t \equiv \Delta p_t$), and the nominal short-term interest rate (i_t).

Frictionless Allocation The potential output allocation (y_t^n) and the natural real rate of interest (r_t^n) represent the levels of output and of the real interest rate that would prevail absent all nominal rigidities and informational frictions (that is, whenever all agents make fully informed and rational decisions under FIRE). These two variables describe the frictionless allocation and define the benchmark—consistent with stable prices—that the central bank aims to achieve with its policies.

In that counterfactual world, potential output (y_t^n) would evolve according to the following equation:

$$\begin{aligned} &\omega y_t^n + \tfrac{1}{(1-\beta\eta)(1-\eta)}\left(y_t^n - \eta y_{t-1}^n\right) - \tfrac{\beta\eta}{(1-\beta\eta)(1-\eta)}\left(\mathbb{E}_t^{FIRE}\left(y_{t+1}^n\right) - \eta y_t^n\right) \\ &= \tfrac{\eta}{(1-\beta\eta)(1-\eta)}\left(\beta\mathbb{E}_t^{FIRE}\left(\gamma_{t+1}\right) - \gamma_t\right). \end{aligned} \tag{7}$$

Given the potential output (y_t^n) in equation (7), the aggregate intertemporal Euler equation implies that the natural rate of interest (r_t^n) can be expressed as:

$$r_t^n = \mathbb{E}_t^{FIRE}\left(\gamma_{t+1}\right) - \omega\mathbb{E}_t^{FIRE}\left(\Delta y_{t+1}^n\right). \tag{8}$$

Here, we denote the expectations operator of FIRE agents as $\mathbb{E}_t^{FIRE}(\cdot)$. Equations (7) and (8) highlight the close connection between potential output and the natural rate of interest, both of which respond to a common shock—the exogenous shock to productivity growth $\gamma_t \equiv \Delta \ln(A_t)$, where A_t denotes total factor productivity (TFP).

Exogenous (Nonmonetary) Shock Processes. The exogenous shock to productivity growth (γ_t) and the cost-push shock (μ_t) are assumed to follow standard AR(1) processes:

$$\gamma_t = \rho_\gamma \gamma_{t-1} + \varepsilon_t^\gamma, \tag{9}$$

$$\mu_t = \rho_\mu \mu_{t-1} + \varepsilon_t^\mu, \tag{10}$$

where $\varepsilon_t^\gamma \overset{iid}{\sim} N\left(0, \sigma_\gamma^2\right)$ and $\varepsilon_t^\mu \overset{iid}{\sim} N\left(0, \sigma_\mu^2\right)$. The persistence of the productivity growth and cost-push shocks is given by the parameters $0 < \rho_\gamma < 1$ and $0 < \rho_\mu < 1$, respectively. Similarly, the volatility of the productivity growth and cost-push shocks is given by $\sigma_\gamma^2 > 0$ and $\sigma_\mu^2 > 0$, respectively. We do not consider spillovers between productivity growth and cost-push shocks and assume that their innovations are uncorrelated at all leads and lags.

2.2 Monetary Policy

The monetary policy framework is defined in terms of the central bank's policy target, the short-term nominal interest rate. To describe the monetary policy strategy in this context, we adopt an inertial form of the Taylor (1993) rule. Accordingly, the nominal interest rate (i_t) tracks the neutral policy rate (i_t^n) factoring in also the previous-period gap between the policy rate and the neutral rate to account for policy inertia. Moreover, monetary policy responds to contemporaneous deviations from the central bank's stated objectives—that is, responds to inflation deviations from the zero-inflation steady-state target (π_t) and possibly also to the output gap ($x_t \equiv y_t - y_t^n$).

In short, we define the policy rule in the following terms:

$$i_t - i_t^n = \rho(i_{t-1} - i_{t-1}^n) + (1-\rho)\left[\chi_\pi \pi_t + \chi_x \left(y_t - y_t^n\right)\right] + \varepsilon_t^{MP} + \sum\nolimits_{l=1}^{L} \varepsilon_{l,t-l}^{FG}, \tag{11}$$

where the Fisher equation

$$r_t \equiv i_t - \mathbb{E}_t(\pi_{t+1}) \tag{12}$$

links the target policy rate (i_t), the short-term real interest rate (r_t), and aggregate inflation expectations ($\mathbb{E}_t(\pi_{t+1})$). Similarly, the neutral short-term policy rate (i_t^n) is related to the natural rate of interest (r_t^n) and aggregate inflation expectations ($\mathbb{E}_t(\pi_{t+1})$) through the corresponding variant of the Fisher equation, i.e., $i_t^n \equiv r_t^n + \mathbb{E}_t(\pi_{t+1})$.

The Taylor (1993) rule in equation (11) is a plausible guide for the conduct of monetary policy that tracks the neutral policy rate to guide the economy toward "operating at full strength and with stable inflation" (Powell (2020)). The smoothing parameter given by $0 \leq \rho < 1$ regulates the degree of inertia in monetary policymaking while the parameters χ_π and χ_x determine the policy response to inflation and the output gap, respectively.

The rule in equation (11) also includes time-contingent forward guidance in the form of anticipated monetary policy shocks (news) as in Del Negro et al. (2012), Cole (2020a), Cole (2020b), and Cole and Martínez García (2023). The unanticipated (surprise) monetary policy shocks ε_t^{MP} are combined with the forward guidance (news) shocks given by $\varepsilon_{l,t-l}^{FG}$ for all $l = 1, ..., L$.[7] The length of the forward guidance horizon provided by the news shocks is determined by $1 \leq L < +\infty$, implying that there is a finite number of L forward guidance shocks in the summation term in equation (11).[8]

Monetary policy surprises and forward guidance shocks are assumed to be purely transitory or *i.i.d.*, i.e.,

$$\varepsilon_t^{MP} \overset{iid}{\sim} N\left(0, \sigma_{MP}^2\right), \tag{13}$$

$$\varepsilon_{l,t-l}^{FG} \overset{iid}{\sim} N\left(0, \sigma_l^{2,FG}\right), \ \forall l = 1, ..., L, \text{ and } 1 \leq L < +\infty. \tag{14}$$

[7]Schmitt-Grohe and Uribe (2012) utilize anticipated shocks and describe them as "news". We embrace this idea to study—in a reduced form—forward guidance and its effects via monetary policy news shocks.

[8]In practice, we consider forward guidance up to 5 quarters ahead because of data limitations on the survey-based forecasts we use and to reduce the number of parameters to be estimated. However, we consider as a robustness check the case where we extend the forecast horizon up to a maximum of 8 quarters ahead. The results do not change qualitatively and are available upon request.

Each $\varepsilon_{l,t-l}^{FG}$ in equation (11) represents anticipated or news shocks that private agents know about in period $t-l$ but that will not directly affect the policy target (the policy rate) until l periods later, that is, until period t. The volatility of the unanticipated and anticipated monetary policy shocks in equations (13)–(14) is given by $\sigma_{MP}^2 > 0$ and $\sigma_l^{2,FG} > 0$ for all $l = 1, ..., L$, respectively. The innovations of the anticipated and unanticipated monetary policy shocks are uncorrelated with each other and with the productivity growth and cost-push shock innovations at all leads and lags.

Recovering Forward Guidance Shocks with Survey-Based Forecasts. Given the productivity growth and cost-push shocks in equations (9)–(10) and the unanticipated (surprise) and anticipated (news) monetary policy shocks in (13)–(14), the vector of three observable macro variables in output growth, inflation, and nominal interest rates ($Y_t = [g_t, \pi_t, i_t]'$) lacks fundamentalness in the sense of Hansen and Sargent (1980) and Martínez García (2020). In other words, the three observables do not contain enough information for us to pin down the vector of structural shocks $\varepsilon_t = \left[\gamma_t, \mu_t, \varepsilon_t^{MP}, \left\{\varepsilon_{l,t-l}^{FG}\right\}_{l=1}^{L}\right]'$.

To remedy this issue, we adopt the identification strategy explored by Doehr and Martínez García (2015) in a VAR setting and employed by Cole and Milani (2017) and Cole and Martínez García (2023) within a DSGE modeling framework. This strategy involves augmenting the vector of observables $[g_t, \pi_t, i_t]'$ with expectations with which to disentangle anticipated from unanticipated monetary policy shocks. Thus, the vector of observables is expanded with a sufficiently large subset of the available survey-based expectations as follows:

$$\overline{Y}_t = \left[g_t, \pi_t, i_t, \mathbb{E}_t\left(\Delta^4 y_{t+1}\right), \mathbb{E}_t\left(\Delta^4 y_{t+2}\right), \mathbb{E}_t\left(\Delta^4 p_{t+1}\right), \mathbb{E}_t\left(i_{t+1}\right), ..., \mathbb{E}_t\left(i_{t+L}\right)\right]', \tag{15}$$

where i_{t+h} denotes the nominal short-term interest rate in percent in period $t+h$ (for $h = 1, ..., L$), $\Delta^k y_{t+h} \equiv (y_{t+h} - y_{t+h+k-1})$ refers to the k-period log difference in output in period $t+h$ (for $h = 1, 2$), and $\Delta^k p_{t+j} \equiv (p_{t+h} - p_{t+h+k-1})$ denotes the k-period log difference in the price level in period $t+h$ (for $h = 1$). For $k = 4$, the notation Δ^k describes the 4-quarter percentage change that we observe in the forecasts of real GDP growth and CPI inflation. For $k = 1$, we obtain the corresponding quarter-over-quarter percentage change for both variables, which we define as $\Delta^1 y_{t+h} = \Delta y_{t+h} \equiv g_{t+h}$ and $\Delta^1 p_{t+h} = \Delta p_{t+h} \equiv \pi_{t+h}$.

To facilitate the estimation of the model, we add two additional measurement equations that approximate the 4-quarter percentage change formula (Δ^4) with the summation of the quarter-over-quarter percentage changes in log-first differences (Δ^1) as follows:

$$\Delta^4 y_t = \sum_{h=1}^{4} g_{t+1-h}, \tag{16}$$

$$\Delta^4 p_t = \sum_{h=1}^{4} \pi_{t+1-h}. \tag{17}$$

The measurement equations (16)–(17) link observable survey-based forecasts of real GDP growth and CPI inflation to their corresponding model-implied aggregate expectations.

Given the structure of the economy described by equations (1)–(2) together with (3)–(6), the frictionless allocation in (7)–(8), the nonmonetary shock processes in (9)–(10), the Taylor (1993) rule in (11), the Fisher equation in (12), and the unanticipated and anticipated monetary policy shocks given by (13)–(14), the vector of observables augmented with expectations $\overline{Y}_t$ in (15), together with the measurement equations (16)–(17) and the definition of output growth in log first differences ($g_t \equiv \Delta y_t$), suffice to ensure under general conditions that we can identify all structural shocks, i.e., recover $\varepsilon_t = \left[\gamma_t, \mu_t, \varepsilon_t^{MP}, \left\{\varepsilon_{l,t-l}^{FG}\right\}_{l=1}^{L}\right]'$.

2.3 Aggregate Expectations

Forward guidance raises the prospect of central banks' managing expectations. Failure to communicate the policy path effectively enough to align private expectations can lead to significant forecasting heterogeneity among private agents.[9] We assume that a fraction of private agents are information-constrained (operating under bounded rationality) and form their expectations about the observables using a standard VAR model to forecast the future path of the economy, ignoring all central bank announcements until they materialize at a later time. That is, some private agents opt to forecast the observable vector $Y_t = [g_t, \pi_t, i_t]'$ —as a well-informed econometrician would—based on the following parsimonious structural VAR(1) process in mind:

$$Y_t = A + BY_{t-1} + u_t, \tag{18}$$

where A and B are reduced-form matrices of conforming dimensions, and u_t is a vector of (nonstructural) residuals. Equation (18) captures well the historical dynamics of Y_t in our sample.[10] By contrast, we assume that other private agents are more sophisticated in how

[9] In this paper, we assume that households own the firms and, accordingly, we refer to the firm-owning households as private agents or private actors. This implies that, in our benchmark economy, the mix of households' expectations does not differ from the mix of firms' expectations. We leave for future research the exploration of richer environments where firms' expectations may differ from households' expectations.

[10] We simplify the model by setting the column vector A to zero ($A = \mathbf{0}$), assuming that the means in the data are addressed through the measurement equations specified in Subsection 3.2. In our estimation,

they process information, adjusting their views about the future in response to the central bank's own forward guidance announcements. We describe these private agents as forming expectations according to the FIRE paradigm.

Following the axiomatic approach for heterogeneous beliefs of Branch and McGough (2009) and Haberis et al. (2019), under certain conditions, aggregate expectations $\mathbb{E}_t\left(Y_{t+1}\right)$ can be expressed as a weighted sum of the expectations of those private agents who incorporate all available information to form their expectations rationally (FIRE) and those who use VAR-based forecasts. Specifically, we define aggregate expectations as follows:

$$\mathbb{E}_t\left(Y_{t+1}\right) = \tau \mathbb{E}_t^{FIRE}\left(Y_{t+1}\right) + \left(1-\tau\right)\mathbb{E}_t^{VAR}\left(Y_{t+1}\right), \tag{19}$$

where $\mathbb{E}_t^{FIRE}\left(Y_{t+1}\right)$ represents the forecasts of private agents under FIRE and $\mathbb{E}_t^{VAR}\left(Y_{t+1}\right)$ denotes the VAR-based expectations of other (boundedly rational) private agents inferred from equation (18). We adopt a timing assumption to align aggregate expectations in the model with the contemporaneous release of survey-based forecasts in our dataset. Specifically, we assume that forecasts at period t, $\mathbb{E}_t\left(\cdot\right)$, correspond to the consensus forecasts from a survey released at the same time t (as detailed in Appendix A).[11]

The parameter $0 < \tau < 1$, which represents the share of FIRE agents in the economy, acts as the model's key aggregation parameter for expectations. Values of τ between zero and one introduce forecast heterogeneity, including variations in expectations about the future policy path. When $\tau \to 1$, all agents adopt FIRE, fully aligning their expectations with the central bank's policy path and incorporating forward guidance, leading to homogeneous

the undetermined coefficients in matrix B are implicitly derived as part of the structural model, with the resulting estimates reflecting the information available over the entire sample period. For the VAR-based forecasts, we adopt the following flexible specification:

$$\begin{bmatrix} \mathbb{E}_t^{VAR}(\Delta y_{t+1}) \\ \mathbb{E}_t^{VAR}(\Delta y_{t+2}) \\ \mathbb{E}_t^{VAR}(\pi_{t+1}) \\ \mathbb{E}_t^{VAR}(i_{t+1}) \\ \mathbb{E}_t^{VAR}(i_{t+2}) \\ \mathbb{E}_t^{VAR}(i_{t+3}) \\ \mathbb{E}_t^{VAR}(i_{t+4}) \\ \mathbb{E}_t^{VAR}(i_{t+5}) \end{bmatrix} = \begin{bmatrix} var_{1x1} & 0 & 0 \\ var_{1x2} & 0 & 0 \\ 0 & var_{2\pi} & 0 \\ 0 & 0 & var_{3i} \\ 0 & 0 & var_{3i2} \\ 0 & 0 & var_{3i3} \\ 0 & 0 & var_{3i4} \\ 0 & 0 & var_{3i5} \end{bmatrix} \begin{bmatrix} y_t \\ \pi_t \\ i_t \end{bmatrix}.$$

Further exploration of the learning dynamics for A and B, as well as the stability properties of a model with learning (e.g., Evans and Honkapohja (2001), Orphanides and Williams (2004), Orphanides and Williams (2007)), is beyond the scope of this paper and remains a topic for future research.

[11] Cole and Martínez García (2023) explore alternative timing conventions that account for publication lags in forecasters' available information set but find these adjustments yield only marginal differences.

expectations: $\mathbb{E}_t(Y_{t+1}) = \mathbb{E}_t^{FIRE}(Y_{t+1})$. Conversely, as $\tau \to 0$, agents disregard the central bank's communications, and while expectations remain homogeneous, they are based entirely on observed outcomes: $\mathbb{E}_t(Y_{t+1}) = \mathbb{E}_t^{VAR}(Y_{t+1})$.

In general, the aggregate expectations of private agents are a convex combination weighed by the parameter τ with a mixture of FIRE and VAR-based agents. This is the benchmark model we estimate and inevitably yields an economy where forward guidance also loses some of its potency when τ is strictly less than one (deviating from the FIRE paradigm).

2.4 Understanding the Mechanism

Before proceeding to our formal estimation, we first compute impulse responses in a stylized version of the model to illustrate how the expectations aggregation parameter τ impacts the efficacy of forward guidance news shocks.

To fix ideas, we parameterize the model so that there is no consumption habit ($\eta = 0$), no price indexation ($\iota_p = 0$), and no interest rate smoothing ($\rho = 0$). This means that our model collapses to the textbook three-equation New Keynesian model with no endogenous state variables where $\tau = 1$ (i.e., where all private agents are FIRE actors). The rest of the structural parameters are fixed to the prior means, as seen in Appendix B, Table B1. Using the definition of output growth, $g_t \equiv \Delta y_t$, we can reformulate the model in terms of y_t instead of g_t to derive the impact of shocks on the output level.

The left column of Figure 1 plots impulse responses to a 25 bp forward guidance shock 5 periods ahead (i.e., a shock to $\epsilon_{5,t}^{FG}$ observed in period t that takes effect in five periods, hence, in period $t+5$). The solid lines show the responses when we assume only FIRE forecasts, i.e. when $\tau = 1$. Output and inflation jump down significantly the moment the forward guidance shock is announced; the peak inflation response is on impact, while output declines somewhat more during the intervening periods, with a peak response in the same period that the shock materializes. The interest rate declines slightly before the period in which the shock is realized because of the endogenous feedback between inflation, output, and the interest rate given by the monetary policy rule in (11). Because the forward guidance shock is transitory and there is no interest rate smoothing and no other endogenous state variables, all variables in the model return to steady state after period $t+5$.

