Living Up to Expectations: Central Bank Credibility, the Effectiveness of Forward Guidance, and Inflation Dynamics Post-Global Financial Crisis

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Living Up to Expectations: Central Bank Credibility, 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 have imperfect credibility. Exploiting unique survey-based measures of expected inflation, output growth, and interest rates, we estimate a small-scale New Keynesian model for the United States and other G7 countries plus Spain allowing for deviations from full information rational expectations. In our model, the key parameter that aggregates heterogeneous expectations captures the central bank's credibility and affects the overall effectiveness of forward guidance. We find that the central banks of the U.S., the U.K., Germany, and other major advanced economies have similar levels of credibility (albeit far from full credibility); however, Japan's central bank credibility is much lower. For each country, our measure of credibility has declined over time, making forward guidance less effective. In a counterfactual analysis, we document that inflation would have been significantly higher, and the zero lower bound on short-term interest rates much less of an issue, in the wake of the Global Financial Crisis had the public perceived central bank forward guidance statements to be perfectly credible. Moreover, inflation would have declined more, and somewhat faster, with perfect credibility in the wake of the inflation surge post-COVID-19.

Keywords: Forward Guidance, Central Bank Credibility, Heterogeneous Expectations

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 the effectiveness of forward guidance relies on shaping private-sector expectations of the future path of policy, central bank announcements must be widely credible and incorporated into the expectations of economic actors. If the public does not believe forward guidance statements, private sector expectations of other macroeconomic variables (e.g., output and inflation) will be unaffected, leading to no contemporaneous influence of forward guidance on the economy. However, if the public perceives central bank commitments as fully credible, forward guidance ought to anchor expectations and stimulate the economy in advance of promised future changes in the path of policy.

Our paper provides analyses of the effectiveness of forward guidance across both time and space (focusing on the experience of different countries) while capturing imperfect central bank credibility through heterogeneous expectations. 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 banks been fully credible.

We construct a small-scale New Keynesian model based on the work of 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 like habit formation and price indexation, and features the usual combination of demand and supply shocks. Monetary policy is conducted according to an inertial Taylor (1993)-type real interest rate rule. The real 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.

We allow for departures from the full information rational expectations (FIRE) structure in order to investigate how credibility influences forward guidance effectiveness. In particular, a fraction of households forms expectations according to rational expectations and consequently incorporate forward guidance announcements into their decision-making. The other fraction of households forms expectations using a backward-looking vector autoregression

(VAR) model that *does not* incorporate announcements about anticipated 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 notation, the fraction of fully informed households with rational expectations is measured by the parameter $\tau \in [0, 1]$. As $\tau \to 1$, all agents have rational expectations. When $\tau \to 0$, aggregate expectations reduce to a backward-looking VAR forecasting model. Consequently, when τ is larger, forward guidance announcements are quite effective at stimulating inflation and output from the moment of the announcement onward (stronger anticipation effects). When τ is instead close to zero, forward guidance becomes ineffective.

Given that the parameter τ determines the convex combination of the different types of expectations (or forecasting models) and, therefore, the heterogeneity of beliefs among private agents, we interpret it as a practical indicator of the degree of imperfect credibility of forward guidance. For the remainder of the paper, we engage in a slight abuse of terminology and reference the parameter τ as a measure of central bank credibility.[1]

The majority of our empirical analysis focuses on four countries—the U.S., the U.K., Germany, and Japan. However, we also present results extending our analysis to incorporate other major advanced economies of the G7+ group (Canada, France, Italy, and Spain).[2] Our data sample extends from third quarter 1990 (third quarter 1994 for Spain) through 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 typical macro aggregates, but also survey-based expectations for the variables of interest of the economies in question. That includes forecast data on one- and two-period ahead real GDP growth and on one-period ahead headline CPI inflation from Consensus Economics. To identify forward guidance shocks and credibility, we exploit interest rate expectations up to 5-quarters ahead from the same source. These forecasts are composed of survey responses about the values of future macroeconomic variables from the world's leading forecasters for all of the countries we consider.[3]

[1] Strictly speaking, τ measures the fraction of agents with forward-looking fully-informed rational expectations that react to forward guidance announcements, not the fraction of agents who believe central bank announcements about the future path of policy. But because agents who use a backward-looking rule do not incorporate forward guidance announcements, we think it is appropriate, with caveats, to refer to τ as a measure of central bank credibility.

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

[3] As a robustness check, we also make use of 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.

The identified forward guidance shocks look quite reasonable—for the U.S. and the other G7+ countries, forward guidance became quite stimulative during and immediately after the GFC, with forward guidance taking a more hawkish turn at the very end of the sample following the high inflation post-COVID-19.

The full sample results show that the major countries have credibility estimates that lie close to 0.5 over the full sample with the exception of Japan. The U.S. is estimated to be the most credible, followed by the U.K. and Germany. Japan is estimated to be the least credible, with a notably lower credibility estimate than the other countries. These estimates mask interesting time series heterogeneity, though. For all four countries, we find larger credibility estimates earlier during the Great Moderation period (1990-2007), and substantially smaller estimates during 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, not Japan. We also perform a rolling estimation exercise, re-estimating the model over successive 69-quarter samples. For each country, we find roughly monotonic declines in the mean estimate of τ, our indicator of central bank credibility. 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 is about two-thirds as effective at raising output and inflation at the end of the sample relative to the beginning of the sample. Put differently, central bank credibility and forward guidance effectiveness seem 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 of time.

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 variables have looked like had each central bank been perfectly credible (i.e., $\tau = 1$), using exactly the same forward guidance shocks estimated in our baseline analysis? In other words, what would have been the effect of forward guidance if it had been deployed when at full potency? 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 had each central bank been more credible.

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 central bank credibility. Japan is a bit of an outlier in the counterfactual analysis in part because Japan hit the ZLB in the early 1990s—while we estimate that the ZLB would have been less of a constraint, the differences in the path of inflation post-GFC would not have been as stark as for the other three major countries. The evidence for Canada, France, Italy, and Spain is largely consistent with that of the U.S., U.K., and Germany.

We then employ our counterfactual exercise to also study inflation dynamics in the aftermath of the short-lived COVID-19 recession, during the subsequent inflation surge. For the U.S., the U.K., and Germany, our analysis reveals that inflation would have started to decline quicker, and somewhat sooner, in 2022 had central banks been fully credible. 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 present paper shows that heterogeneous expectations—and the lack of perfect credibility of forward guidance—dampen the unrealistic strength of the anticipation effects of forward guidance found in DSGE models with only FIRE agents (see, e.g., Del Negro et al. (2012) or more recently Cole and Martínez García (2023)). The results of Kohlhas and Walther (2021) that survey-based measures of expectations are incompatible with standard ways to model rational expectations also support incorporating heterogeneous expectations into macroeconomic models as we do in the paper.[4]

Tetlow (2022) examines expectations formation, credibility, and policy communication relative to determinants of the sacrifice ratio. In a related manner, our work emphasizes outcomes exploring through counterfactuals the role of credibility in the missing inflation puzzle post-GFC and in the inflation surge post-COVID-19. 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 how central bank credibility, and the associated effectiveness of forward guidance, varies across both time and space. Our counterfactual analyses also offer some potential insights into the role of central bank credibility in the recent behavior of inflation.

The remainder of the paper is organized as follows: In Section 2, we discuss our baseline credibility model with forward guidance and heterogeneous forecasts. In particular, we

[4]Caballero and Simsek (2022) characterize forecasting heterogeneity as "mistakes" when interest rate decisions of the central bank misalign with private expectations. Their work puts the focus on differences between markets and the central bank rather than among private agents as our model does. According to Park (2018), monetary authorities typically employ macroeconomic models with rational expectations to forecast future economic activity as well as the future path of inflation and the policy rate—that is, central banks tend to use models that do not incorporate 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.

explore some model properties and show how the effectiveness of forward guidance varies with central bank credibility. Section 3 discusses our dataset and Bayesian estimation strategy. Section 4 presents our main findings on the effectiveness of forward guidance across time and space; it also contains our counterfactual analyses and some additional robustness checks, extending our analysis to all G7+ countries. Section 5 offers concluding thoughts. Appendix A describes the data sources and Appendix B contains additional tables and figures of results.

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 bring 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) real interest rate feedback rule 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 the central bank's forward guidance announcements through the lens of a general equilibrium framework. We describe the monetary policy rule in greater detail in Subsection 2.2 below.

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

If rational expectations forecasts with full information are used, then central bank's announcements are fully incorporated. If some agents have limited information capabilities and form expectations based on standard VAR techniques to fit the observed data, then those announcements are excluded in practice. VAR techniques are fairly easy to implement, yet are immune to attempts on the part of the central bank to "manage expectations" through forward guidance announcements.[5]

[5]A VAR model can be seen as a reduced-form representation of the solution to a forward-looking model of the economy (Martínez García (2020)), more flexible than using the structural specification itself. This

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 a pair of log-linearized equations, the dynamic Investment-Savings (IS) equation and the New Keynesian Phillips Curve (NKPC) respectively:

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

where

$$\tilde{y}_t \equiv y_t - \eta y_{t-1} - \beta\eta\mathbb{E}_t(y_{t+1} - \eta y_t), \quad (3)$$
$$\tilde{y}^n_t \equiv y^n_t - \eta y^n_{t-1} - \beta\eta\mathbb{E}_t\left(y^n_{t+1} - \eta y^n_t\right), \quad (4)$$
$$\tilde{x}_t \equiv \tilde{y}_t - \tilde{y}^n_t = x_t - \eta x_{t-1} - \beta\eta\mathbb{E}_t(x_{t+1} - \eta x_t), \quad (5)$$
$$\tilde{\pi}_t \equiv \pi_t - \iota_p\pi_{t-1}. \quad (6)$$

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 $x_t \equiv y_t - y^n_t$, i.e., the log-deviation of actual output (y_t) from its potential counterpart absent all nominal rigidities (y^n_t).

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 $0 \leq \theta \leq 1$, are 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 and potential output. Based on the actual and potential output transformations in (3) – (4) together with (6), straightforward algebra permits us to further re-write the system of equations in (1) – (2) (that is, the dynamic IS and NKPC equations above) in terms of the same three observable macro variables as in

flexibility allows private actors to remain agnostic about the policy rule (not just about forward guidance) and form their expectations solely based on the observed macro outcomes.

Cole and Martínez García (2023): output (y_t), inflation (π_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. In that counterfactual world, potential output (y_t^n) evolves according to the following equation:

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

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:

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

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 (Non-Monetary) 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 described in terms of the central bank's intermediate policy target, the short-term real interest rate (r_t), rather than in terms of a specific policy instrument or combination of policy instruments that may change over time.[6] To describe the monetary policy strategy in this context, we adopt an inertial form of the Taylor (1993) rule specified in terms of the real rate, r_t, as described in Martínez García (2021). Accordingly, the real interest rate (r_t) tracks the natural real rate (r_t^n) while responding to deviations from the central bank's stated objectives—that is, inflation deviations from its zero-inflation target (π_t) and possibly also fluctuations in the output gap ($x_t \equiv y_t - y_t^n$).

In short, we define the policy rule relating the intermediate target of monetary policy to deviations from the central bank's objectives in the following terms:

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

where the Fisher equation:

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

offers the conventional link between the intermediate target real rate (r_t), the short-term nominal interest rate (i_t), and aggregate inflation expectations ($\mathbb{E}_t(\pi_{t+1})$).

The Taylor (1993) rule in equation (11) is a plausible guide for the conduct of monetary policy with the additional advantage that because it is defined in terms of the intermediate target (the short-term real rate, r_t) rather than directly on the short-term nominal interest rate (i_t), the rule is unaffected by the non-linearities introduced by the ZLB.

The rule in equation (11) includes a smoothing parameter given by $0 \leq \rho < 1$ which introduces inertia. It 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 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]

[6] In the workhorse New Keynesian model, monetary policy influences the policy-relevant short-run trade-off between economic activity and inflation primarily through shifts of the real interest rate path. Here, therefore, we are agnostic about the particular policy instrument or combination of policy instruments required to achieve those shifts and focus instead on how the intermediate policy target, the real rate, relates to the policymakers' response to deviations from the central bank's inflation and output objectives.

[7] Schmitt-Grohe and Uribe (2012) utilize anticipated shocks and describe them as "news". We use the same idea to study forward guidance and its effects via monetary policy news shocks.

[8] In practice, we consider forward guidance up to 5-quarters ahead due to data limitations on the survey-based forecasts we use and also to reduce the number of parameters to be estimated. We also consider as a robustness check the case where we extend the forecast horizon up to a maximum of 8-quarters ahead, but the results do not change qualitatively in that case.

