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Monetary Policy with Uncertain Inflation Persistence

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Monetary Policy with Uncertain Inflation Persistence

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ABSTRACT: When uncertain about inflation persistence, central banks are well-advised to adopt a robust strategy when setting interest rates. This robust approach, characterized by a "better safe than sorry" philosophy, entails incurring a modest cost to safeguard against a protracted period of deviating inflation. Applied to the post-pandemic period of exceptional uncertainty and elevated inflation, this strategy would have called for a tightening bias. Specifically, a high level of uncertainty surrounding wage, profit, and price dynamics requires a more front-loaded increase in interest rates compared to a baseline scenario which the policymaker fully understands how shocks to those variables are transmitted to inflation and output. This paper provides empirical evidence of such uncertainty and estimates a New Keynesian Dynamic Stochastic General Equilibrium (DSGE) model for the euro area to derive a robust interest rate path for the ECB which serves to illustrate the case for insuring against inflation turning out to have greater persistence.

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WORKING PAPERS

Monetary Policy with Uncertain Inflation Persistence

Prepared by Luis Brandao-Marques, Roland Meeks, Vina Nguyen[1]

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Glossary

CEE: Central and Eastern Europe

CGG: Clarida, Galí, and Gertler (2001)

DFR: Deposit Facility Rate

DSGE: Dynamic Stochastic General Equilibrium

ECB: European Central Bank

ELB: Effective Lower Bound

FCI: Financial Conditions Index

HICP: Harmonized Index of Consumer Prices

HPD: Highest Posterior Density

LMW: Laureys, Meeks, and Wanengkirtyo (2021)

SURE: Short-term Worker Retention Scheme

WEO: World Economic Outlook

Executive Summary

Europe has faced a high level of economic and geopolitical uncertainty over the past few years. After more than a decade of subdued inflation, the growth rate of prices in Europe started to increase in early 2021 mainly because of pandemic-driven supply bottlenecks in the non-energy goods sector. By October 2022, energy and food prices had surged because of Russia's invasion of Ukraine, and inflation had exceeded 10 percent, the highest level in the history of the eurozone, and then started to recede.

Even though headline harmonized index of consumer prices (HICP) inflation started to moderate at the end of 2022 thanks to lower energy prices, core inflation—the measure reflecting underlying inflation pressure—peaked later and has been persistent. Its decline has been more modest through 2023 and as of end-2023, it was projected by many forecasters to remain above target for an extended period. Labor costs and firm profits have both contributed to the momentum of core inflation, and yet, there is much uncertainty on the direction and magnitude of these two forces. None of these developments can be easily compared with historical episodes since the start of the currency union. This raised the possibility of a regime shift in inflation, which often comes associated with greater uncertainty about the persistence of inflation—the tendency of the rate of change of prices to remain constant in the absence of an external economic 'force' acting upon it (Fuhrer, 2010).

In other words, monetary policymakers in Europe faced an unusual degree of Knightian uncertainty—structural uncertainty that is not easily captured with probabilities—about the persistence of inflation. This is not the only source of uncertainty that European central bankers face—there is also uncertainty about the natural rate of unemployment, the neutral interest rate, and the strength of the transmission of monetary policy, to name a few—but uncertainty about the persistence of inflation is arguably more important than the rest. This is because the greater the persistence of inflation, the more forceful monetary policy action needs to curtail it. There is, then, a case for adopting a robust approach to monetary policy which entails having a response to inflation that is robust to alternative but plausible assumptions about persistence (Qvigstad, 2006).

This paper argues that, when facing uncertain inflation persistence and robust underlying wage pressure, such as many central banks had to face during most of the post-pandemic period, central bankers should set the policy interest rate under the assumption that inflation is more persistent than their routine baseline forecasts suggest. For example, when inflation persists above target, this argues that maintaining a tightening bias—whereby the policy rate should go beyond what is predicted under a baseline forecast, in which policy is assumed to follow the usual reaction function. This is because the costs of not insuring against the worst-case scenario with very persistent inflation outweighs the higher output gap volatility the results from assuming high persistence when it is in fact, low. Estimates of the cost of using a robust monetary policy rule are generally modest, while the costs of ignoring the rule can be substantially high in a worst-case-scenario.

Moreover, a wait-and-see approach to allow the central banker to learn about the inflation regime (i.e., that of low- or high persistence) is not advisable in such a context of uncertainty. The reason is that, should the central banker assume persistence is low only to learn later that persistence is high, he or she would have to tighten monetary policy much more, and more rapidly, than what would have been required by using from the onset a robust policy response. Such a sharp shift in policy can be disruptive to financial markets and pose challenges for central bank communications and credibility.

To sustainably achieve its inflation objective, a central bank like the ECB must make cautious judgements on inflation persistence. Such a judgement will be based on the progress made on bringing down core inflation, and evolving evidence on the changing structure of the economy. The strategy we advocate in this paper to presume inflation is persistent, until convincing contrary evidence is available. A corollary is that policy easing should not react prematurely to slowing inflation. There are certain to be temporary factors that affect inflation on the way down, just as on the way up. Yet the central bank will also be mindful that protracted tightness may lead imbalances to build up, particularly in the financial sector. As ever, policy must walk a fine line: to beat inflation for good, without breaking too many things.

Introduction

Central bankers always face uncertainty about the path of inflation and in setting the appropriate policy rates. Although some of the drivers of inflation primarily act through aggregate demand channels—and can be straightforwardly dealt with using monetary policy—others are supply-driven and can come from higher energy prices, supply-chain constraints, and shifts in labor supply. Supply disturbances—which push inflation and output growth in opposite directions—require policymakers to make more difficult decisions. Managing the policy trade-off may call for the central bank to partly "see through" these shocks. But that judgement is complicated by the uncertain persistence of the shocks, and by the uncertainty over the persistence generated by potential shifts in wage and price setting mechanisms.

Informally, 'inflation persistence' denotes the tendency of the rate of change of prices (or wages) to remain constant in the absence of an economic 'force' acting upon it (Fuhrer, 2010). The more persistent is inflation, the greater the force (for example, from policy actions) that will be required to reduce it. Knowing the persistence of inflation is, thus, critical for central bankers. However, during a regime shift, uncertainty about the persistence of inflation and inflation expectations increases. For example, during the Great Moderation, econometric estimates indicated that inflation was principally forward-looking with low persistence (Benati, 2008), but this was not case in previous periods. Moreover, estimates of persistence also come with rather wide confidence intervals (see the rolling window estimates of O'Reilly and Whelan, 2005, for example) and, in the face of regime shifts (e.g., as economies transition from low to high inflation regimes), inflation expectations can become more backward looking or persistent (Estrella and Fuhrer, 2003). As we set out in the following section, even without invoking regime changes, real-world decision-makers appear to disagree materially about persistence.

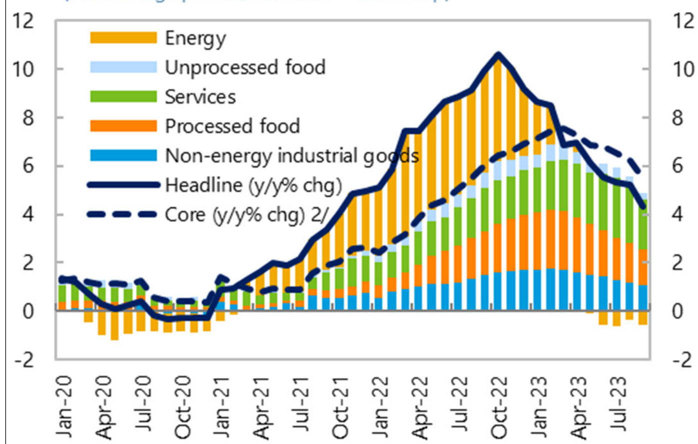
In this paper, we analyze the consequences of monetary policymakers getting inflation persistence wrong with an application to the post-pandemic inflation surge in Europe. Under-estimating inflation persistence is particularly injurious for a central bank. It may lead it to apply too little policy 'force', producing inflation that stays higher for longer than necessary, and which eventually requires higher rates and a deeper slowdown to be tamed. We provide illustrative examples in the body of the paper. Miscalculations will also tend to produce serially correlated errors in the inflation forecasts (i.e., the central bank's forecast is perceived making systematic one-sided mistakes), undermining the central bank's credibility.

