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Monetary policy frameworks away from the ELB

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Abstract

We evaluate the performance of alternative monetary policy rules during and after the post-pandemic inflation surge. We first document that inflation expectations remained well anchored in advanced economies irrespective of differences in monetary policy frameworks. We then show that an aggressive inflation targeting (IT) rule would have contained the inflation surge very modestly relative to a benchmark average inflation targeting (AIT) rule, at the cost of larger negative output gaps. Finally, looking at the post inflation surge period, we compare monetary policy frameworks with respect to potential changes in the slope of the Phillips curve or changes in the level of r^*. We illustrate that the benefits of a dual mandate relative to a single mandate increase when the Phillips curve is flatter; that AIT rules tend to stabilize inflation and interest rates relative to IT rules but at the cost of higher output volatility; and that AIT is more robust than IT to a possible misperception of r^*.

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1 Introduction

In 2020 and 2021 the Federal Reserve, the ECB and the Bank of Canada completed comprehensive reviews of their monetary policy frameworks. A key motivation underpinning these reviews was the perception that the natural rate of interest had considerably declined driven by structural forces. This had reduced the space for monetary easing and increased the risk that central banks would be constrained by the effective lower bound (ELB) for more frequent and prolonged periods of time. In turn, a frequently binding ELB could have weakened public confidence in central banks' ability to achieve price stability, increasing the risk that inflation expectations would de-anchor. A second important consideration behind the reviews was the perceived flattening of the Phillips curve, reflecting a weaker relationship between economic slack and inflation. This implied that a possible overheating of the labor market would likely have only modest effects on inflation.

As a result of these developments, the frameworks were reviewed to be able to provide the necessary degree of monetary accommodation. The Federal Reserve moved from flexible inflation targeting (IT) to average-inflation-targeting (AIT). The Eurosystem changed the definition of the price stability objective, adopting a symmetric one around 2% and later emphasised the use of "enhanced" forward guidance. The Bank of Canada expressed the intention to tighten monetary policy less aggressively when inflation is above target, as a way to probe whether the economy could be brought even closer to the multi-faceted definition of "full employment".

Soon after their adoption, the newly adopted frameworks were put to a test. Unforeseen and persistent supply shortages emerged globally as a consequence of the Covid-19 pandemic. The expansionary monetary and fiscal policies deployed to mitigate the macroeconomic impact of those shortages, together with the pent-up demand that emerged after the removal of restrictions, paved the way for a quick rise in inflation. By the end of 2021, headline inflation was well above central bank targets in most advanced economies. How did the monetary policy frameworks of advanced economies react to the storm? What lessons can we draw for the future?

One first dimension to test the success of the frameworks is the anchoring of inflation expectations. How large and persistent were their movements after the sequence of large and unforeseen shocks experienced globally? We answer this question by analyzing the anchoring of 3- and 5-year ahead inflation expectations of professional forecasters. We also examine whether the sensitivity of inflation expectations changed before and after the framework reviews. We document a remarkable anchoring during the inflation surge across all the countries we consider, irrespective of the finalisation of a recent monetary framework review.

A second dimension of evaluation is the role played by the frameworks during the post-pandemic inflation surge. We provide a model-based assessment using a medium-scale DSGE model similar to the one commonly employed at the New York Federal Bank for policy analysis. An exercise where we simulate the model under the post-Covid shocks and alternative monetary policy rules shows that a more aggressive IT rule relative to our benchmark AIT rule would have delivered only a marginal reduction in inflation, at the cost of larger output gaps. The inflation spike would have remained largely unchanged also under optimally chosen IT and AIT rules. Yet, those rules would have featured a larger reaction coefficient on the output gap and therefore achieved better stabilisation of real activity.

The third dimension of evaluation of the prevailing monetary policy frameworks that we consider is the extent to which they are fit to face the future challenges. How well would they perform if the Phillips curve turned steeper and the natural rate of interest higher than in the pre-Covid period? Should the next reviews reach different conclusions from those emerged in the 2020-21 round? We narrow our focus by considering the role of the slope of the Phillips curve for the decision to adopt a single or dual mandate and the level of the natural rate for the desirability of an AIT vs IT framework. Using the same DSGE model, we find that a dual mandate can improve welfare relative to a single one, particularly when the Phillips curve is flat. Moreover, the welfare gain is larger under an AIT rule relative to a simple IT rule. Intuitively, when the Phillips curve is flat, reacting aggressively to inflation brings little benefit in terms of inflation stabilization, at the cost of increasing the volatility of the interest rate and the output gap. On the contrary, stabilizing the output gap is beneficial and can be done without large increases in the volatility of inflation. The reason why this mechanism is stronger under an AIT rule is that this latter already stabilizes inflation by targeting its average over time.

We also find that AIT tends to deliver more stable inflation and less volatile interest rates but at the cost of greater output volatility. Differences between AIT and IT tend to shrink under a higher natural rate. Finally, we find that AIT would deliver considerably better macroeconomic outcomes if the central bank temporarily misperceived the correct level of the natural rate. For example, a temporary under-estimation of its level would generate less macroeconomic over-heating under

AIT because agents know that the central bank is committed to compensate temporary inflation over-shootings with subsequent under-shootings, thus keeping an overall tighter monetary stance relative to IT.

The paper proceeds as follows. In section 2, we highlight the key motivations behind the reviews of the monetary policy frameworks completed by some major central banks in 2020-21, and their conclusions. In section 3, we provide an overview of the subsequent period. We compare the timing of the inflation surge across six major advanced economies, the response of monetary policy and the behaviour of inflation expectations of professional forecasters. In section 4, we examine empirically the anchoring of inflation expectations during the period of rising inflation. For countries that undertook a framework review, we additionally analyse possible changes in the extent of anchoring following its announcement. In section 5, we evaluate the performance of alternative frameworks, with a focus on the monetary policy rules, during the post-Covid inflation surge. In section 6, we discuss the desirability of a single or dual mandate, depending on the slope of the Phillips curve. We also evaluate the welfare properties of AIT or IT frameworks depending on the level of the natural rate, as well as in case of misperceptions of the level of the natural rate of interest. We conclude in section 7.

2 The 2020/21 reviews of the monetary policy frameworks

The reviews of the monetary policy frameworks completed in 2020-21 by the Federal Reserve, the ECB and the Bank of Canada shared common concerns. First, prevailing estimates suggested that the natural interest rate had declined considerably. Several non exclusive forces, including secular stagnation, ageing, the demand for safe assets and hysteresis in easy monetary conditions were considered as potential culprit for this decline. Second, evidence of a weaker relationship between economic slack and inflation implied that overheating of the labor market would trigger only modest increases in inflation.

To address the challenges posed by the ELB, the Fed and the ECB revised their monetary policy frameworks to signal their determination to provide strong and persistent monetary stimulus when close or at the ELB. The Fed adopted a flexible average inflation targeting framework, trying to achieve a 2 percent average inflation rate over time. Therefore, after periods of inflation running below 2 percent—for example, during an ELB period—monetary policy would try to lift inflation moderately above 2 percent for some time. This approach was meant to strengthen the anchoring of long-term inflation expectations at 2 percent and signal the central bank's intention to sustain monetary accommodation for some time after the exit from the ELB. In turn, the expectation of more sustained accommodation would have lowered real ex-ante interest rates, stimulated aggregate demand and favored a faster exit from the ELB.

The ECB revised its framework by adopting a symmetric inflation target at 2 percent, departing from the previous goal of aiming for a rate of inflation "below, but close, to 2 percent". This change underscored the ECB's determination to lean against an undershooting of the inflation target. Furthermore, the ECB expressively recognized that "forceful and persistent monetary policy measures" to move the economy away from the ELB could "imply a transitory period in which inflation is moderately above target" (European Central Bank, 2021).

Turning to the implications of a flatter Phillips curve, the Fed adopted a more tolerant approach vis-à-vis a strengthening of the labor market. Specifically, the Fed indicated that policy decisions would be informed by the assessment of "shortfalls" of employment from its maximum level and no longer by the assessment of "deviations" from the maximum level. This change may appear subtle but it had tangible effects, allowing the Fed not to tighten monetary policy even if labor market conditions were particularly strong, provided that inflation remained in line with the target.

The review of the flexible inflation targeting framework conducted by the Bank of Canada (BoC) also underscored the challenges posed by a flatter Phillips curve. In particular, the BoC highlighted that inflation approaching 2 percent could no longer be taken as a clear indication that the economy had reached the maximum sustainable employment level. Therefore, the BoC emphasized that it would consider a broad range of labour market and inflation indicators to assess the maximum sustainable employment level. Furthermore, the BoC declared its intention to tighten monetary policy less aggressively when inflation rises towards the 2 percent target in order to probe whether full employment could be higher than assessed. Yet, the Canadian government refrained from assigning a dual mandate to the Bank of Canada because it was expected it would have only a modest impact on employment outcomes while complicating communication and possibly exposing the central bank to greater political pressure.