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

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

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

Each $\varepsilon_{l,t-l}^{FG}$ in equation (11) represents anticipated or news shocks that private agents know about in period $t-l$ but which will not directly affect the intermediate policy target (the real 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 that productivity growth and cost-push shocks are as described in equations $(9)-(10)$ while the monetary policy shocks are split into unanticipated (surprise) and anticipated (news) shocks as in $(13)-(14)$, the vector of three observable macro variables given by $Y_t = [y_t, \pi_t, i_t]'$, which includes actual output (y_t), inflation (π_t), and the nominal short-term rate (i_t), lacks fundamentalness in the sense of Hansen and Sargent (1980) and Martínez García (2020). Accordingly, Y_t does not contain enough information to pin down the vector of structural shocks $\varepsilon_t = \left[\gamma_t, \mu_t, \varepsilon_t^{MP}, \left\{\varepsilon_{l,t-l}^{FG}\right\}_{l=1}^{L}\right]'$. Without additional observable variables, we can only recover residuals that are linear combinations of the underlying structural shocks.

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 model. This strategy involves augmenting the vector of observables $Y_t = [y_t, \pi_t, i_t]'$ with expectations with which to disentangle anticipated from unanticipated monetary policy shocks and recover all structural shocks. For that, we expand the vector Y_t with a sufficiently large subset of the available expectations as follows:

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

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

To facilitate the estimation of the model, we add two additional measurement equations that approximate the four-quarter percentage change formula with the quarter-over-quarter formulas as follows:

$$\Delta^4 y_{t+j} = (g_{t+j} + g_{t+j-1} + g_{t+j-2} + g_{t+j-3}), \tag{16}$$

$$\Delta^4 p_{t+j} = (\pi_{t+j} + \pi_{t+j-1} + \pi_{t+j-2} + \pi_{t+j-3}). \tag{17}$$

The measurement equations (16) − (17) allow us to map the observable forecasts for real GDP growth and headline CPI inflation to their model counterparts.

Given the structure of the economy described by equations (1)−(2) together with (3)−(6), the frictionless allocation in (7) − (8), the non-monetary 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), suffice to ensure that we can identify all structural shocks, i.e., $\varepsilon_t = \left[\gamma_t, \mu_t, \varepsilon_t^{MP}, \left\{\varepsilon_{l,t-l}^{FG}\right\}_{l=1}^{L}\right]'$.

2.3 A Broad Notion of Central Bank Credibility

Forward guidance opens up the possibility for central banks to manage expectations. Failure to communicate the policy path in a fully credible manner results in the real possibility that forecasting heterogeneity will arise among private actors in the economy.[9] We assume that private agents that believe that central bank's commitments are not credible form their expectations about the observables using a standard VAR model to forecast the future path of the economy in that way (ignoring all announcements until they materialize at a later time).

That is, some private agents may opt to forecast the observable vector $Y_t = [y_t, \pi_t, i_t]'$

[9] However, we assume households own the firms and we often 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 in equilibrium. We leave for future research the exploration of richer environments where firms' expectations may differ from those of households.

with the following parsimonious structural VAR(1) process in mind:

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

which captures well the historical dynamics of Y_t in our sample. Here, A and B are reduced-form matrices of conforming dimensions, and u_t is a vector of (non-structural) residuals.[10] By contrast, we assume that other private agents are more sophisticated in the way they process information, adjusting their views about the future outlook in response to the central bank's own forward guidance announcements. We describe those private agents as forming expectations according to the full-information, rational expectations (FIRE) paradigm.

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

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

where $\mathbb{E}_t^{FIRE}(Y_{t+1})$ represents the FIRE forecasts of private agents and $\mathbb{E}_t^{VAR}(Y_{t+1})$ denotes the VAR-based expectations of private agents. As stated above, the latter form expectations based on equation (18).

The parameter $0 < \tau < 1$ determines the share of private agents that form FIRE expectations. We refer to τ as the credibility parameter of the model because any value less than one for this parameter introduces forecasting heterogeneity about the future policy path that would otherwise not be possible in an environment where a credible central bank can steer the views of all private forecasters and anchor them along the central bank's announced policy path. In the limiting case where $\tau \to 1$, all private agents in the economy believe the central bank to be perfectly credible and incorporate forward guidance announcements in their rational expectations. In that case expectations are homogeneous across agents and

[10] In our estimation, the parameters of A and B in equation (18) are recovered jointly as part of the full structural model. One simplifying assumption that we make is to set the column-vector A to zero so $A = \mathbf{0}$. Therefore, the resulting estimates reflect the information available over the estimation sample. We also adopt a timing assumption that matches the information content of the survey-based forecasts in our dataset, that is, we assume that forecasts at time period t used to generate $\mathbb{E}_t^{VAR}(Y_{t+1})$ are based on information observed up to time period $t-1$. In order to enforce this timing convention, we employ $\mathbb{E}_t^{VAR}(Y_{t+1}) = B^2 Y_{t-1}$ constrained such that B is a square diagonal matrix rather than relying simply on equation (18). We leave the issue of learning about A and B, and its stability properties, for future research.

$\mathbb{E}_t(Y_{t+1}) = \mathbb{E}_t\left(Y_{t+1}^{FIRE}\right)$. In the opposite polar case where $\tau \to 0$, the monetary authority is considered not to be credible, and while beliefs are also homogeneous, they imply that $\mathbb{E}_t(Y_{t+1}) = \mathbb{E}_t^{VAR}(Y_{t+1})$.

In general, aggregate expectations of private agents would be a convex combination weighed by the parameter τ. This is the benchmark model we estimate and inevitably leads to an economy where forward guidance loses some of its potency if τ is strictly less than one.

2.4 Understanding the Mechanism

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

To fix ideas, we parameterize the model so that there is no consumption habit ($\eta = 0$) and no price indexation ($\iota_p = 0$). We also assume that there is 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 when $\tau = 1$ (i.e., when all private agents form FIRE expectations and there is perfect central bank credibility). The rest of the structural parameters are fixed to the prior means, which can be found in Appendix B, Table B1.

The first column of Figure 1 plots impulse responses to a 25 basis point forward guidance shock 5-periods ahead (i.e., a shock to $\epsilon_{5,t}^{FG}$ observed in period t, which takes effect in five periods, hence in period $t+5$). The solid lines show responses when we assume perfect credibility, $\tau = 1$. Output and inflation jump down significantly the moment the forward guidance shock is announced; the peak inflation response is on impact, while output declines a bit more during the intervening periods, with a peak response the same period that the shock materializes. The interest rate declines slightly before the period in which the shock is realized due to the endogenous feedback between inflation, output, and the interest rate given by the policy rule. Because there is no interest rate smoothing, and because there are 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 responses to the same forward guidance shock when there is a degree of imperfect credibility ($\tau = 0.5$) and no credibility at all ($\tau = 0$). In the case of no credibility ($\tau = 0$), 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 imperfect credibility ($\tau = 0.5$) lies between the two extreme cases. Output and inflation both decline on impact, but

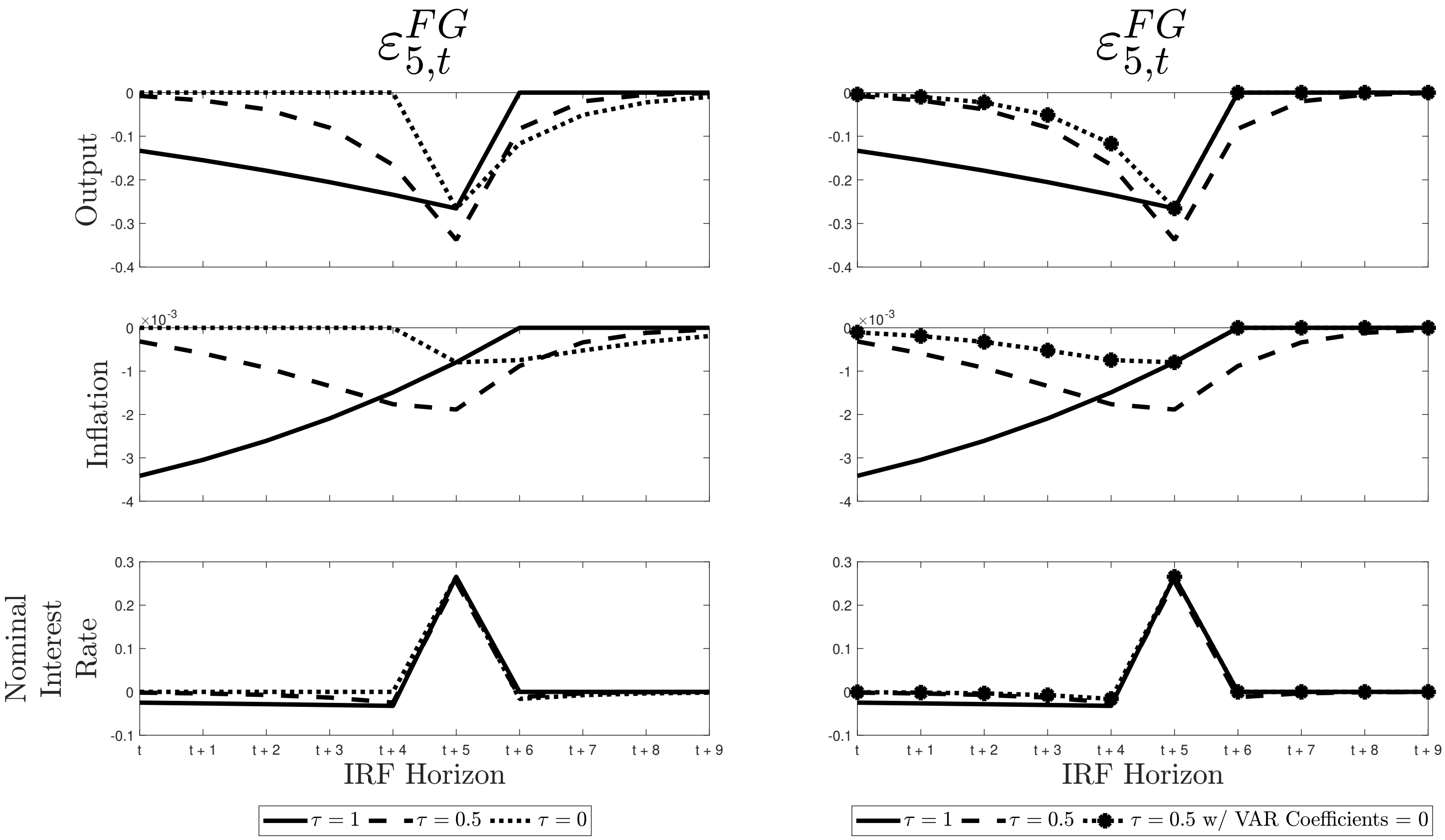

Figure 1: Impulse Responses of Macroeconomic Variables to 5-Period Ahead Forward Guidance Shock

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.

significantly less so than when there is perfect credibility ($\tau = 1$). They continue to decline until the period 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 shows that the behavior of macro aggregates—in particular the anticipation effects—in response to the same forward guidance shock gets attenuated whenever the credibility parameter falls below one. Forward guidance effects also depend on the types of forecasting models used by private agents when imperfect credibility exists (e.g., when $\tau = 0.5$). The second column of Figure 1 plots responses from the same exercise as the first column, except the dashed-circle lines consider the case of imperfect credibility ($\tau = 0.5$)

but with a different forecasting model (the VAR coefficients in the matrix B are set to zero implying transitory rather than persistent macro dynamics). Before $t+5$, forward guidance is not as effective compared to the baseline case of $\tau = 0.5$. The dashed-circle line is above the dashed line for output and inflation. After the shock is realized, output and inflation immediately return to steady-state, which is identical to the $\tau = 1$ case.[11]

Overall, this simple exercise highlights the potentially important role played by the credibility parameter τ in our model. The bigger the value of τ, all else equal, the more effective are forward guidance shocks at impacting output and inflation in anticipation of the realization of a transitory forward guidance shock.

3 Bayesian Estimation

In this section, 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, inflation, and the nominal interest rate in the vector $Y_t = [y_t, \pi_t, i_t]'$ in our model. In addition to these observables, we utilize quarterly 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 of vector $\overline{Y}_t$ in equation (15). 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.[12] The data sources and additional details on the matching of the observed

[11] The VAR model in equation (18) describes the unconditional dynamics of the economy as perceived by the non-FIRE private agents. The exercise in Figure 1, however, is about the conditional responses to a transitory 5-period ahead forward guidance shock (as described in equation (14)). If that was the only driver of the macro aggregates, a VAR model that assumes no persistence does as well as FIRE agents would at describing the macro responses once the forward guidance shock materializes. Even abstracting from endogenous sources of persistence, some of the other exogenous drivers of the economy are themselves persistent and, therefore, non-FIRE agents will gravitate towards VAR models with persistence instead. As a consequence of that, transitory forward guidance shocks after they materialize have persistent effects too.