The dashed and dotted lines in the left column of Figure 1 plot the responses to the same forward guidance shock when there is a degree of heterogeneity in expectations including a significant share of agents operating under bounded rationality ($\tau = 0.5$) and when all agents are homogeneous but act under bounded rationality constraints ($\tau = 0$). In the case

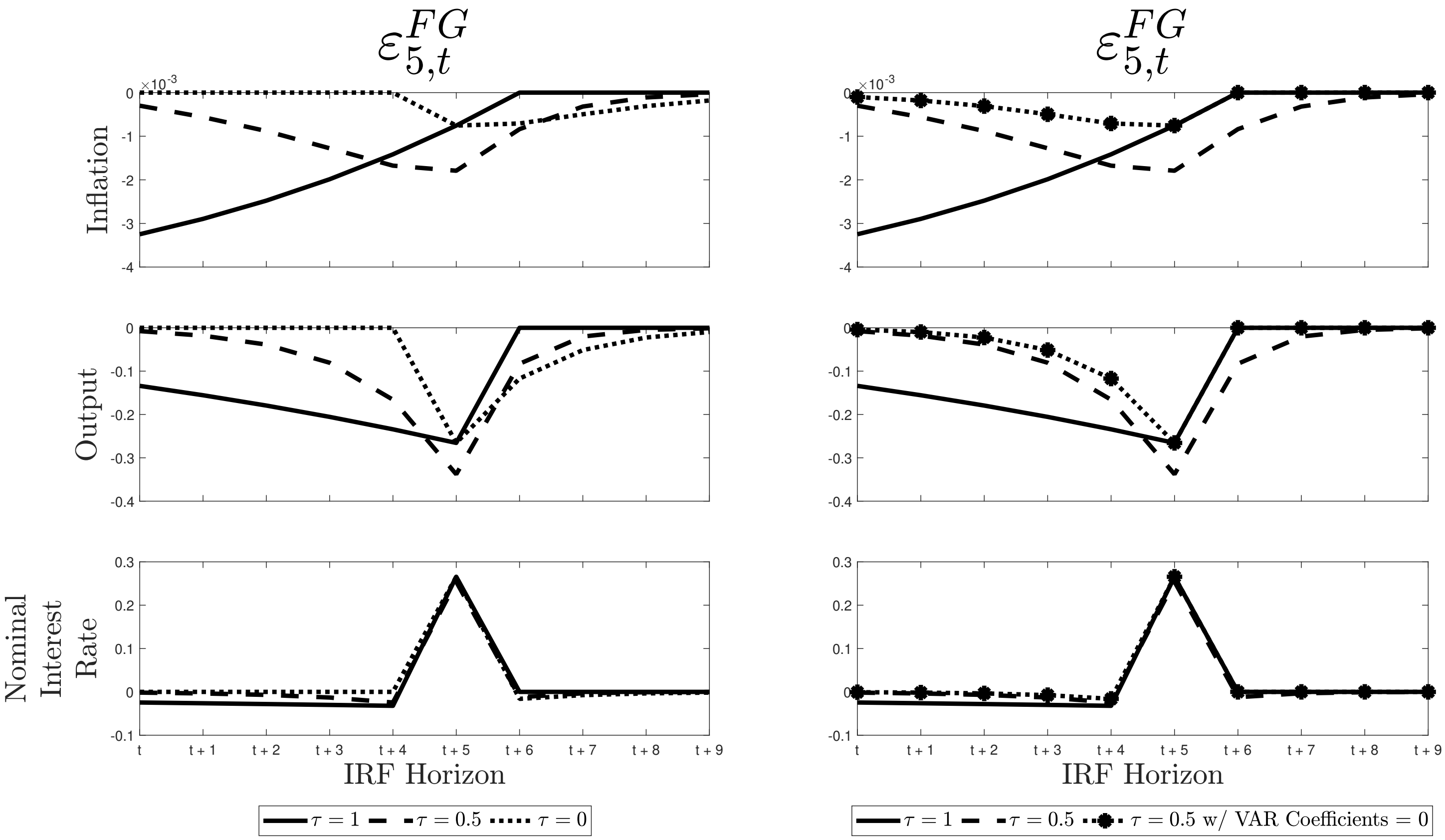

Figure 1: Impulse Responses of Macroeconomic Variables to a 5-Period-Ahead Forward Guidance Shock

Note: Benchmark model of Section 2, but with no habit in consumption ($\eta = 0$), no price indexation ($\iota_p = 0$), and no interest rate smoothing ($\rho = 0$). 25 basis point (bp) increase.

with only VAR-based forecasts ($\tau = 0$), nothing happens before the period in which the shock is realized. Output and inflation jump down in that period and then slowly return to steady state afterward. The case of heterogeneous expectations with a mixture of FIRE and VAR-based agents ($\tau = 0.5$) lies between the two extreme cases. Output and inflation both decline on impact but do so significantly less than when all agents form expectations under FIRE ($\tau = 1$). They continue to decline until the period when the shock is realized, which corresponds to the period of peak response of both variables. Thereafter, they slowly return to steady state (albeit at a faster pace than when $\tau = 0$).

This analysis highlights that the macroeconomic responses, particularly anticipation effects, to a forward guidance shock weaken as τ decreases below one. The effectiveness of forward guidance also hinges on the forecasting model used by non-FIRE agents, especially when some rely on VAR-based forecasts (e.g., $\tau = 0.5$). As shown in the second column of Figure 1, when VAR-based agents assume no persistence (equivalent to setting all coefficients in matrix B to zero), forward guidance is less effective before $t + 5$ compared to the baseline case of $\tau = 0.5$, where agents view macro dynamics as persistent. This is evident as the dashed-circle line for output and inflation exceeds the dashed line. After the forward guidance shock materializes, output and inflation quickly return to steady state, mirroring the $\tau = 1$ case.[12]

This exercise underscores the significant role of the expectations aggregation parameter, τ, in our model. The larger the value of τ, the more effective forward guidance shocks are in influencing output and inflation in anticipation of a transitory forward guidance shock's realization. We have also established that the presence of VAR-based forecasters diminishes the potency of anticipation effects, depending on their perceptions of macroeconomic persistence. Furthermore, VAR-based forecasts introduce endogenous persistence in the propagation of forward guidance shocks once they materialize.

A natural question arises: could differences in the propagation of forward guidance shocks, observed across a range of values of τ, be influenced by other economic features or the monetary policy rule itself? In Appendix B, Figure B1 explores how variations in the Calvo (1983) parameter θ, both above and below the baseline value used in Figure 1, have minimal quantitative impact on impulse response functions. These changes do not qualitatively affect the propagation of forward guidance shocks for any value of τ. While adjustments in θ alter the slope of the New Keynesian Phillips curve (NKPC) and the trade-offs facing policymakers, they do not fundamentally change how forward guidance shocks propagate or their dependence on τ.

Similarly, Appendix B, Figures B2–B3 examine the effects of varying the central bank's policy response to inflation (χ_π) and the output gap (χ_x). In both cases, we find consistent results: while the central bank's weighting of inflation and the output gap may influence the

[12]The VAR model in equation (18) captures the unconditional dynamics of the economy as perceived by non-FIRE (i.e., VAR-based) private agents. However, the analysis in Figure 1 focuses on the conditional responses to a transitory 5-period-ahead forward guidance shock (described in equation (14)). If this forward guidance shock were the sole driver of macroeconomic aggregates, a VAR model assuming no persistence would replicate the responses of FIRE agents when the shock materializes. Nevertheless, even in the absence of endogenous sources of persistence, other exogenous shocks driving the economy exhibit persistent dynamics. As a result, non-FIRE agents gravitate toward VAR models that incorporate persistence. Since VAR-based agents cannot distinguish the transitory nature of forward guidance shocks from the data after the guidance materializes, they interpret the shock as persistent. This expectation leads them to behave accordingly, causing the forward guidance shocks to produce persistent macro effects once implemented.

quantitative effects of forward guidance shocks, these weights do not meaningfully alter how the shocks propagate or how their propagation depends on τ.

Our further exercises suggest that the empirical effectiveness of forward guidance shocks, in the presence of heterogeneous expectations and bounded rationality, is unlikely to be confounded by the simultaneous identification of key features of the transmission mechanism or the policy rule itself.

3 Bayesian Estimation

We use Bayesian techniques to estimate the parameters of the model described in Section 2—including, but not limited to, the parameters governing the strength of forward guidance—for the four main countries of interest in our analysis, that is, the U.S., the U.K., Germany, and Japan, over different subsamples.

3.1 Data

We use quarterly data on real GDP growth, headline CPI inflation, and the nominal short-term (3-month) interest rate as the counterparts of output growth, inflation, and the nominal interest rate in the vector $Y_t = [g_t, \pi_t, i_t]'$ in our model. In addition to these observables, we utilize quarterly consensus forecast data on one- and two-period-ahead real GDP growth, one-period-ahead headline CPI inflation, and one- to 5-period-ahead nominal short-term (3-month) interest rates as the counterpart for the aggregate expectations in the vector $\overline{Y}_t$ in equation (15).[13] These expectations data are retrieved from a novel dataset of quarterly survey responses collected by Consensus Economics from third quarter 1990 until third quarter 2022 (129 observations) for the U.S., the U.K., Germany, and Japan.[14] The data sources and additional details on the matching of the observed data and forecasts to the model counterparts can be found in Appendix A.

[13]Using the shadow rate instead of the policy rate (i_t) poses challenges because survey respondents in our dataset forecast the nominal interest rate, not the shadow rate. Combining the two would conflate distinct measures. Instead, specifying the entire policy path—encompassing the contemporaneous policy rate and its forecasts—offers a clearer and more consistent representation of monetary policy. This approach captures the full range of interventions, including forward guidance, both near the ZLB and in conventional settings away from the ZLB, ensuring alignment between the model and the data and enabling a more coherent exploration of monetary policy's effects.

[14]We collect the same data for Canada, France, and Italy from third quarter 1990 until third quarter 2022 (129 observations). We also collect data for Spain, although these are a slightly shorter time series starting only in third quarter 1994 and ending in third quarter 2022 (113 observations).

3.2 Observation Equations

We add a set of observation equations that define the mapping between each data series and their respective counterparts in the model. The observation equations are given in the following matrix form:

$$\begin{bmatrix} g_t^{obs} \\ \pi_t^{obs} \\ i_t^{obs} \\ \mathbb{E}_t\left(g_{t+1}\right) \\ \mathbb{E}_t\left(g_{t+2}\right) \\ \mathbb{E}_t\left(\pi_{t+1}\right) \\ \mathbb{E}_t^{obs}\left(i_{t+1}\right) \\ \mathbb{E}_t^{obs}\left(i_{t+2}\right) \\ \mathbb{E}_t^{obs}\left(i_{t+3}\right) \\ \mathbb{E}_t^{obs}\left(i_{t+4}\right) \\ \mathbb{E}_t^{obs}\left(i_{t+5}\right) \end{bmatrix} = \begin{bmatrix} \Delta y_t \\ \pi_t \\ i_t \\ \mathbb{E}_t(\Delta y_{t+1}) \\ \mathbb{E}_t(\Delta y_{t+2}) \\ \mathbb{E}_t(\Delta p_{t+1}) \\ \mathbb{E}_t\left(i_{t+1}\right) \\ \mathbb{E}_t\left(i_{t+2}\right) \\ \mathbb{E}_t\left(i_{t+3}\right) \\ \mathbb{E}_t\left(i_{t+4}\right) \\ \mathbb{E}_t\left(i_{t+5}\right) \end{bmatrix} + \begin{bmatrix} \bar{\gamma}^g + \gamma_t \\ \bar{\gamma}^\pi \\ \bar{\gamma}^i \\ \bar{\gamma}^{g^1} + \mathbb{E}_t(\gamma_{t+1}) \\ \bar{\gamma}^{g^2} + \mathbb{E}_t(\gamma_{t+2}) \\ \bar{\gamma}^{\pi^1} \\ \bar{\gamma}^{i^1} \\ \bar{\gamma}^{i^2} \\ \bar{\gamma}^{i^3} \\ \bar{\gamma}^{i^4} \\ \bar{\gamma}^{i^5} \end{bmatrix} + \begin{bmatrix} \mathbf{0}_{3\times 8} \\ \mathbf{I}_{8\times 8} \end{bmatrix} \begin{bmatrix} o_t^{g_{t+1}} \\ o_t^{g_{t+2}} \\ o_t^{\pi_{t+1}} \\ o_t^{i_{t+1}} \\ o_t^{i_{t+2}} \\ o_t^{i_{t+3}} \\ o_t^{i_{t+4}} \\ o_t^{i_{t+5}} \end{bmatrix}, \tag{20}$$

together with the following measurement equations:

$$\mathbb{E}_t^{obs}\left(\Delta^4 y_{t+1}\right) = \mathbb{E}_t\left(\sum\nolimits_{h=1}^{4} g_{t+2-h}\right), \tag{21}$$

$$\mathbb{E}_t^{obs}\left(\Delta^4 y_{t+2}\right) = \mathbb{E}_t\left(\sum\nolimits_{h=1}^{4} g_{t+3-h}\right), \tag{22}$$

$$\mathbb{E}_t^{obs}\left(\Delta^4 p_{t+1}\right) = \mathbb{E}_t\left(\sum\nolimits_{h=1}^{4} \pi_{t+2-h}\right), \tag{23}$$

where the superscript *obs* indicates the observed variables or expectations for which we have a survey-based counterpart in the data. As before, the model-consistent expectations operator $\mathbb{E}_t(\cdot)$ on the matrix equation (20) aggregates the FIRE and VAR-based expectations.

Here, $\Delta^4 y_{t+h}$ refers to the 4-quarter percentage change in real GDP in period $t+h$ (for $h = 1, 2$), $\Delta^4 p_{t+h}$ to the 4-quarter percentage change in the CPI price level in period $t+j$ (for $j = 1$), and i_{t+h} to the nominal short-term interest rate in percent in period $t+h$ (for $h = 1, ..., L$). Furthermore, the quarter-over-quarter percentage change in real GDP and the CPI price level is given by $\Delta y_{t+h} \equiv g_{t+j}$ and $\Delta p_{t+j} \equiv \pi_{t+j}$, respectively.

The matrix equation (20) incorporates variable-specific intercepts alongside trend growth (γ_t) and expected trend growth ($\mathbb{E}_t(\gamma_{t+1})$ and $\mathbb{E}_t(\gamma_{t+2})$) to account for the means in the data.

These intercepts include $\bar{\gamma}^g$, $\bar{\gamma}^{g^1}$, $\bar{\gamma}^{g^2}$, $\bar{\gamma}^{\pi}$, $\bar{\gamma}^{\pi^1}$, $\bar{\gamma}^i$, $\bar{\gamma}^{i^1}$, $\bar{\gamma}^{i^2}$, $\bar{\gamma}^{i^3}$, $\bar{\gamma}^{i^4}$, and $\bar{\gamma}^{i^5}$. Additionally, the observation equations for expectations incorporate *i.i.d.* measurement error terms, specifically $o_t^{g_{t+1}}$, $o_t^{g_{t+2}}$, $o_t^{\pi_{t+1}}$, $o_t^{i_{t+1}}$, $o_t^{i_{t+2}}$, $o_t^{i_{t+3}}$, $o_t^{i_{t+4}}$, and $o_t^{i_{t+5}}$. It is important to note that our expectations data for real GDP growth and headline CPI inflation were originally provided in a year-over-year format. Therefore, measurement equations (21)–(23) are employed to transform the expectations data into the model's quarter-over-quarter format.

3.3 Priors

The choice of priors for the U.S., the U.K., Germany, and Japan are presented in Appendix B, Tables B1–B4. The priors for the structural parameters largely follow from extant literature (e.g., Smets and Wouters (2007), Cole and Milani (2017), and Cole and Martínez García (2023)).[15] For each country, we estimate the model over three different periods. The full sample period is 1990:Q3–2022:Q3. We cut the sample at 2022:Q3 to avoid potential contamination from the Ukraine war and focus on the pre-tightening period of rising inflation, where policy responses primarily shifted expectations of the future policy path before global rate hikes began. We also consider a "great moderation" sample period that runs from 1990:Q3 to 2007:Q3. Finally, we consider a more recent subsample period that includes the run-up to and the fallout from the GFC and the COVID-19 recession and recovery, 2005:Q3–2022:Q3. We label this latter sample the "low-interest-rate" period.

All parameters are estimated separately for each country, except the subjective discount factor (β), the inverse of the Frisch elasticity of labor supply (ω), and the degree of price indexation (ι_p), which are fixed at conventional values of 0.99, 0.8975, and 0.5, respectively. Full posterior estimates for the U.S., the U.K., Germany, and Japan are available in Appendix B, Tables B1–B4.

4 Main Estimation Results

In this section on our findings, we discuss our main estimation results and their implications for the efficacy of forward guidance across both time and space.

[15] For the parameters in the measurement equation (20) we adopt an agnostic set of priors. The intercepts in equation (20) (i.e., $\bar{\gamma}^g, \bar{\gamma}^{\pi}, \bar{\gamma}^i, \bar{\gamma}^{g^1}, \bar{\gamma}^{g^2}, \bar{\gamma}^{\pi^1}, \bar{\gamma}^{i^1}, \ldots, \bar{\gamma}^{i^5}$) have a normal prior distribution centered on the mean of their respective data series over the full sample. In addition, we assume an inverse gamma prior distribution with mean 0.1 and two degrees of freedom for the standard errors of each of the eight measurement errors (i.e., $o_t^{g_{t+1}}$, $o_t^{g_{t+2}}$, $o_t^{\pi_{t+1}}$, $o_t^{i_{t+1}}$, $\ldots$, $o_t^{i_{t+5}}$).

4.1 Posterior Estimates of τ Across Countries and Time

Table 1 shows posterior estimates for the key parameter τ for the U.S., the U.K., Germany, and Japan across the aforementioned three sample periods. For the full posterior estimation results, refer to Appendix B, Tables B1–B4.

Table 1: **Posterior Estimates of τ Across Countries and Time**

	Posterior Distribution								
	Full Sample (1990:Q3–2022:Q3)			Great Moderation (1990:Q3–2007:Q3)			Low-Interest-Rate Period (2005:Q3–2022:Q3)		
	Mean	5%	95%	Mean	5%	95%	Mean	5%	95%
U.S.	0.47	0.44	0.50	0.55	0.49	0.60	0.39	0.35	0.43
U.K.	0.42	0.39	0.45	0.57	0.52	0.62	0.32	0.28	0.36
Germany	0.43	0.40	0.47	0.45	0.40	0.49	0.33	0.29	0.37
Japan	0.23	0.21	0.25	0.33	0.29	0.37	0.12	0.10	0.14

Note: The prior distribution of τ is assumed to be $U(0,1)$ across all countries and periods.

For the full sample, we find that the U.S. has the highest estimate of our key parameter with a posterior mean estimate of $\tau = 0.47$. The estimates for the central banks of the U.K. and Germany come in close behind at 0.42 and 0.43, respectively. Japan is an outlier on the downside, with a full-sample posterior mean estimate of 0.23 for τ.[16]

The full-sample estimation obscures notable subsample instability that is nevertheless concordant across countries. During the Great Moderation sample, the posterior means of τ are higher for all countries. The U.K. exhibits the highest value, with a posterior mean estimate of τ at 0.57, followed by the U.S. at 0.55, and Germany at 0.45. Japan stands out again as an outlier with a lower posterior mean of 0.33. Unlike the other three countries, Japan has experienced a prolonged period of low interest rates since the early 1990s, encompassing much of the Great Moderation period analyzed here.

In the low-interest-rate sample, the aggregate expectations in all four countries are estimated to significantly favor non-FIRE forecasts relative to the great moderation sample. The U.S. has the highest estimate of τ, with a value of $\tau = 0.39$, However, this figure is

[16] As a robustness check, we extend the forward guidance shock horizon from 5 up to a maximum of 8 quarters ahead, finding similar results.

only 71 percent of the great moderation posterior mean. In the U.K., the posterior mean ($\tau = 0.32$) is only approximately half its value for the great moderation period. For Germany, similarly to the U.S., the posterior mean ($\tau = 0.33$) is approximately 73 percent of its great moderation value. Japan continues to be an outlier on the downside, with its estimated posterior mean for the low-interest-rate period (0.12) being only one-third its value for the great moderation period (0.33).

4.2 Forward Guidance Shocks Across Time and Countries

We next use our estimated model to measure the contribution of forward guidance shocks to actual policy.

Our benchmark estimates are based on five forward guidance shocks, with anticipation horizons ranging from one quarter to 5 quarters ahead. Measuring the contributions of forward guidance to policy is potentially challenging because a combination of forward guidance shocks can influence not only the level of the policy path—shifting it upward or downward—but also its shape and slope, potentially steepening, flattening, or even inverting the expected policy rate path. For instance, a negative (expansionary) one-quarter-ahead forward guidance shock combined with a positive (contractionary) 5-quarter-ahead shock could steepen the real interest rate path. Conditional on these news shocks about future monetary policy not being offset by their effects on inflation expectations, this steepening would also appear in the policy path itself, complicating its interpretation and our ability to disentangle the effects of forward guidance.