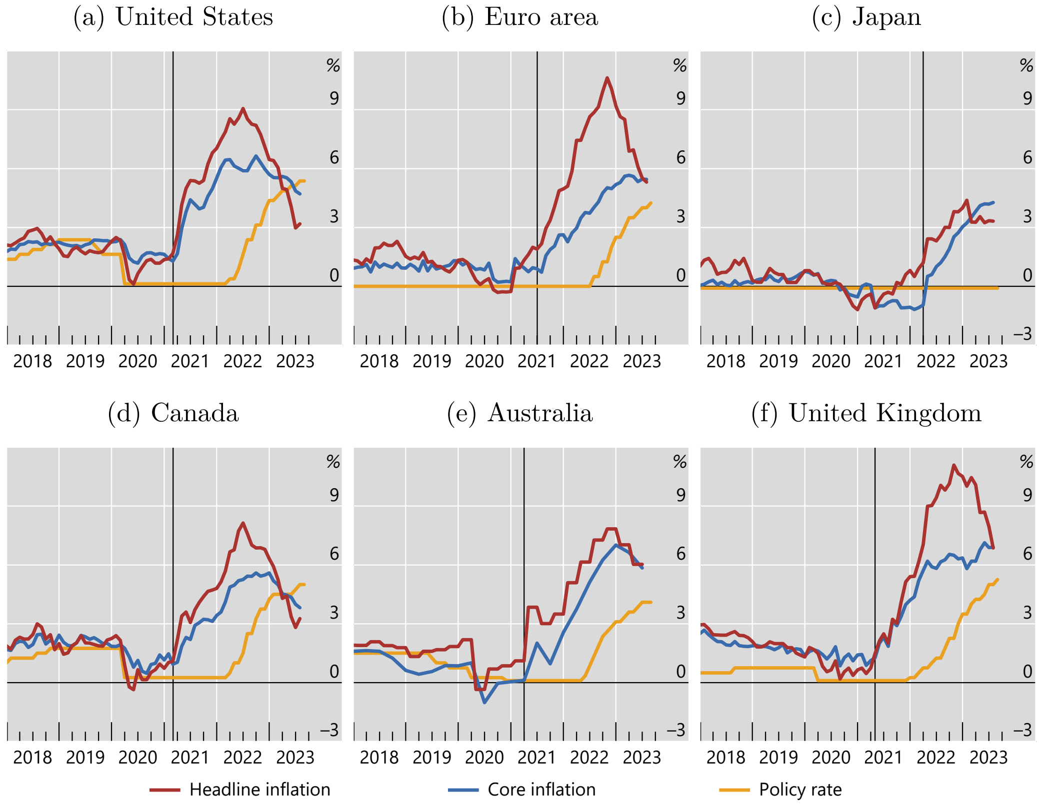
The 2020/21 framework reviews by the Fed, ECB and BoC addressed several other topics, among which the measurement of inflation, the role of financial stability in the conduct of monetary policy, the implications of climate change for central banks, etc. For a comprehensive overview of these issues, we refer the reader to the new monetary framework statements issued by each central bank (Federal Reserve, 2020; European Central Bank, 2021; Bank of Canada, 2021). The BoJ also completed a monetary policy review in 2021 but focused on adjusting the unconventional monetary tools used under the Quantitative and Qualitative Monetary Easing based on a reassessment of their impact on the economy and the financial system.

3 From the framework reviews to the inflation surge

By the end of 2021, when the reviews of Fed, ECB and BoC had been announced, headline inflation was already well above central bank targets in most advanced economies. In February 2022, the Russian invasion of Ukraine increased energy and food prices, further heightening the inflationary pressures.

As shown in Figure A1, the starting point of the inflation surge was surprisingly similar across the six major advanced economies we consider, namely Australia, Canada, the Euro area, Japan, the UK, and the United States. Except for Japan, headline inflation (the red line) crossed 2% around 2021Q2. The vertical black lines denote the month in which headline inflation reached the 2% threshold. Core inflation (the blue line) also started rising around that time. The largest increase in headline inflation, and discrepancy relative to core inflation, was experienced by the net energy importers, in particular the UK and the euro area. In all countries, the policy rate lift-off occurred well after the moment when headline exceeded the inflation target.

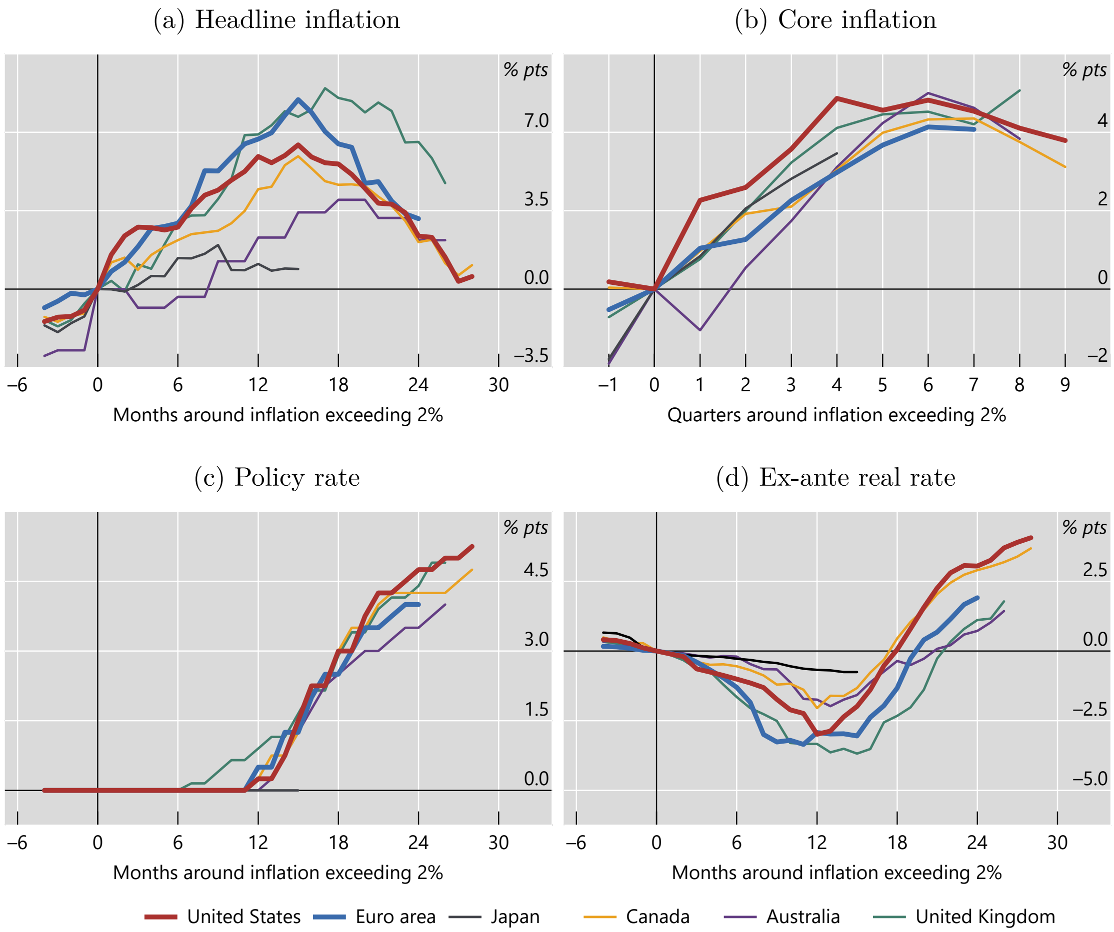
Figure 1: **Inflation and interest rates**



NOTE: Black vertical line: month in which inflation exceeded 2%. Red line: headline inflation. Blue line: core inflation. Yellow line: for United States, mid-point of the Federal Reserve target rate; for euro area, ECB main refinancing rate; for Japan, base rate; for Canada, target for the overnight rate defined as the midpoint of the band, or 25 basis points below the Bank Rate; for Australia, cash rate target; for United Kingdom, official bank rate.

Figure 2 illustrates the dynamics of headline and core inflation around the months when domestic inflation exceeded 2%. The peak level and time profile of headline inflation differed considerably across countries, one main reason being the heterogeneous exposure to the increase in commodity prices. The evolution of core inflation was instead remarkably similar across countries. The tightening of policy rates was also highly synchronised, with interest rates being lifted-off around 12 months after inflation exceeded 2% and the rates reaching above 4% after six quarters. The (ex-ante) real interest rates remained negative for at least four quarters in all countries, before returning to positive levels. The US, the UK and the euro area experienced the largest decline in real rates.