[12] We also collect the same data for Canada, France, and Italy from third quarter 1990 until third quarter 2022 (129 observations). We collect data for Spain, but over a slightly shorter time series that starts only in

data and forecasts to the model counterparts can be found in Appendix A.

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:

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

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

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

where the superscript "*obs*" indicates the observed variables or expectations for which we have an empirical counterpart.[13]

$\Delta^4 y_{t+j}$ refers to the 4-quarter percentage change of real GDP in time period $t+j$ (for $j = 1, 2$), $\Delta^4 p_{t+j}$ denotes the 4-quarter percentage change in the CPI price level in time period $t+j$ (for $j = 1$), and i_{t+j} denotes the nominal short-term interest rate in percent in time period $t+j$ (for $j = 1, ..., L$). Furthermore, the quarter-over-quarter percentage

third quarter 1994 and ends in third quarter 2022 (113 observations).

[13] The expectations operator on the right-hand side of the matrix equation (20) are aggregates of FIRE and VAR-based forecasts. To follow the timing convention requiring that $\mathbb{E}_t^{VAR}\left(Y_{t+1}\right) = B^2 Y_{t-1}$ with B being a square diagonal matrix, we adopt this structure for the VAR forecasts in the measurement equation:

change for real GDP and the CPI price level are given by $\Delta y_{t+j} \equiv g_{t+j}$ and $\Delta p_{t+j} \equiv \pi_{t+j}$, respectively.

Observations for expectations include *i.i.d.* measurement error terms, i.e., $o_t^{g_{t+1}}$, $o_t^{g_{t+2}}$, $o_t^{\pi_{t+1}}$, $o_t^{i_{t+1}}$, $o_t^{i_{t+2}}$, $o_t^{i_{t+3}}$, $o_t^{i_{t+4}}$, and $o_t^{i_{t+5}}$. Note that our expectations data for real GDP growth and headline CPI inflation were originally given to us in a year-over-year format. Thus, the measurement equations (21) $-$ (23) are included to map 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, Table B1 $-$ Table 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)).[14] For each country, we estimate the model over three different time periods. The full sample is $1990 : Q3 - 2022 : Q3$. We also consider a "Great Moderation" sample that runs over the $1990 : Q3 - 2007 : Q3$ period. Finally, we consider a more recent subsample that includes the run-up to, and the fallout from, the GFC, as well as 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, Table B1 $-$ Table B4.

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

[14] The trends 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 over 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 that appear in equation (20).

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.

4.1 Credibility Estimates 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, Table B1 − Table 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 time periods.

For the full sample, we find that the Federal Reserve in the U.S. has the most credibility, with a posterior mean estimate of $\tau = 0.47$. The central banks for the U.K. (Bank of England) and Germany (Bundesbank/European Central Bank) are close behind, with posterior mean estimates for τ of 0.42 and 0.43, respectively. The Bank of Japan is an outlier on the downside, with a full-sample posterior mean estimate of 0.23.

The full sample estimation masks interesting subsample instability that is nevertheless concordant across countries. In the Great Moderation sample, the posterior means of τ are higher for all countries. The U.K. has the most credibility, with a posterior mean estimate of τ of 0.57. The U.S. comes in next, with an estimate of 0.55, while Germany is not too far behind with 0.45. Japan is again an outlier on the downside, with a posterior mean of only 0.33. Unlike the other three countries, Japan has experienced a prolonged period of low interest rates since the early 1990s that spans the part of the Great Moderation period that we cover here.

In the Low Interest Rate period, all four central banks are estimated to be significantly less credible compared to the Great Moderation period. The U.S. is estimated to be the most credible ($\tau = 0.39$), but only 71 percent of the Great Moderation posterior mean. In the U.K., the posterior mean ($\tau = 0.32$) is roughly only half of its Great Moderation period. For Germany, the posterior mean ($\tau = 0.33$) is about 73 percent of its Great Moderation value (similar to the U.S.). Japan continues to be an outlier on the downside, with the estimated posterior mean in the Low Interest Rate period (0.12) only one third its value in the Great Moderation period (0.33).

4.2 Forward Guidance Shocks Across Time and Countries

In addition to estimating values of central bank credibility across time and space, we 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, at anticipation horizons going from one-quarter to 5-quarters ahead.[15] This plethora of shocks makes measuring the contributions of forward guidance to policy potentially challenging. For example, the one-quarter ahead forward guidance shock could be negative (expansionary) while the 5-quarter ahead shock could be positive (contractionary), meaning that the actual path of the real interest rate has steepened with these forward guidance shocks.

To overcome the difficulty of assessing how different shifts in the policy path affect the economy, we 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 one 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 in the auxiliary

[15] As a robustness, we extend the results up to a maximum of 8-quarters ahead with similar results.

model with forward guidance shocks muted), whereas negative values indicate that forward guidance was on net dovish. The plots generally conform with a conventional narrative reading of the historical record.

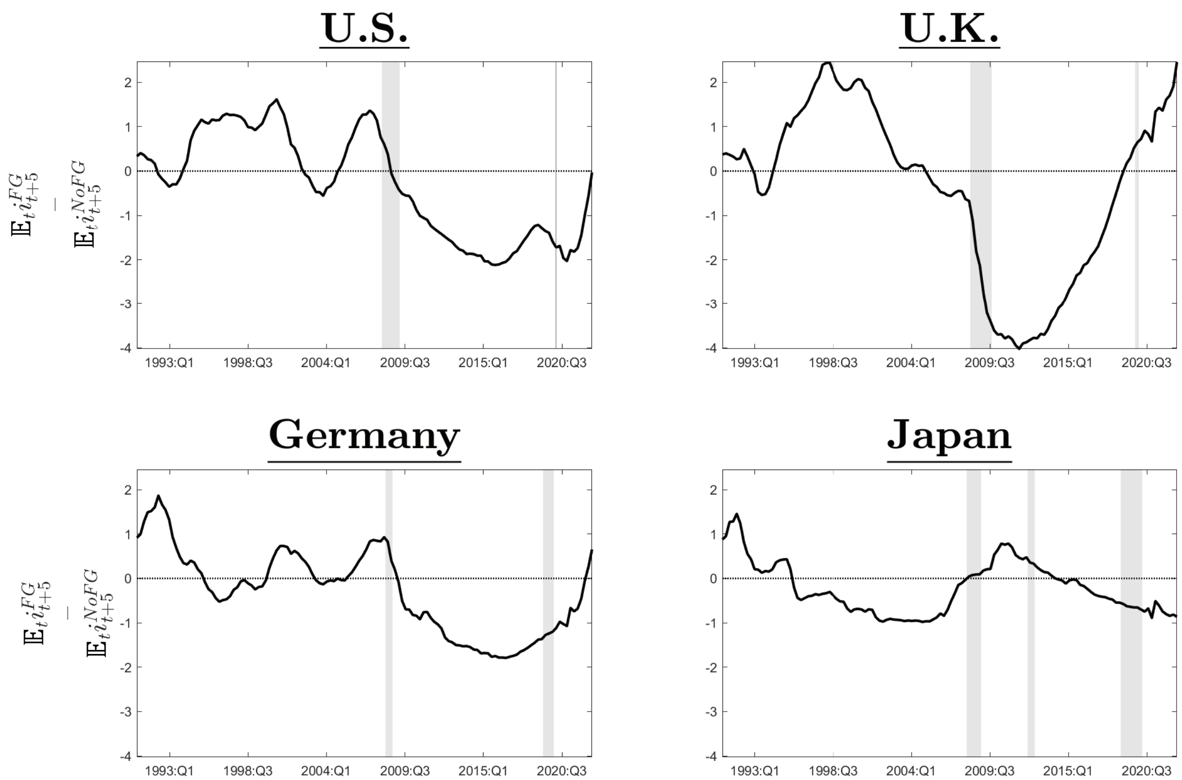

Figure 2: Estimated Forward Guidance Impact on the Expected Nominal Short-Term Interest Rate Five Quarters Ahead Across Time and Countries

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 $\sum_{l=1}^{L}\varepsilon_{l,t-l}^{FG}$ is removed from equation (11) by setting it to zero). Shaded bars denote the recession dates of each country according to the NBER, Cabinet Office of Japan, and 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 time of the Federal Reserve raising policy rates. But, as soon as the GFC hit, the series quickly turns negative and remains there through the end of the sample. This dovish switch coincides with the Federal Reserve actively using forward guidance in an attempt to lower long-term rates vis-a-vis short-term rates to combat the zero lower bound, which became binding in December of 2008. At the nadir, the 5-period ahead forecast of the short-term nominal interest rate was 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 pictures are qualitatively similar for the U.K. and Germany, albeit somewhat different and more muted for Japan. Overall, we view the results presented in Figure 2 as comforting. Our estimated model is picking up estimated forward guidance shocks that generally align well with the narrative historical record. Next, we turn to analyzing the effectiveness of these shocks across time and space.

4.3 The 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 like output and inflation over time.

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 in this rolling window corresponds to the Great Moderation period and the last one to the Low Interest Rate period that we have discussed earlier. Given the estimated posterior means of all parameters, we calculate the impulse responses of output and inflation to a 25 basis point 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 basis points). We also simultaneously track the evolution of the estimated credibility parameter, τ, over time.

The period up to quarter five is most pertinent to policymakers as it focuses on the reaction to future central bank promises (the anticipation effects of forward guidance).[16] 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.

[16]From quarter six onward, an impulse response picks up the effects of an actual, rather than an announced, change in interest rates. We abstract from those to focus on the strength of the anticipation effects only.

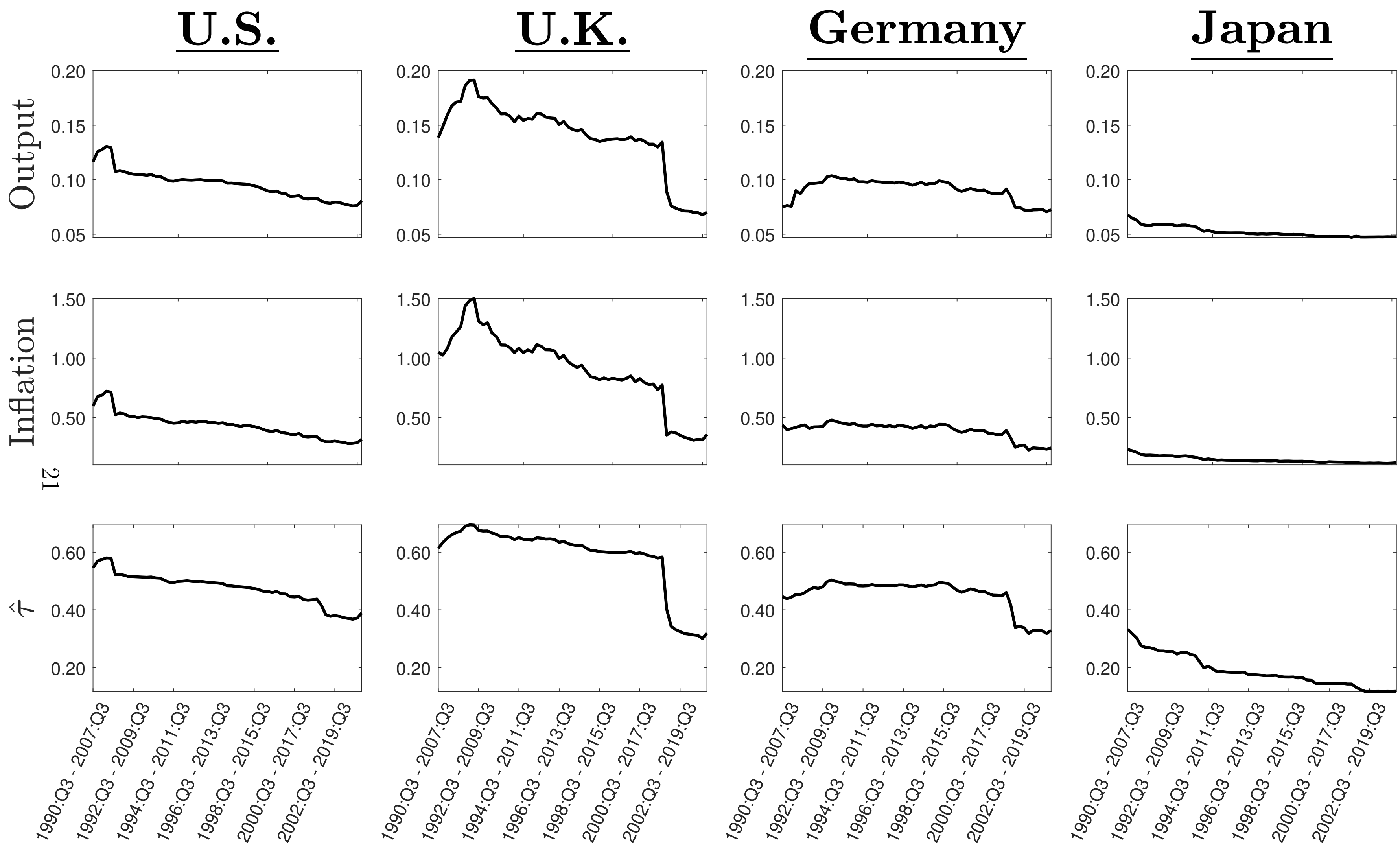

Figure 3: Estimated Impact of a 25 Bps Decrease in $\varepsilon_{5,t}^{FG}$ on Contemporaneous Output and Inflation and Variation of the Credibility Value Over Time and Across Countries

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

For concreteness, we focus first on the column for the U.S. The cumulative output effect of a 5-quarter ahead forward guidance shock is about 0.1 percent on average over all rolling samples. After a mild initial uptick at the beginning of the sample, the output effectiveness of forward guidance steadily declines over time, from an initial value of about 0.12 percent to about 0.08 percent at the end of the sample. 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 about 0.55 to a final value of roughly 0.40.