To overcome the difficulty of assessing how different shifts affect the policy path, we set the parameters at the posterior mean over the full sample and solve an auxiliary version of our model with no forward guidance shocks at all. We use this auxiliary model to measure, at each point in time and for each country, the model-consistent expectation of the nominal short-term interest rate five quarters into the future. We then subtract this expectation from the aggregate expectations of the nominal short-term interest rate five quarters into the future, taking the estimated sequence of smoothed forward guidance shocks into account. The difference between the actual and auxiliary expectation gives us a sense of the contributions of forward guidance to the actual expectations of the nominal short-term interest rate at each point in time and for each country under consideration.

Figure 2 plots the resulting series for each of the four main countries in our sample across time. Positive values of the series indicate that forward guidance was on net hawkish (i.e., the actual expected path of the nominal short-term rate was higher than that in the auxiliary model with forward guidance shocks muted), whereas negative values indicate that forward guidance was on net dovish. The plots generally conform with the conventional narrative of the historical record.

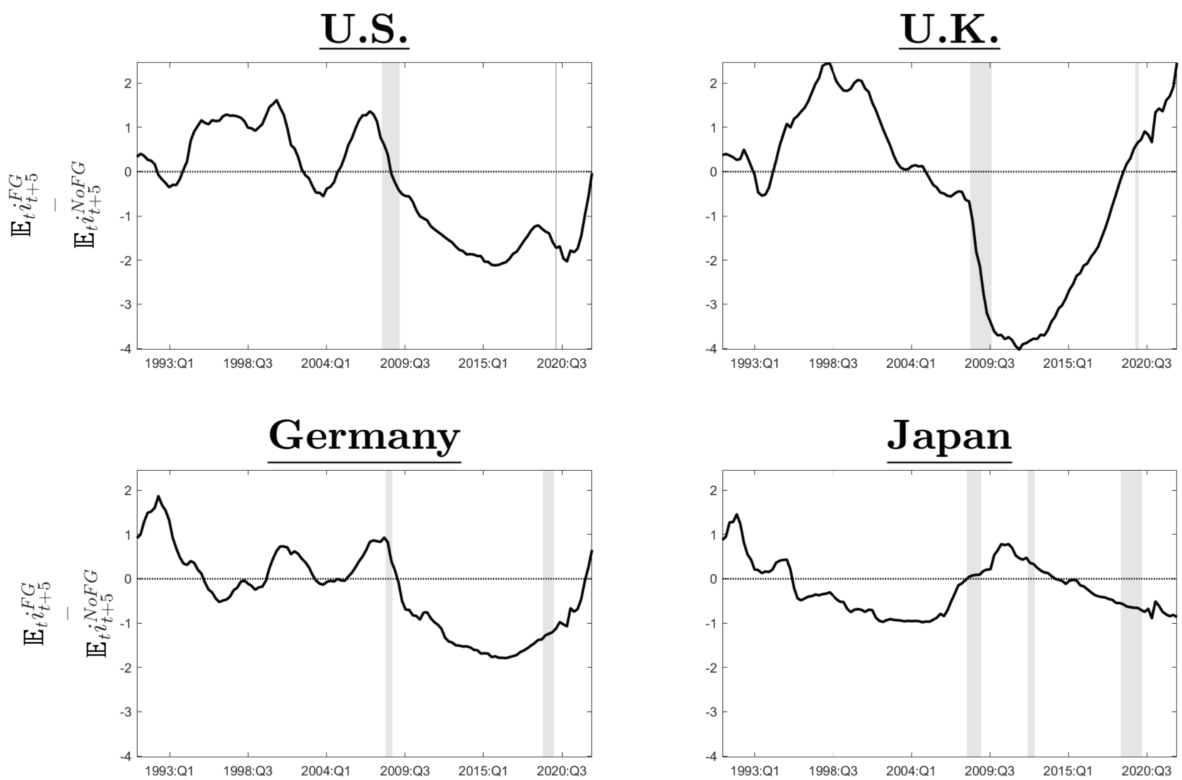

Figure 2: Estimated Forward Guidance Impact on the Expected Nominal Short-Term Interest Rate Five Quarters Ahead Across Time and Countries

Note: $\mathbb{E}_t\left(i_{t+5}^{FG}\right)$ defines the 5-quarter-ahead expectation of the nominal interest rate using equation (19). $\mathbb{E}_t\left(i_{t+5}^{NoFG}\right)$ is defined in the same way as $\mathbb{E}_t\left(i_{t+5}^{FG}\right)$ except in a counterfactual with no forward guidance (that is, where we remove $\sum_{l=1}^{L} \varepsilon_{l,t-l}^{FG}$ from equation (11) by setting it to zero). Shaded bars denote recession dates for each country according to the National Bureau of Economic Research (NBER), Cabinet Office of Japan, and Economic Cycle Research Institute (ECRI).

Consider first the U.S. In the run-up to the GFC, forward guidance switched from dovish to hawkish, putting upward pressure on interest rate forecasts. This coincided with the timing of the Federal Reserve's raising of policy rates. However, as soon as the GFC hits, the series quickly turns negative and remains negative through the end of the sample period.

This dovish switch coincides with the Federal Reserve's actively using forward guidance in an attempt to lower long-term vis-à-vis short-term rates to circumvent the constraint of the ZLB, which became binding in December of 2008. At the nadir, the 5-period-ahead forecast of the short-term nominal interest rate is two percentage points lower than the auxiliary forecast without forward guidance shocks, suggesting that forward guidance in fact had a significant impact on the expected path of short-term nominal rates in the U.S.

The picture for the U.K. and Germany is qualitatively similar, while that for Japan is somewhat different and more muted. Overall, we view the results presented in Figure 2 as reassuring. Our estimated model picks up estimated forward guidance shocks that generally align well with the historical record. Next, we turn to analyzing the effectiveness of these shocks across time and space.

4.3 Effectiveness of Forward Guidance Across Time and Space

In this subsection, we analyze the effectiveness of forward guidance across time and space. Starting from the beginning of the sample period, for each country, we perform a rolling estimation exercise to assess the potential contribution of forward guidance shocks to macro variables such as output and inflation over time.[17]

In particular, for each country, we estimate the parameters over a rolling window of 69 observations (17 years and 1 quarter), beginning with the first observation in our sample. Hence, the first subsample period in this rolling window corresponds to the great moderation period and the last to the low-interest-rate period discussed earlier. Given the estimated posterior means of all parameters, we calculate the impulse responses of output and inflation to a 25 bp expansionary forward guidance shock in each window for each country. For the purposes of the presentation in the text, we focus on the response to a 5-quarter-ahead expansionary forward guidance shock (of 25 bp). We also simultaneously track the evolution of our key parameter τ over time.

The response up to quarter five is most pertinent for policymakers as it captures the reaction to future central bank promises (the anticipation effects of forward guidance).[18] To summarize the effectiveness of these shocks, we sum the output and inflation impulse responses over this announcement period (i.e., the current quarter through quarter five) and display them in Figure 3. In the bottom row, we show rolling estimates of τ for each country.

[17] Defining output growth as $g_t \equiv \Delta y_t$ allows the model to be expressed in terms of y_t to evaluate shocks' impact on output.

[18] From quarter six onward, the impulse response reflects actual interest rate changes, but here we focus solely on the strength of the anticipation effects up to period 5.

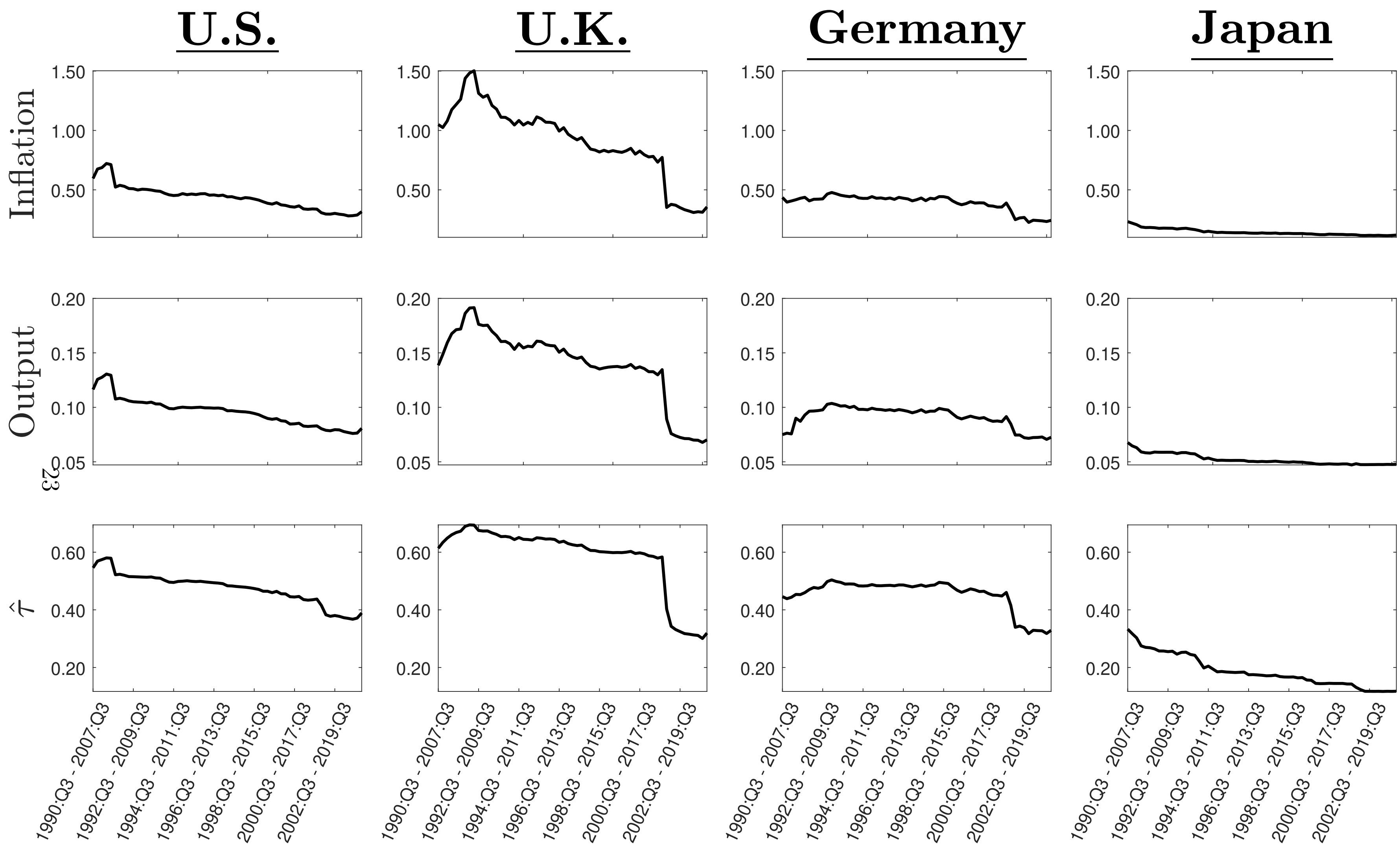

Figure 3: Estimated Impact of a 25 Bps Decrease in $\varepsilon_{5,t}^{FG}$ on Contemporaneous Output and Inflation and Variation in τ over Time and Across Countries

Note: The response of the variables to the forward guidance shock is calculated as the sum under the impulse response function from periods 0 to 5 (aligning with $\varepsilon_{5,t}^{FG}$). We recalculate the responses for each subsample setting the parameter values of the model at their estimated posterior mean for the given subsample. Note that inflation is expressed in annualized percentage points and the impact on output in percentage points.

We focus first on the column for the U.S. The cumulative output effect of a 5-quarter-ahead forward guidance shock is approximately 0.1 percent on average over all rolling sample periods. After a mild initial uptick, the output effectiveness of forward guidance steadily declines over time, from an initial value of approximately 0.12 percent to approximately 0.08 percent by the end of the sample period. The cumulative inflation response displays a similar pattern. Both of these declines coincide with estimated declines in the parameter τ over time, from an initial value of approximately 0.55 to a final value of approximately 0.40.

The patterns of forward guidance effectiveness for both the U.K. and Germany are qualitatively similar to those for the U.S. After brief initial upticks in the cumulative output and inflation responses, they both steadily decline for these two countries. However, unlike the U.S., both the U.K. and Germany experienced abrupt downward shifts in estimated effectiveness coinciding with the onset of the COVID-19 pandemic. Nevertheless, similar to the U.S., these patterns also mirror the estimated values of τ across time.

Japan is an outlier on the downside as noted above. In addition to having the lowest estimated value of τ, Japan's forward guidance is overall least effective at stimulating output and inflation. However, as in the other countries, the effectiveness of forward guidance in Japan is estimated to have declined over time. The declines in the effectiveness of forward guidance at stimulating output and inflation also coincide with estimated declines in the country's already-low levels of τ.

4.4 Missing Inflation Episodes

In the wake of the GFC, central banks around the world struggled with troubling episodes of persistently low inflation. This period coincided with the time when major central banks in developed countries faced a binding ZLB on nominal short-term interest rates and explicitly adopted forward guidance as one more arrow in their policy quiver. Thus, a natural question that arises is what would the effect of forward guidance have been during this period had it been deployed when it was most potent (i.e., when $\tau = 1$)?

To answer the previous question, we engage in a counterfactual exercise. In particular, for each of the four major countries considered to this point, we take the model estimations for the low-interest-rate period (2005:Q3–2022:Q3) and extract the smoothed shocks that drive the model's endogenous variables. The smoothed shocks encompass all shocks within the model, including the forward guidance shocks. Taking the smoothed shocks, we set the other estimated parameters at their posterior mean but fix the parameter τ at 1 (all FIRE agents). We then simulate the counterfactual path for key macro variables in each country.

By comparing the observed macro paths with their counterfactuals under $\tau = 1$, we can assess how outcomes might have differed if the public had FIRE expectations fully incorporating forward guidance. In the U.S. case, Figure 4 shows the observed (solid lines) and counterfactual (dashed lines) paths for inflation (4-quarter percentage change), output growth (4-quarter percentage change), and the nominal interest rate (annualized percent). Our model suggests that, under the most potent forward guidance scenario ($\tau = 1$), inflation would have been slightly higher throughout the GFC and its aftermath, though it would still have dipped into deflation during the 2008 crisis peak. Notably, inflation would have stayed closer to the Fed's 2% target in the years following the GFC, only falling below the observed path after 2015, when forward guidance became more hawkish and the ZLB lifted.

Our counterfactual simulation suggests that a higher inflation path could have been achieved with minimal impact on output growth. While growth would have been more volatile during the GFC—on average higher than in reality but slower in the immediate aftermath—and interest rates would have still briefly reached the ZLB at the peak of the crisis. However, in this scenario, nominal interest rates would have risen above zero before the recession officially ended and remained above zero throughout most of the ZLB period in the U.S. Notably, our counterfactual indicates that the ZLB would not have significantly constrained policy if the public had formed expectations solely with FIRE and the Federal Reserve had followed the same forward guidance path recovered with the estimated model.

The patterns for the U.K. (Figure 5) and Germany (Figure 6) closely resemble those of the U.S. In both countries, inflation would have been higher during and immediately after the GFC, with the difference between the counterfactual and actual inflation paths particularly pronounced in Germany. As in the U.S., output growth would have been more volatile in the counterfactual with $\tau = 1$ during the GFC. Moreover, in both the U.K. and Germany, the ZLB would not have been a significant constraint, as the short-term nominal interest rate in the counterfactual would never have reached zero.

The case of Japan shares some similarities with the U.S., U.K., and Germany, but also exhibits notable differences. In Japan's counterfactual simulation with $\tau = 1$ (Figure 7), inflation would have been higher during the GFC, though lower than the actual inflation for a few quarters thereafter. In the mid-2010s, inflation would have remained consistently higher in the counterfactual scenario compared to actual levels. The counterfactual path for output growth mirrors that of the other countries: higher and more volatile during the GFC, but lower in the immediate aftermath.

The ZLB would have posed a greater constraint in Japan than in the other countries in our counterfactual analysis, which is not surprising given that Japan faced the ZLB even before the GFC, since the early 1990s. Under $\tau = 1$, the counterfactual path for the short-term nominal interest rate in Japan would have been more negative towards the end of the GFC and for several quarters afterward. However, in the mid-2010s, with higher counterfactual inflation, the ZLB would have been less binding. This suggests that the forward guidance policy, as recovered by our model, would have been less effective in steering Japan's economy away from the ZLB.

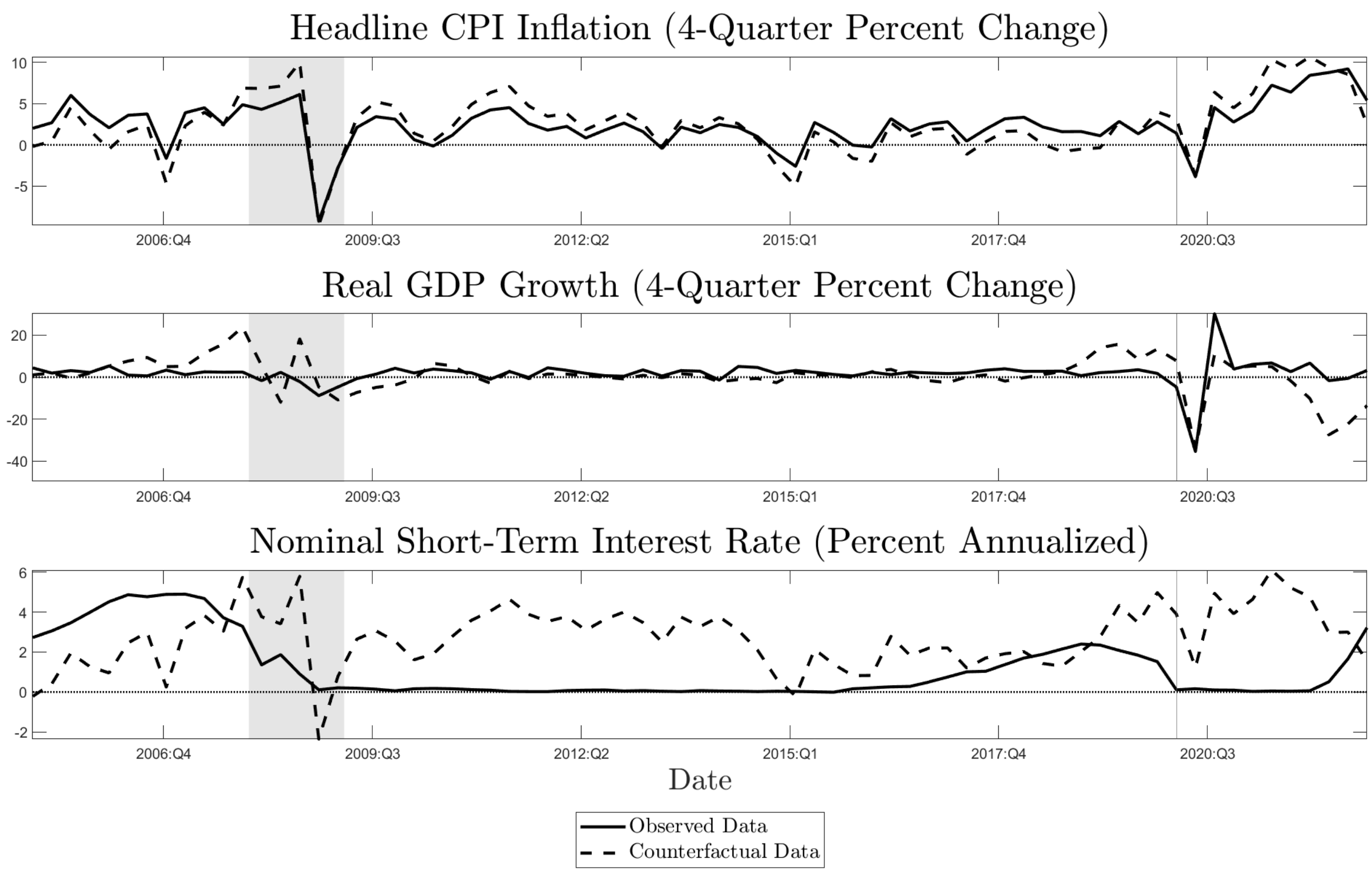

Figure 4: Counterfactual U.S. Inflation, Real GDP Growth, and Nominal Short-Term Interest Rate in the Low-Interest-Rate Period (2005:Q3–2022:Q3) Under $\tau = 1$

Note: The observed and counterfactual inflation and real GDP growth series are reported in 4-quarter percentage change rates, while the nominal short-term (3-month) interest rate series is quoted in percent annualized. We obtain the simulated data by setting the model parameter values to the posterior mean estimated in the low-interest-rate subsample (except for τ, which is fixed at 1) and feeding in the recovered shocks (including the forward guidance shocks). Shaded bars denote NBER recession dates for the U.S.