Figure 2: **Inflation and interest rate dynamics across countries**

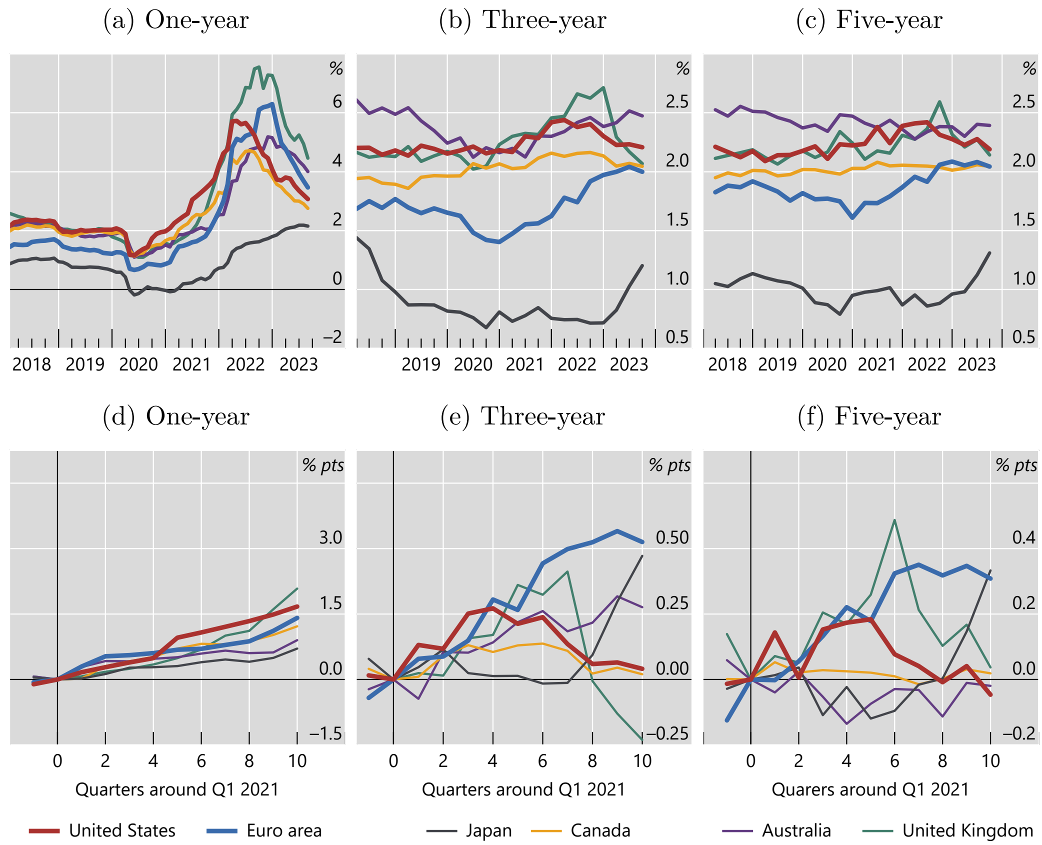


NOTE: x-axis: months around headline inflation exceeding 2%, at which point the level of each variable is normalized to zero.

4 Framework reviews and the anchoring of inflation expectations

Key indicators for testing the resilience of MPFs at times of quickly rising inflation are measures of inflation expectations at various horizons. As shown in Figure 3, Consensus forecasts of short-term inflation expectations followed closely headline inflation. However, medium-term (3-years ahead) and long-term (5 years ahead) inflation expectations remained broadly stable. Medium- and long-term expectations increase more strongly in Japan and the euro area, but this rise helped lift and re-anchor expectations closer to the inflation target.

Figure 3: **Inflation expectations during the inflation surge**



NOTE: The boom panels show the evolution of variables since 2021Q2. Each variable is normalized to zero at that time. SOURCES: Consensus Economics; authors' calculations.

To examine in greater detail the degree of anchoring of inflation expectations, we examine their sensitivity to inflation developments. To this end, we estimate the following equation

$$\pi_t^E = \alpha + \beta \pi_t + \epsilon_t \tag{1}$$

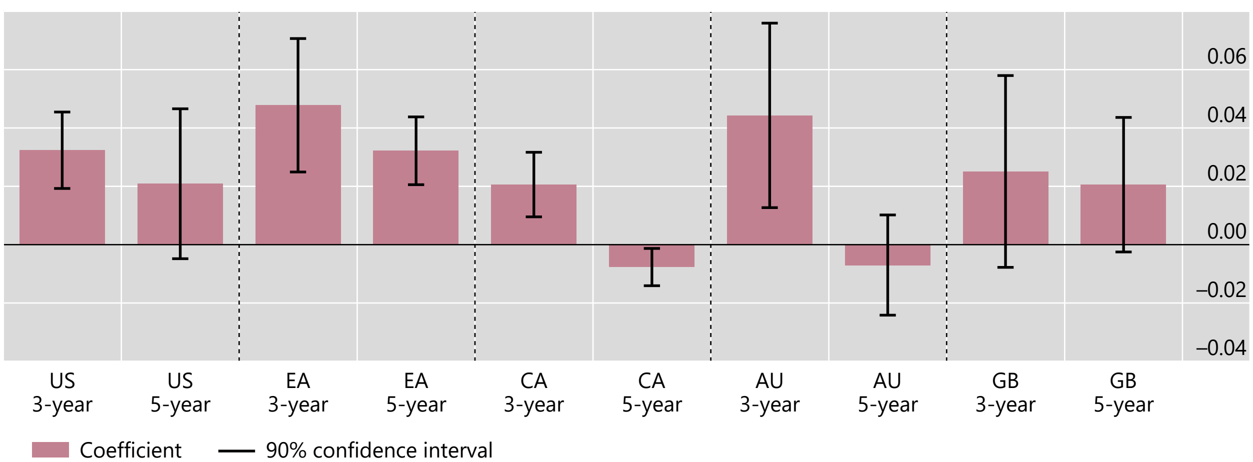
where π_t^E captures inflation expectations at either 3 or 5 year horizons and π_t is the realized inflation rate. The equation is estimated during the post-pandemic inflation surge period, specifically after headline inflation increased above 2 percent in each individual country and until July 2023. The analysis includes countries that revised their monetary policy frameworks in 2020 and 2021 with a tendency to provide greater monetary accommodation against the ELB (US, Euro Area, Canada), as well as Australia and the United Kingdom which did not undertake reviews in those years.[1].

[1]We exclude Japan given the short time-series sample since headline inflation has reached 2%

We focus on the inflation expectations of professional forecasters, collected by Consensus Forecasts. Expectations of professional forecasters tend to track well financial market expectations (Cieslak, 2018), while they can single out the pure component of inflation expectations. On the contrary, market expectations derived from financial prices compound inflation expectations with risk and liquidity premia. The regression is estimated using quarterly or semi-annual data depending on the availability of the inflation expectations provided by Consensus Forecast. Appendix A describes the data sources in greater detail and reports the regression tables.

Figure 4 illustrates the estimates of the regression coefficient β for 3 and 5 year ahead inflation expectations. The coefficient estimates are modest across all countries, ranging bewteen 0.02 and 0.04. Hence, a 1 percent increase in inflation tended to lift medium- and long-term inflation expectations by only 2 to 4 basis points. This underscores the strong anchoring of inflation expectations during the post-pandemic surge. Furthermore, point estimates are generally not statistically different from zero, especially at the 5-year horizon. The only exception is provided by the Euro Area, where we detect a somewhat stronger sensitivity of inflation expectations to inflation (with point estimates ranging between 0.03 and of 0.05), although still quite moderate.

Figure 4: Sensitivity of long-term inflation expectations to current inflation

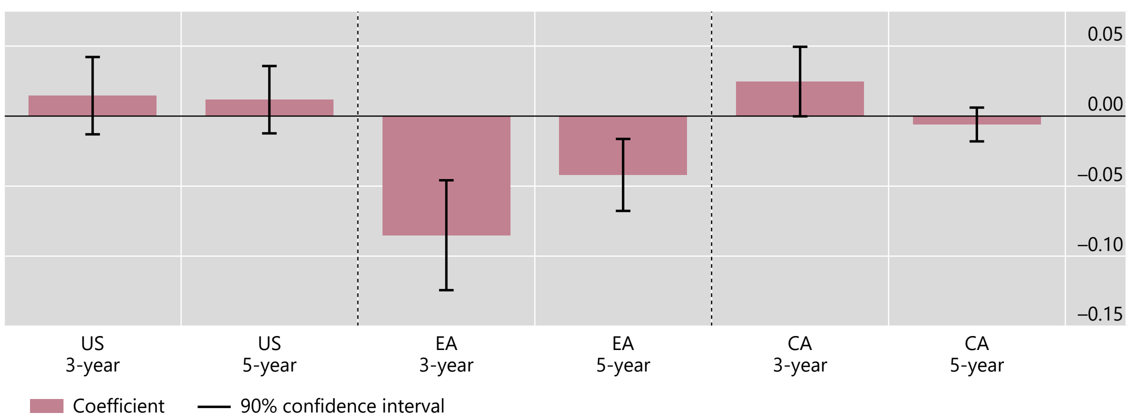


To what extent could the relatively stronger sensitivity of inflation expectations to inflation developments in the Euro Area be related to the 2021 framework review? To shed some light on this issue, we examine whether the sensitivity of inflation expectations to inflation changed in the periods before and after the framework reviews. We do so by estimating the following regression for the countries that undertook framework reviews in 2020/21 (United States, Euro Area, Canada)

$$\pi_t^E = \alpha + (\beta + \gamma * T_R)\,\pi_t + \epsilon_t, \tag{2}$$

where T_R is a dummy variable taking value 1 after each country's review. The estimation period ranges from 2003 to 2023. Figure 5 shows the regression coefficient γ which captures the change in the sensitivity of inflation expectations to inflation following the framework review. We don't detect statistically significant changes in the anchoring of inflation expectations for the US and Canada. In the case of the Euro Area, we find instead that the framework review was followed by a decline in the sensitivity of inflation expectations to inflation, with estimates for γ ranging between -0.04 and -0.08. Therefore, the framework review in the Euro Area seems to have contributed, if anything, to a stronger anchoring of inflation expectations. In line with this interpretation, panel C in Figure 3 shows that medium- and long-term inflation expectations in the Euro Are have trended up toward the 2% target in the post framework review period.