Next, we focus on the remaining columns for the other major countries under consideration. The patterns for forward guidance effectiveness in both the U.K. and Germany are qualitatively similar to the U.S. After brief initial upticks in the cumulative output and inflation responses, they both steadily decline in these two countries. Differently than in the U.S., in both of these countries there are abrupt downward shifts in the estimated effectiveness that both coincide with the onset of COVID-19. However, like the U.S., these patterns also mirror the estimated values of τ across time.

As noted above, Japan is an outlier on the downside. In addition to having the lowest estimated value of τ, forward guidance is the least effective at stimulating output and inflation on average. But, like the other countries, the effectiveness of forward guidance 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 low levels of credibility.

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 zero lower bound on nominal short-term interest rates binding in many developed countries as well as with major central banks adopting explicitly forward guidance as one more arrow in their policy toolkit.

We now ask the following question: had central banks been more credible, would inflation post-GFC have been as low as it was? To answer this question, we engage in a counterfactual exercise. In particular, for each of the four major countries we have considered to this point, we take the estimated models over the Low Interest Rate period ($2005:Q3-2022:Q3$) and extract the smoothed shocks that drive the endogenous variables of the model. The smoothed shocks include all the shocks in the model, including the estimated forward guidance shocks. Taking the smoothed shocks, we set other estimated parameters at their posterior mean but fix the parameter τ at 1 (perfect credibility). We then simulate a counterfactual path for key macro variables in each country.

Comparing and contrasting the observed paths of macro variables like output and inflation with their counterfactual paths under perfect central bank credibility ($\tau = 1$) allows us to say something about how outcomes might have differed had central banks been more credible. Consider first the case of the U.S. Figure 4 plots the observed (solid lines) and counterfactual paths (dashed lines) of inflation, output growth, and the short-term nominal interest rate. Had forward guidance been perfectly credible, our model predicts that inflation would have been slightly higher at all points during the GFC and in its aftermath (although it still would have dipped into deflationary territory at the height of the crisis in the fall of 2008). Importantly, inflation would have been higher than observed, and closer to the Fed's two-percent target, in the years following the GFC, only dipping below the path of realized inflation after 2015, when forward guidance became more hawkish and the ZLB eventually lifted.

According to our counterfactual simulation, the higher path of inflation could have been achieved without much noticeable difference in the path of output growth. Growth would have been more volatile during the GFC, though on average higher than it was in actuality, but a bit slower in the immediate aftermath. Perhaps most interestingly, while the nominal rate would have still hit the ZLB at the height of the crisis, in our counterfactual simulation with perfect credibility interest rates would have risen above zero even before the recession officially ended, and would have stayed above zero for virtually the entire time of the ZLB period in the U.S. Concretely, our counterfactual simulation suggests that the ZLB would not have been much of a hindrance to policy had the Federal Reserve had perfect credibility and pursued the same forward guidance policy path recovered through the lens of our model.

The pictures are quite similar to that of the U.S. for both the U.K. (Figure 5) and Germany (Figure 6). In both countries, inflation would have been higher during and immediately after the GFC. The difference between the counterfactual and observed paths of inflation is particularly noticeable for Germany. For both countries, output growth would have been more volatile in the counterfactual with perfect credibility during the GFC itself, similarly to the U.S. In both the U.K. and in Germany, the ZLB would not have been a major issue either, with the counterfactual paths of the short-term nominal interest rate never even hitting zero.

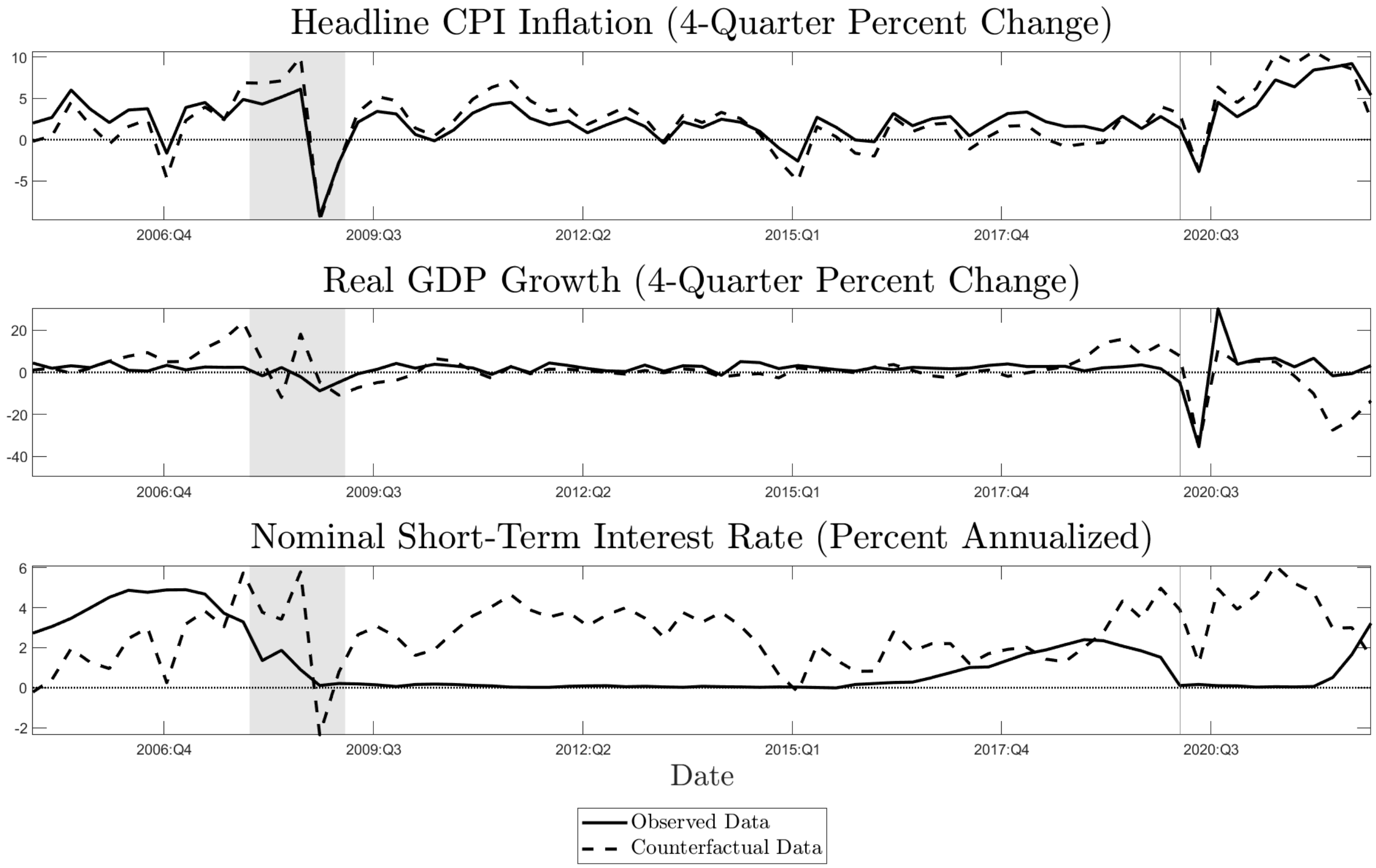

Figure 4: Counterfactual U.S. Inflation, Real GDP Growth, and Nominal Short-Term Interest Rate in the Low Interest Rate Period $(2005 : Q3 - 2022 : Q3)$ Under Perfect Credibility

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. The simulated data is obtained by setting the parameter values of the model at the posterior mean estimated on the Low Interest Rate subsample (except for τ which is fixed at 1) and feeding the recovered shocks (including the forward guidance shocks). Shaded bars denote the recession dates of the U.S. according to the NBER.

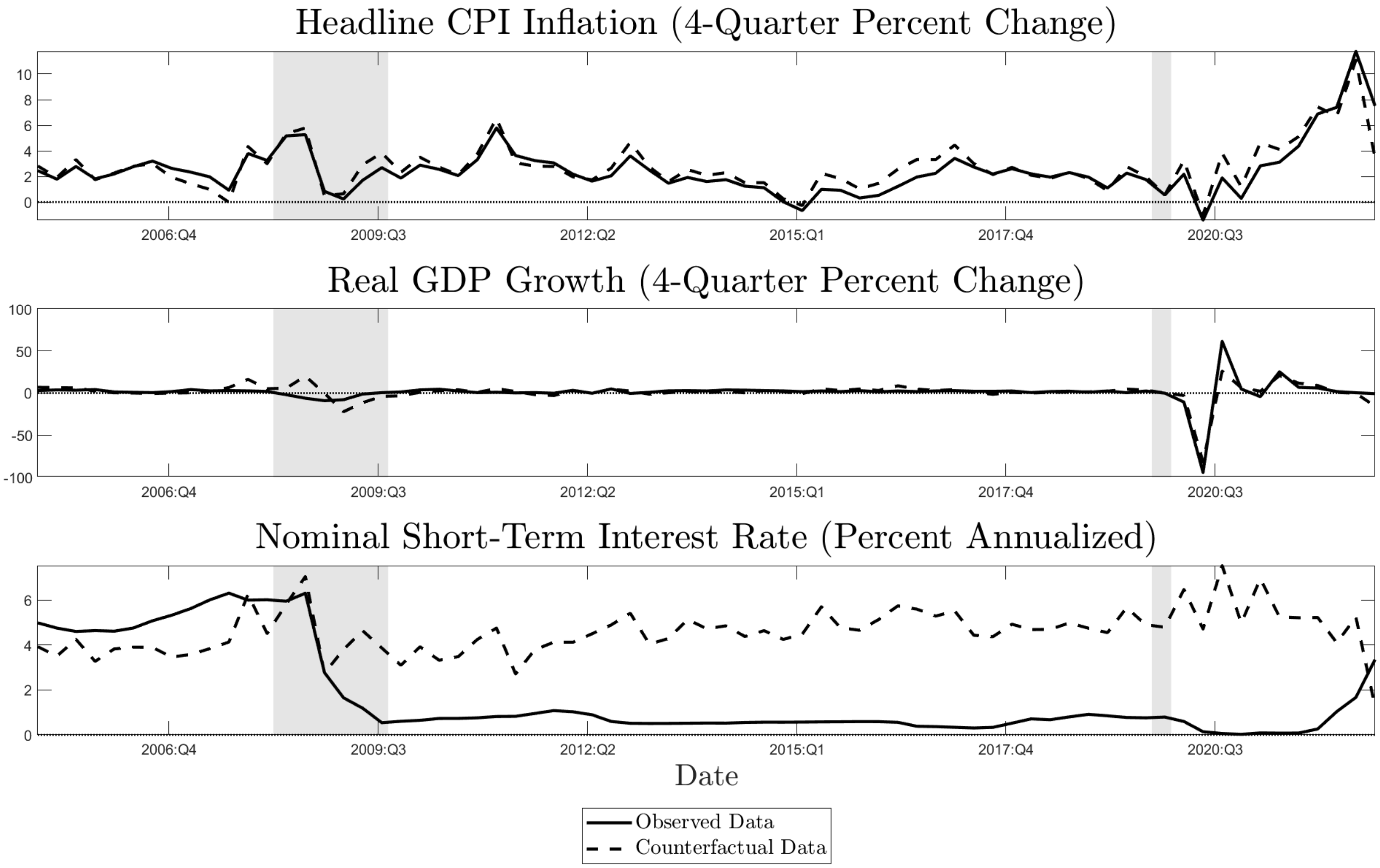

Figure 5: Counterfactual U.K. Inflation, Real GDP Growth, and Nominal Short-Term Interest Rate in the Low Interest Rate Period (2005:Q3-2022:Q3) Under Perfect Credibility

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. The simulated data is obtained by setting the parameter values of the model at the posterior mean estimated on the Low Interest Rate subsample (except for τ which is fixed at 1) and feeding the recovered shocks (including the forward guidance shocks). Shaded bars denote the recession dates of the U.K. according to ECRI.