The reverse argument applies when inflation persistently undershoots the target. In this case, an additional consideration is the effective lower bound (ELB) and the uncertainty surrounding it. A prompt reaction instead of "wait-and-see" approach would avoid the risk of having to cut rates by more later, approaching the ELB and having to utilize other monetary policy tools (Tillman, 2020).

We discuss how to adapt policy strategies when persistence is uncertain. For practical purposes, some baseline or "reference" assumption must be made about the structure of the economy in order to formulate policy. If mistakes are possible, or even likely given the changes wrought by the pandemic, there is a correspondingly strong case for making policy robust to possible error. We will take a robust policy to be one that focuses on avoiding worst-case outcomes, rather than being tuned to produce excellent outcomes in a possibly mistaken reference case.[2]

We illustrate this approach in the case of the ECB with simulations based on the January 2023 WEO baseline. From the vantage point of end-2022 and early-2023, the ECB faced high uncertainty about the persistence of inflation. After more than a decade of subdued inflation, prices in Europe started to accelerate in early 2021. By October 2022, inflation had exceeded 10 percent, the highest level in the history of the eurozone. The surge in inflation was driven by major events such as the legacy of a pandemic, the Russian invasion of Ukraine, and global commodity price increases. None of these factors could have been easily compared with historical episodes since the start of the currency union. European central banks faced greater uncertainty, without easily quantifiable risk (Knight, 1921).

Euro Area: Contributions to Headline Inflation 1/
(Percentage points, 2020 Jan = 2023 Sep)



Sources: Eurostat; Haver Analytics; and IMF staff calculations.
1/ The January euro area HICP has been calculated using Eurostat estimates for Germany due to technical data processing issues in Germany.
2/ Core excludes energy and unprocessed food.

Although our focus is on inflation persistence, which is of course just one aspect of the uncertainty that monetary policymakers face and that notably extends to the uncertain size of the output gap, the level of the natural rates of interest and unemployment, the uncertain duration of exogenous shocks (such as those related to energy prices), and the strength and speed of monetary policy transmission. However, it is widely recognized that uncertainty about the persistence of inflation and how agents form expectations as being of particular import (e.g., Orphanides and Williams, 2007).[3]

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[2] Uncertainty about the persistence of inflation could cause economic agents other than policymakers to also behave as if the "worst case" is the true one. If economic agents are averse to ambiguity (Knightian uncertainty), they will optimize behavior under the assumption that the worst will happen. If they draw their beliefs from a set which includes experts' opinions, the more dispersion there is among experts, the less confident an average household or firm will be about probability assessment of the outlook (Ilut and Schneider, 2014).

[3] Orphanides and Williams (2007) show that monetary policy rules which are robust to uncertainty regarding the natural rates of interest and unemployment, or the persistence of inflation, behave similarly.

This paper argues that in a context of elevated uncertainty (such as the one the ECB faced in the post-pandemic inflation surge) a robust approach – a "better safe than sorry" philosophy – to the conduct of monetary policy is called for. A robust approach to reducing inflation is preferred in that situation because the potential costs associated with high inflation for too long are more severe than those coming from tightening too much.

In practice, under a robust approach to monetary policy when inflation persistence is highly uncertain, the central bank should react forcefully to inflation and keep a tightening bias to bring down inflation. When the intrinsic persistence of inflation is unknown, this paper argues that a central banker should act as if it is high because the cost of underestimating this feature of inflation is higher than the cost of overestimating it. This requires the central bank to hike interest rates more than under the baseline model and the central forecast built around it when inflation is high. For instance, in an application using macroeconomic data from the January 2023 update to the World Economic Outlook (WEO) and incorporating a standard monetary policy reaction, as of 2023Q1 staff projected a baseline scenario where the quarterly average of the ECB policy rate would peak at 3.7 percent. However, applying a robust approach would have required a peak policy interest rate up to 60 basis points higher than that under such the baseline scenario. Since then, the ECB has already hiked its deposit facility rate (DFR) to meet about half that distance.

In that same context of early 2023, we also show that a "wait-and-see" strategy, whereby the central bank starts by acting as if inflation persistence is low and then corrects course as it learns that inflation is much more persistent than thought, can also be very costly as it would require a much sharper monetary policy tightening than the robust approach[4]. Such sharp tightening increases central bank losses relative to the robust policy and raises tail risks for financial stability as it could have a large effect on borrower's ability to meet their variable-rate debt obligations and impair financial market functioning. In practice, the latter result implies that the central bank should react more to upward surprises to inflation than to downward ones to be able to correct course sooner rather than later.

The robust approach has long been applied to the monetary policy literature. Facing massive fundamental uncertainty, a robust control approach argues for a more aggressive response to minimize the likelihood and impact of the worst-case scenario (see, for instance, Hansen and Sargent, 2008, 2011). Earlier applications to monetary policy such as in Walsh (2003, 2004) show that policy makers should act under the assumption of an adverse inflation shock when the economy is slowing, and inflation is above target to prepare for the worst-case scenario. In a more general setting, this approach requires a systematic overestimation of the persistence of any inflation shock.

[4] Hakamada and Walsh (2024) find that policy delay worsens inflation outcomes but this loss is reduced if policy, when it starts reacting, is more aggressive.

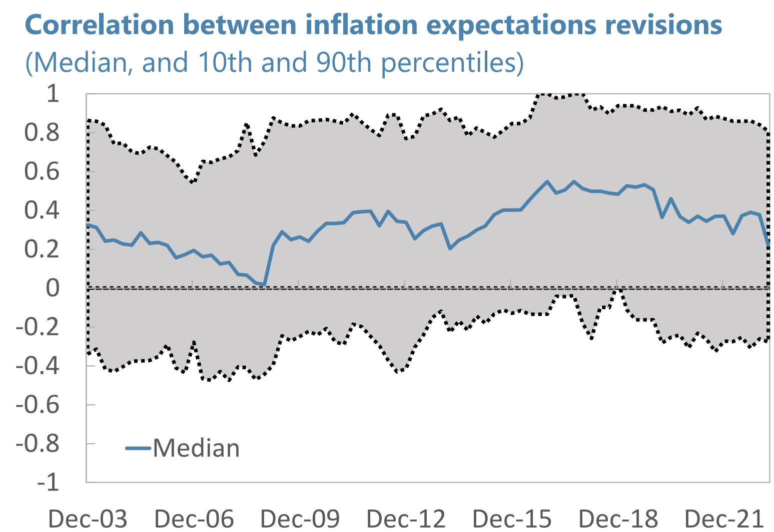
This is in the same vein as Levin and Williams (2003), who argue that central bankers can protect against model uncertainty by using a more backward-looking model than what could truly characterize the economy. In a case of high model uncertainty such as during the pandemic, policy makers should rather err on the side of overestimating the degree of endogenous persistence in the economy (Walsh 2022). Our results also resonate with Orphanides and William's (2007) work on monetary policy under imperfect knowledge of the expectations formation process (i.e., rational expectations versus learning), which concludes that monetary policy should have a higher degree of inertia, should respond aggressively to inflation, and should have a smaller response to the unemployment gap compared to what would be optimal under perfect knowledge.

Sources of Uncertainty

Central bankers are confronted with several sources of uncertainty. Among them, uncertainty about the persistence of inflation is of major importance. Other sources of uncertainty include the natural rate of unemployment or the amount of slack in the economy, the neutral interest rate, and the strength of the transmission of shocks to the macroeconomy, including those associated with monetary policy.

Uncertainty about the persistence of inflation as inferred from surveys of professional forecasters is typically high and varies over time. Figure 1 shows the expected persistence of inflation as seen by 50 respondents to the ECB's Survey of Professional Forecasters (SPF) up to the end of 2022. An estimate of expected persistence is given by the correlation between revisions to 12-month and 24-month ahead inflation forecasts on successive dates. Intuitively, this statistic captures the idea that a shock today that leads to (say) higher expected inflation over the coming year is seen to have greater persistence when it *also* causes expected inflation to be higher two years hence. Conversely, a shock that is seen as purely transitory would produce a zero correlation with two-year expectations. As of end-2022, the correlation statistic varied widely between forecasters, as indicated by the width of the shaded region—different forecasters held views on inflation persistence that ranged from "none" through to "very high" (see Jain, 2019, for a formal econometric approach to measuring perceived persistence).