Figure 5: Changes in the anchoring of inflation expectations around MPF reviews



These results should be interpreted with caution given the very short time sample after the 2020/2021 reviews. Yet, they underscore a remarkable anchoring of inflation expectations across all countries, irrespective of their particular monetary policy frameworks. Furthermore, they also suggest that the 2020/21 framework reviews undertaken to provide greater monetary accommodation against the ELB did not compromise the anchoring of inflation expectations during the subsequent inflation surge.

5 The role of monetary policy rules during the inflationary episode

Another dimension to evaluate the revised monetary policy frameworks is the role they played for the inflation path during the post-pandemic inflation surge. Would a different rule (eg AIT, IT or forward guidance) have had material implications for the inflation surge and for the speed of convergence back to target? We address this question through the lenses of a medium-scale DSGE model similar to the one commonly used at the New York Fed for policy analysis.[2]

5.1 Methodology: estimation and simulations using the New York Fed model

The framework is a rational expectations, representative agent, one-sector, closed-economy growth model. It is enriched by nominal price and wage rigidities, financial frictions, variable capital utilization, adjustment costs in investment and habit formation in consumption. The public sector includes a fiscal authority that sets spending and raises lump-sum taxes, and a central bank that follows a Taylor rule of the form

$$R_t = \rho_R R_{t-1} + (1-\rho_R)\left(\phi_\pi\left(\pi_t - \pi_t^*\right) + \phi_y\left(y_t - y_t^f\right)\right) + \sigma_r \epsilon_{r,t}, \tag{3}$$

where R_t is the policy rate at time t, π_t is the inflation rate, π_t^* is the inflation target of the central bank, $y_t - y_t^f$ is the output gap measured in deviations from the flexible equilibrium level of output, and $\epsilon_{r,t}$ is a monetary policy shock. The parameters ϕ_π and ϕ_y denote the strength of reaction of the policy rate to the deviation of inflation from target and to the output gap. The parameter ρ_r governs the persistence of the policy rate and σ_r is the standard deviation of the monetary policy shock.

The model is estimated on US data over the sample 1984Q1 to 2019Q4, a period when the Federal Reserve had adopted a *de facto* flexible inflation targeting (IT) policy and was given a dual mandate to stabilize both inflation and real activity.[3] The estimated parameters of the rule are $\rho_R = 0.90$, $\phi_\pi = 1.58$ and $\phi_=0.19$. With the estimated parameters in hand, we use the Kalman smoother to recover the structural shocks implied by the model to explain economic outcomes over

[2] Details of the framework are provided in (Del Negro, Eusepi, Giannoni, Sbordone, Tambalotti, Hasegawa, and Linder, 2013; Cai, Del Negro, Herbst, Matlin, Sarfati, and Schorfeide, 2021). The model we use marginally deviates from those described there in that we allow for a share of hand-to-mouth households.

[3] An explanation of the estimation methodology and a table with the estimated parameters and shocks is provided in appendix B.

the period 2020Q1 - 2023Q3.[4]

When doing so, we need to account for the change in the Federal Reserve's monetary policy framework in August 2020, which led to the adoption of average inflation targeting (AIT). We use the approach described in Kulish and Pagan (2017). Specifically, we assume that from the start of the estimation sample until 2020Q2, the Federal Reserve followed a monetary policy reaction function of the form described in equation (3) above. In 2020Q3, we impose an unanticipated and permanent structural change in the monetary policy reaction function as the Federal Reserve adopted an AIT rule of the form:

$$R_t = \rho_R R_{t-1} + (1 - \rho_R) \left[\psi_\pi (1 - \rho_\pi) \widetilde{\pi}_t + \psi_y (y_t - y_t^*) \right] + \sigma_r \varepsilon_{r,t} \tag{4}$$

where $\widetilde{\pi}_t$ is the discounted sum of past deviations between inflation and the inflation target, computed as:

$$\widetilde{\pi}_t = (\pi_t - \pi^*) + \rho_\pi \widetilde{\pi}_{t-1} \tag{5}$$

The discount rate ρ_π controls the window over which the "average" inflation deviation is calculated. We set $\rho_\pi = 0.93$, which corresponds to a half life of 10 quarters. We set the parameters to $\rho_R = 0.85$, $\psi_\pi = 4$ and $\psi_y = 0.25$.[5]

5.2 Monetary policy rules and the inflation surge

Could a more aggressive IT rule than the prevailing one have prevented or limited the post-pandemic inflation surge? Could it have accelerated the return to target? Alternatively, how would a continuation of the previous accommodative monetary policy stance have performed? We consider three rules to characterise alternative possible monetary policies of the Federal Reserve in the period 2019Q4-2023Q3.

The first is the AIT rule described in equation (4). Since this is the rule used to extract the shocks using the Kalman filter, it also replicates the observed data for inflation and output growth. The second rule is an "aggressive" inflation targeting rule, which takes the form of equation (3), with the coefficients set at $\rho_R = 0.85$, $\phi_\pi = 10$ and $\phi_y = 1.25$. The third is an accommodative policy

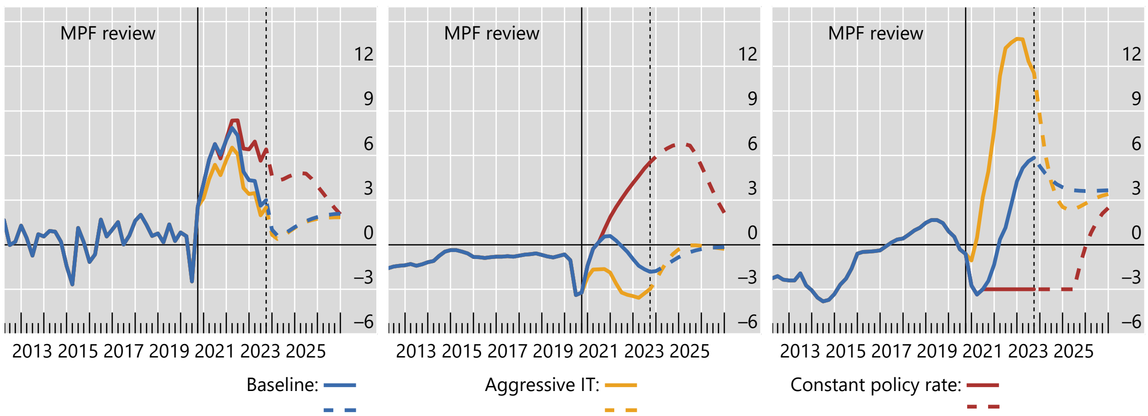
[4] A variance decomposition showing the contribution of the recovered structural shocks to the dynamics of headline inflation is reported in figure A1 of appendix B. The model largely attributes the observed inflation dynamics to supply shocks, namely price and wage markup shocks, investment shocks and productivity shocks.

[5] The calibration of ρ_π, ψ_π and ψ_y matches that used in the latest version of the FRBNY DSGE model.

that provides forward guidance on future policy rates. In particular, it fixes the Federal Funds rate to the ELB until 2025Q2 before returning to a standard IT rule with coefficients equal to the values estimated over the period up to 2019Q2.