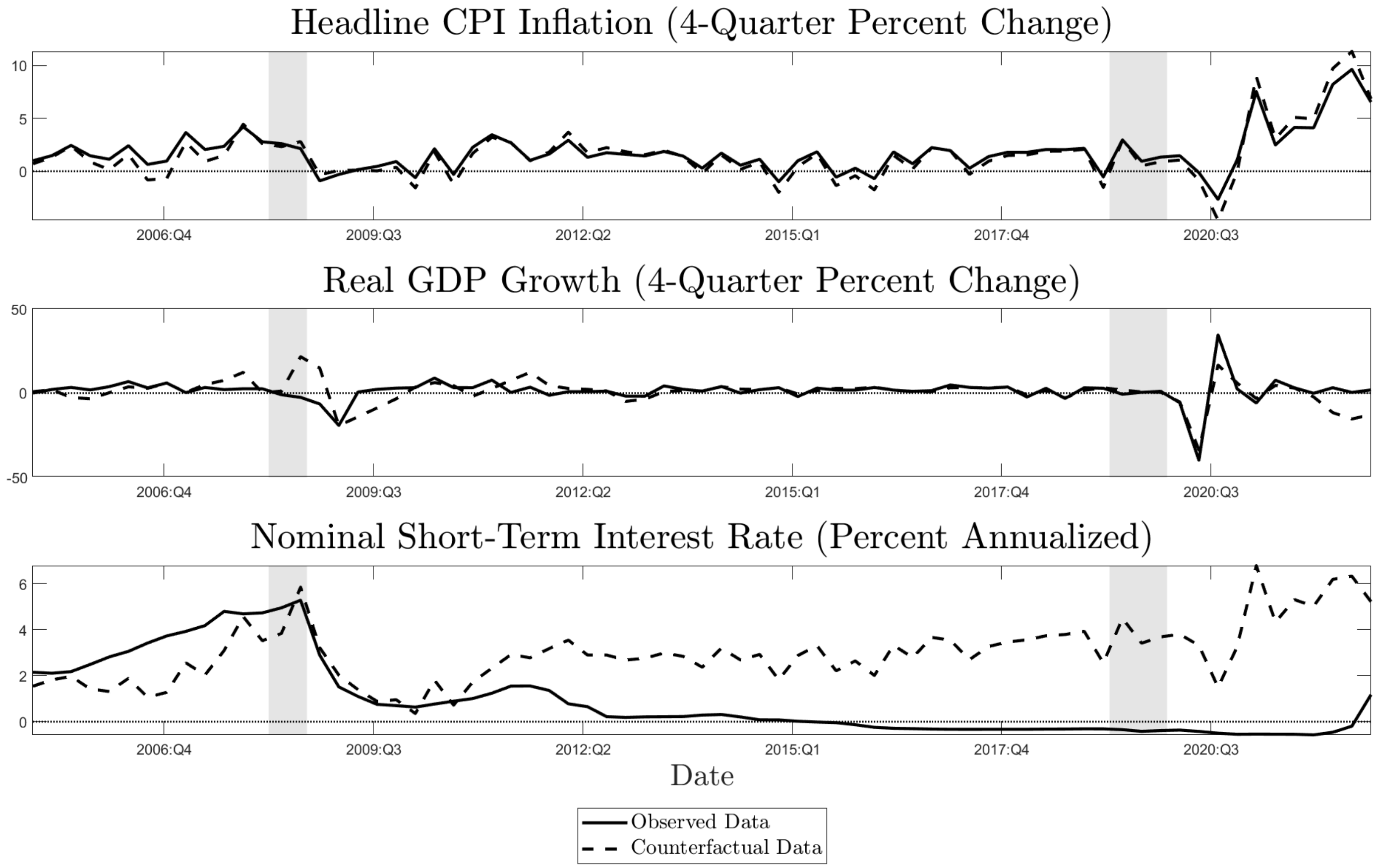

Figure 6: Counterfactual Germany Inflation, Real GDP Growth, and Nominal Short-Term Interest Rate in the Low Interest Rate Period (2005:Q3-2022:Q3) Under Perfect Credibility

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. The simulated data is obtained by setting the parameter values of the model at the posterior mean estimated on the Low Interest Rate subsample (except for τ which is fixed at 1) and feeding the recovered shocks (including the forward guidance shocks). Shaded bars denote the recession dates of Germany according to ECRI.

The case of Japan is similar in some dimensions, but, like with the overall estimates reported earlier, different in other regards. For Japan (Figure 7), in the counterfactual simulation with perfect credibility, inflation would have been higher during the GFC, but it would have been lower than realized inflation for a few quarters thereafter. In the middle part of the 2010s, inflation would have been consistently higher in the counterfactual compared to what actually transpired. The counterfactual path of output growth is similar to that of the U.S., the U.K., and Germany—higher (and more volatile) during the GFC, but lower in the immediate aftermath.

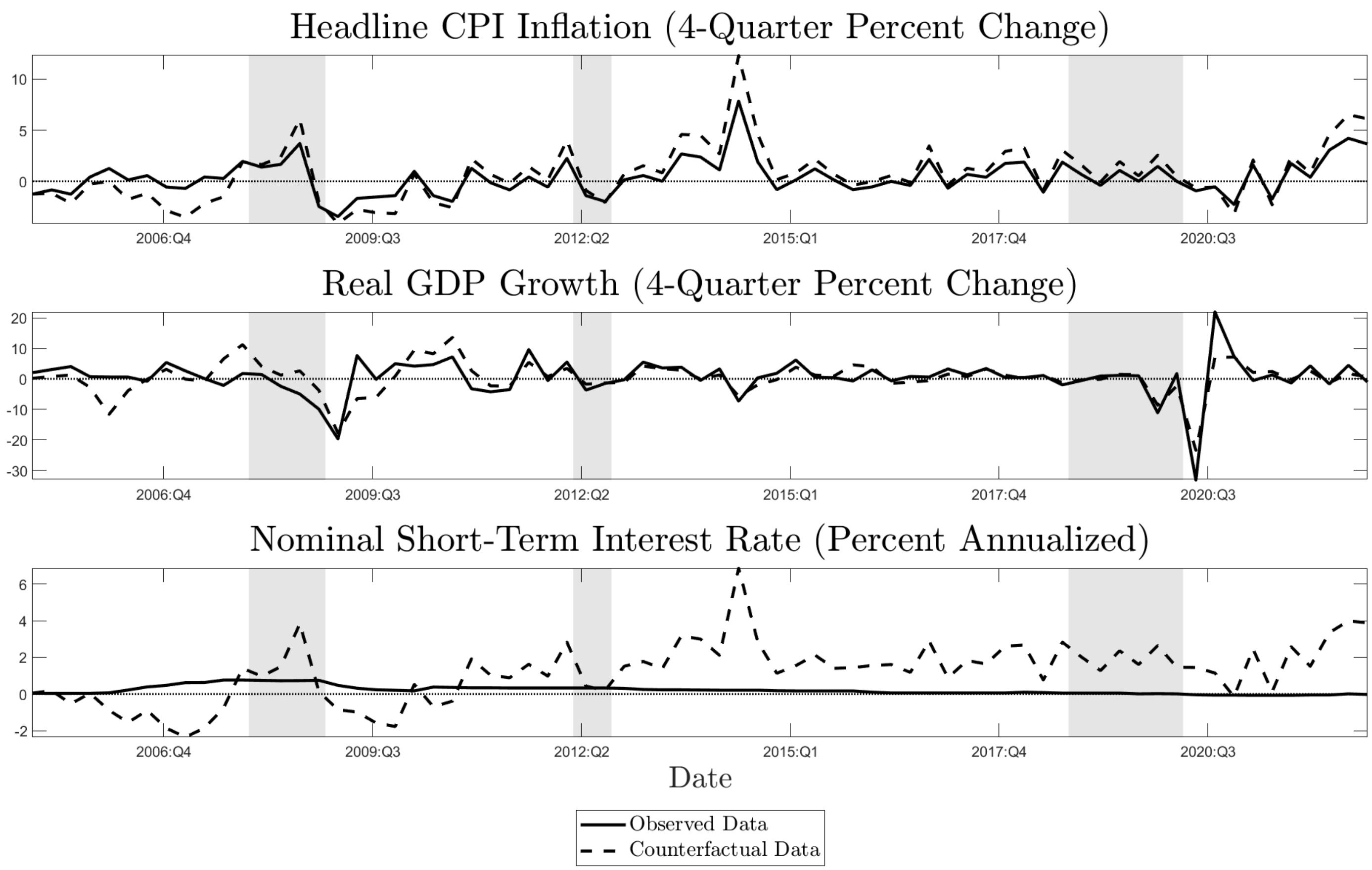

Figure 7: Counterfactual Japan Inflation, Real GDP Growth, and Nominal Short-Term Interest Rate in the Low Interest Rate Period (2005:Q3-2022:Q3) Under Perfect Credibility

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. The simulated data is obtained by setting the parameter values of the model at the posterior mean estimated on the Low Interest Rate subsample (except for τ which is fixed at 1) and feeding the recovered shocks (including the forward guidance shocks). Shaded bars denote the recession dates of Japan according to Cabinet Office of Japan.

The ZLB would have been more of an issue in Japan than in the other countries in our counterfactual exercise. This seems not too surprising given that Japan had been dealing with the ZLB in advance of the GFC (since the early 1990s). The counterfactual path of the short-term nominal interest rate in Japan would have been more negative under perfect credibility towards the tail end of the GFC and for several quarters thereafter. But, in the middle part of the 2010s, with counterfactual inflation much higher, the ZLB would not have been much of an issue. This suggests that deploying the same forward guidance policy path recovered through the lens of the model would have been less successful at steering the Japanese economy away from the ZLB.

4.5 The Return of Inflation During COVID-19

After several years at the ZLB in the wake of the GFC and its aftermath, in the latter half of the 2010s the Federal Reserve in the U.S. lifted off from the ZLB and began to normalize its balance sheet. These efforts at normalization came to an abrupt end in the spring of 2020 when COVID-19 hit. COVID-19 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 they had relied upon 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 the middle of 2021, inflation across the developed world was high and stubbornly so. It has only recently begun to recede, but still remains above pre-COVID-19 levels and central banks' own targets.

In the previous subsection, we used our counterfactual analysis to answer the question of whether or not more credible central banks would have ameliorated the "missing inflation" post-GFC. 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 Figure 4 − Figure 7, but we hone in on inflation during the COVID-19 period here.

Figure 8 plots the observed (solid lines) and counterfactual (dashed lines) paths of inflation for the U.S., the U.K., Germany, and Japan, honing on the period since the pandemic began. There are broad similarities for the U.S., the U.K., and Germany. In the counterfactual world with perfectly credible central banks ($\tau = 1$), inflation would have been higher in 2021 than it actually was. But, importantly, it would have turned lower more dramatically in all three countries with perfect credibility (and earlier in some cases too). For example, in the U.S., inflation would have been back to the 2% target by the third quarter of 2022 with perfect credibility, whereas in actuality it was still above five percent at that time.

As in many of the other pictures we have shown, Japan is a bit of an outlier. Like the other three countries, in the counterfactual simulation, inflation would have been slightly higher than realized inflation in 2021 and into 2022. But, unlike the U.S., the U.K., and Germany, in the counterfactual Japan's inflation would not have turned lower at the very end of the sample.

