CBA Working Paper 2022/04

Getting FIT with Imperfect Policy Credibility

DYNARE/JULIA Workshops with an Application for the US Economy

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October 31, 2022

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ACKNOWLEDGMENTS

We would like to thank the leadership and Board of the Central Bank of Armenia for their leadership and support in exploring new possibilities for monetary policymaking. Additional thanks to CBA Deputy Governor Nerses Yeritsyan for his long-standing innovative thinking in pushing the Board and the staff to move away from a baseline-focused approach. The development of the proposals made in this paper has immensely benefited from their contributions and critical thinking.

We thank John Taylor, Michael Bordo, and Mickey Levy for providing comments on these proposals at Better Policy Project seminars. We also thank David Archer, Archil Mestvirishvili, Shalva Mkhatrishvili, and Lawrence Schembri for their encouragement and continued insights provided at these seminars. See www.thebetterpolicyproject.org for a list of acknowledgements of people that were critical in the development of published endogenous policy baseline projections—the current gold standard for monetary policymaking that we wish to modify in order to take better account of uncertainty—at the Bank of Canada and the Reserve Bank of New Zealand.

ABSTRACT

The Covid-19 pandemic highlighted the need for analytical tools and frameworks that can better deal with significant uncertainty and crucial nonlinearities. This paper explores the foundational elements of such an analytical framework that are relevant for policy analysis today with an emphasis on the role of endogenous policy credibility. We present a simple workhorse model of Flexible-Inflation Targeting (FIT) under imperfect credibility, known as the "ENDOCRED" model. It modifies the canonical models used in Forecasting and Policy Analysis System (FPAS) Mark I central banks in three ways: an endogenous policy credibility process, by which monetary policy can gain or lose credibility over time; non-linearities in the inflation equation and in the credibility-generating process; and an explicit quadratic loss minimization function. We illustrate the logic of this prototypical ENDOCRED model through policy simulation exercises

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via applications to the US economy. The model highlights problems with implementing monetary policy under imperfect credibility where the costs of delaying interest rate hikes increase in response to excess demand shocks or even unfavorable supply shocks. We illustrate this using the 2021 "transitory" versus "persistent" inflation debate. We also discuss potential implications of persistently higher-than-expected core inflation in 2022 for policy outlook in light of highlighted nonlinearities and potential credibility losses. In this paper, we also develop a methodology for generating indices for central bank performance and credibility using the Atlanta Fed's sticky price measure of inflation for the US.

CONTENTS

I. INTRODUCTION

Why build a class of models and analysis centered around credibility?

The notion of central bank credibility is frequently mentioned in conversations about effective monetary policy. The basic intuition is that the loss of credibility is costly, because if the public loses trust in policymakers' ability to achieve their policy objectives, then the central bank has to adjust its policy rate much more aggressively implying larger cumulative output and unemployment costs to reduce inflation. This logic introduces a key general underlying principle that delaying policy actions in response to different types of shocks (such as overheating, or upward shifts in the equilibrium real interest rate) is costly. This is the reason we build this class of models for policy analysis rather than rely on linear models, which neglect this insight.

We employ a similar model as Alichi and others (2009) that analyzes policy when central bank credibility is treated as endogenous rather than exogenous. We refer to this model as the "ENDOCRED" model—based on this principle of endogenous credibility. For simplicity, we consider only the closed economy case.[2] There are three reasons to reinvigorate this class of endogenous credibility models that were employed extensively in vulnerable emerging market economies that have always been sensitive to stagflationary shocks. First, after the Covid-19 pandemic it is clear that endogenous policy credibility matters not only for emerging and developing markets, which has usually been the focus of this strand of literature, but also for advanced country central banks, such as the Fed and the Bank of England. Second, in our recent paper,[3] we argue for a risk-management approach to monetary policy, which shifts the focus from baseline forecasts to scenario analysis and minimization of possible policy errors. In the proposed framework, endogenous credibility plays a much more central role, since it emphasizes the nonlinear costs of policy errors, namely the costs of delay. Third, the 2021 "transitory" versus "persistent" inflation debate in the US economy, as well as the current macroeconomic environment, illustrates that endogenous credibility has first-order policy implications.

The ENDOCRED model contains three novel features relevant to quarterly projection models in use at central banks:[4]

- *Endogenous policy credibility process*—starting from a situation in which inflation is expected to remain high, policymakers may build credibility over time, such that public expectations of inflation only converge gradually to the target, or lose credibility as the public begins to doubt their commitment to achieving inflation target;
- *Number of nonlinearities*—most importantly in the specification of convexity in Phillips curve and in the specification of the process by which credibility changes; and
- *Loss function for monetary policy*—recognizes the costs of deviations of inflation from target and output from potential as well as fluctuations in interest rates, in place of a conventional reaction function for the policy interest rate.

The ultimate stable low-inflation objective is the nominal anchor for the model, which provides the foundation for improved expectations and credibility. The disinflation path is endogenous and depends on the level of credibility at the time that the inflation-reduction program is adopted, as well as other relevant

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[2] This model was developed in Dynare/Julia as a practical example for developing fast and open-source software that will be instrumental in the next generation of macroeconomic analytical tools and models.

[3] See Archer and others (2022).

[4] The model used in this paper belongs to the family of models found in Laxton and N'Diaye (2002), Isard, Laxton, Eliasson (2001), Epstein and others (2006), Argov and others (2007), and Benes and others (2017 a,b).

initial conditions. The loss-minimizing path to the low-inflation goal is more gradual than it would be if policy were 100 percent credible at the outset.

Recent practice has been to calibrate the parameters, using a broad range of relevant evidence, rather than to rely on classical estimation techniques. This approach becomes convenient in the context of emerging-market economies, where time-series data are not abundant, or in economies that have limited variation or policy errors in their recent historical experience.[5]

Models with endogenous credibility have been developed to examine the issue of past disinflations. Some of the key ideas developed by Alichi and others (2009) focus on strategies for disinflation when credibility is imperfect, and what types of shocks make the job of the central bank more difficult or easier managing the short-run output-inflation tradeoff. While initial conditions can affect the desired path for disinflation at the time of the announcement of FIT, shocks along that path can also have an important effect on the eventual optimal path. Model simulations suggest that supply shocks can have an especially large impact on the desirable rate of disinflation. A favorable supply shock, which reduces inflation, can help monetary policy, boosting credibility and reducing the necessary interest rate increase, as well as shortening the path to the long-run objective. A harmful supply shock—e.g., an increase in world food or energy prices—presents, in contrast, the most difficult problem for inflation control. Large interest rate increases may be needed to prevent a self-propagating inflation spiral and de-anchoring of inflation expectations. In such situations, a delay in tightening policy eventually results in even higher interest rates, and a more prolonged period with output below potential. There are also important asymmetries, such that the central bank response to unfavorable supply shocks must be more vigorous than its response to favorable supply shocks.

The variety of outcomes from differing starting points and different shocks reflects the forward-looking, flexible, risk-management approach to FIT embedded in the model. The simplest types of conventional linear reaction functions, in contrast, have fixed inflation targets, and adjust the policy interest rate based on observed movements in target variables, regardless of the source of the shock.[6] Flexibility, however, is useful only when used in line with the low-inflation objective. Actions—or delays—inconsistent with the objective carry a heavy cost in the model; they can result in medium-term and long-term stagflation (dollarization).

We consider this to be an early step for developing and documenting the workhorse model and infrastructure for the evolution of the Forecasting and Policy Analysis System (FPAS), known as FPAS Mark

[5] In several cases, models developed to support FIT regimes have been calibrated because of significant data issues or structural change that made past empirical relationships poor guides for the future. Over time, as more data became available there has been a tendency to employ Bayesian methods to estimate macro models. See Laxton (2008) for a detailed discussion of the development of Bayesian methods and why they have been deployed so extensively after developing user-friendly versions of Bayesian methods in Dynare. It is important to note that Bayesian methods are only as good as the priors, data, and models that they are based on. The methodology we employ examines empirical evidence from a global perspective and not just the country experiences based on a specific historical sample. A good example of this is the experience of the Global Financial Crisis, during which some central banks, such as the Bank of Canada, were agile in revising potential output downward, while other central banks, such as the Fed, made large forecasting errors, believing that the economy would "bounce back" to an unchanged trendline. In this case, the error was based on a presumption that required overwhelming evidence that the trend had shifted, versus a more open-minded understanding of the experiences of financial crises and how they are associated with permanent downward revisions in estimates of the sustainable level of output.

[6] Many central bank models insert a model-based forecast of deviations of future inflation from target in their reaction function, and these are more flexible than the simplest forms of reaction function that use only past or current deviations of inflation from target.

II. This is meant to provide central banks the backbone of the analytical framework associated with avoiding the dark corners of monetary policy, which are especially pertinent now, when high inflation is rampant around the world, at the same time as some worry that underlying secular stagnation forces are lurking.[7] FPAS Mark II essentially builds off the analytical frameworks adopted by seasoned FIT central banks such as the Reserve Bank of New Zealand, the Czech National Bank, and the Central Bank of Chile, to name a few.[8] The FPAS Mark II provides a systematic approach to dealing with uncertainty and incorporating "monetary policy as risk management" in monetary policymaking,[9] and the ENDOCRED model provides an essential analytical tool within that framework.

This paper offers a concrete example of a credibility measure using sticky price inflation in the United States. The concept of sticky prices as a measure of underlying inflation is vastly superior to purely statistical measures, which can be much more confusing than helpful. Sticky price measures of inflation are more consistent with the theory of optimal policy that suggests that monetary policy should place much more emphasis on targeting these measures and allow flexible prices to adjust quickly in response to demand and supply shocks in various commodity markets such as food and energy. Sticky price measures of inflation are more likely to be driven by generalized excess demand pressures, costs, and inflation expectations. For small open economies, they can be proxied by non-tradeable service prices, and can be constructed in almost any country, making the analysis around credibility accessible to most countries. Importantly, we do not view this measure of credibility as a mechanical score to compare different countries, but rather use it as a useful input for the economic narratives, which include heavy doses of judgment.[10]

Furthermore, this paper provides an analytical framework that could have been employed in the Summer of 2021, when ongoing debates about the persistent versus transitory nature of inflation were raging. The debate about "what went wrong" at central banks like the Fed has been led by people like Larry Summers[11] and former Bank of England Governor Mervyn King. One aspect of King's view is, "this was a mistake of the economics profession, which has spread, understandably, into central banks," which had been infected by wrong ideas and "fancy computer models."[12] This paper proposes that, in fact, the flaws in thinking and policymaking at the time were driven at least in part by flaws in analytical models. Specifically, the assumption that monetary policy credibility is *exogenous*—that inflation expectations are always anchored to the 2% target—rather than *endogenous*. This paper applies scenario analysis to demonstrate how this flawed assumption may have misled the Fed into underestimating the magnitude of the policy response needed to bring down inflation, and how this might have been partially avoided if credibility was thought of as endogenous.