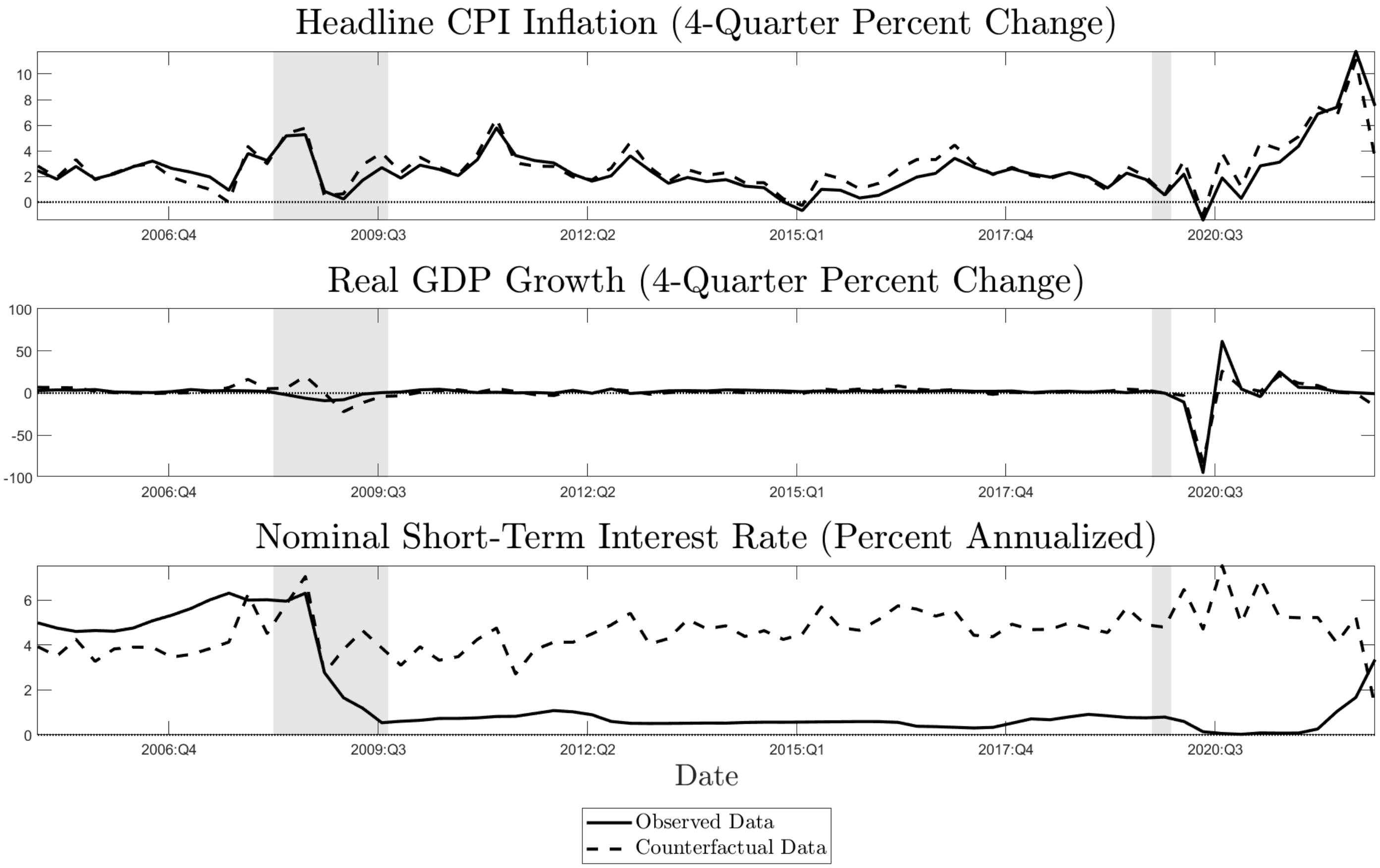

Figure 5: Counterfactual U.K. Inflation, Real GDP Growth, and Nominal Short-Term Interest Rate in the Low-Interest-Rate Period (2005:Q3–2022:Q3) Under $\tau = 1$

Note: The observed and counterfactual inflation and real GDP growth series are reported in 4-quarter percentage change rates, while the nominal short-term (3-month) interest rate series is quoted in percent annualized. We obtain the simulated data by setting the model parameter values to the posterior mean estimated in the low-interest-rate subsample (except for τ, which is fixed at 1) and feeding in the recovered shocks (including the forward guidance shocks). Shaded bars denote ECRI recession dates for the U.K.

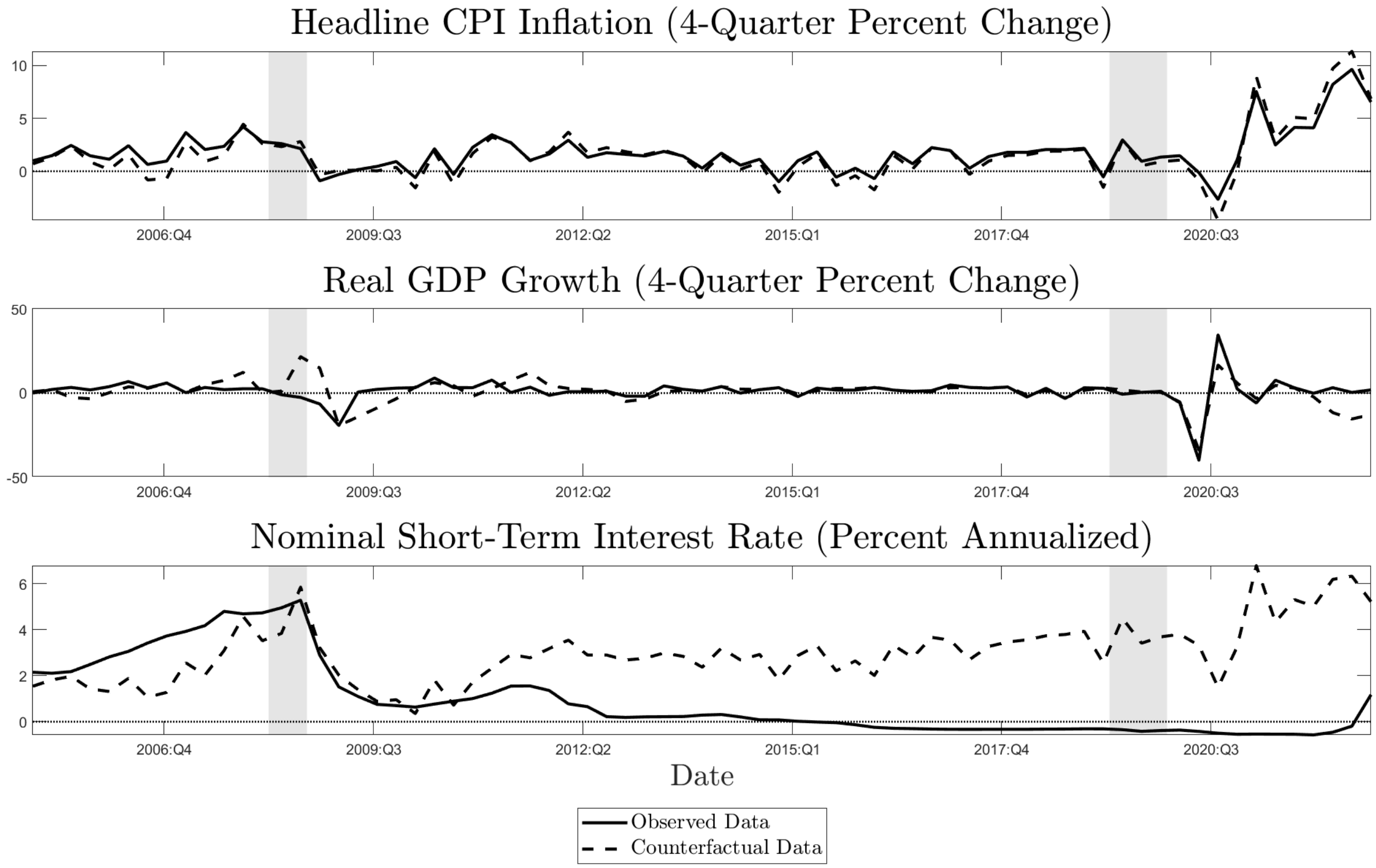

Figure 6: Counterfactual Germany Inflation, Real GDP Growth, and Nominal Short-Term Interest Rate in the Low-Interest-Rate Period (2005:Q3–2022:Q3) Under $\tau = 1$

Note: The observed and counterfactual inflation and real GDP growth series are reported in 4-quarter percentage change rates, while the nominal short-term (3-month) interest rate series is quoted in percent annualized. We obtain the simulated data by setting the model parameter values to the posterior mean estimated in the low-interest-rate subsample (except for τ, which is fixed at 1) and feeding in the recovered shocks (including the forward guidance shocks). Shaded bars denote ECRI recession dates for Germany.

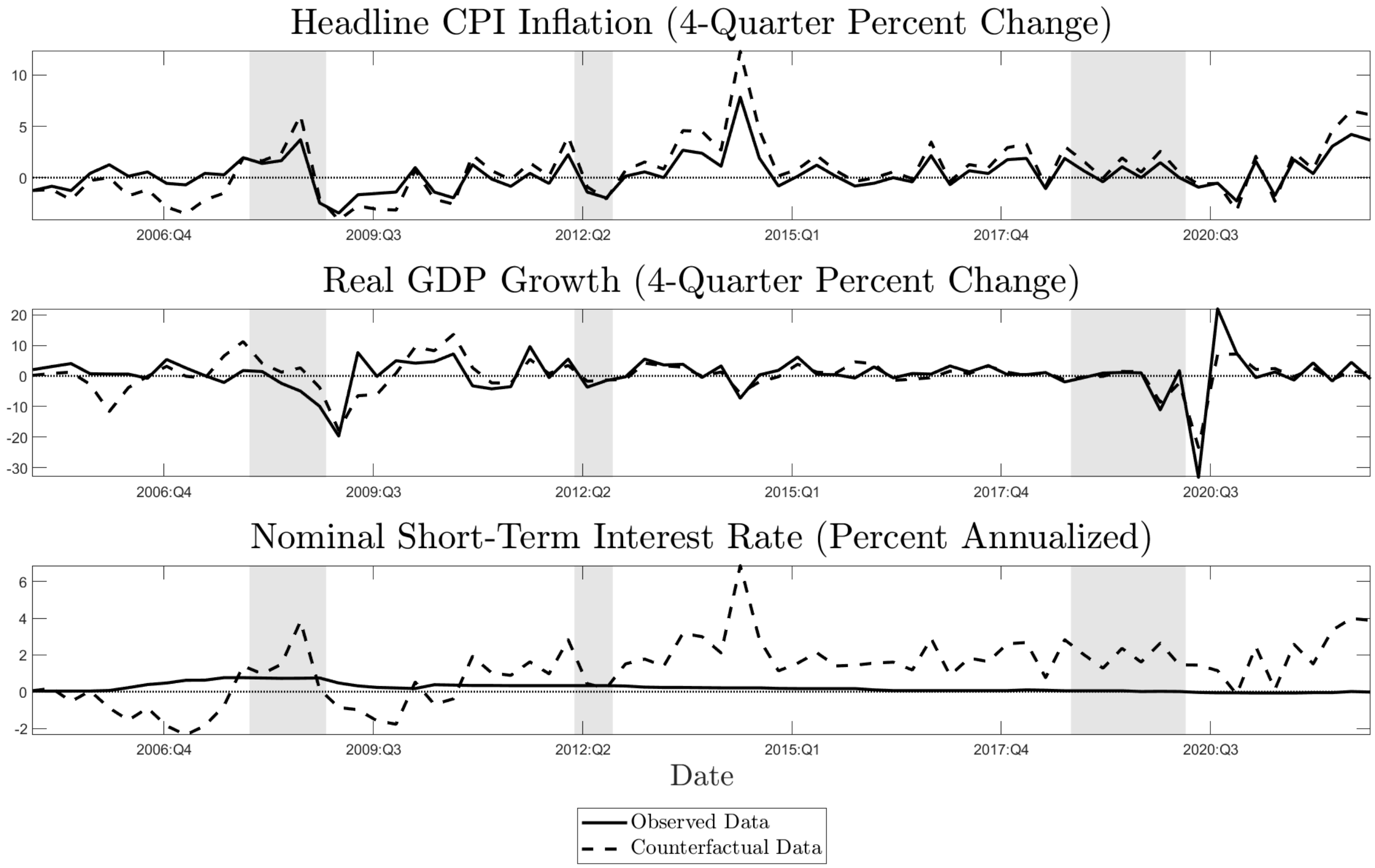

Figure 7: Counterfactual Japan Inflation, Real GDP Growth, and Nominal Short-Term Interest Rate in the Low-Interest-Rate Period (2005:Q3–2022:Q3) Under $\tau = 1$

Note: The observed and counterfactual inflation and real GDP growth series are reported in 4-quarter percentage change rates, while the nominal short-term (3-month) interest rate series is quoted in percent annualized. We obtain the simulated data by setting the model parameter values to the posterior mean estimated in the low-interest-rate subsample (except for τ, which is fixed at 1) and feeding in the recovered shocks (including the forward guidance shocks). Shaded bars denote Cabinet Office of Japan recession dates for Japan.

4.5 The Return of Inflation During COVID-19

In the latter half of the 2010s, after several years at the ZLB in the wake of the GFC and its aftermath, interest rates in the U.S. lifted off, and the Federal Reserve began to normalize its balance sheet. These efforts at normalization came to an abrupt end in spring 2020 when the COVID-19 pandemic broke out. The pandemic precipitated an extremely sharp but short-lived recession. Initially, inflation fell, and the Federal Reserve (and other central banks around the world) resorted to using many of the same tools upon which they had relied during the GFC, including extensive forward guidance. The resuscitation of these policies was followed by a quick economic recovery that soon also featured rising inflation. By mid-2021, inflation in developed economies had become high and persistently so. By the end of our sample in 2022:Q3, inflation had only begun to recede, yet it remained well above pre-COVID-19 levels and central banks' own targets.

In the previous subsection, our counterfactual analysis answered the question: would forward guidance have ameliorated the missing inflation post-GFC had it been deployed when it was most potent? We now use the same counterfactual analysis to explore the dynamics of inflation (and other macro variables) during the COVID-19 era. This period is already included in the counterfactual presented in Figures 4– 7, but we hone in on inflation during the COVID-19 period here.

Figure 8 presents the observed (solid lines) and counterfactual (dashed lines) inflation paths for the U.S., the U.K., Germany, and Japan, focusing on the period following the onset of the pandemic. Broadly speaking, the U.S., U.K., and Germany exhibit similar patterns. In the counterfactual scenario, where central banks interact only with FIRE agents ($\tau = 1$), inflation in 2021 would have been higher than observed. However, it would have decreased more sharply across all three countries under $\tau = 1$, and in some cases, earlier. For instance, in the U.S., inflation would have returned to the 2% target by the third quarter of 2022, whereas in actuality, it was still above 5% at that time.

As with previous figures, Japan stands out as an outlier. In the counterfactual simulation for Japan, inflation would have been slightly higher than realized inflation in 2021 and into 2022, similar to the other countries. However, unlike the U.S., U.K., and Germany, Japan's counterfactual inflation would not have decreased toward the end of the sample period.

Overall, the counterfactual analysis presented in this and the previous subsection provides intriguing and compelling insights. In all countries, had the public formed expectations based on FIRE that fully incorporated forward guidance, inflation would have been higher after the GFC, and the ZLB would have remained binding for a much shorter period. Additionally, for three countries—the U.S., the U.K., and Japan—inflation would have turned around and come nearer its target by the end of 2022 in the counterfactual with $\tau = 1$, before actual policy rates began to rise, rather than remaining elevated as observed.

We conclude this subsection with a brief caveat. Our counterfactual exercises treat the sequence of smoothed monetary policy shocks, including forward guidance shocks, as exogenous. However, in reality, these shocks may not be orthogonal to the value of τ—for example, central banks might have issued smaller forward guidance shocks had they believed τ was closer to 1, as opposed to much smaller than 1. As a result, the interpretation of our counterfactual results should be approached with caution. Despite this, we believe our analysis offers intriguing and provocative insights, suggesting that the paths of inflation, interest rates, and, to a lesser extent, output growth, could have been markedly different during the GFC and COVID-19 if the public had fully incorporated central banks' forward guidance statements, as FIRE agents do.