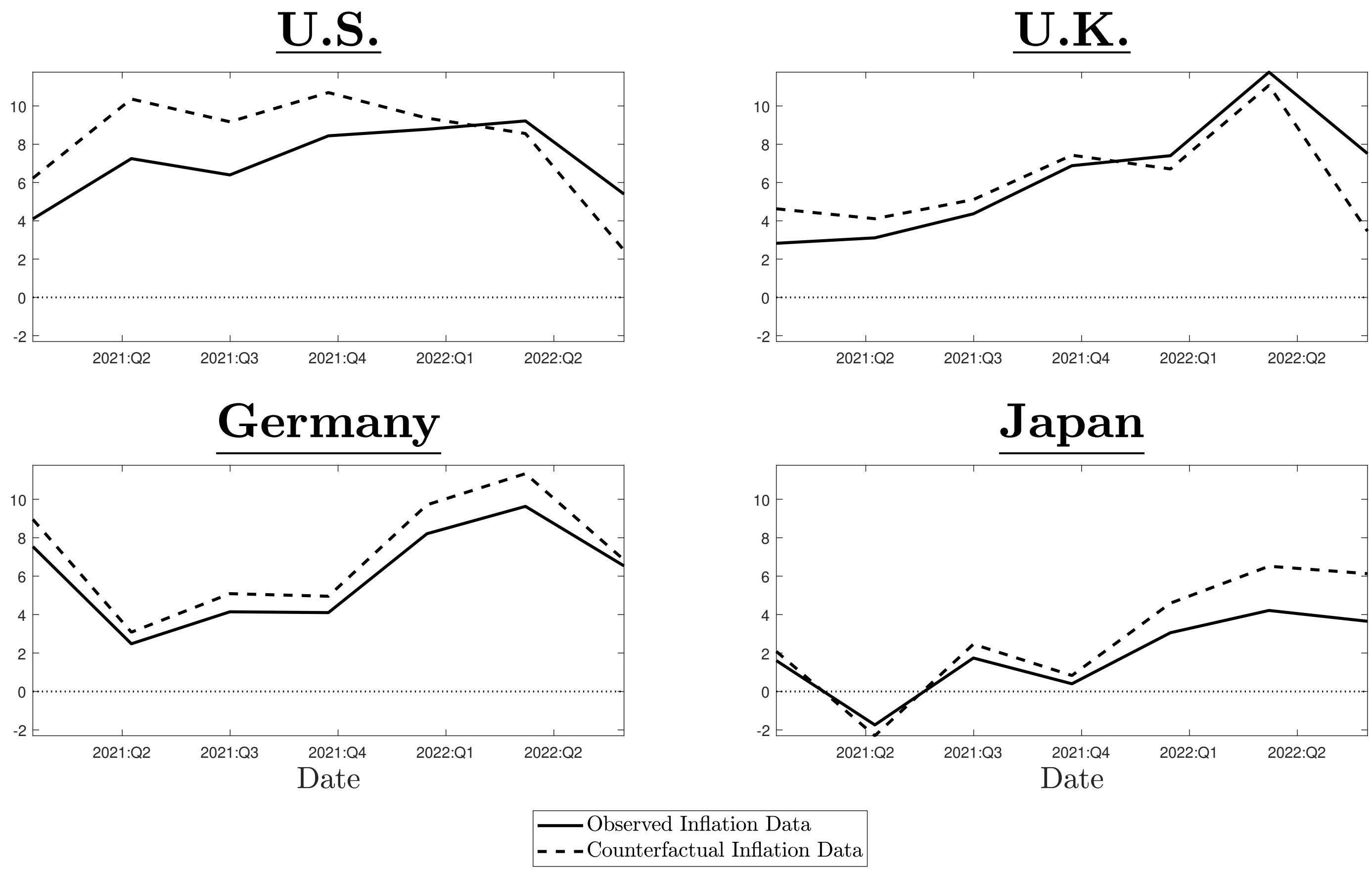

Figure 8: Inflation Counterfactual Across Countries in the Post COVID-19 Period (2020:Q1-2022:Q3) Under Perfect Credibility

Note: The observed and counterfactual inflation series are reported in 4-quarter percentage change rates. The simulated data is obtained by setting the parameter values of the model at the posterior mean estimated on the Low Interest Rate subsample (except for τ which is fixed at 1) and feeding the recovered shocks (including the forward guidance shocks). Shaded bars denote the recession dates for each country according to the NBER, ECRI, and Cabinet Office of Japan.

Overall, we think that the counterfactual analysis in this and the previous subsection provides interesting and compelling results. For all countries, inflation would have been higher, and the ZLB would have bound for much less time than it actually did, in the wake of the GFC, with perfect central bank credibility. Further, for three of the countries (the U.S., the U.K., and Japan), inflation would have turned around and come down near target by the end of 2022 in the counterfactual with perfect credibility, rather than remaining at elevated levels.

We do wish to close this section with a brief caveat. Our counterfactual exercises treat the sequence of smoothed monetary policy shocks, inclusive of forward guidance shocks, as exogenous. In reality, these shocks may not be orthogonal to the level of central bank credibility—e.g., central banks might have issued smaller forward guidance shocks had they been more credible. For this reason, one may wish to take our counterfactual results with a grain of salt. In spite of this caveat, we nevertheless feel that our analysis provides interesting and provocative results that suggest that the paths of inflation and interest rates (and, to a lesser extent, macro variables like output) could have been quite different in major economies during the last two large macro disruptions—the GFC and COVID-19—had central banks been more credible in their forward guidance.

4.6 Additional Countries

We have reviewed in detail the experience of the three largest advanced economies—the U.S., Germany, and Japan—as well as the U.K., which is a "smaller" advanced open economy that often finds itself in between the euro area (Germany) and the U.S.

In this section, we examine the countries of Spain, Italy, France, and Canada in order to explore more broadly the experiences of all G7 countries plus Spain.[17] These four countries are "smaller" advanced open economies, not unlike the U.K., but with somewhat different linkages. Canada is strongly tied to the U.S. By contrast, France, Italy, and Spain are strongly interconnected with Germany in our country sample under a largely common monetary policy (first under the rules of compliance—the "Maastricht Treaty criteria"—for the currency union during the 1990s and then afterward with the adoption of the euro). We present the results in Figure 9 using the same rolling estimation exercise laid out in Subsection 4.3 and in Figure 10 using the same counterfactual exercise of Subsection 4.5.

[17] The G7+ country grouping we consider here includes Spain because this nation is the fourth largest economy in the euro area.

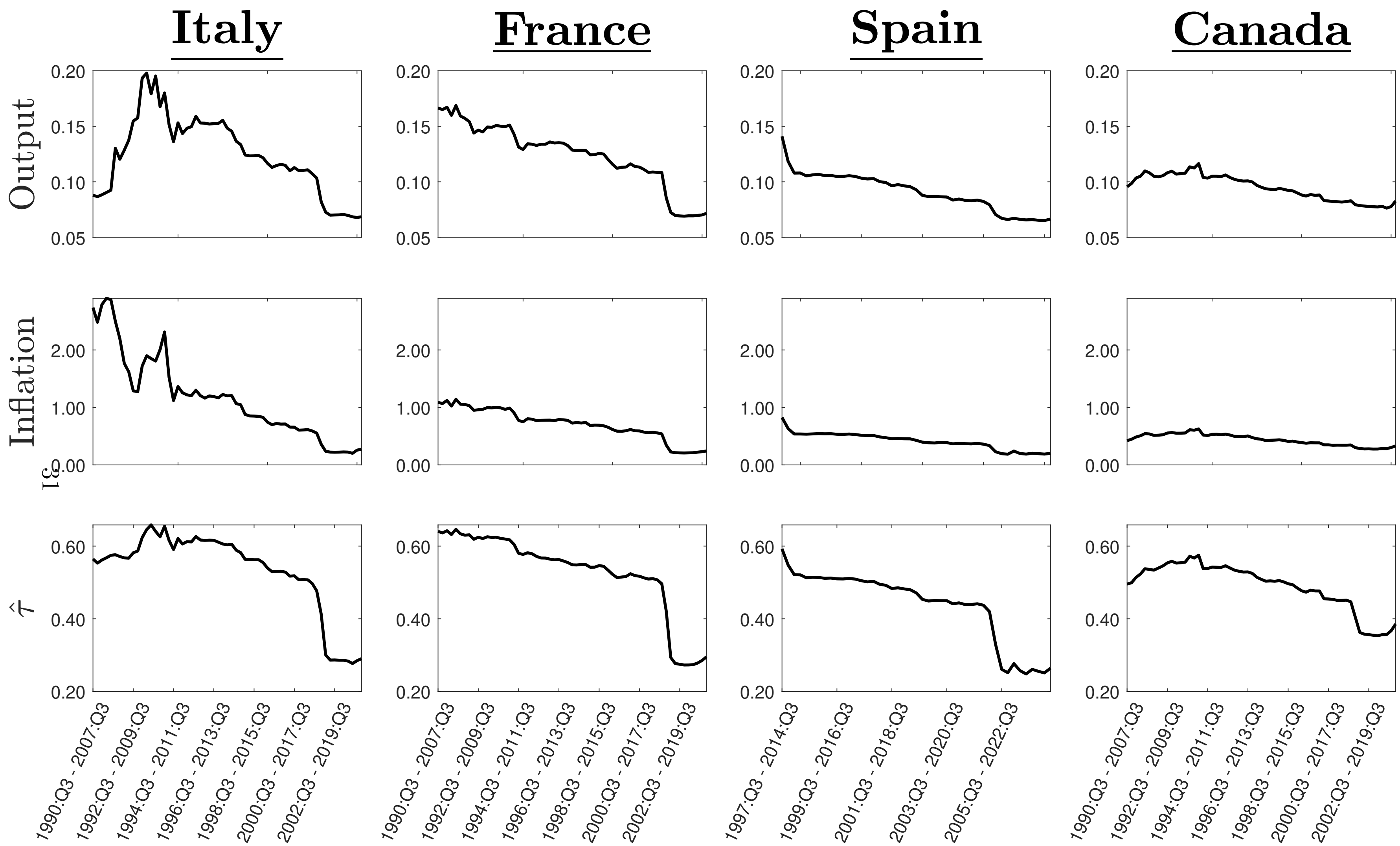

Figure 9: Estimated Impact of a 25 Bps Decrease in $\varepsilon_{5,t}^{FG}$ on Contemporaneous Output and Inflation and Variation of the Credibility Value Over Time and Across Additional Countries

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 $\varepsilon_{5,t}^{FG}$). The responses are recalculated for each subsample setting the parameter values of the model at their estimated posterior mean for the given subsample. Finally, we should note that inflation is expressed in annualized percentage points while the impact on output is in percentage points. Due to sample constraints, Spain's data starts in $1994 : Q3$ (not $1990 : Q3$ like all others).

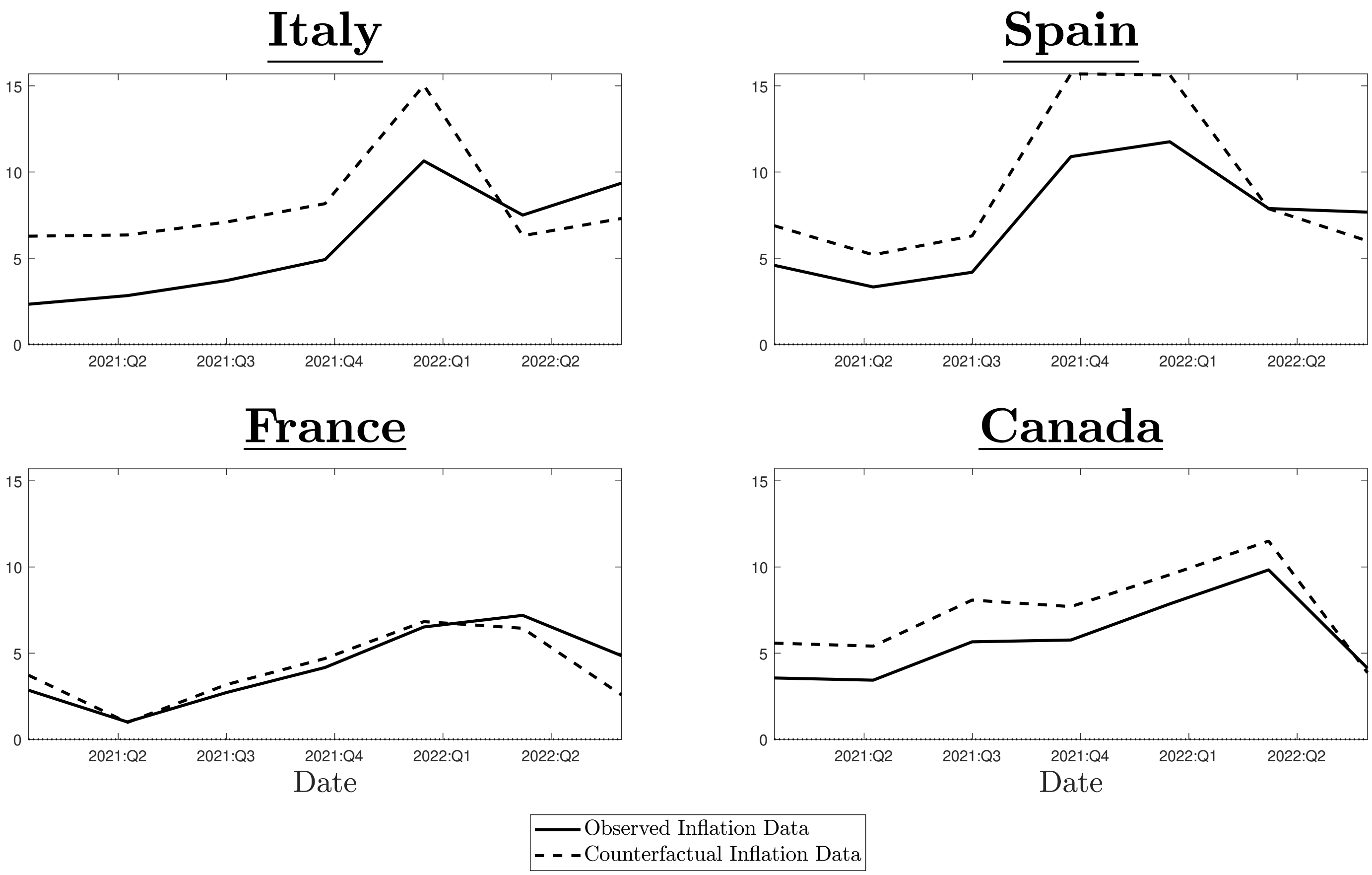

Figure 10: Inflation Counterfactual Across Additional Countries in the Post COVID-19 Period (2020:Q1-2022:Q3) Under Perfect Credibility

Note: The observed and counterfactual inflation series are reported in 4-quarter percentage change rates. The simulated data is obtained by setting the parameter values of the model at the posterior mean estimated on the Low Interest Rate subsample (except for τ which is fixed at 1) and feeding the recovered shocks (including the forward guidance shocks). Shaded bars denote the recession dates for each country according to the ECRI and C.D. Howe Institute.