The paper is organized as follows. Section II describes the methodology of constructing the credibility indices using sticky prices. Section III describes the model. Section IV reports the results of different relevant scenarios using the model. Section V offers concluding remarks. Appendix 1 introduces the Global

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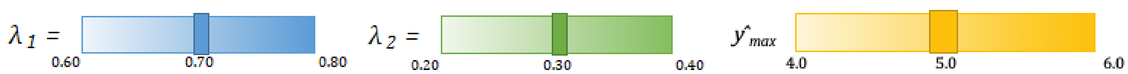
[7] Refer to Chapter 3 of Blanchard (2022), which argues that the equilibrium real interest rate may be low, meaning that the effective lower bound might become an important constraint on future policies.
[8] For a discussion of the state of the art in FIT see Adrian, Laxton and Obstfeld (2018 a,b,c) and Al-Mashat and others (2018 a-g).
[9] See, for example, Bullard (2021), who argues that concerns that inflation could be more persistent highlights the need for the risk management approach to monetary policy.
[10] See Fischer (2017).
[11] See Williams (2021).
[12] Refer to interview with Mervyn King (2022).

Forecasting School's Quarterly Conferences, where Dynare/Julia applications and updates will be discussed.[13] Appendix 2 presents various exercises testing the sensitivity of the calibration of parameters.

II. MODELING CENTRAL BANK CREDIBILITY

To construct our credibility indices, we first need to describe a model of inflation to understand how credibility influences inflation dynamics through expectational mechanisms. Specifically, we are interested in modeling inflation expectations ($\pi 4_t^e$) in our standard-inflation expectations-augmented Phillips curve.

$$\pi_t = \lambda_1 \pi 4_t^e + (1 - \lambda_1)\pi 4_{t-1} + \lambda_2 \left(\frac{\hat{y}_{t-1}}{\hat{y}_{max} - \hat{y}_{t-1}} \hat{y}_{max}\right) + \varepsilon_t^{\pi} \quad (1)$$



where, $\pi 4_t^e$ and $\pi 4_{t-1}$, respectively, are the forward-looking and backward-looking components of our sticky-price quarterly inflation measure π_t; $\hat{y}_{t-1}$ is the output gap in period t–1; and $\hat{y}_{max}$ is the maximum possible excess demand pressures. The term ε_t^{π}represents the critical role for cost-push supply shocks that directly impact inflationary forces and create the short-run tradeoff between the output gap and inflation.

The ^ symbol used throughout the paper will refer to a deviation of some variable from its equilibrium value, measured in percentage points. For example, $\hat{r}$ would represent the percentage point difference between the real short-term interest rate (r) and the equilibrium real short-term interest rate ($\bar{r}$). To put it another way, for example, $\hat{y}_t$ is equal to 100*log(GDP_t) – 100*log($\overline{GDP}_t$). The bar above GDP here refers to the equilibrium, i.e. potential GDP.

The terms in the equation represent, from left to right:

- forward- and backward-looking components to the expectations process [$\lambda_1 \pi 4_t^e$ + (1-λ_1)$\pi 4_{t-1}$] where $\pi 4_{t-1} = \frac{1}{4}\sum_{j=1}^{4} \pi_{t-j}$. We will characterize the way in which inflation expectations ($\pi 4_t^e$) are formed in the next sub-section. Conceptually, our measure of inflation ($\pi 4_t^e$) should represent what inflation is expected to be over the next year, as explained below.
- non-linear output gap effect (λ_2 * [$\frac{\hat{y}_{t-1}}{\hat{y}_{max} - \hat{y}_{t-1}} \hat{y}_{max}$]).

The first parameter λ_1 = {0.60:0.70:0.80} determines the weight on inflation expectations versus lagged inflation. A value for λ_1 = {0.70} implies a weight of 0.30 on past inflation.[14] This would suggest that even in a world where inflation expectations are perfectly anchored to the 2 percent target there would still exist a small amount of inflation persistence in the inflation process. This rule-of-thumb-like behavior in

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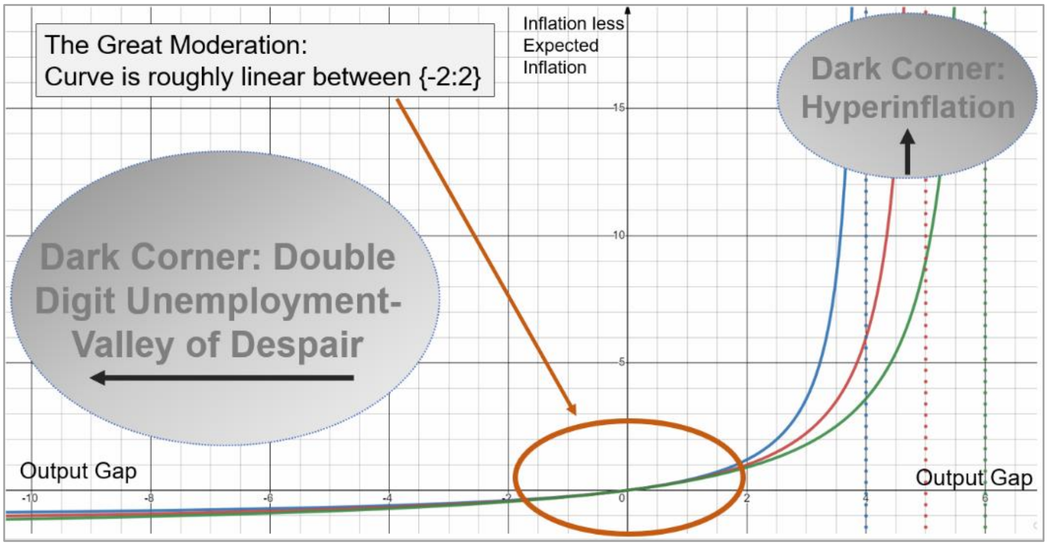
[13] The Global Forecasting School will be hosting a series of quarterly conferences and training sessions, including Dynare/Julia workshops, in hybrid format at the beginning of each quarter in Armenia and Portugal. The next workshop will be held at the Central Bank of Armenia's Dilijan Training Center in Dilijan, Armenia on January 11-13, 2023. Refer to Appendix 1.

[14] Students of the Global Forecasting School (GFS) are encouraged to study the implications of parameter uncertainty. To make things easy, we have provided a plausible range for all the parameters that they might consider in their analysis.

the price-setting process may reflect explicit indexation in high-inflation regimes or simply implicit indexation in low-inflation regimes, as agents follow simple rules of thumb in their pricing behavior.

Figure 1: Convex Phillips Curve According to Different Values of y_{max} between 4 and 6



Source: Authors' calculation

The second parameter λ_2 = {0:30} is the slope of the Phillips Curve when the output gap is zero, or near zero.[15] The y_{max} parameter is the maximum possible excess demand pressures. As the output gap gets closer and closer to this maximum value, the slope of the Phillips curve gets steeper and steeper (see Figure 1).

The y_{max} parameter also follows the logic of the relationship between output gap and unemployment gap set forth by Okun's Law, in that a very high output gap would result in an unsustainably low unemployment gap.

A. Expectations Process and Credibility.

Standard linear models presume perfect levels of central bank credibility, but as periods of high or persistent inflation demonstrate, central bank credibility is often, if not always, imperfect. This observation is critical to understand because, as we describe in the prior section, the concept of central bank credibility depends on how well medium- and long-term inflation expectations are anchored. If the

[15] It is important to remember that inflation is measured at annual rates, and so a slope of the Phillips Curve equal to 0.3 implies that prices on a quarterly basis would be up 0.075, if the model was specified in quarterly, not annualized, rates. The point being that the Phillips Curve is very flat, in the neighborhood of $\pm$ 2%, and becomes super flat as the amount of economic slack in the economy becomes larger and larger. Obviously, studies based on an assumption of a really flat Phillips Curve can be very dangerous, if one does not consider scenarios where the economy can be thrown into periods of significant excess demand because of capacity constraints and so on. See Laxton, Rose and Tambackis (1999), Clark, Laxton and Rose (2001), and Macklem (1997).

former is allowed to deviate persistently from the target, this will eventually result in a loss of credibility, where long-term inflation expectations ratchet upwards and the expectational process that governs wage- and price-setting behavior starts to reflect higher medium-term inflation expectations. In the limit, a central bank can face dollarization, when inflation uncertainty is so high that it no longer is rational for agents to price important goods and services (e.g. housing) in domestic currency.

It can be dangerous to assume that inflation expectations are always forward-looking, as the empirical evidence suggests that they are clearly backward-looking in many environments. In general, inflation expectations are better thought of as having a combination of both forward- and backward-looking components. To make an imperfect analogy, the process by which inflation expectations are formed is not dissimilar to the process of firms fixing prices for a period of time (e.g. one year). Just as firms would look out one year and back one year to understand where to set prices, a similar *ex post* and *ex ante* logic follows how inflation expectations are formed. The following equation contains a mechanism that allows the formation of expectations to become more backward-looking than in standard DSGE models that assume a weight of one on model-consistent expectations.

$$\pi 4_t^e = \gamma_t * \pi 4_{t+4} + (1 - \gamma_t) * \pi 4_{t-1} + ϛ * (1 - \gamma_t) + \varepsilon_t^{\pi^e} \qquad (2)$$

The first two terms in the equation for expected inflation comprise a weighted average of a model-consistent forecast of the 4-quarter ahead year-on-year inflation rate (forward-looking component) and the year-on-year inflation rate observed last quarter (backward-looking component).