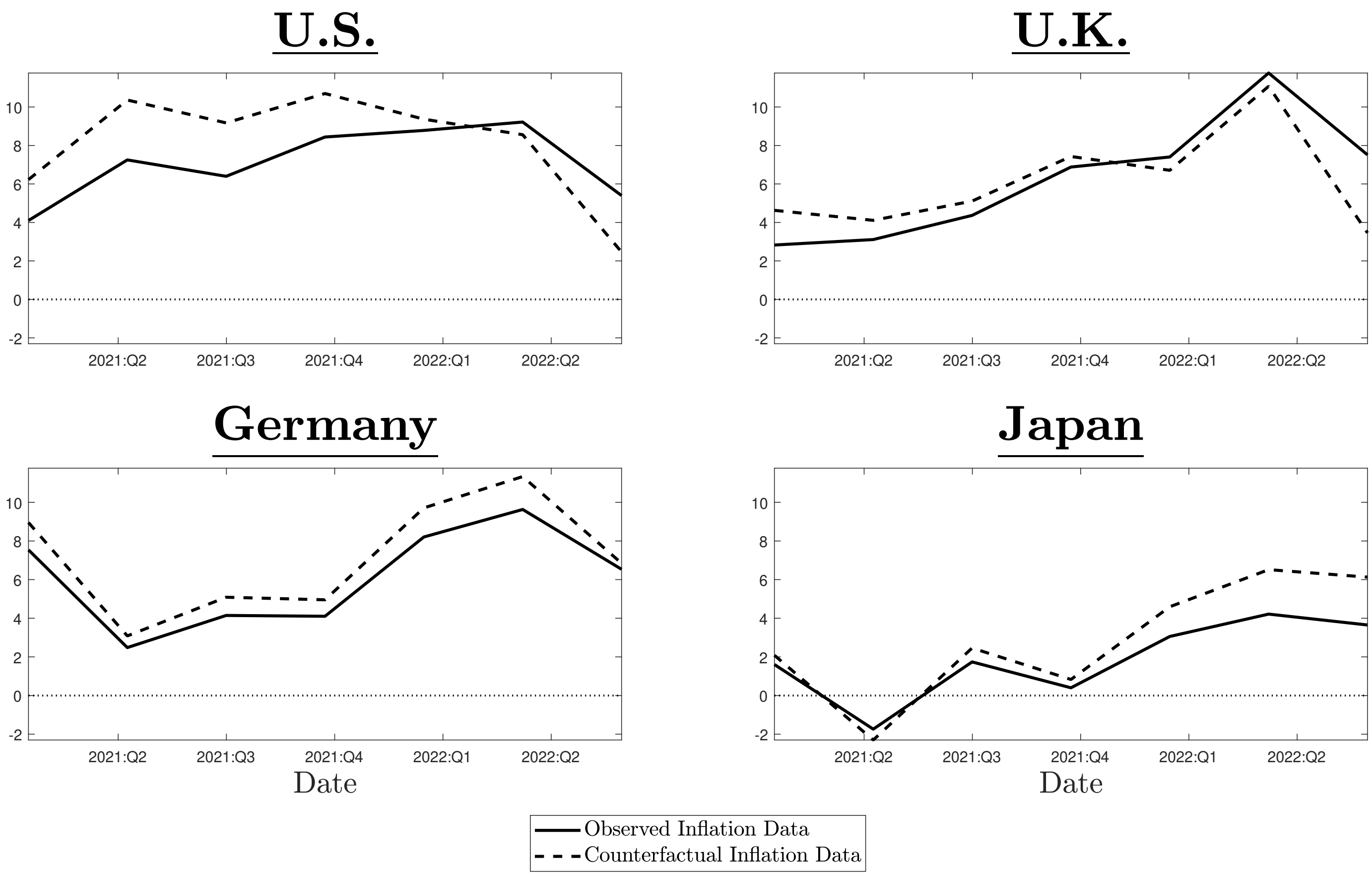

Figure 8: Counterfactual Inflation Across Countries in the Post-COVID-19 Period (2020:Q1–2022:Q3) Under $\tau = 1$

Note: The observed and counterfactual inflation series are 4-quarter percentage change rates. The simulated data are obtained by setting the model parameters to their posterior means estimated for the low-interest-rate period from 2005:Q3 to 2022:Q3, with τ fixed at 1. The recovered shocks, including forward guidance shocks, are then fed into the model. Shaded bars denote the corresponding recession dates according to the NBER, Cabinet Office of Japan, and ECRI.

4.6 Additional Countries

We have thoroughly examined the experiences of the three largest advanced economies—the U.S., Germany, and Japan—along with the U.K., a "smaller" advanced open economy often positioned between the euro area (Germany) and the U.S. In this section, we expand the analysis to include Spain, Italy, France, and Canada, examining the experiences of all G7 countries and Spain, the fourth-largest economy in the euro area. These four countries are "smaller" advanced open economies, akin to the U.K., but with distinct linkages. Canada is closely tied to the U.S., while France, Italy, and Spain have been strongly interconnected with Germany throughout our sample period, initially under the "Maastricht Treaty" criteria for currency union in the 1990s and later through the adoption of the euro. We present the results in Figure 9, based on a rolling estimation exercise similar to that in Subsection 4.3, and in Figure 10, from a counterfactual exercise analogous to that in Subsection 4.5.

Our findings suggest that the behavior of these additional four small open economies did not differ significantly from the baseline results for the U.S. and Germany, in particular. In all these countries, estimates of τ have generally declined over time, leading to a reduction in the effectiveness of forward guidance. As shown in Figure 9, τ estimates have declined over time for all these countries, weakening the impact of forward guidance on output and inflation, as illustrated in the first and second rows. Counterfactual analyses suggest that inflation might have decreased further (and sooner) after COVID-19 if central banks had interacted with FIRE agents fully incorporating forward guidance statements. As shown in Figure 10, the dashed line representing the counterfactual declines faster than the solid line across all countries post-COVID-19. Similar results emerge for the low-inflation period post-GFC. If $\tau = 1$, Appendix B, Figures B1–B4 provide evidence that the ZLB episode would have been shorter, and inflation more in line with central banks' objectives.

Finally, we must add a caveat to these results. An open question remains regarding whether the forward guidance implemented by the central banks of these small open economies was effective on its own or if its impact was due to being "imported" from their respective "anchor" countries (the U.S. for Canada and Germany for France, Italy, and Spain). This issue is especially apparent in the euro area: Was the ECB's forward guidance effective in France, Spain, and Italy because it inherited the credibility of Germany's Bundesbank, or would it have had the same impact if each country's national central bank had implemented it independently? While we cannot fully address this question, we can argue that forward guidance could have at least shortened the low-inflation and low-interest-rate periods had it been deployed when $\tau = 1$—a claim that holds for Canada and the U.K. too.

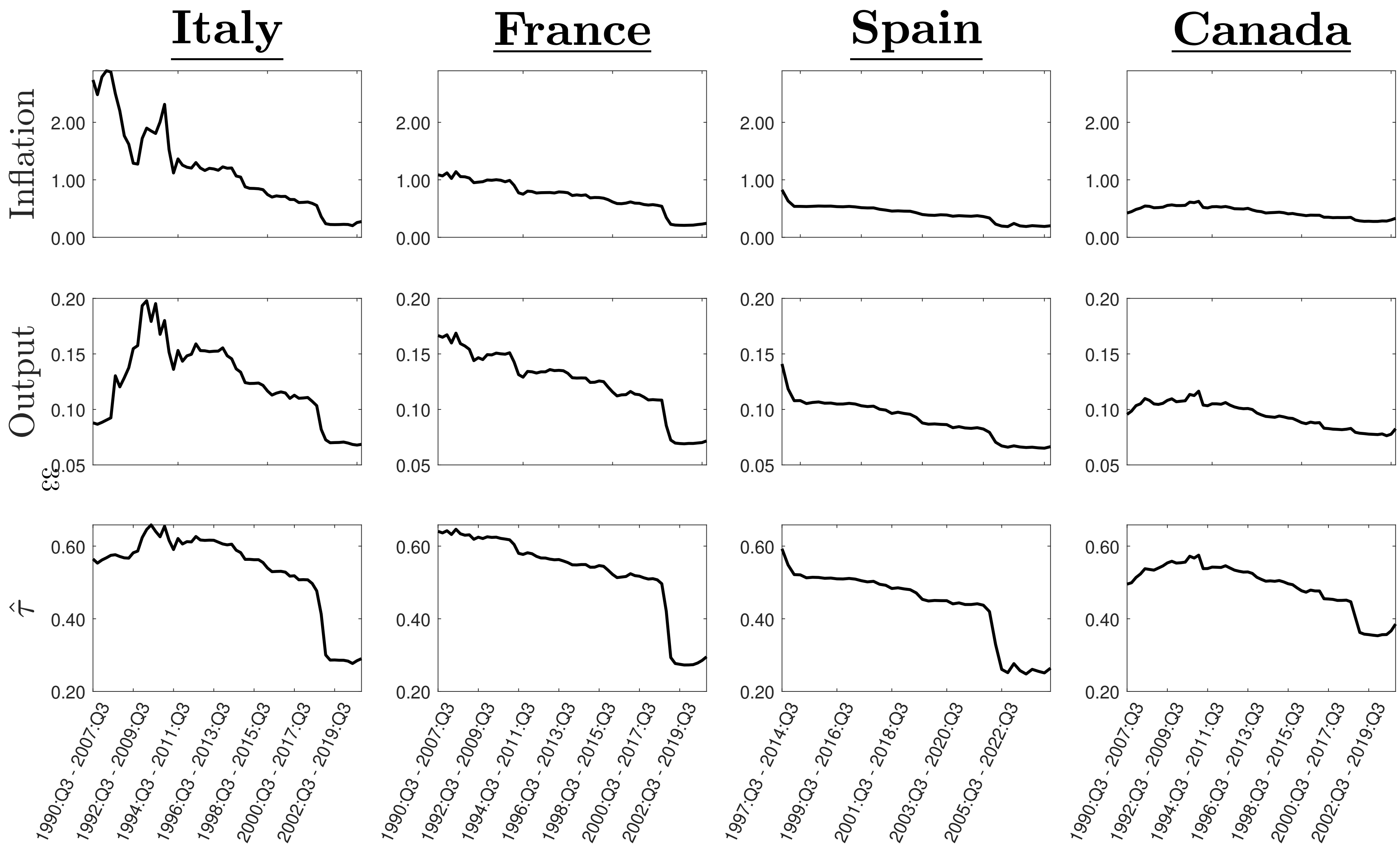

Figure 9: Estimated Impact of a 25 Bps Decrease in $\varepsilon^{FG}_{5,t}$ on Contemporaneous Output and Inflation and Variation in τ over Time and Across Additional Countries

Note: The response of the variables to the forward guidance shock is calculated as the sum under the impulse response function from periods 0–5 (aligning with $\varepsilon^{FG}_{5,t}$). We recalculate the responses for each subsample setting the model parameter values at their estimated posterior mean for the given subsample. Note that inflation is expressed in annualized percentage points and the impact on output in percentage points. Given sample constraints, Spain's data start in 1994:Q3 (not in 1990:Q3, as do those of the other countries).

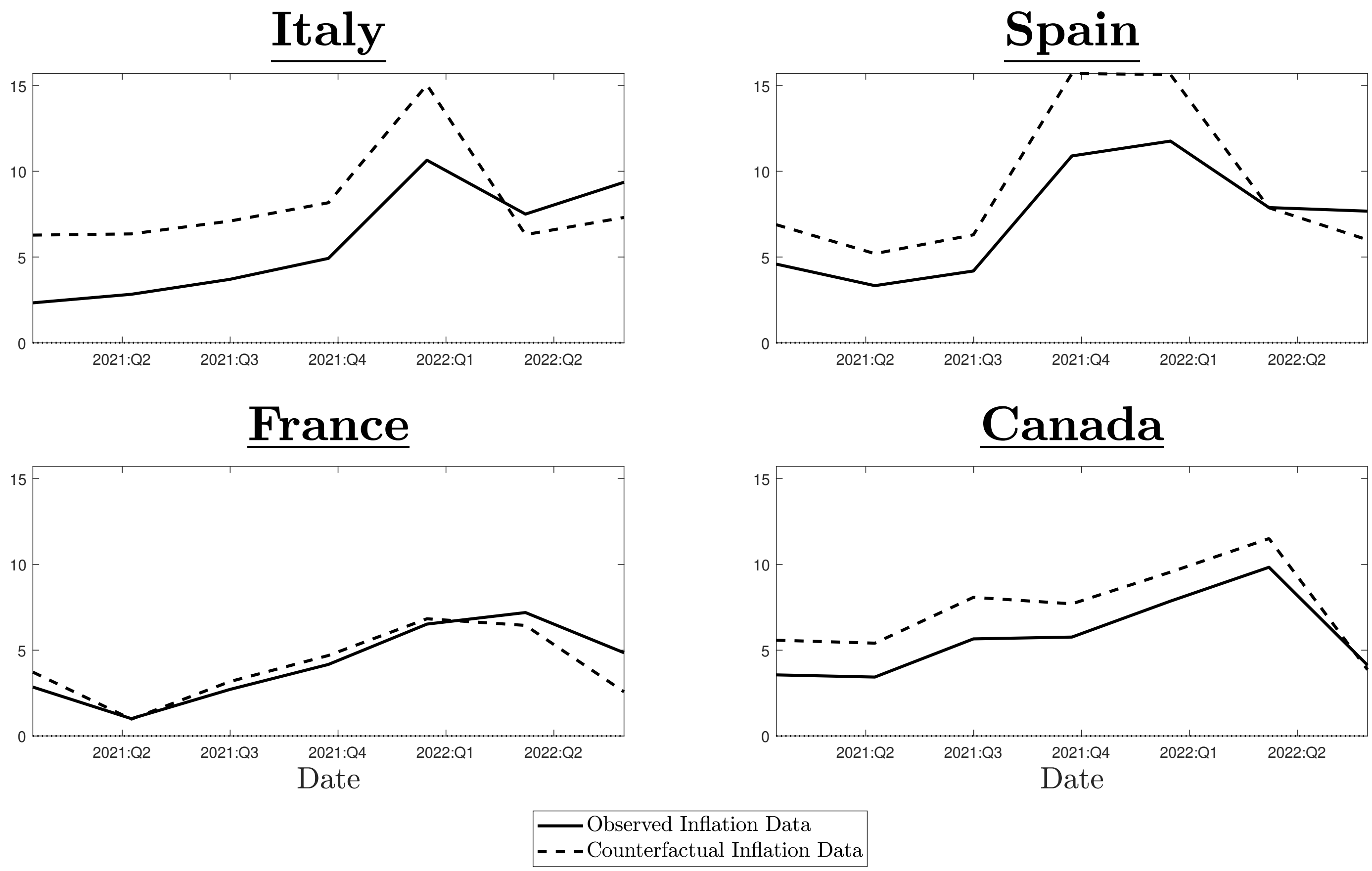

Figure 10: Inflation Counterfactual Across Additional Countries in the Post-COVID-19 Period (2020:Q1–2022:Q3) Under $\tau = 1$

Note: The observed and counterfactual inflation series are reported in 4-quarter percentage change rates. The simulated data are obtained by setting the model parameters to their posterior means estimated for the low-interest-rate period from 2005:Q3 to 2022:Q3, with τ fixed at 1. The recovered shocks, including forward guidance shocks, are then fed into the model. Shaded bars denote the corresponding recession dates according to ECRI and the C.D. Howe Institute.

5 Conclusion

Forward guidance, a key tool in the monetary policy arsenal of central banks worldwide, aims to shape expectations by communicating the future policy path. Its effectiveness hinges on whether the public fully incorporates these announcements into their forecasts. When central bank commitments are disregarded, private-sector expectations remain unchanged, nullifying forward guidance's impact on the economy. Conversely, if the public integrates these commitments into their forecasts, forward guidance can anchor expectations and stimulate the economy ahead of the anticipated policy changes.

This paper examines the effectiveness of forward guidance under heterogeneous expectations, both over time and across countries. Our findings reveal key insights. First, the proportion of agents adhering to FIRE and incorporating forward guidance (denoted by τ) varies by country and time. We observe the highest estimate of τ for the U.S., followed closely by Germany and the U.K., while Japan's estimate is notably lower. Additionally, estimates for each country tend to decline over time.

Second, the effectiveness of forward guidance depends on the fraction of FIRE agents incorporating it into their forecasts. Our evidence suggests that monetary policy could have had a stronger impact on supporting inflation and shortening the ZLB period post-GFC if the public fully integrated central banks' forward guidance, as FIRE agents do. This finding helps address the "missing inflation puzzle" that was a focus of the literature before the COVID-19 recession. Notably, we also find that monetary policy could also have played a role in lowering inflation and mitigating its post-COVID-19 surge if the public had fully incorporated central banks' forward guidance.

Altogether, our results suggest that the monetary policies implemented were not inconsistent with the stated objectives of central banks globally, even if their performance may have surprised policymakers, as their effects were weaker than desired (see, e.g., Caldara et al. (2021)). These surprises can, in part, be attributed to the tendency of many central banks' forecasting models to overlook the impact of heterogeneous beliefs in policy analysis and forecasting (see, e.g., Park (2018)). This oversight can reduce the effectiveness of forward guidance and may have caused central banks to apply it more cautiously, fearing overreaction due to its misperceived potency.

Finally, heterogeneity in expectations may reflect underlying credibility issues in central bank communication and policy, presenting a significant challenge to effective policy transmission. If, as Yellen (2006) suggests, misaligned communication fosters expectation heterogeneity, closing the underlying credibility gaps may be key to aligning private-sector expectations and strengthening forward guidance. The cross-country variation in τ points to potential institutional or policy framework differences, while its decline over time raises concerns about the evolution of central bank communication. Further research is needed to examine how credibility influences expectations and policy effectiveness, how forecast heterogeneity can be endogenized, and what this all means for central banking.[19]

[19] A preliminary sketch of an evolutionary game of central bank credibility underpinning τ is provided as an appendix in Cole and Martínez García (2023).

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Appendix

A Data Sources

Observable Variables. The observable variables we use in our estimation include real GDP, headline CPI, and the nominal short-term (3-month) interest rate. These macro data were obtained from the latest vintage available on February 28, 2023. Each of these three observable series is selected to match as closely as possible the counterpart consensus forecasts generated by the private forecasters pooled by Consensus Economics for each country. Each series is properly transformed to be matched with the corresponding endogenous variables of the model collected in the vector $Y_t = [g_t, \pi_t, i_t]'$.

We transform real GDP by computing the log first difference in percentages $\Delta\ln(\text{GDP}_t) \equiv 100^*(\ln(\text{GDP}_t)\text{-}\ln(\text{GDP}_{t-1}))$, construct headline CPI inflation as the log first difference in percentages $\Delta\ln(\text{CPI}_t) \equiv 100^*(\ln(\text{CPI}_t)\text{-}\ln(\text{CPI}_{t-1}))$, and convert the nominal short-term (3-month) interest rate, which is reported in annualized rates, to nonannualized percentages by dividing each observation by four such that we end up with $\text{INTEREST}_t/4$.

The data are measured at quarterly frequency and, after being transformed, span the period from third quarter 1990 until third quarter 2022 (129 observations) for Canada, France, Germany, Italy, Japan, the U.K., and the U.S. For Spain, we collect a slightly shorter time series that, because of data limitations, starts only in third quarter 1994 but still ends in third quarter 2022 (113 observations).

The sources of the observable variables used in our analysis by country are as follows:

Real GDP: Canada Gross Domestic Product (SA, Mil. Chained 2012 C$) from Haver/Statistics Canada (mnemonic: S156NGPC@G10); France Gross Domestic Product (SWDA, Mil. Chained 2014 Euros) from Haver/Institut National de la Statistique et des Etudes Economiques (mnemonic: S132NGPC@G10); Germany Gross Domestic Product (SWDA, Bil. Chained 2015 Euros) from Haver/Deutsche Bundesbank (mnemonic: S134NGPC@G10); Italy Gross Domestic Product (SWDA, Mil. Chained 2015 EUR) from Haver/Istituto Nazionale di Statistica (mnemonic: S136NGPC@G10); Japan Gross Domestic Product (SA, Bil. Chained 2015 Yen) from Haver/Cabinet Office of Japan (mnemonic: S158NGPC@G10); Spain Gross Domestic Product (SWDA, Mil. Chained 2015 Euros) from Haver/Instituto Nacional de Estadistica (mnemonic: S184NGPC@G10) starting in first quarter 1995 extended backward with the growth rates of another series, Spain Gross Domestic Product, Volume, Market

Prices (SAAR, Mil. Chained 2015 Euros) from Haver/OECD (mnemonic: Q184GDPC@OUTLOOK); U.K. Gross Domestic Product (SA, Mil. Chained 2019 Pounds) from Haver/Office for National Statistics (mnemonic: S112NGPC@G10); U.S. Gross Domestic Product (SA, Bil. Chained 2012$) from Haver/Bureau of Economic Analysis (mnemonic: S111NGPC@G10).