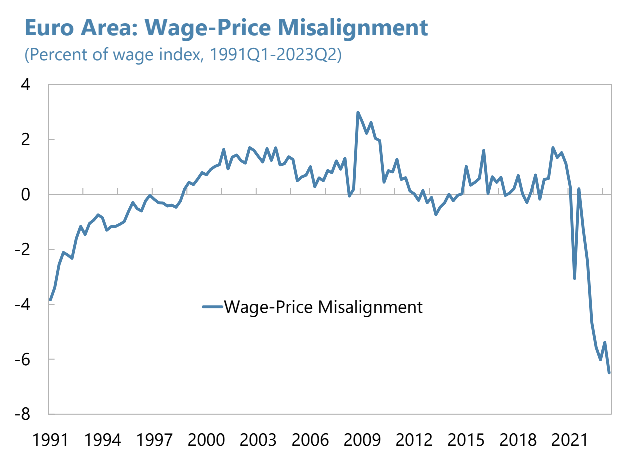
Figure 1: Perceived Inflation Persistence



Sources: ECB; IMF staff estimates

Note: The chart shows the correlation between the change in 1-year and 2-year ahead euro area consumer price inflation expectations of each SPF respondent over a rolling 20-quarter sample. Low persistence of inflation implies low correlation between forecast revisions. Shaded area covers the 10th and 90th percentiles of the distribution of estimated correlation of the cross-section of respondents.

A driver of uncertain inflation persistence is that which comes from an imperfect knowledge of labor market dynamics. One focal point of this uncertainty relates to the transmission of labor market tightness to wage growth. This uncertainty is higher with potentially structural changes in worker preferences such as preference for working from home or for fewer hours, which discourages workers from jobs deemed inflexible.



Sources: Refinitiv; Staff calculations.

Note: The wage-price misalignment is calculated as the residual from a long-run equation of monthly negotiated wage index and HICP.

A second source of uncertainty coming from the labor market relates to the link between wage growth and price inflation. This link works in both directions. On the one hand, after a large bout of inflation like the one observed in Europe in 2022, a certain amount of wage catch-up would have been expected. However, the amount of catch-up and its role in feeding a wage-price spiral depends on how wage-setting institutions respond to a large change in inflation. Although slow moving, institutions like the extent of collective bargaining/unionization, the inclusion of cost-of-living adjustment clauses in wage contracts, and the benchmarking role of public sector wages are endogenous and can change in response to a regime switch (Boissay and others, 2022). This begs the question of how backward-looking (dependent on past inflation) or forward-looking (driven by inflation expectations) wage setting is at a given juncture or economy.[5]

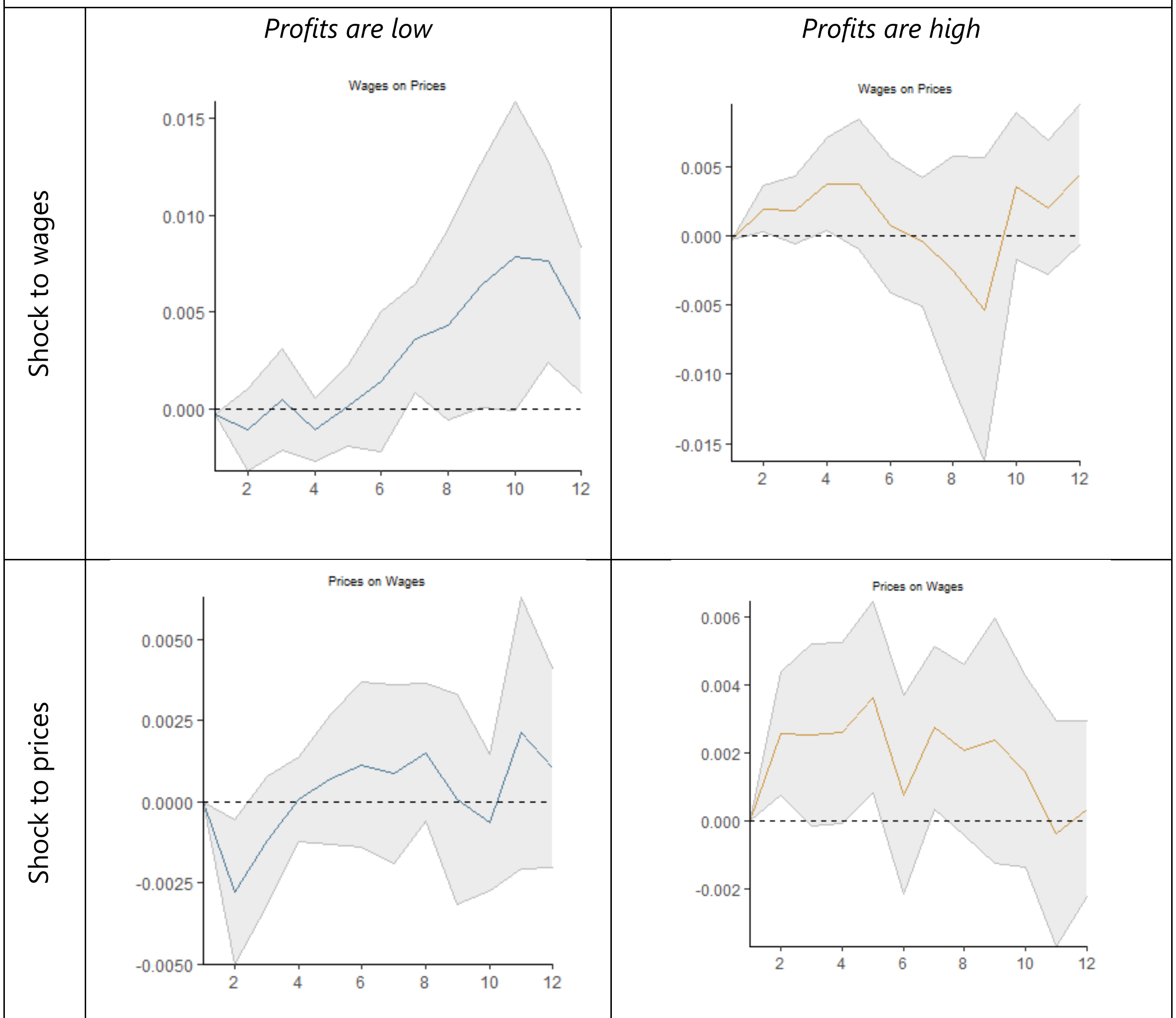
On the other hand, the transmission from wage growth to inflation is also uncertain as it depends on the behavior of firm profits and their ability to absorb wage increases, among other factors. Specifically, the impact of a shock to wages on prices can be persistent, but only if profits are low. Historical evidence suggests that the response of the HICP to a wage shock is contingent on the level of firm profits. Figure 2 shows the impulse responses of prices to wages and vice versa, conditional on profits being high or low. The shocks to wages and prices are identified with a bivariate VAR and a simple Cholesky scheme with prices assumed to move before wages. The impulse responses are then estimated using a linear projection with a smooth transition function which depends on the profit level (see Auerbach and Gorodnichenko, 2012). When firm profits are high, a wage shock has a very small effect on the price level while a shock to the HICP increases wages persistently. The opposite is true when firm profits are low: when wage costs increase, firms update prices upward, but when prices increase, they do not raise wages. The normalization of firm profits to a smaller margin could temporarily absorb some wage gains but would also lead to a higher passthrough from wages to inflation should the wage dynamics remain strong. Knowledge about in which regime of firm profits the economy stands is, of course, imperfect (see the work by Hansen, Toscani, and Zhou, 2023, on how markups in Europe have changed since the Covid-19 pandemic).