The weight on the forward-looking component, γ_t, is a measure of the stock of credibility, and ranges between 0 (no credibility) and 1 (full credibility). When credibility is less than one, two important processes emerge: first, any level of existing inflation tends to become more persistent; and second, inflation expectations tend to ratchet upwards.[16] To model how inflation expectations can ratchet upwards when credibility declines, we include an additional term, ϛ, to capture this bias in the transition from imperfect to perfect credibility. This bias term acts as an important source of stagflationary shocks in vulnerable and highly dollarized Emerging Market countries. We assume ϛ is equal to 0.1, which represents a conservative estimate, even for advanced economies such as the United States. Higher values for this parameter would be appropriate for dollarized economies that are vulnerable to inflation expectations ratcheting upwards in situations where interest rates are too low. The GFS is compiling a list of country case studies to provide better guidance about the range of plausible values based on the international experience.[17]

Credibility is equivalent to the reputation that the central bank has developed by first specifying a numerical objective for long-term inflation, and second by whether or not it has been able to achieve that target on average over time. The term “on average” is simply meant to represent that many measures of inflation contain significant noise in the data, and even if a central bank was behaving perfectly, inflation will not be equal to the target on a period-by-period basis. However, the public will obviously be skeptical if the performance of the central bank has allowed periods of high and variable inflation. We therefore think of credibility as a stock, in the sense that it depends on the accumulated performance of the central

[16] For an explanation of why bank credibility could fall in this context, refer to the forthcoming paper by Kostanyan and others (2023).

[17] This list will be continuously augmented as GFS students explore further case studies, and will be updated on the GFS website.

bank over time. In general, we can think of many different types of regimes that could include, for example, high and variable inflation, double-digit inflation, hyperinflation, low inflation, etc. For the purposes of this paper, we consider two types of regimes: one, where inflation is always expected to converge fairly quickly back to the target; and second, where inflation is expected to be high and variable. [18]

A.1 Regime 1. $\pi^* = 2$

In the first regime, people expect that the central bank is going to be successful in achieving their 2% inflation target ($\pi^* = 2$) over a horizon of one to two years. This would be consistent with believing in a rule-of-thumb forecasting equation that produces a forecast for inflation that gradually adjusts toward 2% over an horizon of one to two years. A specific example of such an equation would be the following:

$$\pi 4_t^{\pi^*=2} = \Upsilon^{\pi^*=2} * \pi 4_{t-1} + \left(1 - \Upsilon^{\pi^*=2}\right) * \pi^* \qquad (3)$$

($\Upsilon^{\pi^*=2}$ = 0.5, π^* = 2.0)

The error term is represented by the following equation, representing the difference between actual and forecasted inflation:

$$\varepsilon_t^{\pi 4^{\pi*=2}} = \pi 4_t - \pi 4_t^{\pi^*=2} \qquad (4)$$

In general, we would assume that agents might not know the value of the error term ($\varepsilon_t^{\pi 4^{\pi*=2}}$) in forming expectations of inflation in period t. In such cases, the error term would represent the forecasting error that they would make by basing their forecast on such an equation ($\pi 4_t^{\pi^*=2} = \Upsilon^{\pi^*=2} * \pi 4_{t-1} + \left(1 - \Upsilon^{\pi^*=2}\right) * \pi^*$), which represents the deviation between using such a forecasting equation and the actual outcome for inflation.

A.2 Regime 2. High Inflation

The second regime corresponds to a 'High Inflation' scenario, where there is a suspicion in the public mind that monetary policy might become like in the 1970s, where inflation is much higher than the announced target—we suppose that rate to be 10 percent. The idea of the high and variable inflation regime is that people think that inflation is very persistent, and has a tendency to drift up toward the double digits, which we approximate with the numerical value of 10 percent. Inflation uncertainty would be much higher in this regime, because inflation is also assumed to be much more persistent. In practical terms, people would believe in such a regime versus the stationary inflation-targeting regime (where inflation always converges to the target) if they observe that inflation was highly persistent and had a tendency to gradually rise over time (to the 10%). In the context of a standard monetary policy model, one can think of this 10% as what people think inflation will converge to in the long-run, which in these standard models, is the

[18] To study economies such as Japan or the Euro area, we have an extended version of the model that also allows for a low-inflation state where the perceived target is below the actual 2% target of the Bank of Japan and ECB. This allows us to model situations where long-term inflation expectations can ratchet downwards and the economy can become vulnerable to further contractionary shocks when the economy is at the effective lower bound. Refer to Adrian, Laxton, and Obstfeld (2018).

perceived inflation target. Under the 'H' scenario, inflation would converge at a much slower rate, gradually approaching 10 percent:

$$\pi 4_t^H = \Upsilon^H * \pi 4_{t-1} + (1 - \Upsilon^H) * \pi^* \tag{5}$$

$(\Upsilon^H = 0.9, \pi^H = 10)$

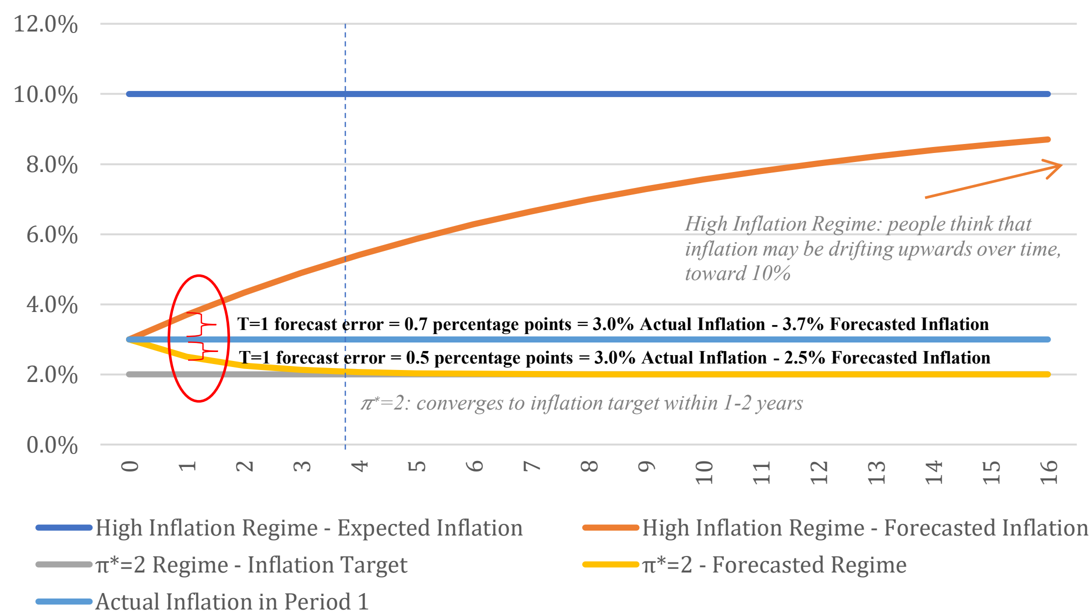
The error term for the high-inflation regime would be constructed similarly as above:

$$\varepsilon_t^{\pi 4^H} = \pi 4_t - \pi 4_t^H \tag{6}$$

An important distinguishing characteristic of the two regimes is that in one case, inflation is expected to converge fairly quickly to the target, while in the second regime, inflation has a tendency to drift upward toward double-digit inflation, albeit at a more gradual pace. This characteristic of the model allows it to explain key stylized facts, including that higher inflation is typically associated with higher inflation uncertainty, as inflation becomes more persistent.

Figure 2 below presents these two inflation regimes, described above, graphically. Whereas the "$\pi^* = 2$" regime sees inflation converge to the expected inflation of 2% (since people believe the central bank will be able to achieve the target inflation rate) in one to two years, the "H" regime sees inflation very slowly and gradually to the 10% expected rate.

Figure 2: Forecast Errors in "$\pi^* = 2$" and "High Inflation" Regimes



Source: Authors' calculations

In the "$\pi^* = 2$" regime, if actual inflation in period one is assumed to be 3.0% (represented by a constant line in the chart), the period zero forecasted inflation of 2.5% would represent a forecasting error of 0.5

percentage points. In the "H" regime, assuming the same actual inflation of 3.0% in period one, the forecasted inflation of 3.7% represents a forecasting error of 0.7 percentage points, higher than in the "$\pi^* = 2$" scenario. These forecasting errors provide important inputs to the model as discussed in Section III, where the costs of inflation deviations from forecasts and targets are considered signals that enter the process that governs the evolution of credibility.

We use these two hypothetical inflation regimes to define a central bank sticky-price inflation indicator (CBSPII), η_t

$$\eta_t = \frac{\left(\varepsilon_t^{\pi 4^H}\right)^2}{\left(\varepsilon_t^{\pi 4^H}\right)^2 + \left(\varepsilon_t^{\pi 4^{\pi*=2}}\right)^2} \tag{7}$$

The variable η_t provides a rough measure of the extent to which inflation outcomes are seen as consistent with the '$\pi^* = 2$' inflation scenario. Consider two extreme cases. In the '$\pi^* = 2$' case, inflation converges gradually to the inflation target as implied by equation (3). η_t equals 1 since the term ($\varepsilon_t^{\pi 4^{\pi*=2}}$) in the denominator of equation (7) equals 0. If inflation is at the level postulated in the 'H' case, on the other hand, the numerator ($\varepsilon_t^{\pi 4^H}$) equals 0, and thus η_t equals 0, implying a complete lack of credibility. Credibility is lost—people give increased weight to the possibility of experiencing a high inflation scenario—if inflation outcomes are above the announced target.