Our findings suggest that the behavior of these additional four small open economies did not depart substantially from the baseline set of larger countries—particularly the U.S. and Germany. In fact, central bank credibility has generally declined over time and forward guidance has consequently become less effective in all of them. Figure 9 displays the estimates of τ, which have declined across time for all these countries. Consequently, the effects of forward guidance on output and inflation have become attenuated, as displayed in the first and second rows. In addition, counterfactual analyses for these countries also suggest that inflation might have fallen further (and in some countries even sooner) after COVID-19 had central banks been more credible. Figure 10's dashed line declines faster post-COVID-19 than the solid line across all countries. We also find similar results for the period of low inflation post-GFC. In Appendix B, Figure B1 − Figure B4 display evidence that the ZLB episode would have been shorter and inflation more in line with central banks' objectives had forward guidance been fully credible also in these countries.

Finally, we should add another caveat to these results. The open question that we cannot fully address here is whether forward guidance implemented by the central bank was effective for these small open economies or whether it was effective because it was "imported" from the anchor countries (the U.S. for Canada and Germany for France, Italy, and Spain). The most obvious illustration of this is the euro area countries: was the ECB forward guidance effective in France/Spain/Italy because the ECB partly inherited the "credibility" of Germany's Bundesbank or would have it been equally impactful had it been implemented independently by each country's national central bank? While we cannot answer that question, we certainly can say that the common monetary policy could have shortened the low inflation and Low Interest Rate period had it been more credible (and the same is true outside the euro area for Canada or the U.K.), whether that credibility was imported or not.

5 Conclusion

Forward guidance—aimed at communicating the future policy path—is by now a standard part of the arsenal of central banks around the world. However, its intended effects depend on the public's perception of the credibility of policymakers to follow through with their interest rate announcements. If a monetary authority is perceived as very credible, forward guidance has immediate stimulating effects as the public incorporates those announcements in their decisions today. If not, theory suggests that the effectiveness of forward guidance will be limited.

This paper investigates the heterogeneous effects of forward guidance under imperfect central bank credibility—across time, but also across a variety of countries. Our results offer two main takeaways. First, forward guidance is a potentially powerful tool but depends on the perceived credibility of the central bank's announcements. The estimates of credibility are similar across many countries (with the notable exception of Japan, where we find credibility to be lower than in all other countries). The estimates of credibility also tend to be noticeably lower in the post-GFC period for most countries. Consequently, output and inflation react less to forward guidance announcements later in our sample.

Second, the potency of forward guidance, like credibility, is time-varying. Our evidence suggests that monetary policy as implemented could have had stronger effects propping up inflation and shortening the ZLB period post-GFC than it actually did if central banks around the world had been fully credible in their implementation. This finding contributes to explaining the so-called "missing inflation puzzle" that preoccupied the literature prior to the COVID recession. Interestingly, we also find evidence that monetary policy would have generally contributed to lowering inflation and shortening its post-COVID surge in a counterfactual scenario where forward guidance is again fully credible.

Although the counterfactual exercise has some limitations, our results suggest that the policies put in place were not inconsistent with the stated objectives of the central banks around the world, even if their performance may have surprised policymakers by being weaker than desired (see, e.g., Caldara et al. (2021)). This could be in part because, for many central banks, their own forecasting models tend to ignore the role that different beliefs in forecasting and the central bank's credibility to shape those forecasts can play muting the potency of forward guidance (see, e.g., Park (2018)).

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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 interest rate. These data were obtained from the latest vintage available on February 28, 2023. Each one of these three observable series is selected to match as closely as possible the corresponding counterpart measures being forecast 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 $Y_t = [y_t, \pi_t, i_t]'$.

The real GDP is transformed by computing the log-first-difference in percentages $\Delta\ln(\text{GDP}_t) \equiv 100*(\ln(\text{GDP}_t)\text{-}\ln(\text{GDP}_{t-1}))$, headline CPI inflation is constructed 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 the nominal short-term interest rate, which is reported in annualized rates, is converted to non-annualized percentages 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 due to data limitations starts only in third quarter 1994 but still ends in third quarter 2022 (113 observations).

The sources of each observable variable 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 the 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;[18] 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, henceforth 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:

[18] 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, or CPI, only starting in 2004.

N023RI3E@G10) starting in first quarter 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;[19] 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 dates used for the recession shaded bars are from the Economic Cycle Research Institute (ECRI), Cabinet Office of Japan, C.D. Howe Institute, and National Bureau of Economic Research (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, we collect the mean forecasts for $\left(\mathbb{E}_t\left(\Delta^4 y_{t+1}\right), \mathbb{E}_t\left(\Delta^4 y_{t+2}\right), \mathbb{E}_t\left(\Delta^4 p_{t+1}\right), \mathbb{E}_t\left(i_{t+1}\right), ..., \mathbb{E}_t\left(i_{t+L}\right)\right)$—which are part of the vector of observables $\overline{Y}_t$ (as indicated in (15)). The mean forecasts correspond to the arithmetic average 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 could use is that of July 2, 1990 (except for Spain, for

[19] 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 also adopt the same switch date implemented by private forecasts for the corresponding observable series.

which complete forecasting data starts only with the release of December 12, 1994).[20] There are four quarterly releases of private forecasts per year that are made available simultaneously for each country at fairly regular intervals since 1992; however, there are only three forecast releases for the years 1990 and 1991 that we need to appropriately interpolate.

We map the two years of 1990 and 1991 that have three releases each 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 those 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 completeness sake, 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 is available in all subsequent releases.[21]

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 same 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 since 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 Certificates of Deposit [Gensaki] Rate prior to second quarter 2010. We adopt the same conceptual

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

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

switches for the observed data.

Variable matching for forecasts. In order to make sure that the mapping is as close as possible between the model-based expectations and the forecasting data from Consensus Economics 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. In order 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)). The nominal short-term (3-month) interest rate forecasts in percent per annum are simply divided by 4 in order to express them in (non-annualized) percent terms as we do with the corresponding observed nominal 3-month interest rate.

Timing of the forecasts. The timing of the forecasts is conditioned on the information available to the private forecasters. All forecasting data is 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 data collection among private forecasters requires that the forecasts included in the December 5, 2022 release must have been 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 FOMC meeting—and to also 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 up to third quarter 2022 only.[22] We adopt this timing convention when matching model-based expectations to the survey-based forecasts for all releases and across all countries. Other timing matching con-

[22]As indicated earlier, the date of each release is the same for all countries. However, over time, the timing of the release 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.

ventions were explored by Cole and Martínez García (2023) who found that the impact on the results was largely negligible.

Forecasting horizon selection. As indicated in Subsection 2.2, we collect the forecast data one-quarter ahead and two-quarters ahead for the real GDP growth rate (4-quarter percent change) and the one-quarter ahead 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 does not require any manipulation or interpolation/extrapolation). What 5-quarter ahead forecasts means is that from the last available release of December 5, 2022 we obtain 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-quarters ahead 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 that rely on a VAR model are,

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

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.

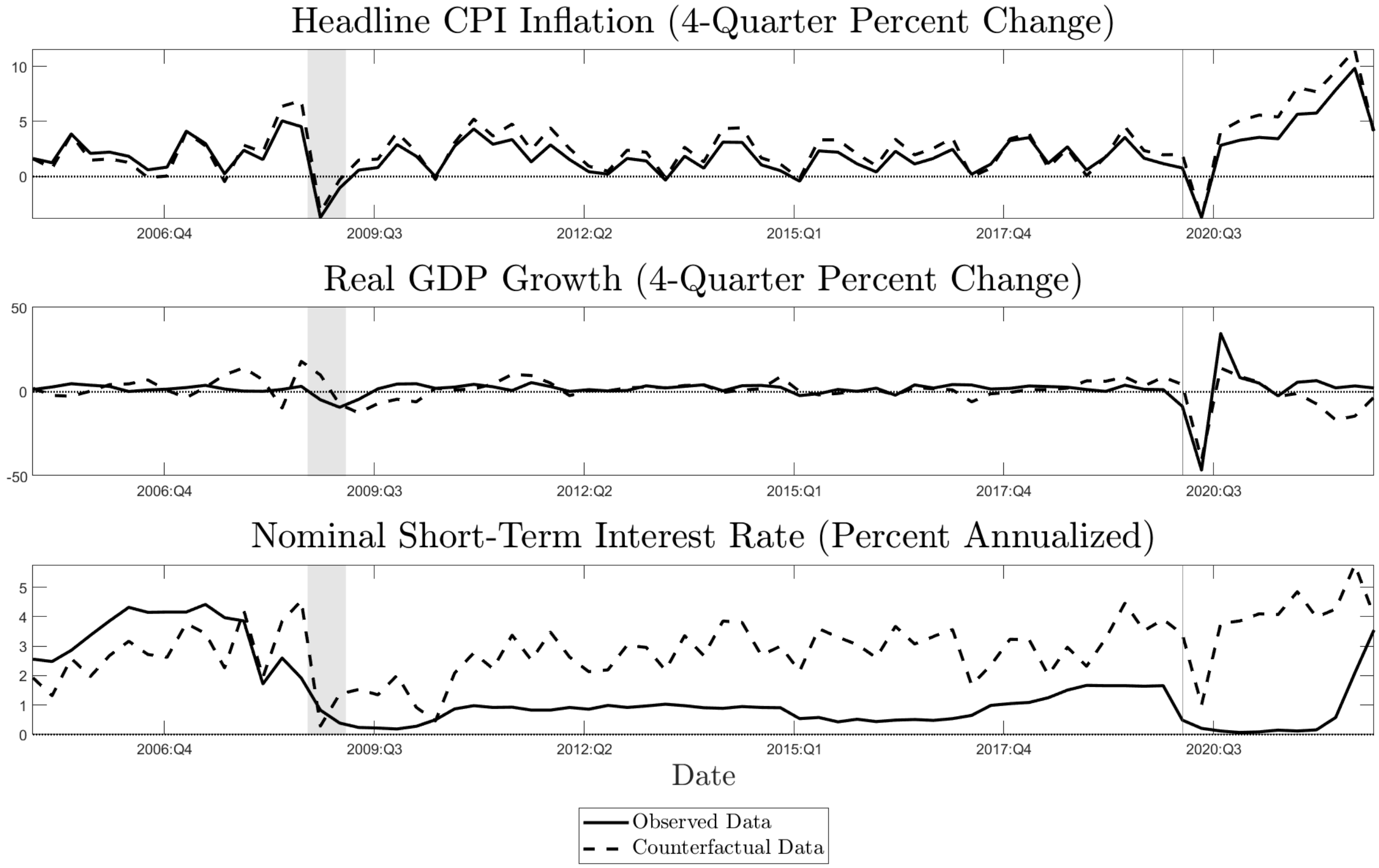

Figure B1: Counterfactual Canada Inflation, Real GDP Growth, and Nominal Short-Term Interest Rate in the Low Interest Rate Period $(2005 : Q3 - 2022 : Q3)$ Under Perfect Credibility

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. The simulated data is obtained by setting the parameter values of the model at the posterior mean estimated on the Low Interest Rate subsample (except for τ which is fixed at 1) and feeding the recovered shocks (including the forward guidance shocks). Shaded bars denote the recession dates of Canada according to the C.D. Howe Institute.