Figure 6: Alternative monetary policy rules during the inflation surge

(a) Inflation (annualised) (b) Output gap (c) Federal funds rate



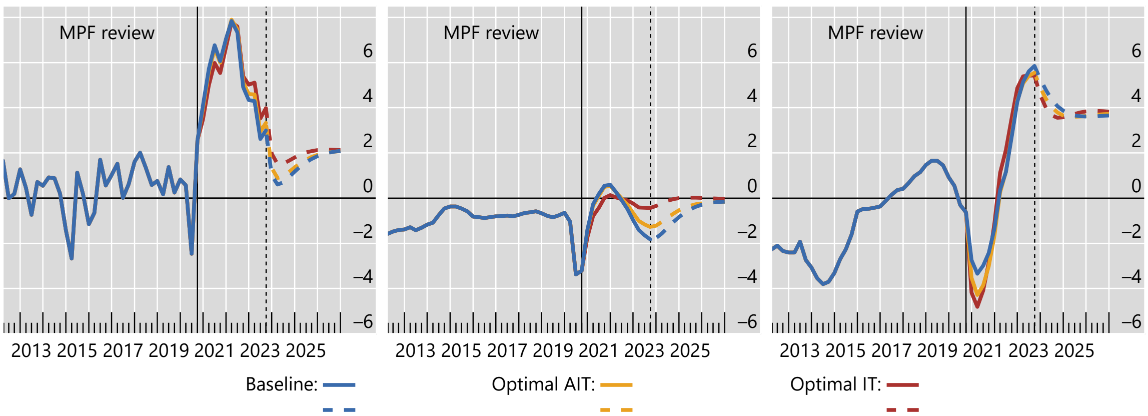
NOTE: Estimation of the counterfactuals is based on the DSGE model developed in Del Negro et a. (2013). The solid vertical line denotes the time of MPF review of the Federal Reserve. The dashed vertical line denotes the date of the latest available data point. The blue line is based on the estimated IT rule up to the MPF review and then on an AIT rule with $\rho_R = 0.85$, $\psi_\pi = 4$ and $\psi_y = 0.75$. The yellow line (Aggressive IT) is based on an IT rule with $\rho_R = 0.85$, $\phi_\pi = 10$ and $\phi_y = 1.25$. The red line corresponds to a forward guidance policy that fixes the rates to the ELB until of 2025Q2 before returning to a standard IT rule with coefficients equal to the values estimated over the period up to 2019Q4.

Figure 6 shows that none of the three policy rules we consider would have prevented the combination of shocks hitting the economy from abruptly increasing inflation. Comparing the baseline scenario in which the central bank follows the AIT rule after the MPF review (blue line) to a scenario in which policy is tightened according to a more aggressive IT rule (yellow line) shows only a marginal decline in the peak of inflation (of around 1.5% at the peak) but a substantial additional contraction of the output gap (of around 2%). At the same time, if the policy rule does not tighten at all in reaction to the inflation surge (red line), this results in a much stronger increase of inflation which later also fails to revert towards target. These results highlight the importance of a sound framework that credibly commits to bring inflation back to target even in the face of large shocks.

To show that the observed increase in inflation was not due to a sub-optimal choice of the coefficients in the rules, we compare the outcome under the baseline AIT policy with the outcome

Figure 7: Alternative optimized monetary policy rules during the inflation surge

(a) Inflation (annualised) (b) Output gap (c) Federal funds rate



NOTE: The solid vertical line denotes the time of MPF review of the Federal Reserve. The dashed vertical line denotes the date of the latest available data point. The blue line is based on the estimated IT rule up to the MPF review and then on an AIT rule with $\rho_R = 0.85$, $\psi_\pi = 4$ and $\psi_y = 0.75$. The yellow line (Optimal AIT) is based on an optimized AIT rule with $\rho_R = 0.85$, $\psi_p = 4.7$ and $\psi_y = 1.5$, and the red line (Optimal IT) on an optimized IT rule with $\rho_R = 0.85$, $\phi_\pi = 1.01$ and $\phi_y = 3.0$.

under optimized IT and AIT policies. In these rules, the coefficients are chosen to minimize the welfare loss, defined as the discounted stream of future period-by-period losses. The time-t loss function takes an ad-hoc functional form that penalizes deviations of inflation from target and deviations of output from its flexible equilibrium level with the same weight, while it penalizes deviations of the interest rate from its flexible equilibrium level with half that weight:

$$L_t = (\pi_t - \pi_t^*)^2 + \left(y_t - y_t^f\right)^2 + 0.5\left(R_t - R_t^f\right)^2. \tag{6}$$

Figure 7 shows that the inflation spike would have largely remained unchanged under optimally chosen IT and AIT rules (left panel). Yet, those rules would both have chosen a larger reaction coefficient on the output gap, therefore achieving better stabilisation of real activity (middle panel).

6 Looking ahead: monetary rules after the inflation surge

Next we compare different monetary rules in a hypothetical post-inflation surge stochastic steady steady. Our analysis reflects the current uncertainty about the slope of the Phillips curve and the level of the natural rate of interest.

We first consider the benefits of a dual versus a single mandate, depending on the slope of the

Phillips curve. We then examine the relative benefits of AIT versus IT, depending on the level of the natural rate r*. Finally, we examine the robustness of AIT and IT to misperceptions about the level of r*. We do so through the lenses of the model presented in section 5.

6.1 Dual versus single mandate

A key motivation of the MPF reviews, particularly at the Fed and BoC, was the weakening of the relationship between economic slack and inflation observed over the last decades, often referred to as the flattening of the Phillips curve. This feature of the economy can contribute to slow down the transmission of monetary policy to inflation through real activity. In turn, periods of inflation levels persistently below the inflation target may be conducive to a de-anchoring of inflation expectations, raising questions about the appropriate response of monetary policy to inflation and output developments. Recent research, however, has pointed to strong non-linearities in the Phillips curve and provided suggestive evidence for a marked steepening during the post-Covid period (Cerrato and Gitti, 2022) and (Benigno and Eggerston, 2023).

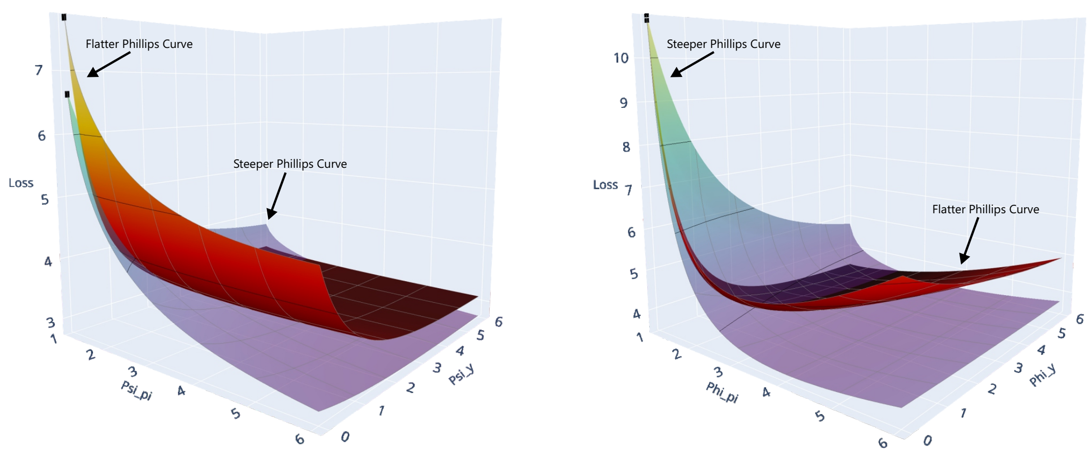
We use the model presented in section 5 to compute the welfare loss under alternative monetary policy rules, for different slopes of the Phillips curve. The estimated model parameters (see table A3) include a Calvo price parameter of 0.87 (consistent with those estimated in (Del Negro, Eusepi, Giannoni, Sbordone, Tambalotti, Hasegawa, and Linder, 2013) and (Del Negro, Giannoni, and Schorfeide, 2014)), implying a remarkably flat Phillip curve. We simulate the model under the IT rule given by (3) and the AIT rule given by (4). For each rule, we set grids for the two parameters, ie $\{\phi_\pi, \phi_y\}$ for the IT rule, and $\{\psi_\pi, \psi_y\}$ for the AIT rule. For each combination of points in the grids, we simulate the model after drawing from the shock distribution a large number of times. The simulation results are then used to compute the time-t welfare loss, defined according to equation (6).

Figure 8 shows the surfaces of the welfare measure we consider—the average loss across all simulation periods—on the space of the reaction coefficients. Panel (a) reports the losses for AIT and panel (b) for IT. Within each panel, the red surface denotes the losses arising under the estimated Phillips curve and the purple one the losses when the curve is steep (corresponding to a Calvo parameter of 0.6).