Central bankers also face uncertainty about the strength and length of the transmission of monetary policy and of other shocks to economic activities and prices. A common way to summarize this uncertainty is to make it about the slope of the Phillips curve (e.g., see Meyer et al. 2001 and Tillman 2011). During a long period of low inflation, the slope of the Phillips curve was deemed rather flat. However, the debate about the steepness of the slope has recently been reignited by the move from a regime of low and stable inflation to one of high and variable inflation after the 2020-21 Covid-19 pandemic shock. A steeper slope means that policies affecting economic activity and the output gap will have a stronger and sometimes unintended effect on inflation (Hodge et al., 2022). A nonlinear Phillips curve imply a stronger transmission of shocks when inflation is high (Hardin et al., 2022). A consequence of this reassessment is that a high level of inflation may come down faster given the same tight monetary policy stance. It could also mean that the last mile of bringing inflation down to

[5] In the European context, there is evidence supporting the view that wage setting is more forward-looking in advanced economies than Central, Eastern, and Southeastern Europe (IMF, 2023).

the target could run into more difficult trade-offs due to higher sacrifice ratios. Central bankers, therefore, cannot neglect this source of uncertainty.

Figure 2: Impulse Responses of Prices and Wages Contingent on Firm Profits



Note: The charts show the impulse responses of prices to wages when profits are low (top left) or high (top right), and of wages to prices (HICP) when profits are low (bottom left) or high (bottom right). The impulse responses are estimated using the nonlinear local project method with two states and switching depending on profits being high or low through a smooth transition function with a 90 percent condidence band Shocks are identified with a choleski decomposition as in Jordá (2005). Data on wages and HICP (both in logs) come from the OECD and on profits (detrended EBITDA over market value of equity) from Refinitiv.

A final source of uncertainty which policymakers must confront concerns the measurement of the monetary policy stance—the difference between the real policy rate (*r*) and the natural rate of interest (*r**), two quantities which are measured imperfectly. For example, to measure the real policy rate using the ex-ante real policy rate (i.e., the nominal rate minus the expected rate of inflation) may lead to results that vastly differ from the ex-post real policy rate (i.e., the nominal interest rate minus the actual rate of inflation). Moreover, *r** itself as it is unobservable, affected by both real and financial drivers, and driven by both long-term structural factors and some short-to-medium term cyclical factors.[6] The uncertainty about the stance, in turn, also implies uncertainty about the slack in the economy as the interest rate gap is a key determinant of the output gap or the unemployment gap. This uncertainty is, of course, compounded by that caused by low-frequency movements in the natural rate of unemployment and potential output driven by structural changes. Thus, the uncertainty about the monetary policy stance and the amount of slack in the economy provide additional arguments in favor of an approach to monetary policy which is robust to many sources of uncertainty (Orphanides and Williams, 2007).

During this period of high uncertainty, central bank communication plays a crucial role. Signaling an intention for decisive action and an emphasis on meeting the inflation target can help anchor inflation expectations. In the next section, we show how to use, in practice, an approach to monetary policy which is robust to uncertainty about the persistence of inflation. Explicitly adopting this approach could amplify its benefits

A Robust Approach to Monetary Policy

A SIMPLE ILLUSTRATIVE MODEL WITH ROBUST POLICY

In this section, we demonstrate the costs of miscalculating inflation persistence in an environment where monetary policy is set optimally and is robust to some of the sources of uncertainty mentioned earlier. We show that the costs of getting persistence wrong—as in, for example, a "wait-and-see" strategy—can be considerable. And we further show that—in a context such as the ECB found itself in the post-pandemic inflation surge compounded by significant commodity price increases from the war in Ukraine—by acting *as if* inflation were persistent, even if it turns out not to be, produces outcomes that are only moderately inferior to those obtained under a fully optimal policy without uncertainty.

ECONOMIC ENVIRONMENT

We use the open economy New Keynesian model set out in Clarida, Galí, and Gertler (2001) (CGG hereafter). The equations of the model are as follows:

[6] There are many approaches to estimate r* and they are all inherently imprecise even in normal times, even if they are still useful as indication of the stance (Kaplan, 2018). However, in the pandemic and post-pandemic world, it has been even more challenging to assess the trajectory of r* (Barrett and others, 2023).

$$\pi_t - \phi_p \pi_{t-1} = \delta_p \beta E_t\left(\pi_{t+1} - \phi_p \pi_t\right) + \lambda_\omega x_t + c_t, \quad \text{(PC)}$$

$$x_t - \phi_x x_{t-1} = E_t(x_{t+1} - \phi_x x_t) - \frac{\omega}{\sigma}(i_t - E_t \pi_{t+1} - rr_t^*) \quad \text{(IS)}$$

$$s_t = \frac{\sigma}{\omega} x_t + s_t^* \quad \text{(RER)}$$

Eq. (PC) and (IS) are the open economy New Keynesian supply and demand functions, which deliver domestic inflation (π), understood as a quarter-on-quarter measure, and the output gap (x); Eq. (RER) delivers the real exchange rate (s) as a function of the output gap and the efficient terms of trade s^* (readers are referred to Clarida, Galí, and Gertler, 2001, Section II, for details). Our focus will be on the effect of the cost-push disturbance (c) in Eq. (PC), which follows a first order autoregressive process with a coefficient ρ.

Two modifications are introduced to the set-up described by CGG. First, we add intrinsic inertia in prices and demand, the extent of which is controlled by ϕ_p and ϕ_x respectively; such modifications help the model to reproduce the type of hump-shaped impulse-response function of inflation that is consistent with the empirical evidence provided by monetary vector autoregressions (Christiano, Eichenbaum, and Evans, 2005). Second, we allow for behavioral discounting in the open economy Phillips curve, similar to the approach in Kolasa, Ravgotra, and Zabczyk (2022) (δ_p).[7] Table 1, below, details the values of the model parameters adopted for our simulations. We take the central bank to place a relatively high weight on output gap stabilization, and choose the openness parameter imply a relatively closed economy, similar to that of the euro area or United States.[8]

The model described by Eq. (PC)-(RER) is closed using a policy *targeting rule* (Svensson, 2002). To obtain the policy rule, we specify as a primitive the preferences of the policymaker. We assume a period loss given by:

$$\mathcal{L}_t = (\pi_t)^2 + \alpha(x_t)^2, \quad \text{(LOSS)}$$

and that the central bank uses its policy instrument to minimize the discounted sum of all future values of this criterion, taking as constraints (AS), (IS), and (RER). We consider a 'timeless perspective' (TP) policy that supposes that the central bank has committed itself to following an optimal control policy far in the past. The central bank then acts as if constrained by the past promises it would have

[7] Allowing in addition for behavioral discounting in the IS curve was not found to be important for our results.

[8] The value of α implies equal weight on inflation and the output gap when the former is expressed at an annual rate.

made, had that been the case.[9] The TP solution to an optimal policy problem takes the form of the 'targeting rule' given in Eq. (TR):

$$\left(1+\beta\delta_p\phi_p^{cb}\right)\mathrm{x}_t=\beta\phi_p^{cb}\mathrm{E}_t\mathrm{x}_{t+1}+\delta_p\mathrm{x}_{t-1}-\frac{\lambda_\omega}{\alpha}\pi_t, \quad \text{(TR)}$$

where ϕ_p^{cb} is the central bank's belief about structural persistence ϕ_p.

Although rule (TR) may look complex, it nests some useful special cases that help with intuition. Notably, if inflation is believed to be purely forward-looking with no structural persistence ($\phi_p^{cb}=1$), the rule becomes:

$$\mathrm{x}_t-\mathrm{x}_{t-1}=-\left(\frac{\lambda_\omega}{\alpha}\right)\pi_t,$$

which says that the change in the output gap should be negative as long as inflation runs above target. This commits the central bank to maintaining a persistently tight policy in response to markup shocks that push up inflation. Because inflation is forward-looking, the perception that the central bank will keep the level of the output gap negative well after the shock has dissipated helps to restrain inflation without requiring it to sharply tighten today. Of course, this reaction function can be highly problematic if inflation has a high degree of intrinsic persistence and is not very forward-looking. To see this, the optimal rule in the case in which inflation is completely backward-looking ($\phi_p^{cb}=0$) is given by:

$$\mathrm{x}_t=\beta\mathrm{x}_{t+1}-\left(\frac{\lambda_\omega}{\alpha}\right)\pi_t.$$

By iterating forward, this indicates that the output gap today should be pushed to very negative values today if future inflation is expected to run persistently high—consistent with an aggressive rather than inertial monetary policy response. It follows that misjudging the persistence of inflation will have at times serious adverse consequences for welfare, as measured by (LOSS).