Headline CPI: Canada Consumer Price Index (SA/H, 2002=100) from Haver/Statistics Canada (mnemonic: H156PC@G10); France Consumer Price Index (SA/H, 2015=100) from Haver/Institut National de la Statistique et des Etudes Economiques (mnemonic: H132PC@G10); Germany Consumer Price Index (SA, 2020=100) from Haver/Deutsche Bundesbank (mnemonic: S134PC@G10); Italy Consumer Price Index (SA, 2015=100) from Haver/Istituto Nazionale di Statistica (mnemonic: H136PC@G10); Japan Consumer Price Index (SA/H, 2020=100) from Haver/Ministry of Internal Affairs and Communications of Japan (mnemonic: H158PC@G10); Spain Consumer Price Index (SA, 2021=100) from Haver/Instituto Nacional de Estadistica (mnemomic: H184PC@G10); U.K. CPI Harmonized: All Items (SA, 2015=100) from Haver/Office for National Statistics (mnemonic: H112PC@G10) starting in fourth quarter 2003 to compute the corresponding inflation rates from first quarter 2004 onward and U.K. Retail Price Index: All Items excluding Mortgage Interest Rates (SA, 2010=100) from Haver/OECD (mnemonic: C112PRXN@OECDMEI) to compute the inflation rates up to fourth quarter 2003;[20] U.S. Consumer Price Index (SA, 1982-84=100) from Haver/Bureau of Labor Statistics (mnemonic: S111PC@G10).

Nominal Short-Term (3-month) Interest Rate (end of period (EOP)): Canada 3-Month Treasury Bill Yield (EOP, % per annum) from Haver/Bank of Canada (mnemonic: N156G3ME@G10); 3-Month EURIBOR Euro Interbank Offered Rate Rate (EOP, % per annum) from Haver/Deutsche Bundesbank (mnemonic: N023RI3E@G10) starting in first quarter 1999 and France 3-Month PIBOR Paris Interbank Offered Rate (EOP, % per annum) from Haver/OECD (mnemonic: C132FRIO@OECDMEI) until fourth quarter 1998; 3-Month EURIBOR Euro Interbank Offered Rate (EOP, % per annum) from Haver/Deutsche Bundesbank (mnemonic: N023RI3E@G10) starting in first quarter 1999 and Germany 3-Month FIBOR Frankfurt Interbank Offered Rate (EOP, % per annum) from Haver/OECD (mnemonic: C134FRIO@OECDMEI) until fourth quarter 1998; 3-Month EURIBOR Euro Interbank Offered Rate (EOP, % per annum) from Haver/Deutsche Bundesbank (mnemonic: N023RI3E@G10) starting in first quar-

[20]The retail price index excluding mortgage interest payments was the U.K.'s target inflation measure from fourth quarter 1992 to fourth quarter 2003 and was replaced as the Bank of England's official inflation target by the consumer price index starting only in 2004.

ter 1999 and Italy 3-Month Interbank Deposit Rate (EOP, % per annum) from Haver/OECD (mnemonic: C136FRIO@OECDMEI) until fourth quarter 1998; Japan 3-Month Japanese Yen TIBOR Tokyo Interbank Offered Rate (EOP, % per annum) from Haver/Refinitiv (mnemonic: T158Y3ME@INTWKLY) starting in second quarter 2010 and Japan 3-Month Certificates of Deposit (Gensaki) Rate (EOP, % per annum) from Haver/OECD (mnemonic: C136FRIO@OECDMEI) until first quarter 2010;[21] 3-Month EURIBOR Euro Interbank Offered Rate (EOP, % per annum) from Haver/Deutsche Bundesbank (mnemonic: N023RI3E@G10) starting in first quarter 1999 and Spain 86–96 Day Interbank Rate (EOP, % per annum) from Haver/OECD (mnemonic: C184FRIO@OECDMEI) until fourth quarter 1998; U.K. 3-Month LIBOR London Interbank Offered Rate based on the British Pound (EOP, % per annum) from Haver/Intercontinental Exchange (mnemonic: N112RI3E@G10); U.S. 3-Month Treasury Bill Rate, Secondary Market (EOP, % per annum) from Haver/Federal Reserve Board (mnemonic: FTBS3@DAILY).

Recession dates: The recession dates used for the shaded bars are from ECRI, the Cabinet Office of Japan, C.D. Howe Institute, and the NBER (Haver mnemonic for Canada: N156VRM@G10; Haver mnemonic for France: N132VRM@G10; Haver mnemonic for Germany: N134VRM@G10; Haver mnemonic for Italy: N136VRM@G10; Haver mnemonic for Japan: N158VRM@G10; Haver mnemonic for Spain: N184VRM@G10; Haver mnemonic for the U.K.: N112VRM@G10; and Haver mnemonic for the U.S.: N111VRM@G10).

Private Forecasts. We collect the mean of all relevant private forecasts—that is, the mean forecasts for $(\mathbb{E}_t(\Delta^4 y_{t+1}), \mathbb{E}_t(\Delta^4 y_{t+2}), \mathbb{E}_t(\Delta^4 p_{t+1}), \mathbb{E}_t(i_{t+1}), ..., \mathbb{E}_t(i_{t+L}))$—which are part of the vector of observables $\overline{Y}_t$ (as indicated in (15)). The mean (consensus) forecasts correspond to the arithmetic average of the forecasts of all private forecasters pooled by Consensus Economics for each variable and country. Given that not every forecasting organization specializes in the same countries, the pool of private forecasters varies across the eight G7+ countries included in the sample.

The last release of private forecasts available for our analysis is that of December 5, 2022, while the first near-complete release we can use is that of July 2, 1990 (except for Spain, for which the complete forecasting data start only with the release of December 12,

[21] The Japanese yen TIBOR rate was introduced in fourth quarter 1995 as the daily reference interest rate at which banks offer to lend unsecured funds to each other in the interbank market. However, the private forecasters pooled by Consensus Economics were not asked to start forecasting the TIBOR rate until second quarter 2010, once the TIBOR rate was already well established. For consistency, we adopt the same switch date implemented for the private forecasts for the corresponding observable series.

1994).[22] There are four quarterly releases of private forecasts per year that are available simultaneously for each country at fairly regular intervals from 1992 onward; however, there are only three forecast releases for the years 1990 and 1991, and we need to complete the data for those two years by interpolating appropriately.

We map each of the two years that have three releases (1990 and 1991) into four-quarterly series per year, matching the release of July 2, 1990, with third quarter 1990, the release of November 5, 1990, with fourth quarter 1990, the release of February 4, 1991, with first quarter 1991, the release of July 1, 1991, with third quarter 1991, and the release of November 4, 1991, with fourth quarter 1991. Then, we complement these series by averaging the corresponding forecasts from the releases of February 4 and July 1, 1991, to impute a series of plausible forecasts for the missing series corresponding to second quarter 1991. For the sake of completeness, the first full release that we end up using for all countries other than Spain is the November 5, 1990, one because the release of July 2, 1990, has a shorter forecasting horizon than that available in all subsequent releases.[23]

Measurement concept. From each release, we collect the mean forecasts for real GDP growth (4-quarter percent change), headline CPI inflation (4-quarter percent change), and the nominal short-term (3-month) interest rate (EOP, % per annum). All forecasts are based on the measurement concept of the observed real GDP, headline CPI, and nominal 3-month interest rate series described earlier for each country. As indicated before, the inflation forecasts for the U.K. switched from an inflation rate based on the retail price index (all items excluding mortgage interest rates) prior to first quarter 2004 to the headline CPI inflation rate from first quarter 2004. Similarly, Japan's 3-month interest rate forecasts switched to the TIBOR rate starting in second quarter 2010 but refer to the 3-month certificate of deposit (gensaki) rate prior to second quarter 2010. We adopt the same conceptual switches

[22] There are two prior releases from November 10, 1989, and March 5, 1990, that we simply cannot use because they do not include any forecasts of the 3-month interest rate.

[23] In our empirical analysis, we are able to reasonably extrapolate the forecasts for the nominal short-term interest rate up to 8 quarters ahead to consider this longer forecasting horizon in a robustness check. Forecasts for the nominal 3-month interest rates are available up to 7 quarters ahead in almost all cases except for July 2, 1990, for which the forecasts are available only up to 6 quarters ahead. Furthermore, for approximately half the releases, there is a full set of 8-quarter-ahead forecasts. We drop the July 2, 1990, release and extend the missing eighth forecast for the 7-quarter-ahead releases by simply replicating the last forecast reported in place of the forecast for eighth-quarter horizon. Dropping the first release of July 2, 1990, to avoid dealing with the two missing observations, however, is without loss of generality and does not appear to materially affect our results. As an additional robustness check, we considered dropping the years 1990 and 1991 to start our sample in first quarter 1992 to avoid entirely the years with only three forecast releases. Our findings with a 5-quarter-ahead (and even an 8-quarter-ahead) forecasting horizon are robust when we use this shorter time series sample, as well.

for the observed data.

Variable matching for forecasts. To ensure that the mapping between the model-based expectations and the forecasting data from Consensus Economics is as close as possible, we need to transform the forecasted variables. Both the real GDP growth rate and the headline CPI inflation rate forecasts are given in 4-quarter percentage changes that can be approximated as $\Delta^4\ln(\text{GDP}_t) \equiv 100{*}(\ln(\text{GDP}_t)\text{-}\ln(\text{GDP}_{t-4}))$ and $\Delta^4\ln(\text{CPI}_t) \equiv 100{*}(\ln(\text{CPI}_t)\text{-}\ln(\text{CPI}_{t-4}))$, respectively. To make practical the estimation of the model with the given forecasts, we added two measurement equations that approximate the relationship between the quarter-over-quarter growth rates defined by the model and the 4-quarter percentage change forecast data we collect (as can be seen in Subsection 2.2, equations (16)–(17)). We simply divide the nominal short-term (3-month) interest rate forecasts in percent per annum by 4 to express them in (nonannualized) percent terms as we do for the corresponding observed nominal 3-month interest rate.

Forecast timing. The timing of the forecasts is conditioned on the information available to the private forecasters. All forecasting data are expressed at quarterly frequency, and each release adds forecasts up to at most 8 quarters ahead starting from the current quarter. For example, the latest release available at the time of this analysis came out on December 5, 2022, for all countries and included seven forecasts from fourth quarter 2022 until second quarter 2024. The private forecasters' data collection procedures require that the forecasts included in the December 5, 2022, release were submitted by the middle of the fourth quarter 2022, if not earlier. Hence, given that monetary policy shifts that can meaningfully alter the nominal 3-month interest rate are infrequent—in the U.S., for example, six or seven weeks pass between each regular Federal Open Market Committee (FOMC) meeting—and to account for the known publication lags on macro data in particular, we argue that the information set available to private forecasters when predicting fourth quarter 2022 and subsequent quarters for the December 5, 2022 release is likely based on information only up to third quarter 2022.[24] We adopt this timing convention when matching the model-based expectations to the survey-based forecasts for all releases and across all countries. Other

[24]As indicated earlier, the date of each release is the same for all countries. However, over time, the timing of the releases has varied somewhat between mid-February and mid-March for the first quarter of the year, between mid-May and mid-June for the second quarter, between mid-August and mid-September for the third quarter, and between mid-November and mid-December for the fourth quarter. The earlier dates on prior releases, however, reinforce our view that the information set used for forecasting likely contained information up to the quarter preceding the release.

timing matching conventions are explored by Cole and Martínez García (2023), who find that the impact on the results is largely negligible.

Forecasting horizon selection. As indicated in Subsection 2.2, we collect the one-quarter-ahead and two-quarter-ahead forecast data for the real GDP growth rate (4-quarter percent change) and the one-quarter-ahead data for the headline CPI inflation rate (4-quarter percent change). For the nominal 3-month interest rate, we collect forecasts completed or extrapolated up to 8 quarters ahead. However, in our benchmark estimation, we rely on data up to 5 quarters ahead (all of which require no manipulation or interpolation/extrapolation). What our use of 5-quarter-ahead forecasts means is that, from the last available release of December 5, 2022, we have forecasts based on information up to third quarter 2022 that start with the 3-month interest rate projected for fourth quarter 2022 to fourth quarter 2023. (In turn, the extension to 8-quarter-ahead forecasts that we pursue as a robustness check means that these projections go from fourth quarter 2022 up to third quarter 2024, with the last quarter being extrapolated based on the prediction for second quarter 2024).

B Additional Tables and Figures

Table B1: **U.S. Prior and Posterior Estimates of Structural Parameters**

	Prior Distr.	Posterior Distribution								
		Full Sample (1990:Q3–2022:Q3)			Great Moderation (1990:Q3–2007:Q3)			Low-Interest-Rate Period (2005:Q3–2022:Q3)		
Par.	Prior	Mean	5%	95%	Mean	5%	95%	Mean	5%	95%
τ	U(0, 1)	0.47	0.44	0.5	0.55	0.49	0.6	0.39	0.35	0.43
ρ	B(0.75, 0.10)	0.98	0.97	0.99	0.97	0.95	0.98	0.98	0.97	0.99
χ_π	N(1.50, 0.10)	1.48	1.31	1.64	1.48	1.32	1.65	1.49	1.32	1.65
χ_x	N(0.125, 0.05)	0.12	0.04	0.19	0.13	0.04	0.21	0.12	0.04	0.20
ρ_μ	B(0.50, .20)	0.03	0.00	0.06	0.03	0.00	0.06	0.08	0.01	0.14
ρ_γ	B(0.50, 0.10)	0.10	0.09	0.11	0.14	0.11	0.17	0.10	0.09	0.11
η	B(0.50, 0.01)	0.47	0.45	0.48	0.50	0.48	0.51	0.48	0.47	0.50
ξ_p	G(0.15, 0.05)	0.16	0.07	0.24	0.15	0.07	0.22	0.15	0.07	0.22
σ_γ	IG(0.30, 0.30)	1.83	1.64	2.02	0.72	0.61	0.82	2.27	1.96	2.58
σ_μ	IG(0.30, 2.00)	0.44	0.4	0.49	0.31	0.26	0.35	0.56	0.48	0.63
σ_{MP}	IG(0.30, 2.00)	0.21	0.18	0.24	0.18	0.14	0.21	0.23	0.18	0.29
σ_1^{FG}	IG(0.30, 2.00)	0.18	0.14	0.22	0.17	0.13	0.20	0.17	0.08	0.26
σ_2^{FG}	IG(0.30, 2.00)	0.12	0.10	0.14	0.09	0.07	0.11	0.18	0.12	0.24
σ_3^{FG}	IG(0.30, 2.00)	0.06	0.05	0.06	0.06	0.04	0.07	0.07	0.05	0.09
σ_4^{FG}	IG(0.30, 2.00)	0.04	0.04	0.05	0.05	0.04	0.06	0.06	0.05	0.07
σ_5^{FG}	IG(0.30, 2.00)	0.07	0.06	0.08	0.06	0.05	0.07	0.07	0.06	0.09
var_{1x1}	B(0.50, 0.20)	0.97	0.92	1.00	0.32	0.07	0.55	0.72	0.49	0.94
var_{1x2}	B(0.50, 0.20)	0.91	0.86	0.97	0.72	0.49	0.95	0.62	0.32	0.94
$var_{2\pi}$	B(0.50, 0.20)	0.08	0.03	0.13	0.06	0.01	0.10	0.10	0.03	0.16
var_{3i}	B(0.50, 0.20)	0.90	0.86	0.94	0.85	0.78	0.91	0.87	0.82	0.93
var_{3i2}	B(0.50, 0.20)	0.84	0.78	0.90	0.83	0.75	0.91	0.85	0.78	0.92
var_{3i3}	N(0.50, 0.20)	0.81	0.74	0.89	0.81	0.72	0.90	0.82	0.74	0.90
var_{3i4}	N(0.10, 0.20)	0.78	0.69	0.87	0.76	0.66	0.86	0.79	0.70	0.88
var_{3i5}	N(0.10, 0.20)	0.73	0.63	0.83	0.66	0.55	0.78	0.75	0.65	0.85

Note: The forecasting relationships for the private agents who rely on a VAR model are

$$\begin{bmatrix} \mathbb{E}_t^{VAR}(\Delta y_{t+1}) \\ \mathbb{E}_t^{VAR}(\Delta y_{t+2}) \\ \mathbb{E}_t^{VAR}(\pi_{t+1}) \\ \mathbb{E}_t^{VAR}(i_{t+1}) \\ \mathbb{E}_t^{VAR}(i_{t+2}) \\ \mathbb{E}_t^{VAR}(i_{t+3}) \\ \mathbb{E}_t^{VAR}(i_{t+4}) \\ \mathbb{E}_t^{VAR}(i_{t+5}) \end{bmatrix} = \begin{bmatrix} var_{1x1} & 0 & 0 \\ var_{1x2} & 0 & 0 \\ 0 & var_{2\pi} & 0 \\ 0 & 0 & var_{3i} \\ 0 & 0 & var_{3i2} \\ 0 & 0 & var_{3i3} \\ 0 & 0 & var_{3i4} \\ 0 & 0 & var_{3i5} \end{bmatrix} \begin{bmatrix} y_t \\ \pi_t \\ i_t \end{bmatrix}.$$

Table B2: **U.K. Prior and Posterior Estimates of Structural Parameters**

	Prior Distr.	Posterior Distribution								
		Full Sample (1990:Q3–2022:Q3)			Great Moderation (1990:Q3–2007:Q3)			Low-Interest-Rate Period (2005:Q3–2022:Q3)		
Par.	Prior	Mean	5%	95%	Mean	5%	95%	Mean	5%	95%
τ	U(0, 1)	0.42	0.39	0.45	0.57	0.52	0.62	0.32	0.28	0.36
ρ	B(0.75, 0.10)	0.94	0.92	0.95	0.94	0.92	0.96	0.94	0.92	0.95
χ_π	N(1.50, 0.10)	1.47	1.31	1.63	1.49	1.32	1.65	1.49	1.33	1.66
χ_x	N(0.125, 0.05)	0.21	0.16	0.27	0.15	0.08	0.20	0.21	0.15	0.27
ρ_μ	B(0.50, .20)	0.04	0.01	0.08	0.10	0.01	0.18	0.07	0.01	0.12
ρ_γ	B(0.50, 0.10)	0.12	0.11	0.13	0.15	0.12	0.19	0.12	0.11	0.13
η	B(0.50, 0.01)	0.45	0.44	0.46	0.50	0.49	0.52	0.47	0.45	0.48
ξ_p	G(0.15, 0.05)	0.18	0.09	0.26	0.18	0.09	0.27	0.17	0.08	0.26
σ_γ	IG(0.30, 0.30)	3.75	3.36	4.13	0.71	0.59	0.82	4.88	4.21	5.54
σ_μ	IG(0.30, 2.00)	0.25	0.22	0.28	0.23	0.18	0.27	0.29	0.25	0.33
σ_{MP}	IG(0.30, 2.00)	0.26	0.23	0.30	0.16	0.13	0.19	0.35	0.28	0.43
σ_1^{FG}	IG(0.30, 2.00)	0.27	0.23	0.32	0.17	0.14	0.21	0.36	0.28	0.44
σ_2^{FG}	IG(0.30, 2.00)	0.14	0.12	0.16	0.09	0.07	0.11	0.20	0.15	0.24
σ_3^{FG}	IG(0.30, 2.00)	0.07	0.05	0.08	0.06	0.05	0.07	0.09	0.07	0.11
σ_4^{FG}	IG(0.30, 2.00)	0.05	0.04	0.06	0.05	0.04	0.06	0.07	0.05	0.08
σ_5^{FG}	IG(0.30, 2.00)	0.07	0.06	0.08	0.06	0.05	0.07	0.08	0.06	0.10
var_{1x1}	B(0.50, 0.20)	0.98	0.96	1.00	0.99	0.98	1.00	0.96	0.93	0.99
var_{1x2}	B(0.50, 0.20)	0.74	0.66	0.83	0.88	0.82	0.94	0.72	0.58	0.86
$var_{2\pi}$	B(0.50, 0.20)	0.73	0.67	0.80	0.35	0.12	0.57	0.76	0.68	0.84
var_{3i}	B(0.50, 0.20)	0.84	0.82	0.87	0.79	0.74	0.84	0.85	0.81	0.89
var_{3i2}	B(0.50, 0.20)	0.77	0.74	0.81	0.73	0.66	0.79	0.78	0.73	0.83
var_{3i3}	N(0.50, 0.20)	0.73	0.68	0.77	0.67	0.59	0.75	0.73	0.67	0.79
var_{3i4}	N(0.10, 0.20)	0.69	0.64	0.74	0.62	0.52	0.72	0.70	0.63	0.77
var_{3i5}	N(0.10, 0.20)	0.66	0.61	0.72	0.60	0.49	0.71	0.66	0.58	0.74

Note: The parameters $var_{1x1}, var_{1x2}, \ldots, var_{3i5}$ are defined in Table B1.