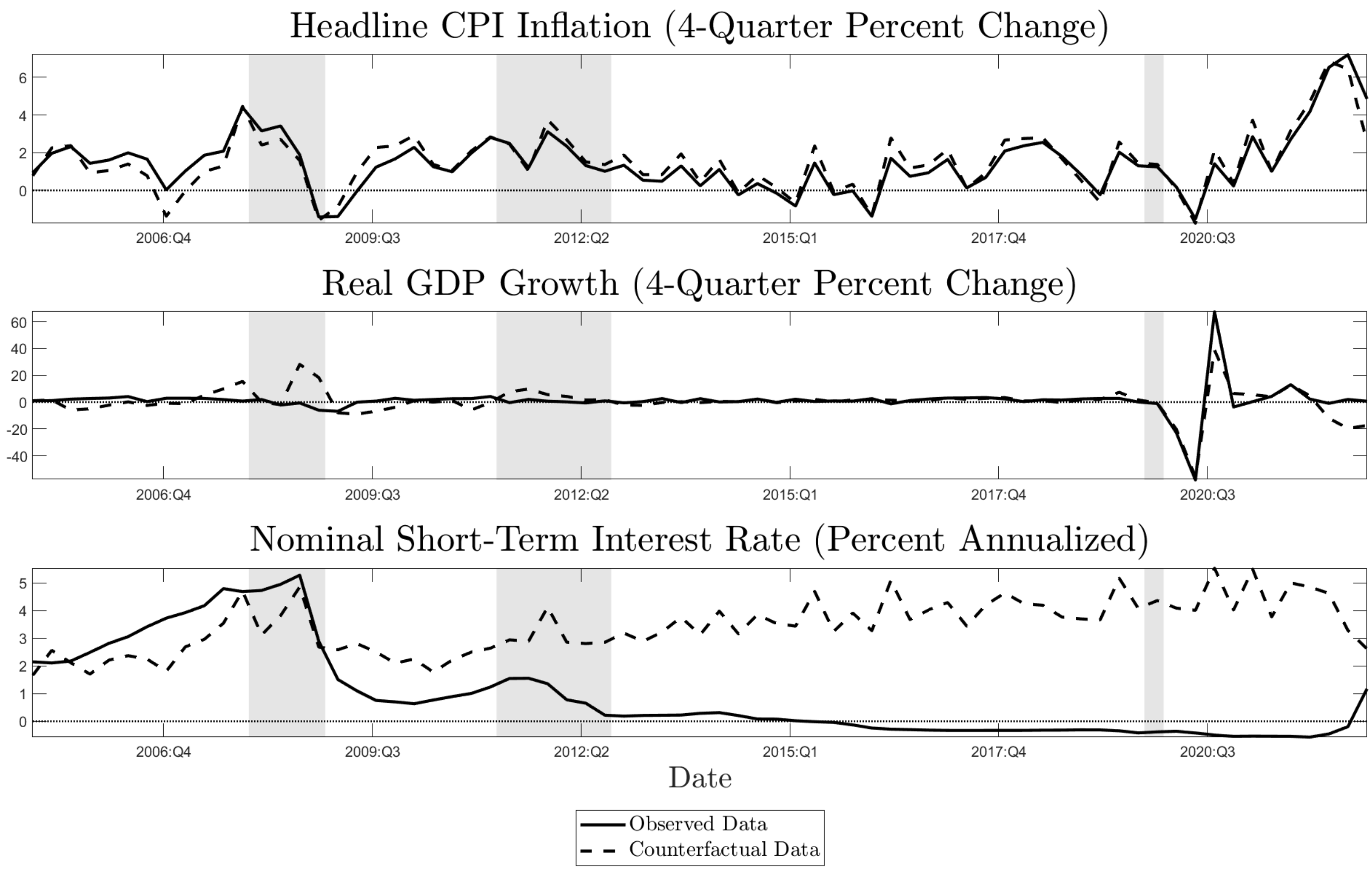

Figure B2: Counterfactual France Inflation, Real GDP Growth, and Nominal Short-Term Interest Rate in the Low Interest Rate Period $(2005:Q3-2022:Q3)$ Under Perfect Credibility

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. The simulated data is obtained by setting the parameter values of the model at the posterior mean estimated on the Low Interest Rate subsample (except for τ which is fixed at 1) and feeding the recovered shocks (including the forward guidance shocks). Shaded bars denote the recession dates of France according to ECRI.

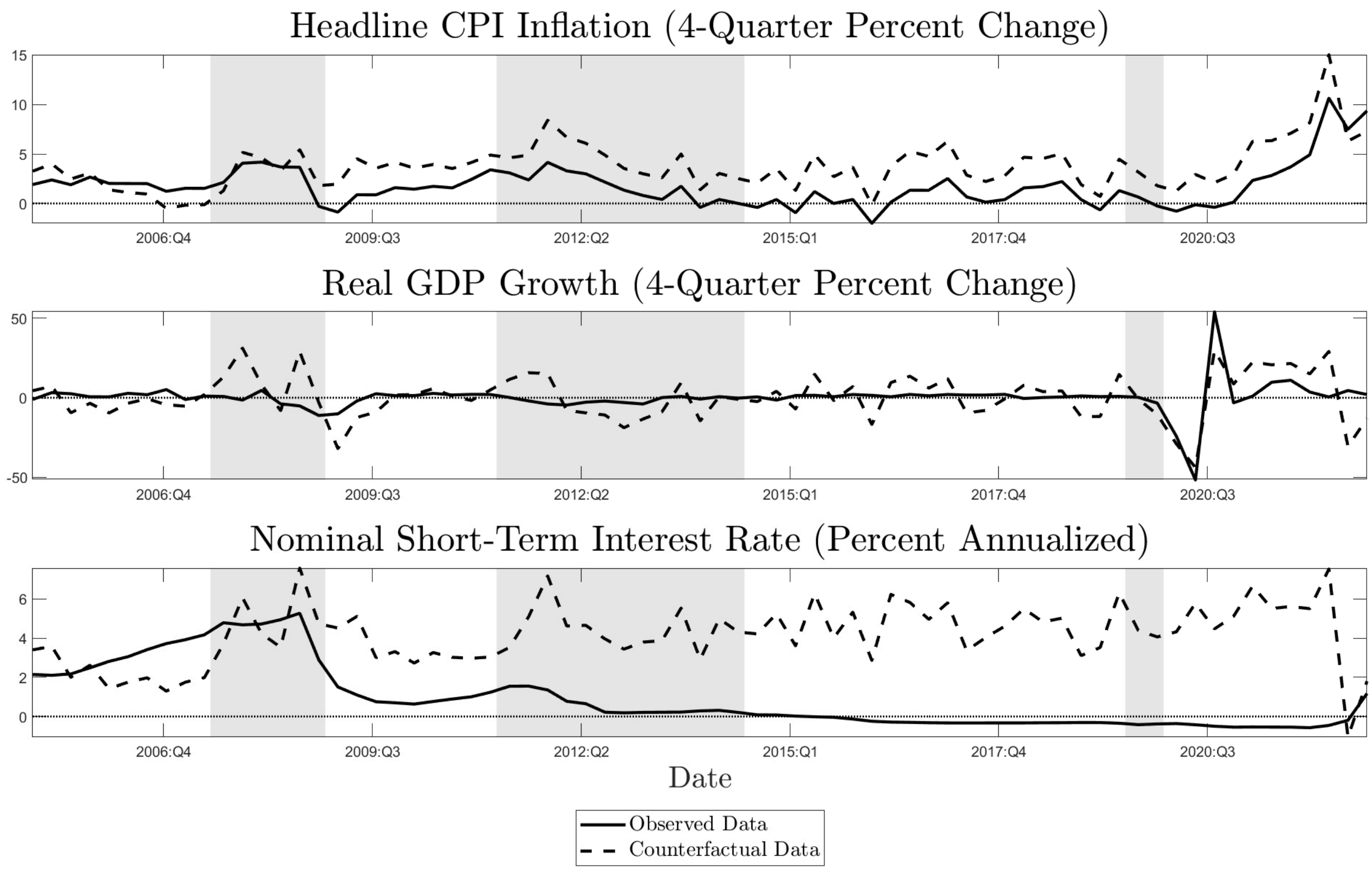

Figure B3: Counterfactual Italy Inflation, Real GDP Growth, and Nominal Short-Term Interest Rate in the Low Interest Rate Period $(2005:Q3-2022:Q3)$ Under Perfect Credibility

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. The simulated data is obtained by setting the parameter values of the model at the posterior mean estimated on the Low Interest Rate subsample (except for τ which is fixed at 1) and feeding the recovered shocks (including the forward guidance shocks). Shaded bars denote the recession dates of Italy according to ECRI.

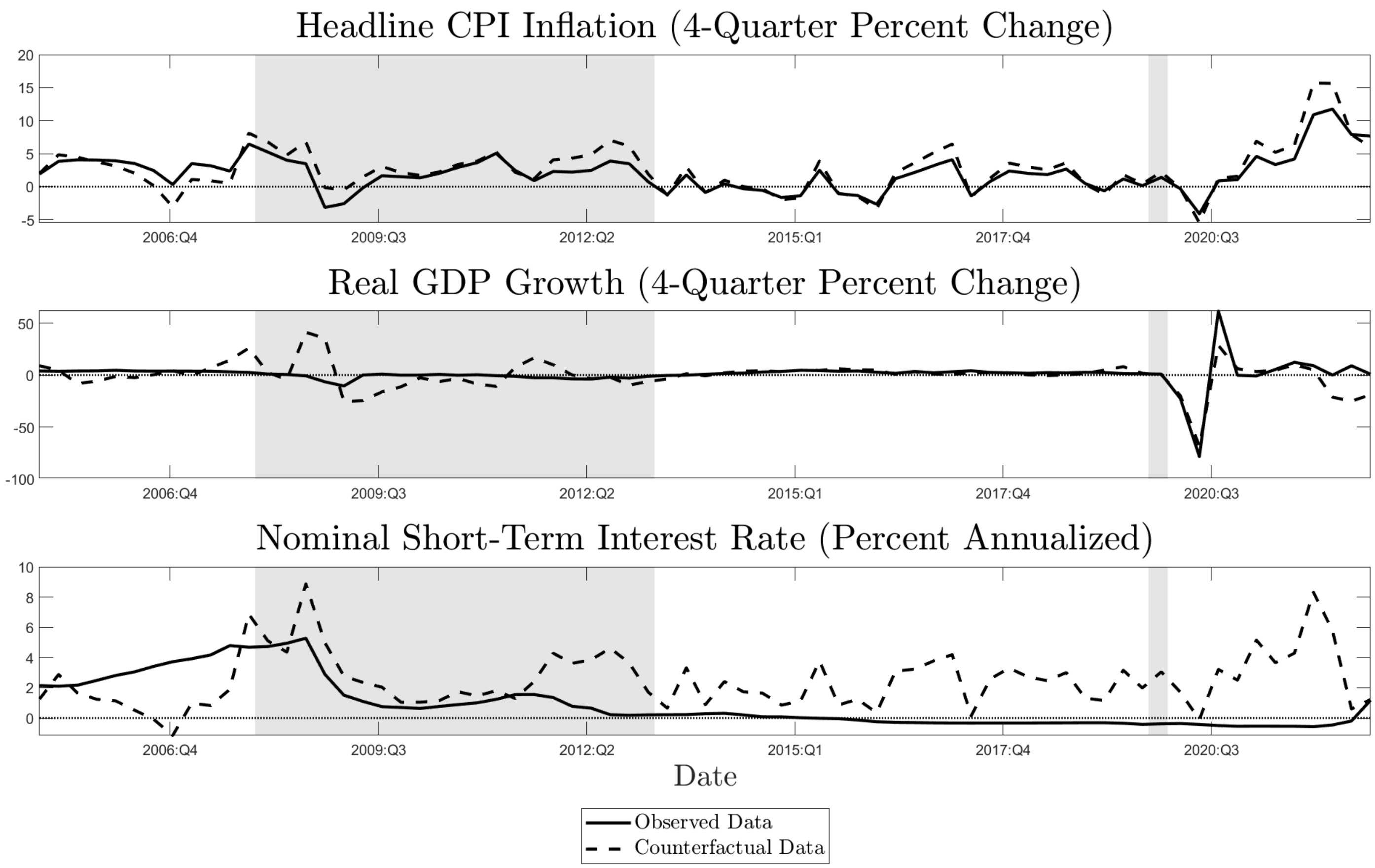

Figure B4: Counterfactual Spain Inflation, Real GDP Growth, and Nominal Short-Term Interest Rate in the Low Interest Rate Period ($2005:Q3-2022:Q3$) Under Perfect Credibility

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. The simulated data is obtained by setting the parameter values of the model at the posterior mean estimated on the Low Interest Rate subsample (except for τ which is fixed at 1) and feeding the recovered shocks (including the forward guidance shocks). Shaded bars denote the recession dates of Spain according to ECRI.