Consider first panel (a) and the loss arising under the AIT rule when the Phillips curve is flat (red surface). In particular, start at the black dot where $\psi_\pi = 1.2$ and $\psi_y = 0$. Increasing

Figure 8: Loss surfaces under alternative monetary policy rules

(a) Average inflation targeting | (b) Inflation targeting



NOTE: Panel (a) shows the loss arising for each combination of parameters under the AIT rule. Panel (b) does the same under the IT rule. In both panels, the red surface corresponds to the scenario when the estimated Phillips curve is flat (ie Calvo parameters are $\theta_p = 0.87$ and $\theta_w = 0.77$). The purple surface corresponds to a scenario with average inflation targeting and steeper Phillips Curve (ie Calvo parameters are $\theta_p = \theta_w = 0.6$). The black dots indicate the loss in correspondence of $\psi_\pi = 1.2$ and $\psi_y = 0$.

the response to inflation generates some initial reduction in the welfare loss, up to values of ψ_π of around 2, while additional gains from further increasing the reaction to inflation are modest. Similarly, aggressive reactions to the output gap, ie moving ψ_y from low to high values, produces material reductions in the welfare loss, particularly at low values of ψ_y. On the contrary, moving from the black dot on the surface corresponding to a steep Phillips curve (purple surface) produces different welfare losses. Now, for all the coefficients considered, limited gains arise from increasing the reaction to output ψ_y, while increasing ψ_π markedly reduces the losses. Intuitively, when the Phillips curve is flat, reacting very aggressively to inflation brings little benefit in terms of inflation stabilization, at the cost of increasing the volatility of the interest rates and the output gap. Some degree of stabilization of the output gap is beneficial as it can be done without large increases in the volatility of inflation.

Similar results arise when comparing the case of flat or steep Phillips curve under an IT rule. However, under IT, when the Phillips curve is flat (red surface), there are more limited gains from increasing the reaction to the output gap if the rule responds to inflation with sufficient strength. Intuitively, the IT rule stabilizes inflation less than the AIT (for given coefficients), imposing lower volatility of the output gap under markup shocks.

Our results suggest that a dual mandate can improve welfare but the welfare gains are larger under an AIT rule, and when the Phillips curve is flat. These findings are in line with previous analysis by (Debortoli, Kim, Linde', and Nunes, 2018), where welfare is found to increase with a large weight on measures of resource utilisation in the loss function. In that model, the high weight stems from the combination of various model characteristics, including a low elasticity of substitution between monopolistic goods, price indexation, and a small interest rate elasticity of demand. Our results highlight the role of the slope of the Phillips curve for the welfare gains arising from a more aggressive reaction to the output gap. They also show that the gains are larger under AIT than under IT.

6.2 AIT vs IT depending on r*

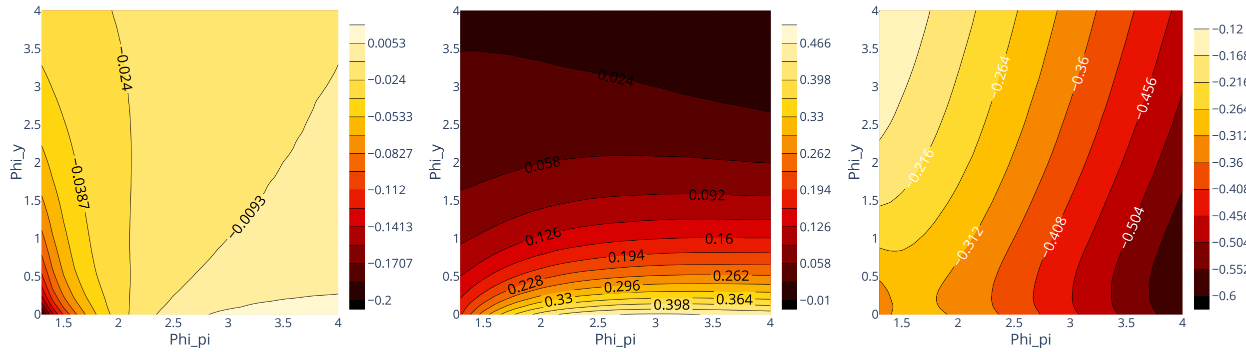
We compare next the performance of AIT and IT policy rules under different levels of r*. In principle, many factors can determine variations in r*, among which for example changes in productivity growth and intertemporal discount factors. In the context of our exercise, we are interested in isolating the effect of changes in r* on the monetary policy space to provide accommodation. Therefore, we implement changes in r* by simply altering the level of the ELB in the model simulations. Specifically, a higher level of r* implies a lower level of the ELB, hence allowing more space for monetary stimulus.

We first consider an environment with a low r*, equal to 0.5 percent. Figure 9 shows differences in volatility outcomes under an AIT rule relative to an IT rule for different combinations of the parameters governing the interest rate response to inflation ψ_π and the output gap ψ_y. The left chart shows that AIT reduces the volatility of inflation relative to IT across the entire parameter space. This is because an AIT rule is able to reduce the incidence and persistence of ELB periods. The AIT rule also leads to lower interest rate volatility, as illustrated in the right chart since the central bank adjusts rates more gradually based on the average (rather than current) inflation rate. However, the benefits of AIT in terms of lower volatility of inflation and policy rates must be traded off against an increase in the volatility of the output gap. An AIT rule prevents indeed the central bank from looking through temporary supply-driven shocks to inflation, forcing more persistent movements in the output gap to ensure that average inflation returns to the target level.

Figure 10 replicates the analysis under a higher level of r*, equal to 2 percent. By providing greater space for monetary accommodation and thus making the ELB less binding, a higher r*

Figure 9: Differences in volatilities between AIT and IT under low r*

(a) Inflation (b) Output gap (c) Policy rate

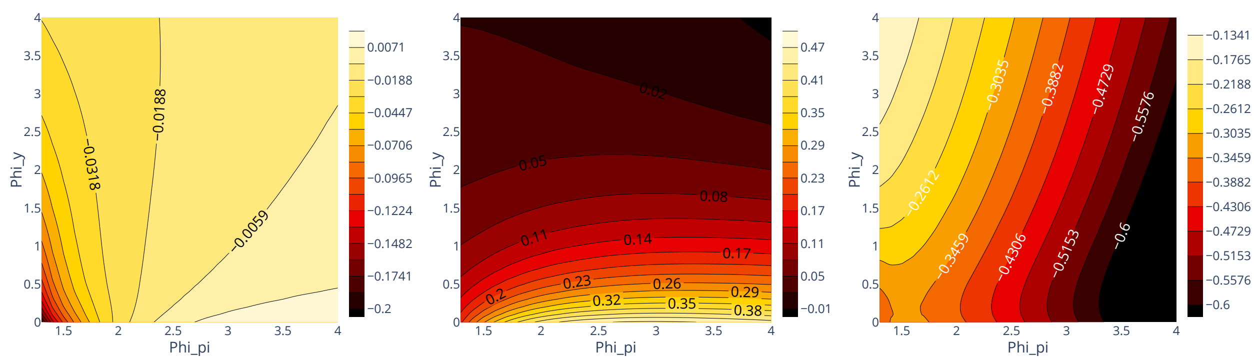


Note: The three panels show the difference in volatilities of each variables under the AIT and the IT rule when $r^* = 0.5\%$. Panel (a) shows differences in inflation volatilities, panel (b) differences in volatilities of the output gap, and panel (c) differences in volatilities of the policy rate. Negative (positive) values denote a lower (higher) volatility of a given variable under the AIT rule relative to the IT rule.

dampens the differences in the volatility of inflation and the output gap between the AIT and IT rules. However, an AIT framework continues to deliver a similar reduction in the volatility of interest rates.

Figure 10: Differences in volatilities between AIT and IT under high r*

(a) Inflation (b) Output gap (c) Policy rate



Note: The three panels show the difference in volatilities of each variables under the AIT and the IT rule when $r^* = 2\%$. Panel (a) shows differences in inflation volatilities, panel (b) differences in volatilities of the output gap, and panel (c) differences in volatilities of the policy rate. Negative (positive) values denote a lower (higher) volatility of a given variable under the AIT rule relative to the IT rule.

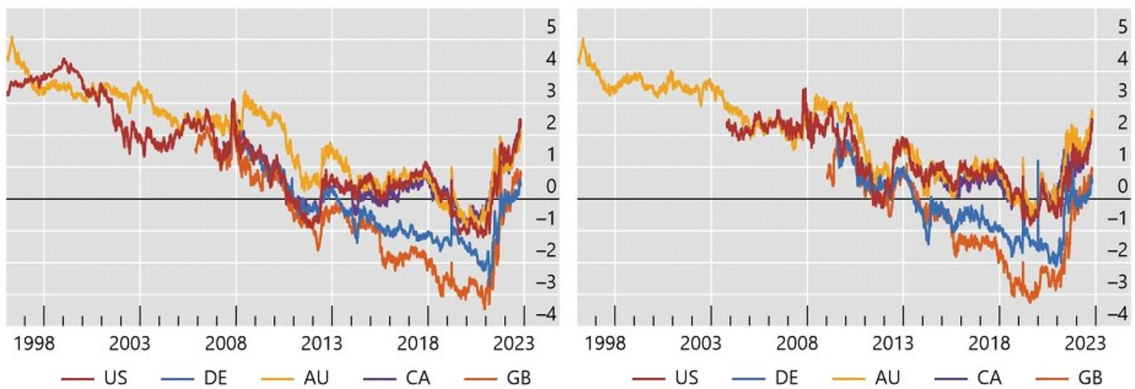
6.3 Robustness to misperceptions about r*

In the previous section, we examined the performance of AIT and IT rules under different levels of r^*. In doing so, we assumed that the central bank had perfect knowledge about the exact value of r^*. However, r^* is proverbially difficult to measure, with different modelling tools often providing substantially different estimates. Uncertainty about the level of r^* is particularly pronounced at this time. Before the COVID-19 pandemic, there was growing consensus that r^* had trended down for several decades, reaching historic lows. This decline was generally interpreted as reflecting structural forces, among which lower productivity growth, aging population and the shortage of safe assets and the better hedging property of bonds in business cycles where risks of deflation are more prevalent than risks of stagflation (see (Marx, Mojon, and Velde, 2021) and references therein). Most of these forces still prevail after Covid. Low levels of interest rates may also reflect the activism of monetary policy in the aftermath of the GVC. In particular large asset holdings by the central banks following Quantitative Easing following the GFC and Covid may also have kept risk premia below their historical average.