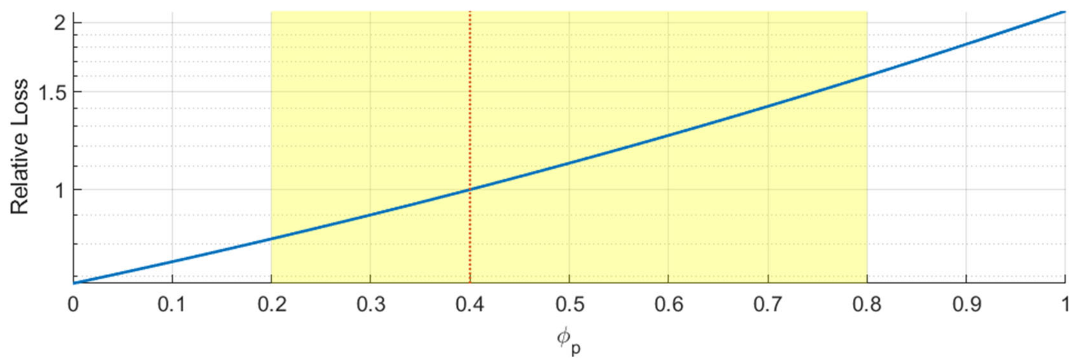
HOW THE RULES ARE SET IN A ROBUST POLICY APPROACH

How can the central bank make its policy (TR) robust to errors in its assessment of inflation persistence? As a prelude to our discussion, we observe that policy conducted under a rule such as (TR) *already* includes certain important elements of robustness. Svensson (2010, p. 1263) points out that a targeting rule that describes the relationship between endogenous variables in an optimal policy equilibrium is invariant to additive judgments and the stochastic processes describing additive shocks. In a standard purely forward-looking version of the New Keynesian model, Walsh (2004)

[9] TP policies are similar to optimal commitment (OC) policies, which deliver the best achievable outcomes and which are therefore a natural benchmark against which other policies may be judged. However unlike an OC policy, a TP policy does not exploit initial macroeconomic conditions to engineer a 'surprise' while also committing never to do so again.

demonstrates that the optimal control policy in a model mis-specified in the sense of Hansen and Sargent (2003) is equivalent to the optimal policy computed in the manner of Svensson.[10]

Figure 5: Relative Costs of Misjudging Persistence



Memo: The unconditional loss associated with alternative degrees of inflation persistence (blue line) when the central bank's reference model takes $\phi_p = .4$ (red dot line). The shaded area is the range of potential ϕ_p values entertained by policymakers. Log scale.

The preceding discussion has hinted at a novel element in our analysis of the targeting rule: the central bank can be mistaken in its belief about the degree of structural persistence in inflation. Concretely, the central bank takes persistence to be $\phi_{\mathrm{p}}^{\mathrm{cb}}$, which may be different from its actual value ϕ_p. Three cases are of interest: (i) when policymakers' beliefs are correct, $\phi_{\mathrm{p}}^{\mathrm{cb}} = \phi_{\mathrm{p}}$; (ii) when persistence is high but believed by policymakers to be moderate, $\phi_{\mathrm{p}}^{\mathrm{cb}} < \phi_{\mathrm{p}}$; and (iii) when persistence is moderate but the central bank acts *as if* it is high, $\phi_{\mathrm{p}}^{\mathrm{cb}} > \phi_{\mathrm{p}}$. Case (i) leads to textbook optimal policy outcomes. Case (ii) produces what we refer to as the *worst* outcomes, for reasons explained momentarily. We will also argue that case (iii) plausibly produces the best *robust* outcomes.

The language used to describe case (ii) derives from an analysis of the following scenario, which is illustrated in Figure 5: the central bank's 'reference' model features inflation persistence that is 'moderate', which we take to mean $\phi_{\mathrm{p}} = .4$. However, it is uncertain about this reference model, and entertains a range of possibilities $\phi_{\mathrm{p}} \in R = [.4, .8]$ but without being able to formulate a probability distribution over this range. For a grid of ϕ_{p} values in R, we compute the outcomes, as measured by the unconditional expectation of Eq. (LOSS), under the assumption $\phi_{\mathrm{p}}^{\mathrm{cb}} = .4$. As can be observed, losses rise steeply with inflation persistence, relative to the reference case (where losses are normalized to unity in the figure). Losses are therefore highest—outcomes are 'worst'—when ϕ_p lies

[10] Hansen and Sargent (2003) envisage a situation in which the central bank sets policy without full knowledge of the economy's structure. In their analysis the central bank acts on its uncertainty when setting policy, whereas in our analysis the central bank is taken to act as if certain (even though it may subsequently turn out to have been mistaken, and to recognize that fact).

at the upper end of the range of possibilities that policymakers consider.[11] By contrast, lower losses are suffered when persistence is lower than in the reference case.[12]

RESULTS OF THE ILLUSTRATIVE MODEL

Failure to recognize high inflation persistence is costly—and surprisingly, so is a policy of wait-and-see. The response of the model economy to a cost shock is shown in Figure 6(a). The dashed red line indicates outcomes when inflation persistence is high, but the central bank believes it to be moderate. The solid blue line indicates optimal policy. As might be expected, domestic inflation (shown relative to its target rate) takes far longer to come down when the central bank errs. But inflation also peaks far higher than otherwise. The underlying reason is that real interest rates—roughly, the policy rate minus inflation—remain below the level needed to cool the economy quickly. This can be seen from the middle panel, showing the output gap, which although negative in the case of a policy mistake, is not negative enough to rein in demand and tame price rises.

Table 1. Parameters Used in the Illustrative Simulations

Symbol	Value	Description
α	.0625	Relative weight on output gap stabilization
β	.995	Discount factor
σ	1	CRRA
ξ	.85	Share of fixed prices (Calvo parameter)
γ	.1	Openness (import share)
η	1.5	Import elasticity of substitution
ω	1.095	Interest elasticity of demand $= 1 + \gamma(\sigma\eta - 1)(2 - \gamma)$
λ_ω	.052	PC slope $= \left[\frac{(1-\xi)(1-\beta\xi)}{\xi}\right]\left(\frac{\sigma}{1+\omega} + 1\right)$
ϕ_x	.75	Habit/demand persistence
ρ	.92	Cost shock autoregressive coefficient
δ_p	.8	Behavioral ("Gabaix") discount factor, Phillips Curve

[11] Notwithstanding the result of the numerical analysis, it should come as no particular surprise that the higher degrees of inflation persistence do indeed pose greater stabilization challenges; for example, the polar case of $\phi_p = 1$ and $\delta_p = 0$, which we do not consider here the 'accelerationist' Phillips curve, in which the change of inflation depends on slack (see Rudebusch and Svensson, 1999).

[12] At first glance it may seem that better-than-optimal outcomes are possible when persistence is low, an apparent paradox. Heuristically, though, higher persistence means that the constraint on central bank action is 'tighter', whereas lower persistence means that it is 'looser' (the constraint in question is given by the Phillips curve in this model). A looser constraint allows a policy that is incorrect for the circumstance of low persistence to achieve better outcomes than optimal policy in the reference case.