The central bank credibility stock index (CBCI), γ_t, then evolves according to a standard stock accumulation process, where credibility depends partly on its lag and partly on the signal of recent central bank performance:

$$\gamma_t = \rho * \gamma_{t-1} + (1-\rho) * \eta_{t-1} + \varepsilon_t^{\gamma} \tag{8}$$

($\rho = 0.10$)

An increase in η_t results in a rise in the weight on the forward-looking component of expectations, $\boldsymbol{\gamma_t} * \pi 4_{t+4}$, as in equation 2, presented again below for the reader's convenience.

$$\pi 4_t^e = \gamma_t * \pi 4_{t+4} + (1-\gamma_t) * \pi 4_{t-1} + ϰ * (1-\gamma_t) + \varepsilon_t^{\pi^e} \tag{2'}$$

This reduces inflation persistence and ties inflation more tightly to the target, such that the central bank must do less in response to shocks, and convergence to the target rate is faster. The disturbance term, ε_t^{γ} represents a shock to central bank credibility, which may be positive or negative. We provide two examples below in which credibility has shifted: one in which a surprise interest rate cut results in a loss in credibility (Israel); and another, where a dramatic improvement in fundamentals to support central bank independence leads to a large increase in credibility (United Kingdom). Both of these examples are extreme, in the sense that most of the time, it takes an enormous amount of time to develop credibility once it has been lost, while in the latter case, this happened within one year or so.

First, is the example of Israel in the period from 2001 to 2003, which was a highly dollarized economy.[19] In late 2001, amidst a weakening economy, the central bank cut the policy rate by an unexpected

[19] The process of de-dollarization took years, and started with the pricing of important non-traded goods, such as housing, which were previously set in US dollars. Over time, as the low-inflation regime became more credible, these

magnitude of 200 basis points, causing the country risk premium to increase and the shekel to depreciate, which, of course, resulted in very strong upward pressure on prices because of high exchange-rate pass-through (headline inflation increased to 7% y-o-y by July 2002).[20] Only five months later, the central bank reversed course and hiked interest rates by 450 basis points in three steps, worsening exchange depreciation and the recessionary environment. In this high-rate environment and amidst a global economic slowdown, growth stalled and the economy struggled to get out of a long recession, but the central bank held rates at around 9% until mid-2003. The cost of the 200 basis point rate cut, given the loss in credibility, meant that the central bank had to keep policy rates high for a long period of time. Combined with a slowdown in global economic activity, this not only pushed inflation into negative territory for a long period (2003Q3 to 2004Q2), but also led to high unemployment (11% by end of 2003) and hampered economic recovery. This period was characterized by a serious deterioration of Israeli central bank credibility, reflected in a high country risk premium where longer-term inflation expectations consistently exceeded the target range of 1-3%, even as actual inflation had entered negative territory.[21]

The second is the example of the United Kingdom, where, before 1997, monetary policy had been the responsibility of the Chancellor of the Exchequer rather than the Bank of England. In May 1997, a monetary policy regime under the Bank of England was created, the inflation target *range* was replaced with a well-defined *point* target, and central bank instrument independence was guaranteed to allow the central bank to adjust policy rates to reach its policy objectives. While the early and mid-1990s had seen inflation remain in its target range, by May 1997, long-term inflation expectations were still stubbornly above the target range. While the Chancellor of the Exchequer had been successful in delivering low inflation for several years in the early- to mid-1990s, financial market participants were skeptical that they might not be able to resist the temptation of exploiting the short-run output-inflation tradeoff at some point in the future, resorting back to the types of boom-bust monetary policies that had been experienced during earlier periods. One such period, of course, was the 1970s, when long-term inflation expectations were allowed to ratchet up to levels well beyond what would be consistent with the mandate of price stability. The transformation of the role and independence of the Bank of England in 1997 gave markets sufficient confidence in the bank's credibility to re-anchor inflation expectations to the expected target. Despite conflicts in the market about whether the bank's monetary policy would be effective, following the establishment of monetary policy with a clear point target under the mandate of the Bank of England, long-term inflation expectations (measured as conventional bond yields) fell, and the built-in excessive inflation premium was eliminated, at least in the medium term.[22] In contrast to the Israeli case, the English example demonstrates how improvements in bank credibility can help anchor inflation expectations.

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non-traded goods prices quickly became set in shekels, when they experienced circumstances in 2001 where it made no sense to continue setting rent and for-sale housing prices in US dollars.

[20] Argov and others (2007) show that the pass-through from month-on-month changes in the exchange rate to month-on-month changes in the CPI was a remarkable 0.27, 0.24 of which was accounted for by housing.

[21] Refer to Argov and others (2007).

[22] One interpretation is that the Bank of England's ability to temporarily anchor inflation expectations was the result of its introduction of a "lite" version of inflation targeting, as presented above. However, because the Bank of England did not institute a full-fledged flexible inflation-targeting regime (the FPAS), these impacts were only temporary, and long-term inflation expectations again rose, and remain higher than in developed-economy FPAS central banks. For a detailed discussion of the role of the FPAS versus a lite inflation-targeting approach in anchoring long-term expectations, refer to the Appendix of Kostanyan and others (2022).

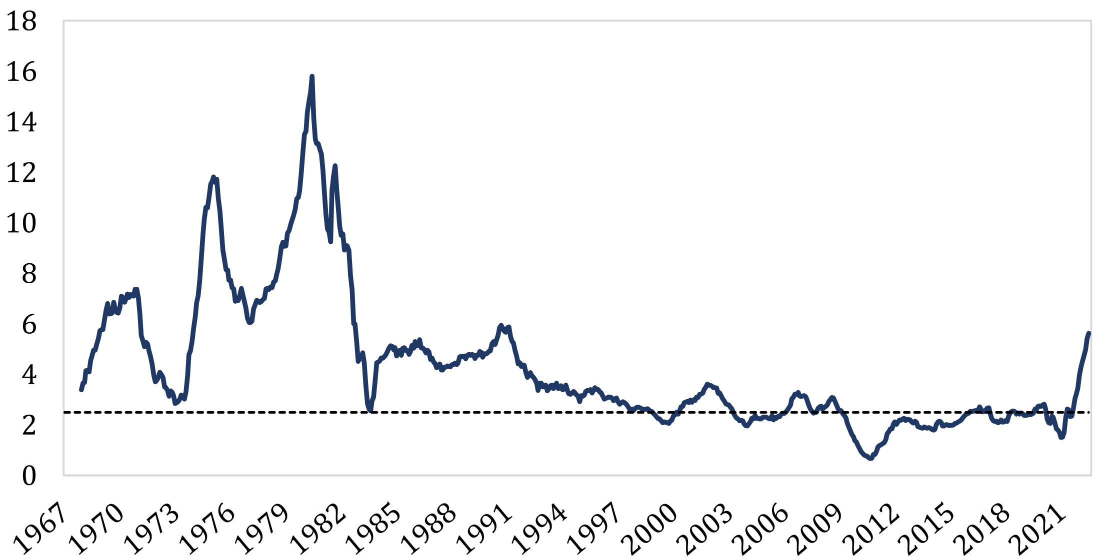
B. Applying this methodology to the United States.

For the United States, we take the sticky price index from the Atlanta Fed as our preferred measure for tracking central bank performance, specifically in thinking about how well they have been anchoring long-term inflation expectations and managing the short-run output-inflation tradeoff. Sticky prices also better reflect the type of prices that are most relevant to central bankers because they contain information on the underlying price-setting behavior of the entire economy. In a broad sense, they can be considered as the components in the CPI basket that are non-tradeable services. A commonly used example by economists is haircut prices. In most cases, a haircut would be a non-traded service that requires domestic labor to produce. Haircut prices are usually very stable in countries that have anchored long-term inflation expectations. Haircut prices in most countries would be a sticky price that would be adjusted periodically to keep up with underlying inflation, but it would also depend importantly on the demand and supply for haircuts.

The two indices show a plausible story behind how credibility of the Fed has evolved over time, beginning with the period of high credibility in the 1960s, which was ultimately lost under Burns' Fed in the 1970's by allowing inflation and inflation expectations to significantly ratchet up and become entrenched. This leads to a critical insight from the model: when credibility is lost, the magnitude of monetary tightening necessary to bring inflation down to the target increases (i.e., the sacrifice ratio increases). This brings us to the Volcker era, when the key task was to restore price stability under a low credibility regime, which indeed required a more draconian response by monetary policy. In the decades which followed, inflation never exceeded a high threshold, allowing the Fed to accumulate credibility—whether due to good policy or sheer luck. That lasted until the latest Covid-era inflation spell, which has brought the notion of credibility back into focus. The potential for the Fed to lose credibility has built up and is rising, the longer sticky price inflation remains elevated. This would hence require more drastic actions to bring inflation and inflation expectations down in a reasonable time horizon (see Figure 1).

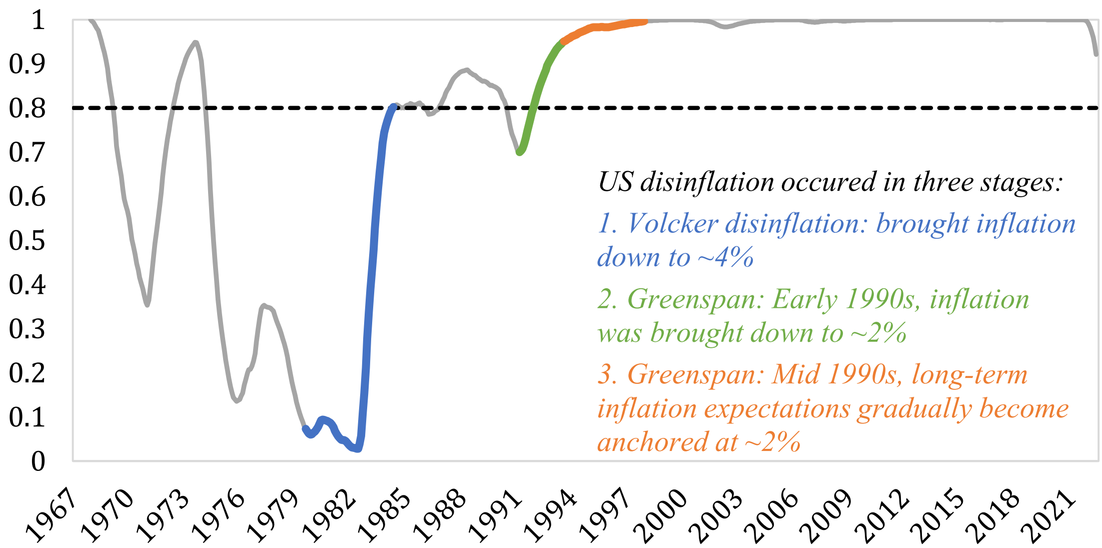
Figure 3: CBSPII and CBCSI for the United States based on Atlanta Fed's Sticky-Price Inflation