Table B3: **Germany Prior and Posterior Estimates of Structural Parameters**

	Prior Distr.	Posterior Distribution								
		Full Sample (1990:Q3–2022:Q3)			Great Moderation (1990:Q3–2007:Q3)			Low-Interest-Rate Period (2005:Q3–2022:Q3)		
Par.	Prior	Mean	5%	95%	Mean	5%	95%	Mean	5%	95%
τ	U(0, 1)	0.43	0.40	0.47	0.45	0.40	0.49	0.33	0.29	0.37
ρ	B(0.75, 0.10)	0.96	0.95	0.97	0.98	0.97	0.99	0.98	0.97	0.99
χ_π	N(1.50, 0.10)	1.47	1.31	1.63	1.49	1.32	1.66	1.50	1.33	1.66
χ_x	N(0.125, 0.05)	0.21	0.14	0.29	0.11	0.03	0.19	0.12	0.04	0.21
ρ_μ	B(0.50, .20)	0.03	0.00	0.06	0.03	0.00	0.06	0.12	0.02	0.21
ρ_γ	B(0.50, 0.10)	0.11	0.10	0.12	0.11	0.09	0.13	0.11	0.10	0.12
η	B(0.50, 0.01)	0.46	0.44	0.47	0.50	0.48	0.51	0.47	0.46	0.49
ξ_p	G(0.15, 0.05)	0.16	0.07	0.24	0.16	0.07	0.24	0.14	0.07	0.22
σ_γ	IG(0.30, 0.30)	2.14	1.92	2.36	1.28	1.09	1.46	2.62	2.25	2.97
σ_μ	IG(0.30, 2.00)	0.38	0.34	0.41	0.35	0.31	0.40	0.38	0.32	0.43
σ_{MP}	IG(0.30, 2.00)	0.19	0.16	0.22	0.19	0.15	0.23	0.23	0.18	0.28
σ_1^{FG}	IG(0.30, 2.00)	0.17	0.13	0.22	0.19	0.13	0.24	0.13	0.08	0.19
σ_2^{FG}	IG(0.30, 2.00)	0.14	0.11	0.17	0.10	0.07	0.13	0.23	0.17	0.29
σ_3^{FG}	IG(0.30, 2.00)	0.06	0.05	0.07	0.06	0.05	0.08	0.08	0.06	0.10
σ_4^{FG}	IG(0.30, 2.00)	0.05	0.04	0.06	0.06	0.04	0.07	0.07	0.05	0.08
σ_5^{FG}	IG(0.30, 2.00)	0.06	0.05	0.07	0.06	0.05	0.07	0.07	0.05	0.08
var_{1x1}	B(0.50, 0.20)	0.98	0.97	1.00	0.90	0.86	0.94	0.78	0.62	0.94
var_{1x2}	B(0.50, 0.20)	0.84	0.78	0.90	0.67	0.55	0.78	0.67	0.41	0.93
$var_{2\pi}$	B(0.50, 0.20)	0.05	0.01	0.09	0.05	0.01	0.09	0.09	0.02	0.16
var_{3i}	B(0.50, 0.20)	0.89	0.86	0.92	0.88	0.84	0.92	0.86	0.81	0.91
var_{3i2}	B(0.50, 0.20)	0.81	0.77	0.86	0.81	0.76	0.86	0.81	0.75	0.87
var_{3i3}	N(0.50, 0.20)	0.74	0.69	0.8	0.72	0.66	0.79	0.78	0.72	0.84
var_{3i4}	N(0.10, 0.20)	0.69	0.63	0.75	0.65	0.58	0.73	0.77	0.70	0.83
var_{3i5}	N(0.10, 0.20)	0.65	0.58	0.72	0.59	0.51	0.68	0.75	0.68	0.83

Note: The parameters $var_{1x1}, var_{1x2}, \ldots, var_{3i5}$ are defined in Table B1.

Table B4: **Japan Prior and Posterior Estimates of Structural Parameters**

	Prior Distr.	Posterior Distribution								
		Full Sample (1990:Q3–2022:Q3)			Great Moderation (1990:Q3–2007:Q3)			Low-Interest-Rate Period (2005:Q3–2022:Q3)		
Par.	Prior	Mean	5%	95%	Mean	5%	95%	Mean	5%	95%
τ	U(0, 1)	0.23	0.21	0.25	0.33	0.29	0.37	0.12	0.10	0.14
ρ	B(0.75, 0.10)	0.98	0.97	0.99	0.98	0.97	0.99	0.98	0.96	0.99
χ_π	N(1.50, 0.10)	1.46	1.37	1.52	1.49	1.32	1.66	1.49	1.32	1.65
χ_x	N(0.125, 0.05)	0.19	0.15	0.23	0.12	0.04	0.20	0.12	0.04	0.21
ρ_μ	B(0.50, .20)	0.04	0.01	0.07	0.05	0.01	0.08	0.10	0.02	0.19
ρ_γ	B(0.50, 0.10)	0.12	0.11	0.13	0.13	0.11	0.15	0.11	0.10	0.12
η	B(0.50, 0.01)	0.50	0.49	0.51	0.49	0.48	0.51	0.48	0.46	0.49
ξ_p	G(0.15, 0.05)	0.18	0.14	0.22	0.15	0.07	0.22	0.15	0.07	0.22
σ_γ	IG(0.30, 0.30)	1.67	1.54	1.80	0.91	0.78	1.03	2.16	1.86	2.45
σ_μ	IG(0.30, 2.00)	0.41	0.37	0.45	0.38	0.32	0.43	0.42	0.36	0.48
σ_{MP}	IG(0.30, 2.00)	0.17	0.15	0.20	0.15	0.12	0.19	0.19	0.14	0.22
σ_1^{FG}	IG(0.30, 2.00)	0.11	0.08	0.14	0.10	0.07	0.14	0.09	0.07	0.12
σ_2^{FG}	IG(0.30, 2.00)	0.14	0.11	0.16	0.11	0.08	0.14	0.12	0.08	0.15
σ_3^{FG}	IG(0.30, 2.00)	0.06	0.05	0.07	0.06	0.05	0.08	0.09	0.06	0.11
σ_4^{FG}	IG(0.30, 2.00)	0.05	0.04	0.06	0.06	0.04	0.07	0.08	0.06	0.11
σ_5^{FG}	IG(0.30, 2.00)	0.07	0.06	0.08	0.07	0.05	0.08	0.08	0.06	0.10
var_{1x1}	B(0.50, 0.20)	0.62	0.52	0.73	0.55	0.33	0.77	0.67	0.50	0.85
var_{1x2}	B(0.50, 0.20)	0.29	0.12	0.49	0.42	0.14	0.69	0.44	0.15	0.73
$var_{2\pi}$	B(0.50, 0.20)	0.07	0.02	0.11	0.07	0.02	0.12	0.08	0.03	0.13
var_{3i}	B(0.50, 0.20)	0.84	0.82	0.86	0.83	0.81	0.86	0.86	0.79	0.93
var_{3i2}	B(0.50, 0.20)	0.81	0.78	0.83	0.80	0.77	0.84	0.79	0.71	0.87
var_{3i3}	N(0.50, 0.20)	0.79	0.76	0.82	0.79	0.74	0.83	0.72	0.63	0.81
var_{3i4}	N(0.10, 0.20)	0.79	0.76	0.83	0.78	0.72	0.83	0.73	0.64	0.83
var_{3i5}	N(0.10, 0.20)	0.80	0.76	0.84	0.78	0.72	0.84	0.77	0.67	0.87

Note: The parameters $var_{1x1}, var_{1x2}, \ldots, var_{3i5}$ are defined in Table B1.

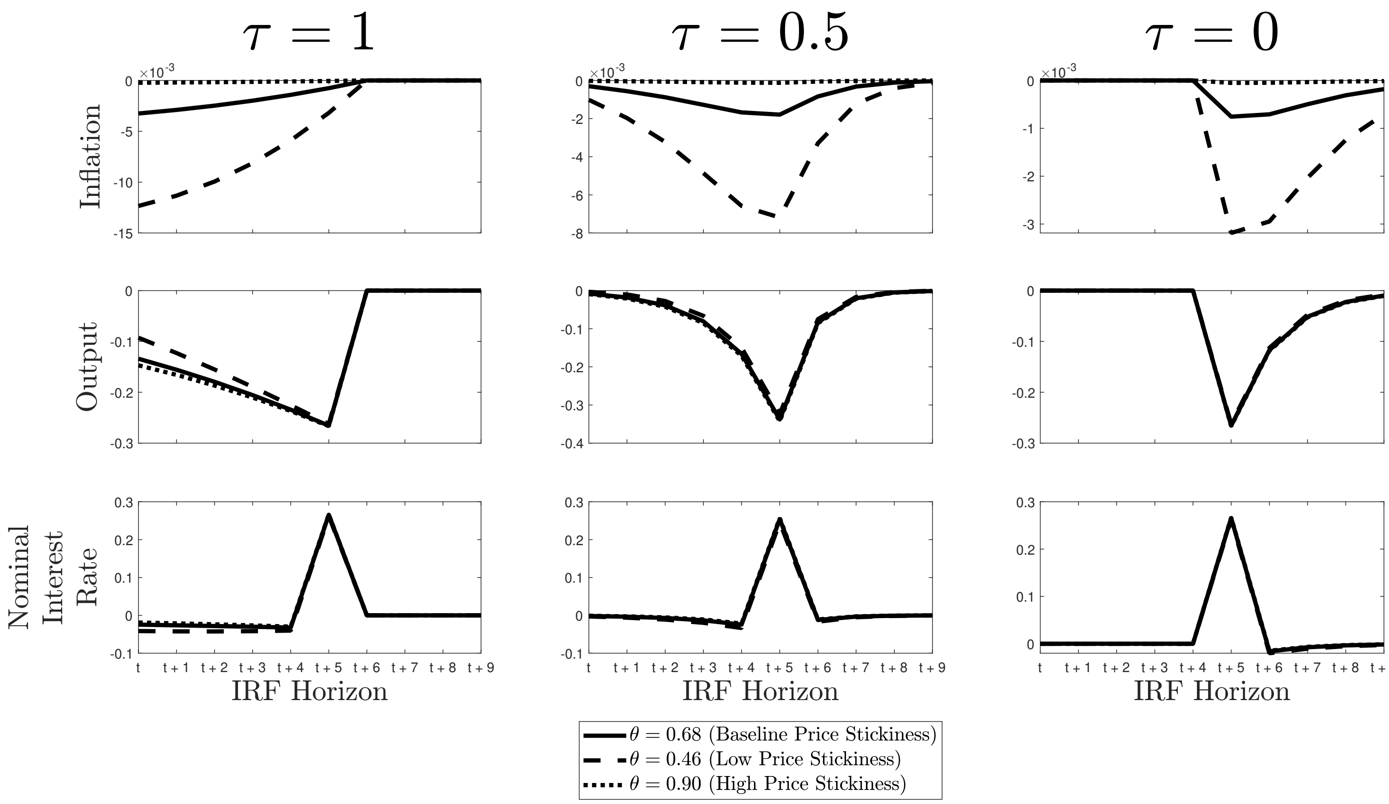

Figure B1: Impulse Responses Under Varying Degrees of Price Stickiness

Note: Benchmark model of Section 2, but with no habit in consumption ($\eta = 0$), no price indexation ($\iota_p = 0$), and no interest rate smoothing ($\rho = 0$). 25-basis-point (bp) increase.

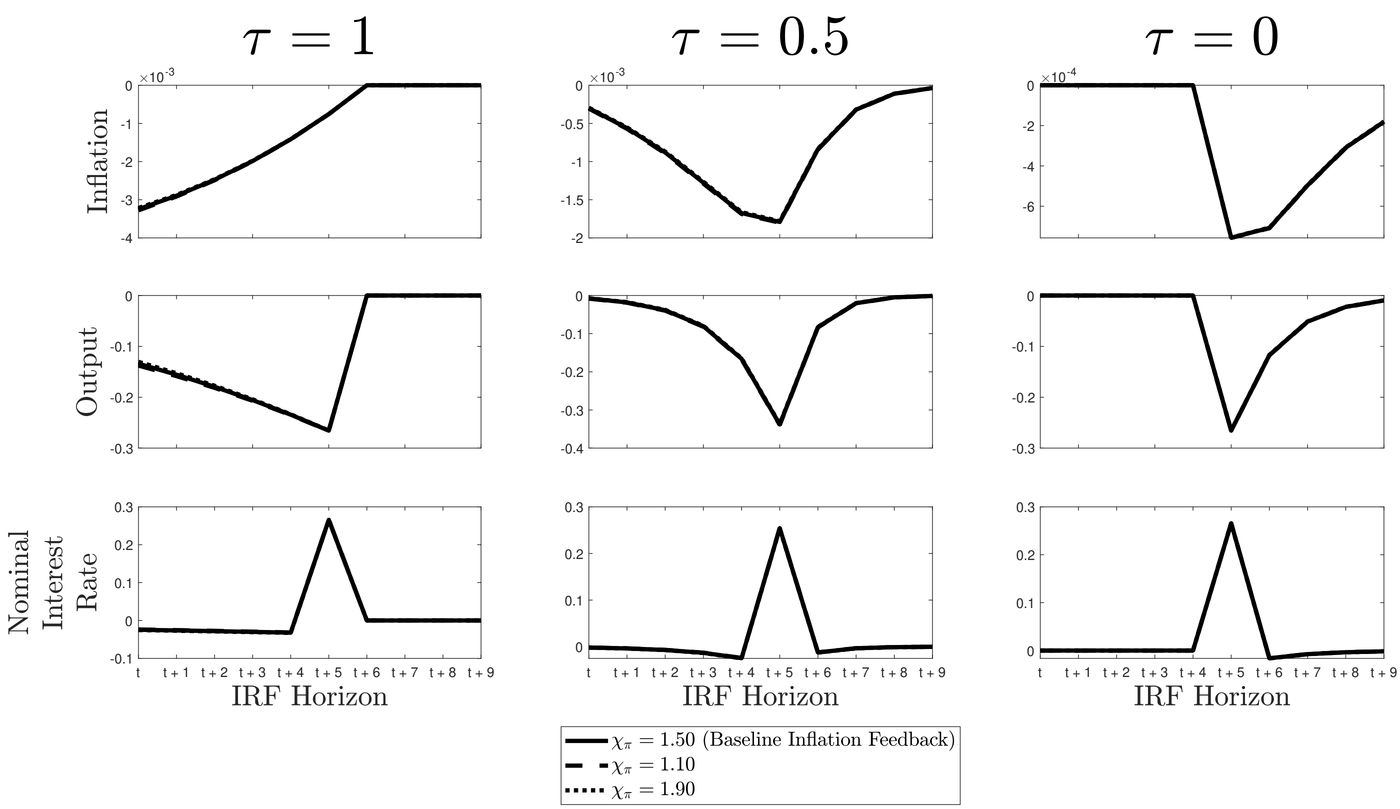

Figure B2: Impulse Responses Under Lower and Higher Values of the Inflation Feedback Parameter

Note: Benchmark model of Section 2, but with no habit in consumption ($\eta = 0$), no price indexation ($\iota_p = 0$), and no interest rate smoothing ($\rho = 0$). 25-basis-point (bp) increase.

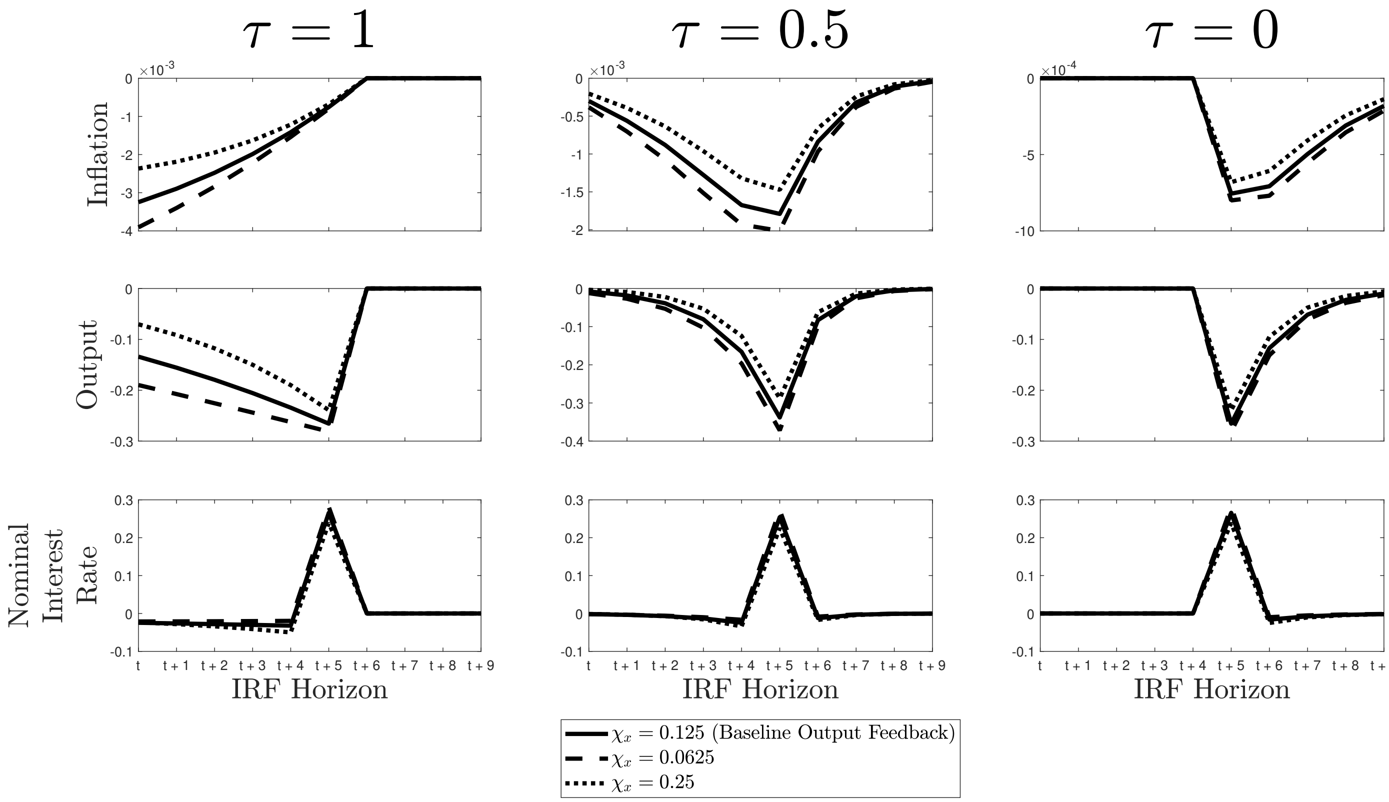

Figure B3: Impulse Responses Under Lower and Higher Values of the Output Gap Feedback Parameter

Note: Benchmark model of Section 2, but with no habit in consumption ($\eta = 0$), no price indexation ($\iota_p = 0$), and no interest rate smoothing ($\rho = 0$). 25-basis-point (bp) increase.