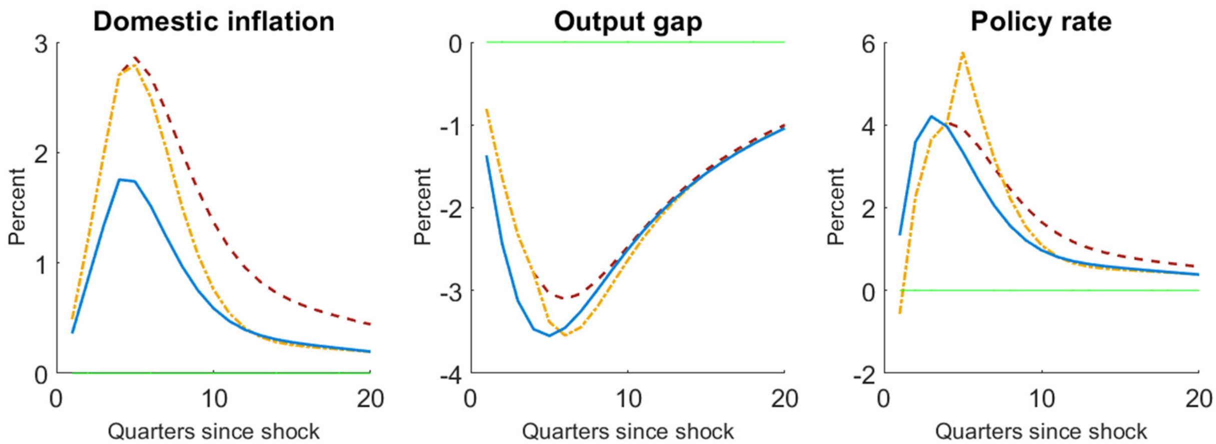
A policy of wait-and-see entails a course correction when the truth emerges, which we somewhat arbitrarily assume to occur five quarters after the shock (the economy runs hot for a year) and assume is completely unanticipated by the private sector. When the central bank in our example recognizes that inflation persistence is high, it raises the policy rate sharply (rates are shown relative to their nominal neutral value). This has an immediate dampening effect on demand, the output gap, and so on inflation. However, the inflation inertia that has built up cannot be quickly reversed. The new policy regime brings inflation back towards target (in the figure, the zero line), but there is a considerable delay. There is a correspondingly greater period of tight policy.

We now provide a justification for the description of case (iii) as a 'robust' policy. The robust policy rule is Eq. (TR) with $\phi_{\mathrm{p}}^{\mathrm{cb}} = .8$, the 'worst case' for inflation persistence. As just discussed, such a rule implies far better outcomes than the reference assumption $\phi_{\mathrm{p}}^{\mathrm{cb}} = .4$ if persistence is truly high. Figure 6 shows that the robust rule also implies *reasonably good* outcomes (in a sense we make precise momentarily) when persistence is truly moderate. Compared to the reference case (in green), the robust policy produces both a lower peak in inflation, and a quicker return to target. The flip side of that desirable outcome is the wider output gap. The nominal interest rate is initially raised more under the robust response but falls back more quickly too.

Comparing the outcomes associated with each policy using Eq. (LOSS), we find that the robust policy is around 9 percent worse than the policy in a moderate persistence world. The benefit of a robust approach can be high and its cost very moderate in the event of cost-push shock, and superior to a wait-and-see approach. But erring in the opposite direction, the worst case, produces losses that are 60 percent greater.

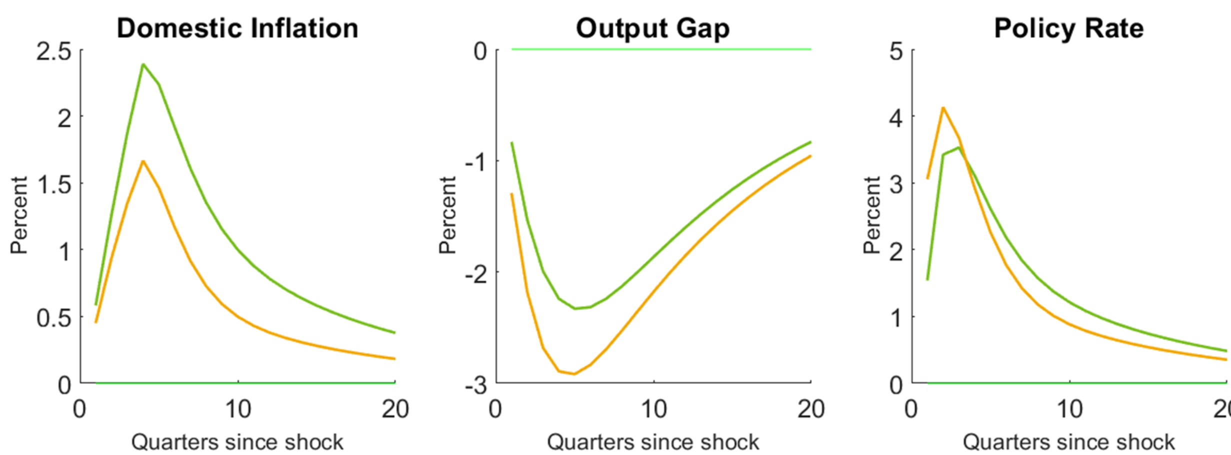
Figure 6: The Effects of an Adverse Cost-Push Shock When Inflation Persistence Is Unknown

(a) A high-persistence environment: Course correction when policy is initially mistaken



--- policy error | — optimal policy (high persistence) | -.- wait and see

(b) A moderate-persistence environment: Comparison of optimal and robust policies



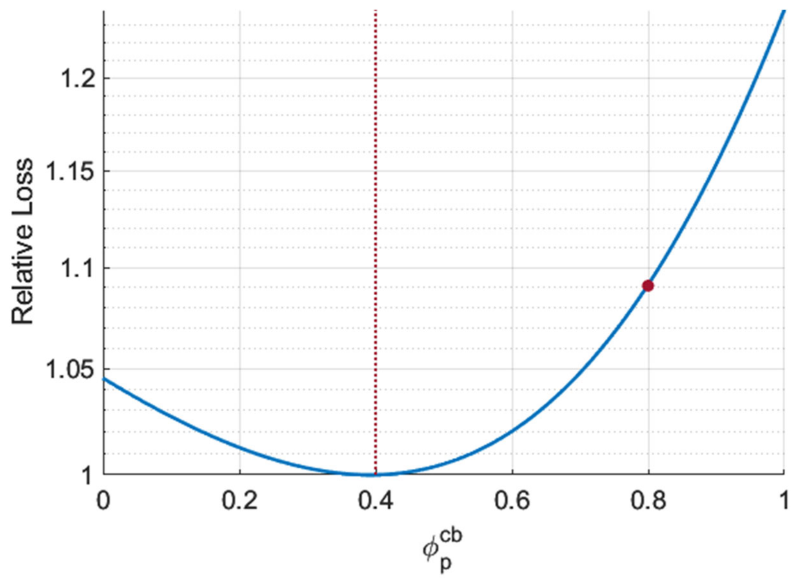
— optimal policy (moderate persistence) | — robustly optimal policy

Memo: Inflation is shown as a year-on-year rate, relative to the inflation target; Policy rates are annualized, and shown relative to the nominal neutral rate.

COST OF ROBUSTNESS

We have argued that when the central bank acts tough on inflation, it guards against bad outcomes and avoids volatility associated with changing course if persistence turns out to be high. However, if the reference case ("moderate persistence") is correct, a robust policy will, by definition, produce outcomes that are worse than those of following standard optimal policy. Figure 7 illustrates just how much worse, by plotting the unconditional loss, relative to optimal policy, for a range of central bank policies indexed by ϕ_p^{cb} while holding true inflation persistence fixed at $\phi_p = 0.4$. The robust policy, which is aggressive on inflation, raises the loss by around 9% relative to optimal policy, marked as a red dot. Notably, the cost function in Figure 7 reveals an asymmetry: the costs of being excessively dovish (acting as though persistence is lower than the truth) are lower than those of being aggressive (acting as though persistence is higher than the truth). By construction then, deviating from optimal policy is costly, but the costs of erroneously acting tough, in the name of robustness, are dwarfed by the cost of pursuing a 'baseline' or 'reference case' policy when persistence turns out to be high.

Figure 7: The Relative Cost of Deviating from the Optimal Policy in the Baseline Case



Note: Unconditional loss under alternative policies indexed by the central bank's assumed inflation persistence, relative to optimal policy when inflation persistence $\phi_p = 0.4$. The red dot indicates the value of ϕ_p^{cb} prescribed by the robust approach and the associated loss relative to $\phi_p^{cb} = \phi_p$.