Figure 3.1: Central-Bank Sticky-Price YoY Inflation Indicator for United States, Y-o-Y, %



Source: Atlanta Fed, Authors' Calculations

Figure 3.2: Central Bank Credibility Stock Index for United States

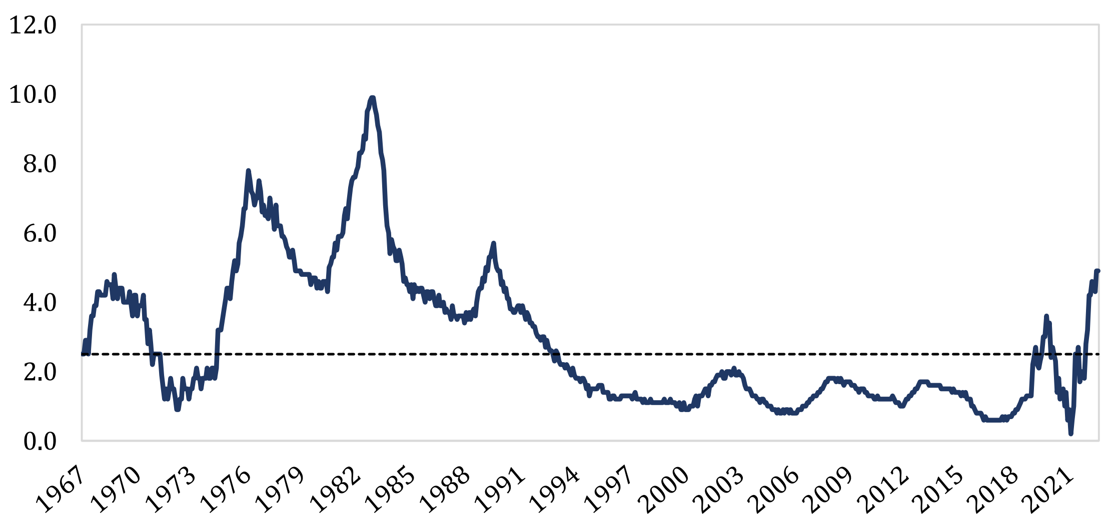


Source: Atlanta Fed, Authors' Calculations

Sticky price measures are not available for many countries. Our approach suggests that we can approximate those by other non-tradable services prices. One example would be the rents that landlords charge to tenants. Many countries have one-year leases for apartments. Landlords will set prices based on how much their prices have fallen behind market conditions, as well as what they believe market conditions will be in the future. We applied the methodology to Canada as well, as demonstrated in Figure 4.

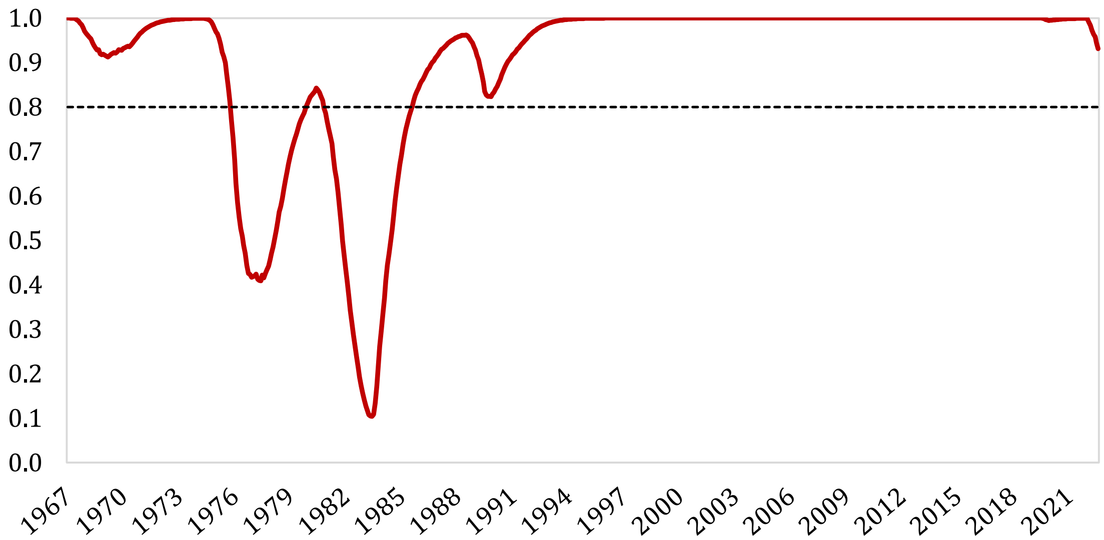
Figure 4: CBSPII and CBCSI for Canada based on Rented Accommodation Prices

Figure 4.1: Central-Bank Sticky-Price YoY Inflation (Rented Accommodation Proxy) Indicator for Canada, Y-o-Y, %



Source: Statistics Canada, Authors' Calculations

Figure 4.2: Central Bank Credibility Stock Index for Canada



Source: Statistics Canada, Authors' Calculations

Figure 4 tells a good story about the monetary policy stance and credibility of the Bank of Canada. In the late 1960s and early 1970s, inflation was increasing in response to a sequence of supply shocks, including lower productivity growth and a rising NAIRU.[23] Conditions worsened further due to the oil-price shock in 1973, pushing inflation even higher and causing inflation expectations to ratchet up. The Bank of Canada was only able to regain credibility and bring down inflation in the 1980s after aggressive policy action in the form of sharp increases in interest rates. These aggressive policies brought inflation and expected inflation back to targets, and the later adoption and implementation of an inflation-targeting framework in 1992, helped the Bank of Canada keep credibility at high levels until Covid-19 and further pandemic-related shocks.

III. THE MODEL

Some of the central banks that pioneered IT in the 1990s had extensive sources of data, and reasonably sophisticated macro-modeling and forecasting capabilities.[24] Some economists worried that having such a

[23] In Canada, the starting point for the Great Inflation in the 1970s starts off in 1966, when a labor arbitration agreement that granted union workers massive wage increases. This increase in market power was then cemented by further arbitration agreements as well as a revision to the unemployment insurance compensation scheme, which granted very high replacement rates and increases in coverage to include seasonal workers. This regime was obviously unsustainable, as it resulted in an upward trend in unemployment, as Canadians started using it as a transfer program, instead of an unemployment insurance program.

[24] This was certainly the case for the Bank of Canada, which had a long history of macro modeling and using such models for forecasting and policy analysis. At the beginning of 1990s, the Bank of Canada developed solution methods for solving a class of useful nonlinear models with plausible representations of the monetary policy transmission mechanism, led by Douglas Laxton and Robert Tetlow. The methods were incorporated in the Bank's Quarterly Projection Model (QPM). The Reserve Bank of New Zealand (RBNZ), with help from the Canadians, then implemented and expanded upon this approach to support its novel IT regime, launching what it is known today as the Forecasting and Policy Analysis System (FPAS). Publicly-disclosed forecasts used to inform and explain decisions taken in pursuit of clear policy targets, became the gold standard for monetary policy. See, for reference: Black and others (1994);

capability was a prerequisite for successfully introducing IT.[25] As more and more central banks have successfully adopted the IT approach, however, such concern has faded. A survey of IT central banks found that most have usually embarked on the strategy without having sophisticated models (Batini, Kuttner and Laxton (2005) and Batini and Laxton (2007)). Very few had models that could produce forecasts conditional on different assumptions about monetary policy. However, the adoption of an IT framework often stimulated the development of such models and encouraged their use in a forecasting and policy analysis system. The experience suggests that limited analytical capacity within the central bank need not be an overriding obstacle to introducing IT, but that any central bank introducing IT should, with high priority, develop appropriate models and forecasting procedures.

Technical developments in model-building have made this task considerably easier. Whereas classical econometric estimation requires large data sets and long time series, more recent approaches involve calibrating parameters based on a broad range of relevant evidence or using Bayesian estimation techniques. A traditional econometric approach is unlikely to yield reliable parameter values, because data series—especially in developing and emerging economies—are generally short and affected by structural change or non-stationary processes.[26]

Moreover, in macro models for IT, the linkage between instruments and policy objectives is clearly established. Thus, even though they may contain technically complicated dynamics, the basic way that they work is relatively intuitive to describe to a wide audience. This means the central bank can use them (even informally, depending on the audience) to explain central bank actions within a transparent and consistent analytical framework. Good communications are particularly important during the phase of inflation reduction, since the more effective the central bank is in persuading people that its policy is credible, the lower the costs are of bringing inflation back to target.

In the end, the achievement of low and stable inflation itself alters behavior. The widespread movement to lower inflation over the past twenty years not only has lowered the inflation rate anticipated by the public, but also has changed the process by which expectations are formed. Whereas, previously, expectations drifted with current and past inflation rates, transforming one-off shocks to the price level into prolonged inflation spirals, they are now closely anchored to the low rate targeted by the central bank in many IT countries, with the result that price shocks have only a quickly damped effect on the inflation rate.[27] Our model captures such a shift by means of an inflation expectations process that over time

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Coletti and others (1996); Hunt, Rose and Scott (2000). For a discussion of the history of macro modeling in central banks, see: The Economist, 2006; Berg, Karam, and Laxton (2006a and 2006b); and Botman and others (2007). Many non-FPAS central banks, such as the Bank of England, were simply held back because they did not have access to robust methods for solving non-linear forward-looking models. For an exploration of the development of these methods, see Armstrong and others (1995), Juillard and others (1998), and Armstrong and others (1998). The development of these algorithms then also supported the development of large-scale, multi-country, non-linear OLG models that incorporated fiscal policy and stock-flow dynamics, which, of course, are quite relevant now, given the massive increases in government debt that have accumulated since the Global Financial Crisis. See Ford and Laxton (1995), Freedman and others (2009), Coenen and others (2010), Kumhof and others (2010a), Kumhof and others (2010b), Clinton and others (2011), and Kumhof and Laxton (2013). The historical narrative approach that MPMOD uses builds off the approach pioneered by Romer and Romer (2010) on fiscal policy.