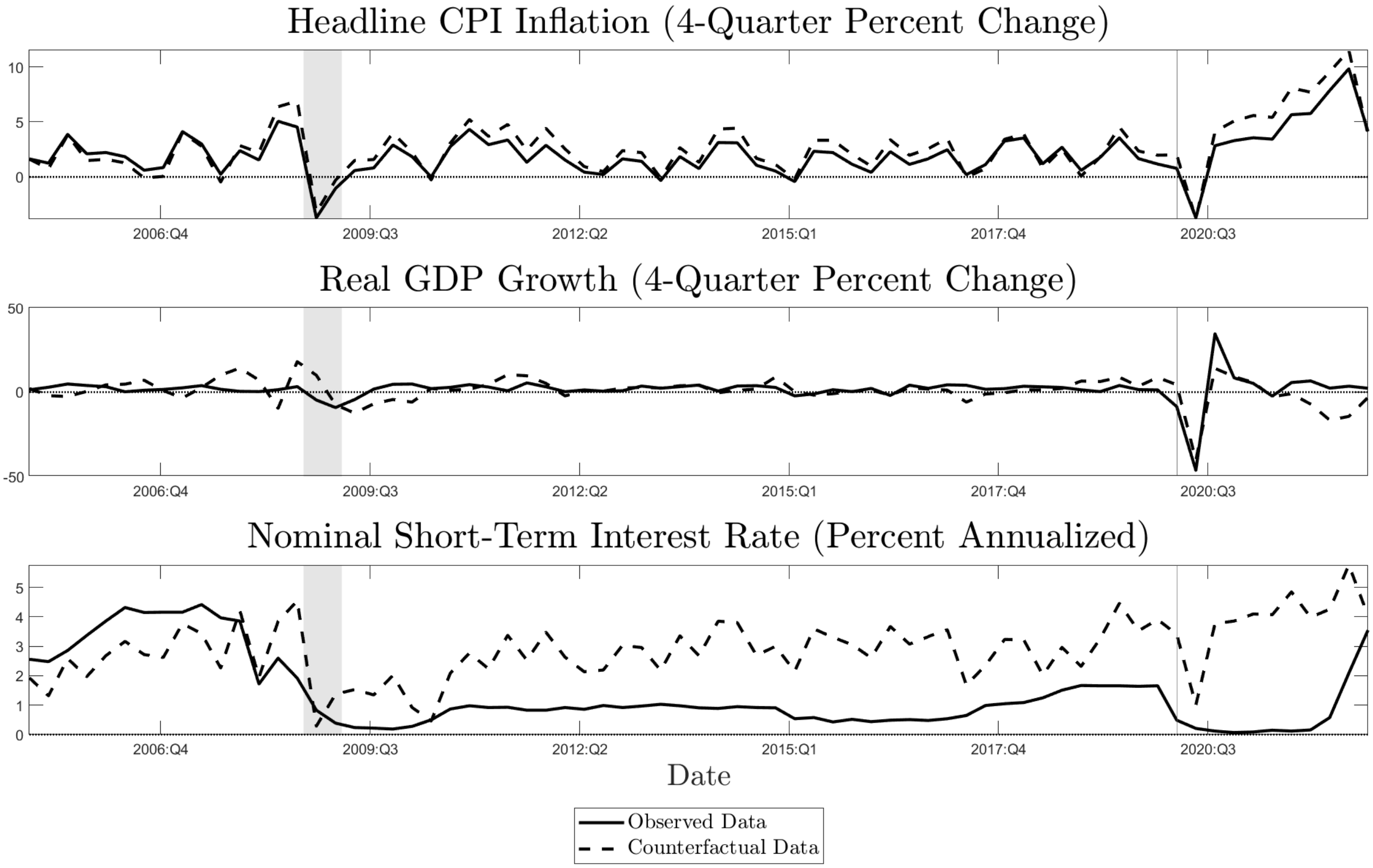

Figure B4: Counterfactual Canada Inflation, Real GDP Growth, and Nominal Short-Term Interest Rate in the Low-Interest-Rate Period (2005:Q3–2022:Q3) Under $\tau = 1$

Note: The observed and counterfactual inflation and real GDP growth series are reported in 4-quarter percentage change rates, while the nominal short-term (3-month) interest rate series is quoted in percent annualized. We obtain the simulated data by setting the model parameter values at the posterior mean estimated in the low-interest-rate subsample (except for τ, which is fixed at 1) and feeding in the recovered shocks (including the forward guidance shocks). Shaded bars denote C.D. Howe Institute recession dates for Canada.

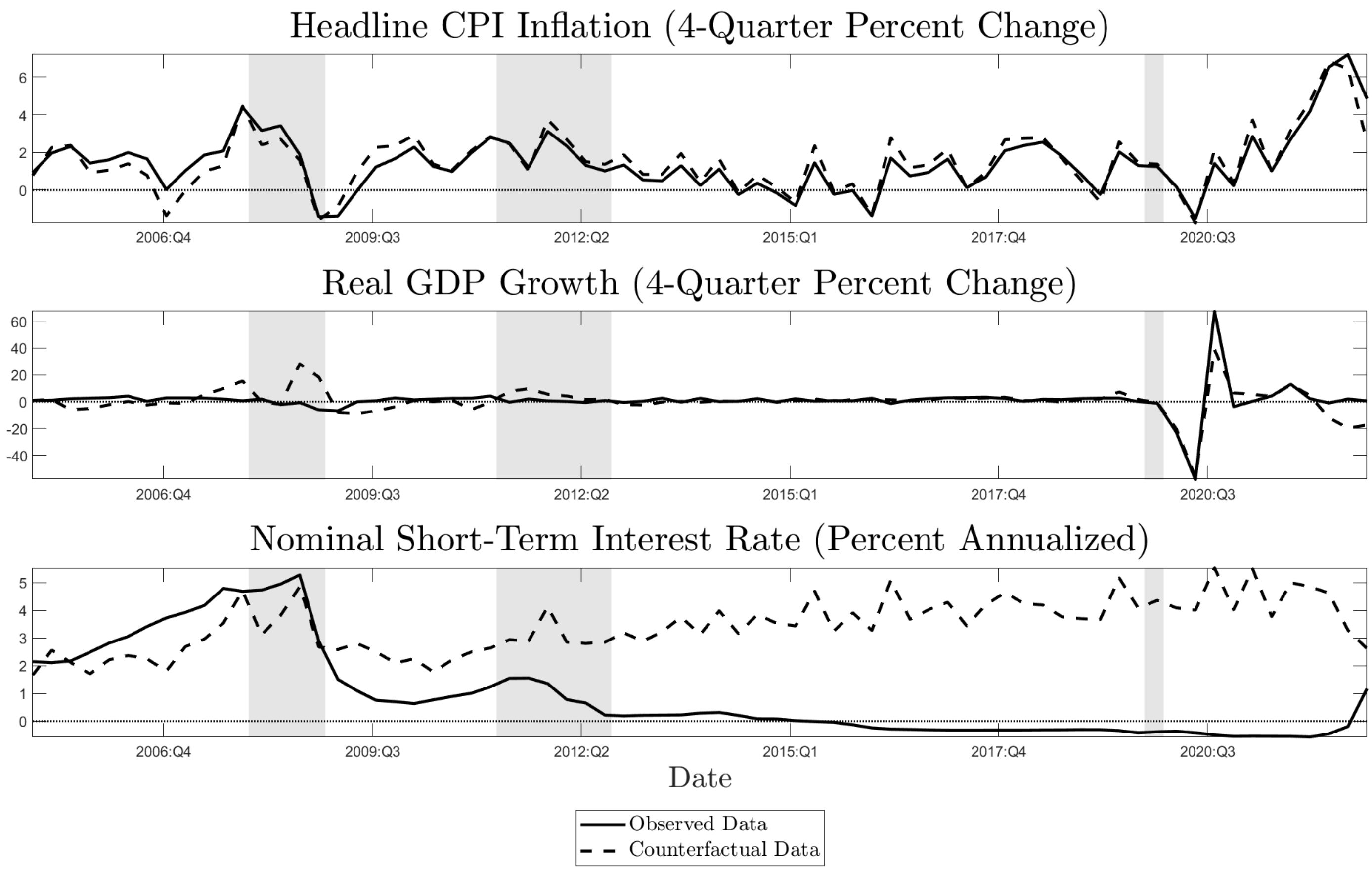

Figure B5: Counterfactual France Inflation, Real GDP Growth, and Nominal Short-Term Interest Rate in the Low-Interest-Rate Period (2005:Q3–2022:Q3) Under $\tau = 1$

Note: The observed and counterfactual inflation and real GDP growth series are reported in 4-quarter percentage change rates, while the nominal short-term (3-month) interest rate series is quoted in percent annualized. We obtain the simulated data by setting the model parameter values at the posterior mean estimated in the low-interest-rate subsample (except for τ, which is fixed at 1) and feeding in the recovered shocks (including the forward guidance shocks). Shaded bars denote ECRI recession dates for France.

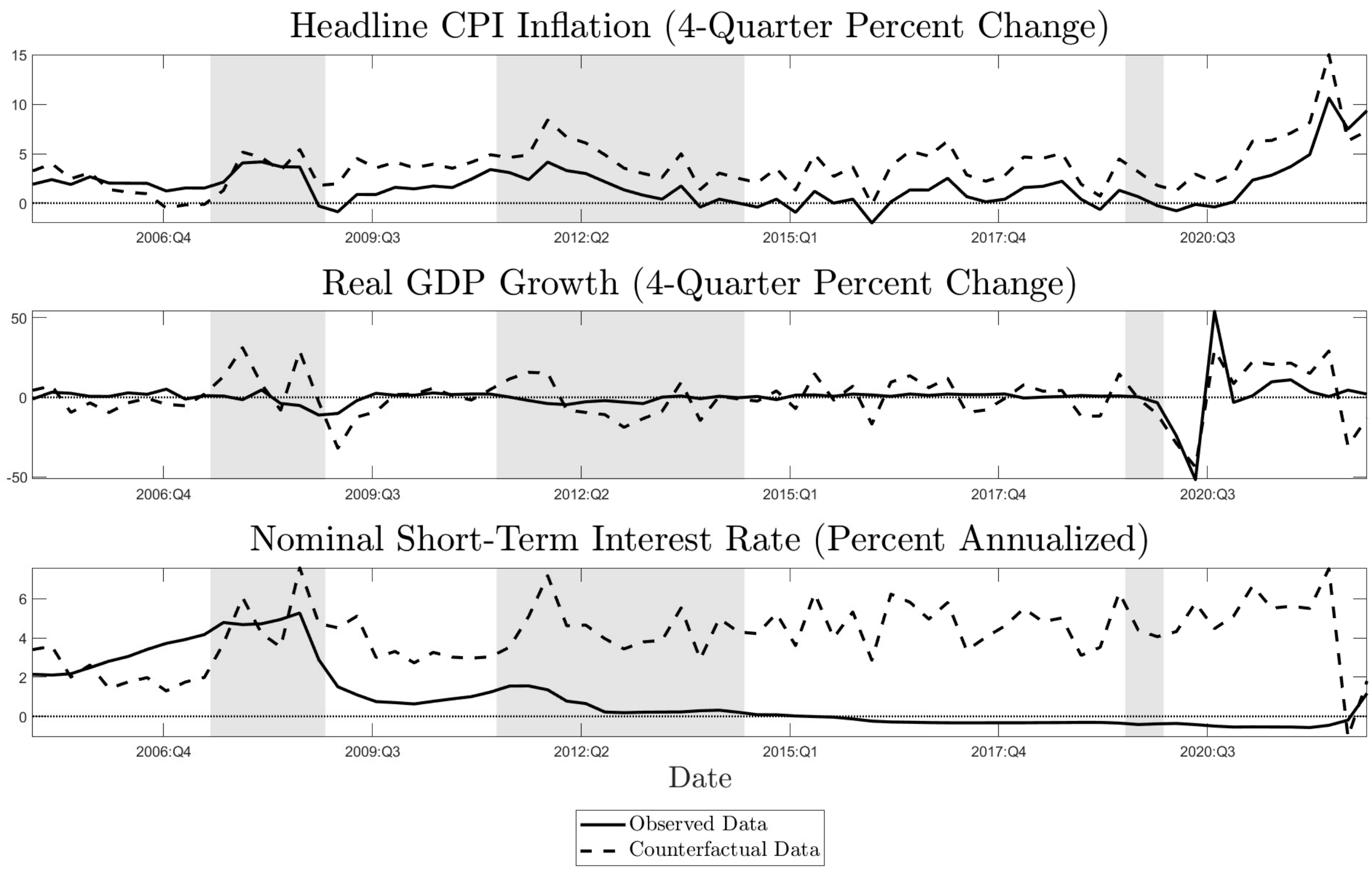

Figure B6: Counterfactual Italy Inflation, Real GDP Growth, and Nominal Short-Term Interest Rate in the Low-Interest-Rate Period (2005:Q3–2022:Q3) Under $\tau = 1$

Note: The observed and counterfactual inflation and real GDP growth series are reported in 4-quarter percentage change rates, while the nominal short-term (3-month) interest rate series is quoted in percent annualized. We obtain the simulated data by setting the model parameter values at the posterior mean estimated in the low-interest-rate subsample (except for τ, which is fixed at 1) and feeding in the recovered shocks (including the forward guidance shocks). Shaded bars denote ECRI recession dates for Italy.

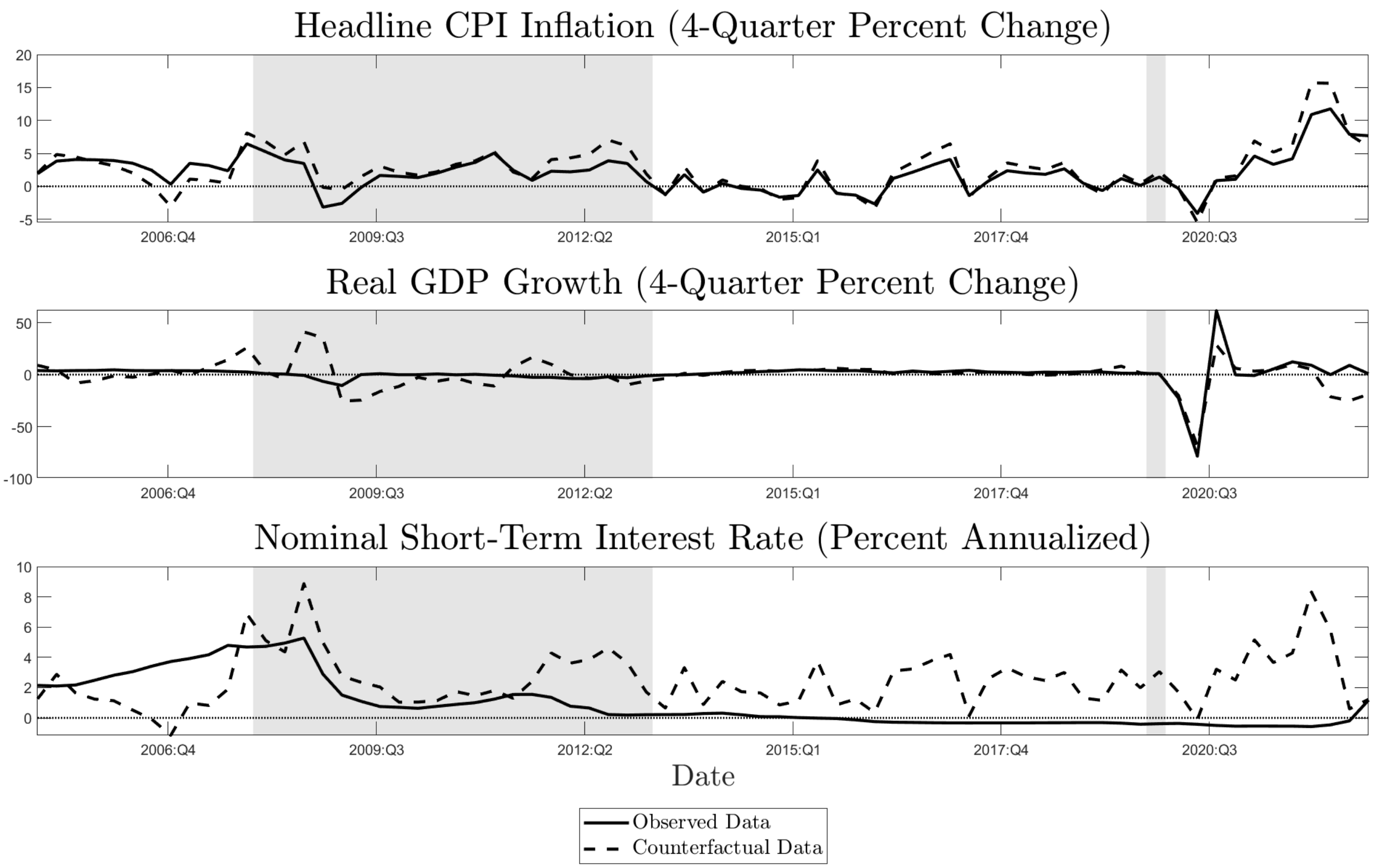

Figure B7: Counterfactual Spain Inflation, Real GDP Growth, and Nominal Short-Term Interest Rate in the Low-Interest-Rate Period (2005:Q3–2022:Q3) Under $\tau = 1$

Note: The observed and counterfactual inflation and real GDP growth series are reported in 4-quarter percentage change rates, while the nominal short-term (3-month) interest rate series is quoted in percent annualized. We obtain the simulated data by setting the model parameter values at the posterior mean estimated in the low-interest-rate subsample (except for τ, which is fixed at 1) and feeding in the recovered shocks (including the forward guidance shocks). Shaded bars denote ECRI recession dates for Spain.