CONSIDERATIONS FOR CENTRAL AND EASTERN EUROPEAN ECONOMIES

The benefits of a robust approach may be higher for countries in Central and Eastern Europe (CEE) with some level of control over its monetary policy. Unlike the euro area, central banks in CEE that do not have the euro as a currency operate in a small open economy environment in which external shocks are more frequent and persistent, and inflation expectations are less resilient to de-anchoring. Moreover, the degree of backward indexation in wage and price setting can be significantly higher in these economies given weaker central bank credibility and the slope of the Phillips curve being less than in a more closed economy (i.e., monetary policy is less effective in dealing with trade-off-inducing shocks). Hence, the benefits of using a robust approach in the sense mentioned above may yield appreciable gains. Regardless, the existence of more significant financial frictions and a higher risk of inflation de-anchoring could justify the use of other tools besides the interest rate, such as foreign exchange interventions, provided that financial markets are shallow and currency mismatches material (IMF 2020). Still, even if using other tools in conjunction with the interest rate (or as a substitute) could be optimal, the case for a robust approach remains.

ROBUST POLICY WHEN WAGE AND PRICE PERSISTENCE MAY BE ELEVATED

This section considers how from the perspective of end-2022 / early 2023, model uncertainty may impact the ECB's monetary policy strategy. In contrast to the previous section, our simulations are based on an empirically-orientated model of the euro area, and the projections embedded in the January 2023 *World Economic Outlook* Update.

ECONOMIC ENVIRONMENT

We use a medium-scale dynamic stochastic general equilibrium (DSGE) model estimated on euro area data to perform the simulations reported in this section. It features a rich array of nominal and real distortions, including financing and investment frictions that produce variation in credit spreads, and flexible parameterization geared toward facilitating its fit to euro area data. It was estimated using historical macroeconomic data for the period 1980-2016. The reader is referred to Laureys, Meeks, and Wanengkirtyo (2021), LMW hereafter, for complete details of the model and its estimation (see also Smets and Wouters, 2003).

Two aspects of the model economy are particularly germane for the exercise we conduct: the presence of price and wage stickiness; and of intrinsic price and wage inertia. Stickiness arises because pricing decisions are time dependent, according to the standard Calvo mechanism. Inertia arises because of presumed (partial) indexation to past price or wage inflation. Together, these model elements have a powerful effect both on the transmission of monetary policy, and on the outcomes that can be achieved using policy tools.

Monetary policy is set according to a simple instrument rule. The target short term nominal interest is taken to depend upon deviations in inflation from target and output from potential, as is standard. Interest rates adjust gradually towards their target level:

$$r_t = \rho_r r_{t-1} + (1-\rho_r)\left(\phi_\pi \pi_t + \phi_y y_t + \phi_{\Delta y} \Delta y_t\right) + \varepsilon_t^r \qquad \text{(SR)}$$

The coefficients of the rule were estimated on the historical data by LMW. Fiscal policy is passive.

THE ROBUST POLICY ANALYSIS FOR THE ECB

In this section we describe how we go about constructing and analyzing alternative paths for policy interest rates, starting from a baseline projection for the economy. The robust policy analysis we conduct therefore differs in several respects from the stylized model example discussed earlier in this paper, because as stated above we wish to place a greater emphasis upon descriptive verisimilitude than on the presentation of sharply defined normative prescriptions.

The analysis proceeds in several steps:

Step 1. Given a set of projected paths for observable macroeconomic and financial variables (output, consumption, investment, employment, nominal rates, and CPI inflation), we use the baseline economy—described by the LMW model with parameters set to their posterior modal values (LMW, Table 3)—to recover a set of fundamental shocks to total factor productivity, investment-specific technology, household consumption preferences, autonomous spending incl. government, price mark-ups, and wage mark-ups. Using the language of the previous section, the economic structure estimated on historical data is the *reference case* in the present exercise, and the WEO January 2023 vintage baseline may be considered the *outcome* under the reference case.

Step 2. With the fundamental shocks and policy rule held constant, we consider alternative economic structures by allowing the parameters governing price stickiness, and intrinsic price and wage inertia, to deviate from their estimated modal values. As detailed below, we choose parameter values to make the economy "inflation prone". For consistency with the previous section, we will continue to refer to this situation—a less-favorable environment combined with an unchanged policy rule—as the *worst case* (although we do not formally establish it as such),[13] making the paths generated for the observable macroeconomic variables the *worst case outcomes*.

Step 3. Given the alternative economic structure described in Step 2, and the fundamental shocks described in Step 1, we look for the simple rule that would minimize the sum of squared deviations of inflation from a 2% target, squared deviations of output from its efficient level, and squared changes in nominal interest rates. We constrain the parameters of the rule to lie in the region [1,5] for inflation, [0,5] for the output gap, and [0,.99] for the adjustment of nominal rates towards their target value. Applying the optimized rule in the structurally altered economy is referred to as the *alternative case*.

Step 4. The final step of the analysis involves what we term the *robust policy* rule; that is, the rule that would perform best in the inflation-prone economy. We hold the fundamental shocks constant and set all parameter values (aside from those that enter the policy rule) to their estimated modes as in the reference case. The parameters of the policy rule are those obtained in Step 3. The resulting paths for the endogenous variables are the robust outcomes.

[13] Our approach resonates with that of Onatski and Williams (2003) who apply minimax policy rules over a restricted set of empirically plausible perturbations of the reference model to avoid results being driven by "unlikely models".

In summary, we will consider how macroeconomic outcomes forecast in the January 2023 WEO would change under an "inflation-prone economy" scenario. Our robustness analysis will identify how variations in the parameterization of a simple instrument rule produce alternative interest rate paths that may contribute to improved inflation outcomes. In contrast to the stylized scenario in the previous section, in which the only disturbance was a cost-push shock, in this section multiple shocks are affecting the economy and the optimal policy rule.

CALIBRATING THE INFLATION-PRONE ECONOMY

As discussed above, the parameterization we adopt in Step 2 of our robust policy approach is designed to generate what we term an "inflation-prone economy". This parameterization involves both higher levels of wage and price inertia—which we loosely interpret as reflecting the effect of adaptive expectations in an environment where inflation is elevated compared to historical experience—and a steeper price Phillips curve. The latter is a simple way to capture the possible non-linear effects of marginal cost shocks on inflation in the conjuncture (Harding, Lindé, and Trabant, 2022).

Table 2: Parameterizing the Inflation-Prone Economy

	Price inertia (ι_p)	Wage inertia (ι_w)	Price stickiness (γ)
Baseline value	.0315	.2274	.7975
Alternative value	.0908	.4030	.7543

Note: Baseline value is the estimated posterior mode. Alternative value is the upper (lower) bound of the 90% HPD interval. Symbols match LMW (2021, Table 3).

To impose discipline on the "inflation-prone" economy, we choose parameter values from within the estimated 90 percent highest posterior density (HPD) interval (Table 2). It is notable that the baseline economy features a low-price inertia, with a modal estimate for the price inertia parameter, ι_p, being very close to zero. This conclusion is tightly supported, in the sense that the upper bound of the 90 percent HPD interval is only slightly higher than the mode. Price inertia will accordingly play only a minor role in our findings. By contrast, the modal estimate for the wage inertia parameter, ι_w, is of moderate size and is estimated with lower precision.[14] Lastly, the price stickiness parameter γ is inversely related to the slope of the price Phillips curve (a larger parameter value connotes a greater degree of fixity in prices, and therefore a shallower slope). The difference between the baseline and alternative values of the price stickiness parameter may appear small, but it translates into an average duration of price fixity that is almost one full quarter less (4 rather than 5) in the "inflation

[14] We note that the two inertia parameters are estimated under identical prior distributions. It follows that differences in the posterior estimates reflect the influence of the price and wage data used in estimation alone.

prone economy"—an economically meaningful distinction (see Galí, 2008, p. 43 for a textbook explanation).

RESULTS FOR THE EURO AREA

In the baseline, interest and inflation rate paths follow the projection in the January 2023 Update to the WEO. The simulation starts in 2023Q1. The January 2023 WEO baseline forecast would have seen interest rates peaking at about 3.7 percent in 2024Q1 (Figure 8). This baseline IMF projection for the DFR was higher than the market pricing of the future interest rates at that time, which peaked at 3.3 percent as depicted in the top right panel of Figure 4. In the simulation, inflation falls in 2023, but remains marginally above its target, even in 2025. In the "inflationary economy" scenario, outcomes deteriorate notably. An elevated path for inflation entails much tighter policy, under the estimated policy rule, resulting in a sharp and prolonged recession. The rule that does best at stabilizing inflation in this scenario is given in Table 3.