[25] See, for example, Masson, Savastano and Sharma (1997) and Eichengreen and others (1999).

[26] Berg, Karam, and Laxton (2006a and 2006b), discuss in depth this issue as well as the process of model calibration. In a recent speech, Mervyn King indicated that the failure to account for non-stationarities were the problems in the work of classical econometricians, such as David Hendry, who still promote methodologies that ignore the essential role of expectations. See, for example, Hendry and Muellbauer (2018).

[27] Relevant evidence is included in Laxton and N'Diaye (2002), Levin and others (2004), Goretti and Laxton (2005) and Mishkin (2007).

becomes more forward-looking as stable low inflation is established. But it also allows for the fact that even if credibility has been established, there can be the possibility that a failure to respond sufficiently aggressively to inflation developments can result in a loss in credibility and a deterioration in the output-inflation tradeoff. In other words, failing to respond sufficiently aggressively can require Volcker-style interest rate hikes to generate the economic slack needed to reduce inflation and re-anchor long-term inflation expectations.

A. Nonlinear Output Gap Effect

Empirical evidence suggests that the effect of the output gap on inflation is nonlinear (e.g., Debelle and Laxton, 1997). In equation (1), we introduced a strongly increasing impact on inflation as output approaches its maximum value, as follows:

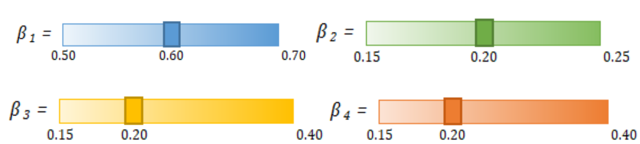
$$\lambda_2 * \left(\frac{\hat{y}_{t-1}}{\hat{y}_{max} - \hat{y}_{t-1}} \hat{y}_{max} \right)$$

The parameter λ_2 captures the marginal effect of an increase in the output gap on inflation, when the output gap is near zero. This term also implies that the output gap cannot exceed a maximum value of $\hat{y}_{max}$. The students of the GFS typically set $\hat{y}_{max}$ equal to 5 percent in the model simulations. Thus, as the gap approaches 5 percent, it has an ever-increasing effect on the inflation rate. This places a limit on the extent to which the expansion of demand can stimulate an increase in output: at $\hat{y}_{max}$, increases in demand result only in increasing inflation. Because of this non-linearity, an economy operating with an output gap near the maximum will subsequently have to incur long periods of negative output gaps to restore the desired inflation rate.

B. Output Gap Equation

The equation for the output gap is expressed in terms of deviations from equilibrium values. The output gap represents the deviation, in percentage points, of actual output from a measure of the potential level of GDP. A positive number indicates that output is above potential, while a negative number indicates that output is less than its potential. The output gap equation is a function of past and future output gaps, lagged reaction to the real interest rate gap, and the term premium gap:

$$\hat{y}_t = \beta_1 * \hat{y}_{t-1} + \beta_2 * \hat{y}_{t+1} - \beta_3 * \hat{r}_{t-1} + \beta_4 * \hat{\varphi}_t^{10YR} + \varepsilon_t^{\hat{y}} \qquad (9)$$



The short-term real interest rate gap ($\hat{r}_t$) is simply the real short-term interest rate minus the equilibrium real short-term interest rate, expressed in percentage points. The model also includes a real term-premium gap ($\hat{\varphi}_t^{10YR}$), that measures the deviation between the 10-year term premium and the equilibrium value. The latter has been a very useful addition to standard models, as it allows us to take a first stab at thinking about the effects of unconventional monetary policies such as the Fed's large-scale asset purchase programs and unconventional forward guidance.[28] Shocks where demand rises by more (less) than supply are represented by the $\varepsilon_t^{\hat{y}}$ shocks.[29]

The importance of each variable in equation 9 is determined by the β parameters. A rough guide to parameter uncertainty for these weights is shown in the slider scales above. The weights for the past output gap (β_1) and future output gap (β_2) are dependent on the degrees of rigidities of the economy in question. For example, an economy that produces a meaningful amount of investment goods would have greater economic rigidities (given the relatively higher cost of adjusting the level of investment in the production of these goods) than an economy that produces a smaller share of investment goods, implying a higher weight for these factors. The weights for the interest rate are represented by β_3, while the weight for the term premium is expressed as β_4.

GFS students can easily study the implications of uncertainty in these parameters by simply adjusting them and recreating their scenarios or creating any scenarios they wish to study. This approach, in the short run, is much more fruitful than specifying distributions for the parameters, as it allows the economist to understand and communicate more clearly specific types of uncertainty. In addition, much Bayesian estimation is conducted without thinking through the implications of parameter distributions for the multivariate distribution of the macroeconomic variables under consideration. As such, it is probably best to start with understanding the implications of perturbations to parameters before conducting extensive formal analysis. However, with that being said, the availability of Dynare/Julia will likely create an explosive amount of research examining parameter, as well as other sources of uncertainty. It, in combination with Latin hypercube sampling, will allow us to work out multivariate distributions in nonlinear models. See, for reference, Chen and others (2009).

C. Monetary Policy Loss Function

Under FIT, by definition, the loss function will attach a high cost to deviations of inflation from target. In the short run, monetary actions also affect interest rates and output, and policymakers are averse to deviations of output from potential and to significant variability of the policy rate from one period to the next. Aiming to keep output near its potential level—i.e., minimizing the amplitude of the business cycle—has an obvious justification, since this is a fundamental objective of macroeconomic policy.

Aversion by central banks to sharp movements in the policy rate, which is evident in their widely observed practice of adjusting policy rates only gradually in response to changes in economic conditions, has a more technical rationale. Whereas the policy rate controlled by the central bank is a very short-term interest rate, the market interest rates that affect consumer and investment spending and output are medium-term and longer-term. Effective transmission of policy actions is facilitated by market rates responding

[28] See Engen, Laubach, and Reifschneider (2015), Adrian, Laxton, and Obstfeld (2018a, b, c), Kuttner (2018), and Laxton and Rhee (2022a).

[29] Sometimes shocks in these types of models can be mislabeled by inexperienced users as simply "demand" or "supply" shocks, when it makes much more sense to think of the economy as being hit by shocks like Covid-19, which can have both demand- and supply-side implications for the economy. For example, during the early stages of Covid where there was massive uncertainty, the lockdowns obviously reduced supply and potential output, but they also had important implications for aggregate demand, which most economists believe likely fell more than aggregate supply. Of course, blindly updating the Kalman filter estimates of potential output from some semi-structural model cannot begin to pick up the dramatic shifts in aggregate supply associated with lockdowns. In FPAS Mark I and Mark II central banks, these effects need to be incorporated through judgment and supported research. Refer to the Monetary Policy Statements of the Reserve Bank of New Zealand.

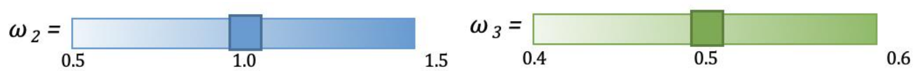
predictably to movements in the expected path of the policy rate. If policy rates move gradually in response to changes in economic conditions, financial markets will project that a change this quarter will have some duration in the quarters ahead. Medium-term and longer-term rates, which incorporate expectations of the future policy rate, then respond relatively strongly to policy actions. High quarter-to-quarter variability in the policy rate, on the other hand, would reduce its impact on relevant market rates, and thereby weaken the effectiveness of the monetary policy transmission mechanism.

With these considerations in mind, the loss function in the model cumulates a weighted sum of:

- squared deviations from the inflation target (year-on-year)
- squared output gaps, and
- squared one-quarter changes in the policy rate

$$Loss_t = \sum_{j=0}^{\infty} \rho^j [\, \omega_1 (\pi 4_{t+j} - \pi^*)^2 + \omega_2 y_{t+j}^2 + \omega_3 (i_{t+j} - i_{t+j-1})^2] \quad (10)$$

$\rho = 0.95$, $\omega_1 = 1$,



The term ρ represents the discount rate. The weights (ω_i) embody the costs that policymakers attach to each of these items. Monetary policy minimizes this loss function, subject to the constraints imposed by the structure of the model. Monetary policy has choices with respect to the speed at which inflation returns back to the target. This may be faster, if the cost of missing the inflation target is high relative to the costs of output gaps and interest rate instability. Or, it may be slower, if the cost of inflation-targeting errors is relatively low, such as when long-term inflation expectations are well-anchored and there is a high degree of confidence in the inflation-targeting regime.

For most FIT central banks, the quadratic loss function implies symmetric aversion to overshoots and undershoots with respect to the inflation target. One might argue that policymakers' preferences would not be symmetric under a program of inflation reduction. They might regard an undershoot of inflation as a benign, albeit unexpectedly rapid, approach to the low-inflation objective, but an overshoot as a serious threat to the program. Despite the symmetric loss function, the full model does not imply symmetric policy responses, since endogenous credibility results in a stronger interest rate response to overshoots than to undershoots. For the United States, the loss function has been extended to include an asymmetric loss function where the Fed has been assumed to care about full employment and not excess demand in the labor market. This has the potential to create an inherent upward bias in inflation, in circumstances when the economy is being hit by a combination of strong demand shocks such as fiscal and unconventional forward guidance and stagflationary shocks related to easing pandemic-related social distancing requirements.[30] The model that is being employed is based on an IMF working paper that proposed a modest overshooting strategy,[31] but one based on a symmetric loss function, which implies that the central

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[30] For good examples of potential inflation-bias problems, see Barro and Gordon (1981) and Kydland and Prescott (1977). Freedman and Laxton (2009) argue that the two intellectual roots of inflation targeting and the cause of the Great Inflation of the 1970s are the absence of long-run trade-offs and the time-inconsistency problem. The former calls for high levels of transparency to ensure that central banks have a state-of-the-art analytical framework; the latter calls for strong institutions to make sure that central banks are committed to their long-term inflation objectives, and don't try to exploit the short-run unemployment-inflation tradeoff at the expense of achieving their long-term inflation expectations.