The sharp rise in long-term real interest rates during the last two years raise the question whether r^* might be substantially higher than previously considered. Figure 11a shows that real yields on 10-year bonds have increased since the end of 2021 by several percentage points. This increase partly reflects the unwinding of Quantitative Easing and central banks' determination to keep rates high for as long as needed to bring inflation back to target levels. But even if we focus on 5y5y forward rates—which are less influenced by current monetary policy decisions—we still see a considerable increase in real rates (Figure 11b). Term structure models suggest that only part of this increase is due to rising term premia. Hence, financial markets seem to expect that short-term real rates will be higher in the future, consistent with an increase in r^*.

Figure 11: Real yields on long-term bonds

(a) 10-year yields (b) 5-year/5-year forward rates



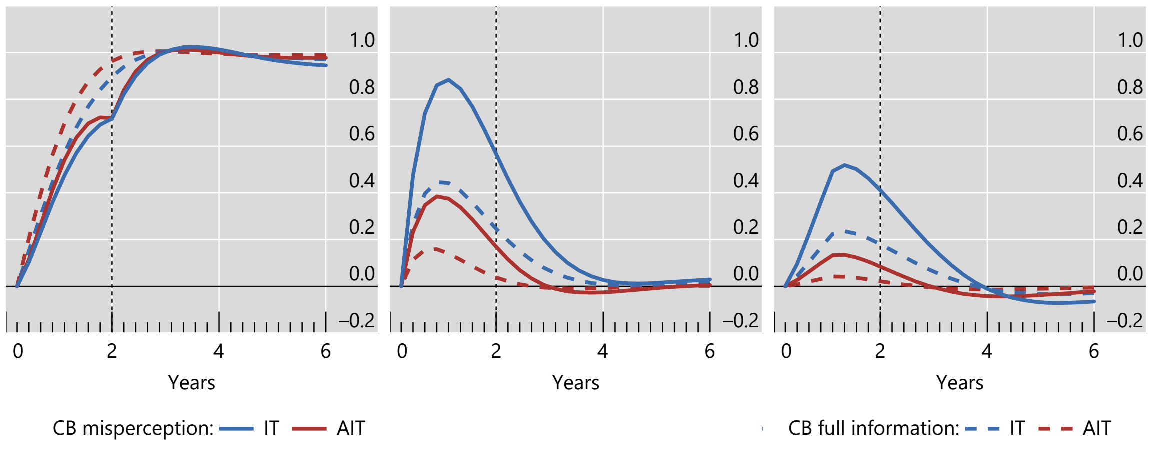
NOTE: Sources: Bloomberg; Refinitiv; BIS.

The uncertainty surrounding the level of r^* raises the important question of which policy rule between AIT and IT is more robust to a misperception of r^*. To shed light on this issue, we consider the following exercise. Starting from the steady-state equilibrium of the model, we assume that r^* increases by 1 percent. We compare the performance of AIT and IT rules under two scenarios which are illustrated in Figure 12. In the "full information" scenario (red lines), the central bank promptly recognizes that r^* has increased and responds by raising the policy rate. The increase in rates is gradual because of the inertial component of the Taylor rule. This leads to a modest over-heating of the economy, with the output gap turning positive and inflation increasing above target. The AIT rule performs relatively better than the IT rule. By committing the central bank to match the inflation overshooting with a future undershooting to keep average inflation at target, the AIT rule implies an overall tighter monetary stance that deters private consumption.

What if the central bank does not promptly recognize the increase in r^*? The "misperception" scenario assumes that the central bank realizes that r^* has increased only with a 2 year delay.[6] In this case, the central bank still increases policy rates when r^* rises since it responds to the signs of economic over-heating. However, the monetary tightening is more gradual than under the "full

[6]Note that agents in model promptly recognize that r^* has increased, for example reflecting a change in their intertemporal discount factor. Furthermore, they know that the central bank will realize that r^* has increased only after a two year delay, thus expecting a temporary over-heating of the economy which boosts their consumption demand. Alternatively, we could assume that agents believe at each point in time that the central bank will recognize the increase in r^* in the following quarter and thus adjustment the monetary policy stance. This would imply considerably less over-heating.

Figure 12: Robustness of AIT and IT rules to misperceptions of r*



NOTE: The panels show the dynamics of the Fed Funds rate, the output gap, and inflation triggered by a 1% increase in r*. All variables are in deviations from their initial steady state. The "CB full information" scenario assumes that the central bank promptly recognizes that r* has increased. The "CB misperception" scenario assume that the central bank recognizes that r* has increased with a 2 year delay.

information" case since the central bank is unaware of the increase in r^* and thus believe its stance to be already sufficiently tight. This leads to a considerably stronger over-heating relative to the "full information" scenario, especially under the IT rule. Output increases 0.8 percent above potential and inflation rises 0.4 percentage points above target. The extent of over-heating is more modest under the AIT rule. For example, inflation exceeds target by less than 0.2 percentage points. Note that this is the case despite the fact that the AIT rule implies a more gradual increase in interest rates compared to the IT rule. The reason is that under AIT the central bank is committed to keep interest rates higher for longer to compensate a temporary inflation over-shooting with a future under-shooting.

These results suggest that an AIT rule is more robust to possible misperceptions of r^* by the central bank relative to an IT rule. In interpreting these results, it is critical to consider that the model uses a symmetric AIT rule, whereby the central bank is committed to bring inflation below target after a temporary over-shooting and vice versa. If the AIT rule was asymmetric—aiming only at compensating periods of inflation under-shooting with above target inflation—an underestimation of r^* by the central bank may imply much stronger over-heating, possibly beyond the levels under an IT rule.

Finally, aside from the comparison of monetary policy frameworks, it is important to stress that the magnitude of the inflationary effects of a large and persistent underestimation of r^* by the central bank appear small. It is about 0.5 percentage points at the peak. Hence it cannot account for the large inflation spike we witnessed over the last two years. Two caveats are in order, however. While this policy error would imply a larger excess inflation should the slope of the Philips curve be larger, it is also likely that the central bank would also tighten its policy stance sooner to this extra inflation.

7 Conclusions

In this paper, we illustrate and evaluate along some key dimensions the performance of the monetary policy frameworks of major central banks during the recent inflation surge and looking forward considering the possibility of steeper Philips curves and higher levels of r^*. We compare average inflation targeting (AIT), which the Federal Reserve adopted in November 2020 and inflation targeting (IT). We show that inflation expectations have remained well anchored in the US as well as in other countries whose central bank has not adopted AIT. We also show that aggressive inflation targeting rules would have contained the inflation surge very modestly relative to current rules and at the cost of larger negative output gaps. Finally, we show that AIT is more stabilizing than IT even if the Phillips Curve steepens or if the central bank fails to realize that r^* has increased. These results are useful for the next round of reviews which the Bank of Canada and the Fed announced recently will begin in 2024. Future research could extend our volatility based welfare criterion in several respects. One is to consider a fully micro-founded welfare measure based on consumption losses. This would require deploying non-linear methods to solve the DSGE model we use. Another is to replicate our simulation exercises in models where inflation expectations are formed under learning and the expectation channel of monetary policy are less powerful than under rational expectations. A third one would consider international comparisons of such simulations.

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8 Appendix

A Anchoring of inflation expectations

The inflation expectation data are retrieved from Consensus Forecast and refer to the expectations of professional forecasters. Consensus asks forecasters to report inflation forecasts several years in the future. For the countries in our sample, expectations were collected on a semi-annual frequency until 2014 and then at quarterly frequency.