Compared to the historical rule, the robust rule features a stronger response to inflation, a weaker overall response to output developments, and a higher degree of smoothing. For these reasons, it is important to note that the results that follow depend in part on the power of the implicit commitment to tighter future policy that is inherent in the robust rule when inflation is above target.

Table 3: Policy Rule Parameters

	ϕ_π	ϕ_y	$\phi_{\Delta y}$	ρ_r
Estimated historical value	1.68	.019	.15	.84
Robust value	1.94	.00	.13	.90

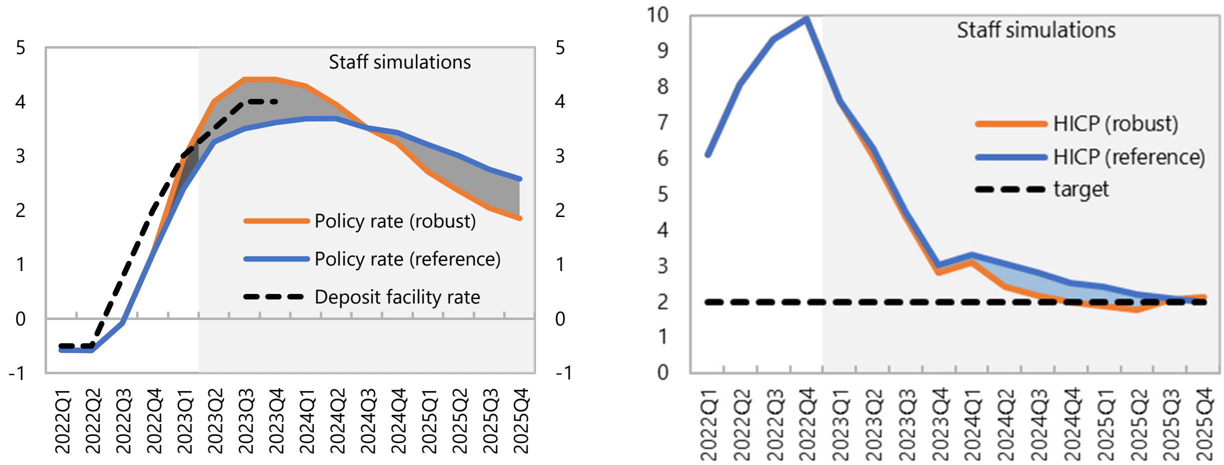
Note: The policy rule is given by Eq. (SR)

When we apply the robust policy rule to the baseline January 2023 WEO projection, we find that rates are raised faster, and peak materially higher. Compared to the reference case centered around the January 2023 WEO forecast, the policy rate peaks at 4.3 percent instead of 3.7 percent.[15] As a result, in the simulation inflation comes down faster and reaches the ECB's target of 2 percent before the end of 2024. It follows from the form of the policy rule that rates are eased starting in 2024, because inflation has come close to the 2 percent target, rather than plateauing. The shading in Figure 8 indicates a potential range of policy interest rate paths and inflation outcomes consistent with variations in the parameters of the policy rule. Since 2023Q1, the realized ECB's DFR has increased more than both the market expectation and the reference IMF path (Figure 8).

[15] After the publication of this forecast, the ECB raised its interest rate twice to 4 percent and the WEO updated its terminal rate forecast to that value.

Figure 8. A Historical Robust Policy Counterfactual for the ECB Based on January 2023 WEO Update Forecast

(a) Deposit facility rate (b) Consumer price inflation (y/y)



Sources: ECB; and IMF staff calculations.

Note: The charts show the results of simulations of the LMW model based on the January 2023 WEO update and the interest rate projections available in 2023Q1. There is usually a small spread (on average 10-12 basis points) between the DFR and the ESTR used in the simulation.

In practice, a robust policy generally refers to a set of policy rate paths selected by the policymaker to reduce the losses in a designated worst-case scenario, as exemplified in Figure 8. This overall strategy can be best described as having a tightening bias. It must be understood as the upper bound of a set of interest rate paths that align the following four elements: (i) the baseline conditional forecast of the target variables (inflation and the output gap), (ii) the central bank's judgment add-ons to such forecast (Svensson, 2003), (iii) the desire of the central bank for robustness, i.e., or its aversion to uncertainty concerning the level of backward indexation in prices and wages, and (iv) the tightness of its priors about backward indexation. In our example, we opted for a fairly pessimistic but still credible worst-case scenario.

However, if a central banker operates with a narrower credible region for the parameters determining the persistence of wage and price inflation than the ones we have selected, they would choose a path for future interest rates that falls somewhere between the reference and the robust paths (shaded area in Figure 8). In fact, by communicating the central bank's preference for robustness, including its aversion to inflation persistence and backward indexation, central bank can influence these parameters and potentially work with a narrower credible region. Therefore, and in a general setting, the policy advice to a given central banker should not be perceived as a singular path for the policy interest rate, but a range of options available, guided by a tightening bias (relative to the reference case). This implies that, in a setting where the persistence of inflation is highly uncertain, a central banker should tighten monetary policy more (and possibly for longer) than what is indicated by the baseline forecast and react more aggressively to positive inflation surprises than to negative ones.

Conclusion

When the persistence of the underlying inflation and wage dynamics is uncertain and inflation is too high, the best policy response may imply interest rate paths which are higher and/or more frontloaded than what would be implied by a routine, baseline policy reaction function. On the flip side, should inflation indicate a tendency to persistently dip below target, a prompt and decisive action by the central bank would prevent a prolonged period of inflation undershooting. In addition, the risk of hitting the ELB reinforces the case for the robust approach. Adopting a "wait-and-see" strategy would incur additional costs, as there is the risk of being forced to cut rates to the ELB and resort to unconventional monetary policy tools. We illustrate the substantial costs associated with erroneous assumptions about persistence and the adoption of a "wait-and-see" approach. Conversely, embracing a robust approach, even if inflation ultimately proves less persistent, results in only marginal deviations from the outcome under an ideal policy rule in a world devoid of uncertainty. As an application, this paper proceeds by constructing and analyzing various policy rate paths tailored to the European Central Bank (ECB) based on the January 2023 WEO forecast.

For the example of the ECB in early 2023, in line with the baseline interest rate path for the January 2023 WEO, in which interest rates peaked at 3.7 percent, we observe a scenario in which inflation begins to recede but remains above the target in 2025. However, in the simulation, should inflation prove more persistent, policy must be tightened more aggressively, potentially leading to a severe and protracted economic downturn. On the other hand, the robust rule prescribes a quicker ascent in interest rates, culminating in a higher peak of up to 4.3 percent in the simulation based on the January 2023 WEO. This proactive approach is aimed at expeditiously steering inflation back to target levels by early 2025 rather than allowing it to plateau. Furthermore, other factors, such as the possibility of a more expansionary fiscal policy, underscore the merits of adopting a robust stance in monetary policy.

Nonetheless, central bankers must grapple with additional sources of uncertainty. Incorporating scenario analysis into policy deliberations, as highlighted by Bordo, Levin, and Levy (2020), is a valuable complement to the conventional focus on the modal outlook. Such scenarios can illustrate risks to the outlook and additional dimensions of model uncertainty. They could also be useful tools to inform monetary policy strategy and communication in periods of high uncertainty. Moreover, the pace of monetary policy transmission remains a crucial factor. For example, depending on agents' discounting behavior, transmission may either strengthen or weaken. Cognitive discounting, as elucidated by Gabaix (2020), potentially diminishes the potency of monetary policy. Strong communication strategy to signal the central bank's preference for a decisive action such as the robust approach could offset some of the impact of cognitive discounting and the degree of backward indexation. Moreover, if the slope of the Phillips curve is very flat, the central banker needs to raise rates a lot to create a large output gap before it can have a meaningful effect on inflation. Under either of these conditions, monetary policy may need to tighten significantly and for a long time if it is to bring inflation back to target, but the opposite could also be true. Although this paper shows simulations for the robust path of monetary policy interest rates which assume that transmission can be stronger than thought, it does not provide an explicit account of that aspect of model uncertainty.[16]

[16] Tillmann (2011), however, reaches a similar conclusion that central banks applying a max-min strategy (i.e., wishing to avoid a worst case) would respond more strongly to inflation than under a baseline model.

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