[31] See Alichi and others (2009).

bank raises interest rates much more aggressively in the short run in response to overheating. We emphasize the word *short run* because aggressive increases in policy rates early on will mean less aggressive policy rate hikes later, which are, in this case, much higher than they would otherwise need to be if medium-term inflation expectations would have remained better anchored and prevented sticky-price inflation from ratcheting up as much as it did.

IV. SCENARIO ANALYSIS: IMPLICATIONS FOR POLICY

We use some well-defined and plausible narratives during the Covid-era economy to construct some ex-post scenarios to illustrate how the model could have been used effectively during such an unprecedented period of heightened uncertainty. We use the model to simulate what scenario analysis would have looked like when there was a raging debate about inflation being transitory or persistent.

We also provide forecast scenarios using the initial conditions from August 2022 to illustrate how the model is being used for current analysis, and importantly, for thinking about the dark corner of high inflation confronting many central banks around the world.

We also nest these scenarios within the framework that is being developed for the FPAS Mark II (see Archer and others (2022)) process, where the bank should produce multiple scenarios that maintain macro-consistency. These scenarios are labeled as Case A's, Case B's and Case X's.

- *Case A's* are scenarios where the policy rate would need to be higher than the rate the market currently expects. A hawkish scenario.
- *Case B's* are scenarios where the policy rate would need to be lower than the rate the market currently expects. A dovish scenario.
- *Case X's* are tail risk scenarios as well as scenarios that incorporate avoiding the dark corners of monetary policy; for example, high and variable inflation or a low inflation trap.

A. Summer of 2021 Scenarios – Endogenous Credibility

Case A: Inflation is persistent.

On the heels of a large fiscal stimulus in early 2021, there were early criticisms by people like Olivier Blanchard and Lawrence Summers that the stimulus was too large. The primary concern articulated by Blanchard, Summers, and others was that aggregate demand was already pushing up against aggregate supply, and this was translating into higher inflation. Indeed, core inflation had been accelerating for a few months as we entered the summer season, and debates emerged about whether inflation was going to be more persistent or transitory. This Case A scenario reflects a belief at the time that core inflation was going to stay elevated due to the previously stated concerns requiring a faster lift-off of interest rates to cool demand and keep core inflation from ratcheting upwards.[32]

[32] Refer to "Not the Teal Book" (Papikyan and others (2022a)) for recent estimates of potential output and the natural rate of unemployment that are used by the GFS, as well as how the effects of Covid have been incorporated judgmentally into the estimates.

Case B: Inflation is transitory.

The Case B reflects the predominant view held by the Fed at the time, which was that supply-side factors connected to the COVID-era economy of supply-chain disruptions were the main contributor to the rise in inflation. These temporary supply-side shocks were therefore expected to dissipate over the coming months. The policy rate could normalize in line with the still-recovering labor market that did not materially cross the NAIRU threshold, where it would be considered a tight labor market.

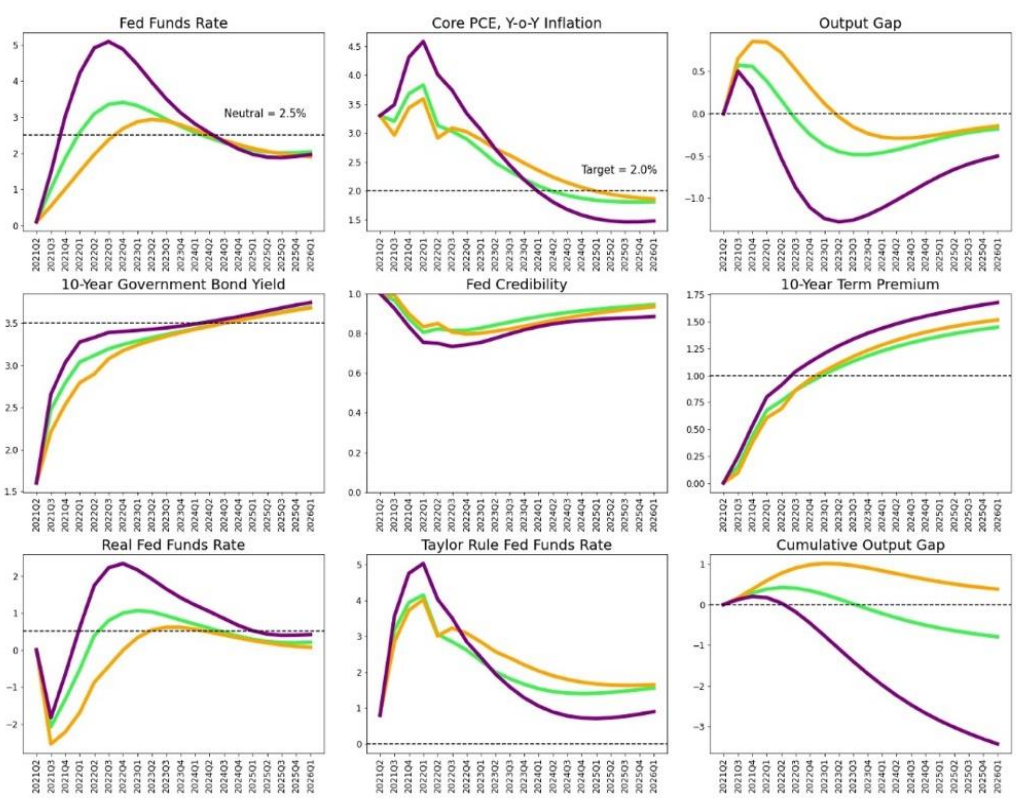
Case X: Stagflationary shock.

Regardless of whether someone is in the Case A or B camp, inflation was expected to rise (whether for either supply- or demand-side reasons), making the economy more susceptible to shocks that would exacerbate the problem and threaten the dark corner of high inflation. With this backdrop it is reasonable to consider a stagflationary shock such as an oil price shock. Given the relative vulnerability of the economy where inflation is already edging higher, the stagflationary shock feeds into core inflation much stronger than it otherwise would. Central bank credibility takes a modest hit and policy must respond forcefully otherwise it risks compounding the shock with a further loss in credibility.

The three corresponding scenarios are plotted in Figure 5.

Figure 5: Summer 2021 Scenarios – Endogenous Credibility

Case A ---, Case B ---, Case X ---



Source: Authors' calculations

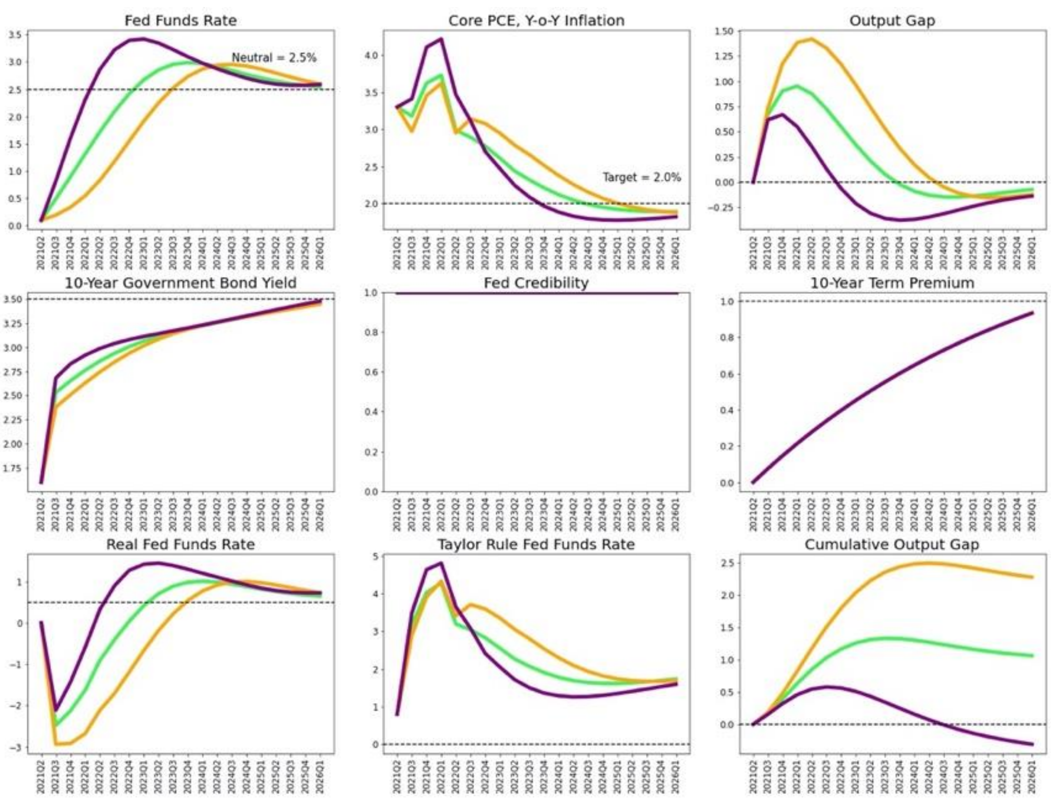
B. Summer of 2021 Scenarios – Exogenous Credibility

To demonstrate the value that an endogenous credibility framework would have had if it had been employed in the Summer of 2021, we present the same exact Case A, B, and X scenarios as above, but instead, using a model that presumes *exogenous* credibility. What happens if we fail to consider that credibility is endogenous when we are making policy decisions? In other words, what went wrong in policymakers' thinking in the Summer of 2021?

The results, presented in figure 6 below, provide hints to the answer.

In the Case A scenario, assuming exogenous credibility, the implied policy rate is one percentage point lower than when we assume endogenous credibility. The implication is that even if the Fed had assumed that inflation was persistent rather than transitory, because it employed analytical methods that assumed exogenous credibility, it would have failed to appreciate the *scale* of policy rate increases that would have been necessary to bring inflation back to target in a timely manner.