It is important to note that the forecast horizon declines during subsequent survey waves within in each. This is because people are asked about the expected inflation rate for specific calendar years, rather than over a fixed horizon relative to the time of the survey. To account for this feature of the survey and construct inflation expectations at constant forecast horizons, we work with weighted averages of inflation across nearby calendar years. For example, 3-year inflation expectations for the survey wave in April 2020 are constructed by taking a weighted average of the inflation forecasts for the year 2023 and 2024, with a weight of 8/12 and 4/12 respectively. To keep the same forecast horizon, the 3-year inflation expectations for the survey wave in August 2020 are constructed as a weighted average of the inflation forecasts for the year 2023 and 2024, with a weight of 4/12 and 8/12 respectively.

The inflation data refer to year-on-year headline numbers. Table A1 and A2 report the regression estimates for equation (1) and (2), respectively.

Table A1: Sensitivity of long-term inflation expectations to current inflation

	United States		Euro area		Canada		Australia		United Kingdom	
	3-year	5-year	3-year	5-year	3-year	5-year	3-year	5-year	3-year	5-year
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
CPI	0.03***	0.02	0.05***	0.03***	0.02***	-0.01*	0.04**	-0.01	0.03	0.02
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.00)	(0.02)	(0.01)	(0.02)	(0.01)
N	10	10	9	9	10	10	9	9	9	9
adj. R^2	0.40	0.11	0.44	0.60	0.33	0.37	0.40	-0.07	-0.01	0.11

Robust standard errors in parentheses.

* $p < .1$, ** $p < .05$, *** $p < .01$

Table A2: Changes in the anchoring of inflation expectations around MPF reviews

	United States		Euro area		Canada	
	Three-year	Five-year	Three-year	Five-year	Three-year	Five-year
	(1)	(2)	(3)	(4)	(5)	(6)
CPI	0.02	0.01	0.12***	0.07***	0.001	0.001
	(0.02)	(0.01)	(0.02)	(0.01)	(0.01)	(0.01)
MPF review	-0.07*	-0.05	0.08	0.06	-0.04	0.07***
	(0.04)	(0.05)	(0.16)	(0.07)	(0.03)	(0.02)
CPI *	0.01	0.01	-0.09***	-0.04***	0.02	-0.01
MPF review	(0.02)	(0.01)	(0.02)	(0.02)	(0.01)	(0.01)
N	60	60	60	60	60	60
adj. R^2	0.15	0.04	0.56	0.49	0.18	0.09

Robust standard errors in parentheses

* $p < .1$, ** $p < .05$, *** $p < .01$

B Estimation

We estimate the model using data on nine observable variables: real GDP per capita, real consumption per capita, real investment per capita, average weekly hours of production and non-supervisory employees, PCE inflation, the Employment Cost Index, the Federal Funds rate, long-term inflation expectations and the BAA-Treasury bond spread. Our measure of inflation expectations comes from the Philadelphia Fed Survey of Professional Forecasters. To account for unconventional policies while the Federal Funds rate was at its effective lower bound we replace the Fed Funds rate with the Shadow rate published by the Atlanta Federal Reserve in these quarters Wu and Xia (2016).

Table A3: Estimation Results: Structural parameters

Parameter	Prior			Posterior		
	Shape	Mean	Std	Mean	Mode	95% p.i.
h	B	0.60	0.05	0.68	0.68	[0.62 – 0.73]
π^*	N	0.50	0.20	0.49	0.49	[0.31 – 0.67]
μ	N	0.40	0.10	0.27	0.27	[0.18 – 0.35]
β	G	0.25	0.10	0.11	0.10	[0.05 – 0.18]
ν	N	2.00	0.75	2.84	2.61	[2.15 – 3.68]
ω_r	B	0.70	0.10	0.93	0.95	[0.86 – 0.98]
Υ	N	3.00	1.50	7.31	7.51	[5.50 – 9.05]
θ_w	B	0.60	0.05	0.76	0.76	[0.71 – 0.80]
θ_p	B	0.60	0.05	0.87	0.87	[0.84 – 0.90]
$S\bar{P}$	G	2.00	0.10	2.06	2.07	[1.91 – 2.21]
χ_w	B	0.50	0.20	0.77	0.82	[0.57 – 0.92]
χ_p	B	0.50	0.20	0.37	0.37	[0.21 – 0.54]
ρ_r	B	0.80	0.10	0.90	0.90	[0.88 – 0.91]
ϕ_π	N	1.50	0.25	1.63	1.58	[1.38 – 1.91]
ϕ_y	N	0.12	0.05	0.19	0.19	[0.13 – 0.26]
κ	U	0.00	∞	6.77	6.97	[3.20 – 10.37]

Notes: B = Beta, N = Normal, G = Gamma, U = Uniform.

Table A4: Estimation Results: Shock processes

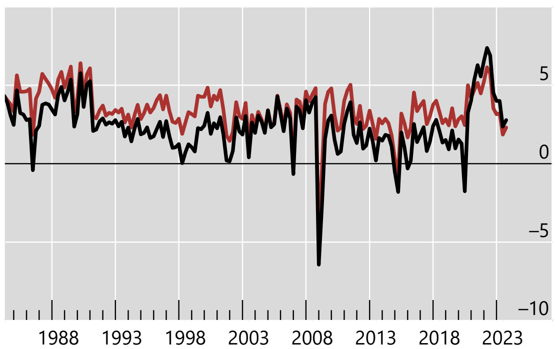
Parameter	Prior			Posterior		
	Shape	Mean	Std	Mean	Mode	95% p.i.
ρ_g	B	0.85	0.10	0.97	0.99	[0.97 – 1.00]
ρ_ξ	B	0.85	0.10	0.93	0.94	[0.90 – 0.95]
ρ_{rk}	B	0.50	0.20	0.83	0.82	[0.77 – 0.89]
ρ_μ	B	0.50	0.20	0.36	0.37	[0.15 – 0.57]
ρ_Υ	B	0.50	0.20	0.81	0.82	[0.75 – 0.87]
σ_r	IG	0.10	2.00	0.13	0.12	[0.11 – 0.14]
σ_g	IG	0.10	2.00	1.96	1.94	[1.76 – 2.19]
σ_w	IG	0.10	2.00	0.12	0.12	[0.10 – 0.15]
σ_p	IG	0.10	2.00	0.28	0.28	[0.24 – 0.32]
σ_ξ	IG	0.10	2.00	1.02	1.18	[0.77 – 1.74]
σ_{rk}	IG	0.10	2.00	0.08	0.08	[0.07 – 0.09]
σ_{π^*}	IG	0.03	6.00	0.01	0.01	[0.01 – 0.02]
σ_μ	IG	0.10	2.00	0.45	0.46	[0.35 – 0.56]
σ_Υ	IG	0.10	2.00	0.36	0.36	[0.27 – 0.46]

Notes: B = Beta, IG = Inverse Gamma.

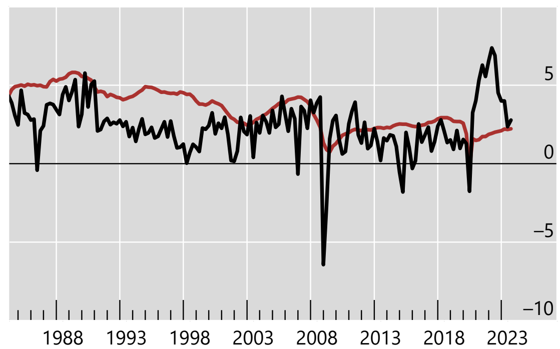
We use the Kalman smoother to recover the structural shocks implied by the model to explain economic outcomes over the period 2020Q1 - 2023Q3. Figure A1 shows the contribution of the recovered structural shocks to the dynamics of headline inflation.

Figure A1: **Historical decomposition of headline inflation**

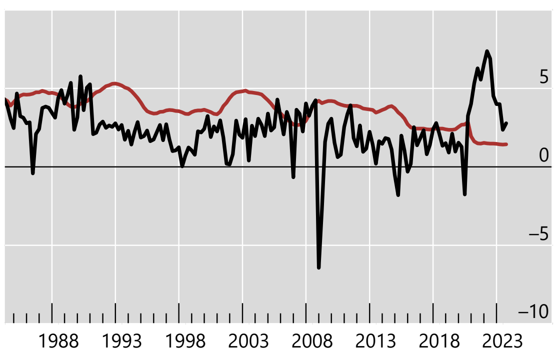
(a) Supply shocks



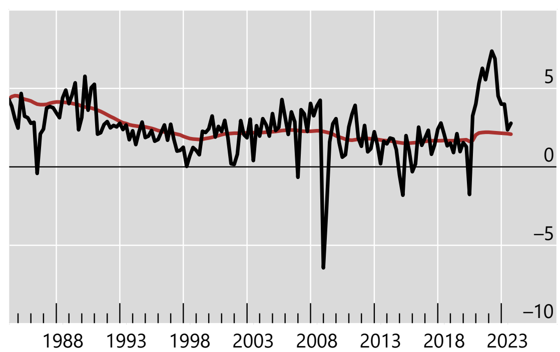
(b) Demand shocks



(c) Policy shocks



(d) Inflation target shocks



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