Figure 6: Summer 2021 Scenarios – Exogenous Credibility



Source: Authors' calculations

But this is true even in the Case X scenario when we assume exogenous credibility: the implied Fed Funds rate is still meaningfully lower (peak of 3.5%) than when we assume credibility is endogenous (around 5%). This conceptual flaw has real-world policy implications that we saw play out after the Summer of 2021. The conceptual ingredients that form the basis of the Summer 2021 Case X scenario—that underlying inflation was going to rise, making the economy vulnerable to stagflationary shocks—have essentially materialized in the economy since then. Thus, even if the Fed had believed the ingredients of this Case X to be likely representations of where the economy was headed, it would not have grasped the magnitude of the aggressive policy response needed to quell inflation because its analytical tools did not assume endogenous credibility. This is in many ways a representation of former Bank of England Governor Mervyn King's idea that central banks had been infected by flawed ideas in the economics profession, which in this case is the assumption expectations are always firmly anchored to their 2% targets.

C. Summer of 2022 Scenarios

We perform the same exercise for the Summer of 2022. Core inflation has risen substantially since the Summer of 2021 due to a combination of ingredients that were included in the above Summer 2021 Case A and Case X scenarios. Underlying inflation has turned out to be much higher than was initially expected by the Fed, with various measures of core inflation ranging between 4% and 5%. The labor market has continued to remain strong, in spite of two contractions in GDP in the first half of 2022. At the time, the data for the real economy had not suggested an imminent recession was in the cards for Q3 2022, despite media reports by financial-market experts that the economy was already in a recession. Given the uncertainty about the Q3 estimates for GDP growth, it was decided that we wanted to encompass scenarios that would involve a significant contraction in GDP, as well as a bounce back from the first half of the year.

Case A: Core inflation is driven by domestic demand.

Amidst a moderately hot economy, excess demand compounds existing inflationary pressures and requires higher interest rates to cool the economy and bring core inflation back to the target.

Case B: Core inflation will moderate from lower external demand.

This view reflects concerns that the European Union is on the verge of a recession, and China's growth prospects are being revised lower. These factors have led many to believe a global recession is imminent. This, coupled with asset price corrections, would be expected to naturally cause demand in the US to moderate and help bring core inflation down.

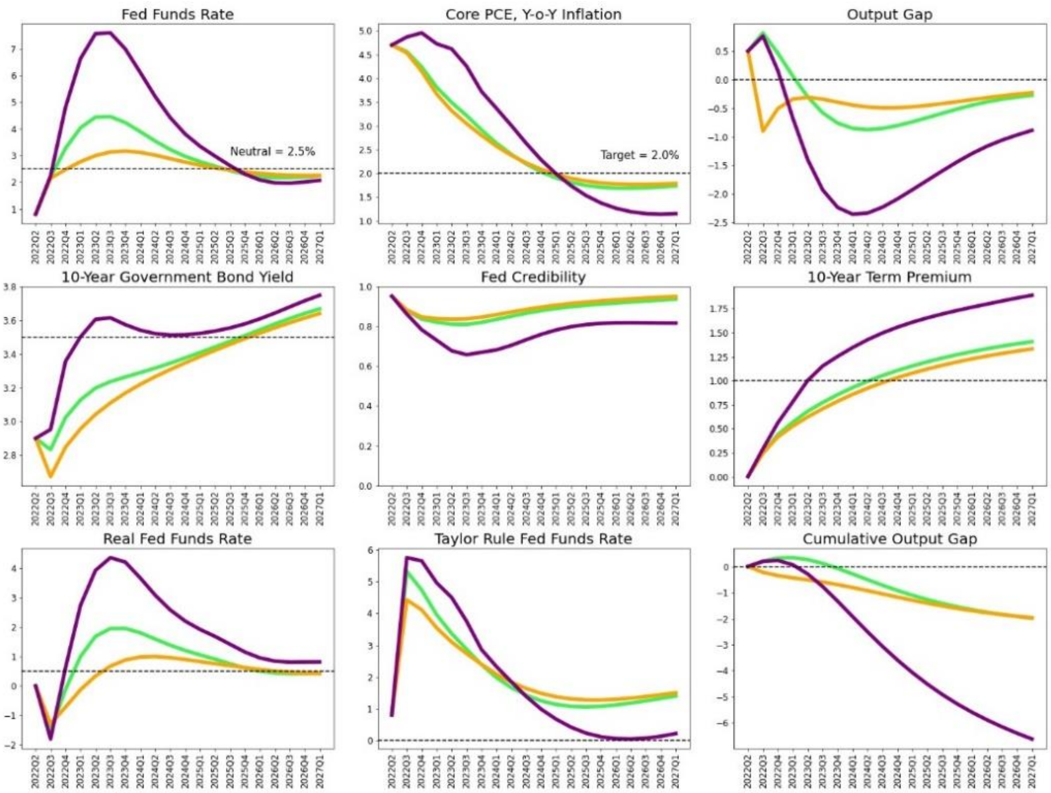
Case X: Inflation is entrenched.

Higher prices have started to feed into wage growth, reaching around 7%, and have now become entrenched. Given this, the Case X view reflects the expectation that core inflation remain elevated as wages continue to grow well above what would be consistent with a 2% inflation target. In this case, with nominal wages growing by 7% and real growth being around 2%, a rough estimate of 5% for core inflation is plausible. Core inflation remaining persistently high hurts the stock of credibility and requires a higher interest rate response.

The three corresponding scenarios are plotted in Figure 7.

Figure 7. Summer 2022 Scenarios

Case A ---, Case B ---, Case X ---



Source: Authors' calculations

V. CONCLUDING REMARKS

This paper introduces the foundational components of an analytical framework that can help tackle the key challenges that must be confronted by policymakers today: important nonlinearities and significant uncertainty. The ENDOCRED model that presented in this paper provides a simple workhorse model incorporating these components, which include:

- **Endogenous policy credibility**: in periods of higher and persistent inflation, credibility can either be built over time (as long-term inflation expectations converge gradually to the target), or be lost (if doubts emerge in the central banks' commitment to the inflation target);
- **Non-linearities**: including convex Phillips Curve and the process of credibility generation;
- **Explicit policy loss function**: authorities tend to have a preference to contain deviations of output from its potential level, and to limit the variability in the interest rate, in addition to limiting deviations of inflation from its target.

This paper presents a practical demonstration of how this analytical framework can support effective policymaking in times of high inflation and significant uncertainty. We present a policy simulation exercise for two such periods, taking the United States as an illustrative example: the summer of 2021 (when debates raged about whether inflation was transitory or persistent) and the summer of 2022 (the implications of core inflation being consistently higher than previously thought).

These examples illustrate the value of analytical frameworks that treat monetary policy credibility as *endogenous*—in other words, the understanding that central bank credibility is not fixed and unchanging, but rather, that the central bank's policy actions may have implications on its credibility. When policymakers such as (but certainly not limited to) the Fed neglect to treat credibility as endogenous, they fail to appreciate the magnitude and aggressiveness of policy actions that are necessary to bring inflation back to target in a reasonable timeframe in the context of an efficiently managed inflation-output and inflation-unemployment tradeoff. In the Summer of 2021, an approach that treated credibility as endogenous may have helped the Fed act more aggressively sooner, potentially allowing the central bank to tackle high inflation more efficiently and in a less costly manner.

In a series of media appearances and speeches in 2021 and 2022, Lawrence Summers raises a number of issues about central bank communications that have spurred open debates about the future of monetary policymaking and the analytical frameworks needed to support this. These comments have also been echoed by prominent economists such as William White, who argues convincingly that, "banks can restore their lost credibility, as guardians of price stability, only by admitting their errors and specifying clearly how they intend to improve their performance in the future."[33] The case studies in this paper, dovetailed with Summers' and White's remarks, highlight a basic conclusion: in times of incredible uncertainty, such as adverse supply shocks, a failure to act quickly, aggressively, and flexibly can lead to a very costly loss of credibility. This results in the need to adjust policy rates much more aggressively to reduce inflation, at much greater costs to output and unemployment: in a word, stagflation!

[33] See White (2022).

APPENDIX 1. DYNARE/JULIA WORKSHOPS

The Central Bank of Armenia, in conjunction with the Global Forecasting School, will be hosting Hybrid Quarterly Conferences & Training Sessions.

These conferences will discuss the following topics:

- Dynare/Julia Updates
- RAISE Updates
- FPAS Mark II Hot Topics
- DSGE Hot Topics

The format will be a conference and workshop setting, where guests are encouraged to present papers and be part of the Global Forecasting School's signature *Dynamic Learning Environment*.

The first conference will be held on January 11-13, 2023 at the Central Bank of Armenia's Dilijan Training and Research Centre, in Dilijan, Armenia. This paper, including the ENDOCRED model and applications to Dynare/Julia, will be discussed at the January conference.

The remaining three conferences will be held at the beginning of each quarter:

- January 11-13, 2023 – Dilijan Training Center (DTC)
- April 2023 – Carcavelos, Portugal
- July 2023 – Annual Conference at DTC
- October 2023 – Carcavelos, Portugal

Refer to www.thebetterpolicyproject.org for more information.

APPENDIX 2: SENSITIVITY TESTING

Note on calibration

Given that there is uncertainty around parameters, and we can never be too confident about their settings. It is therefore important that calibration explores different settings to test the model's sensitivity. Calibration is an important learning component to analysis, so we selected parameters within a reasonable range to ensure that the model generates dynamics that capture the data in a way that is consistent with stylized facts. The most critical parameter variables are those of the Phillips curve (λ's) and the output gap (β's). The parameters have been chosen such that a typical Phillips curve is generated. In this Phillips curve, there is considerable weight on both forward- and backward-looking components, consistent with the data and agents' behavior. In the output gap equation, we test different sensitivities on the interest rate term.

Sensitivity Analysis 1. Inflation Expectations Channel in the Phillips Curve

$$\pi_t = \lambda_1 \pi 4_t^e + (1 - \lambda_1)\pi 4_{t-1} + \lambda_2 \left(\frac{\hat{y}_{t-1}}{\hat{y}_{max} - \hat{y}_{t-1}} \hat{y}_{max} \right) + \varepsilon_t^{\pi}$$

Sensitivity Analysis 1 examines the impacts of different parameter values for λ_1 on monetary policy credibility. λ_1, the parameter in front of the inflation expectation term, determines the weight on inflation expectations versus lagged inflation and reflects the degree of monetary policy credibility. The lag term captures the intrinsic inertia in the adjustment coming from sources other than expectations, such as adjustment costs or contracts.

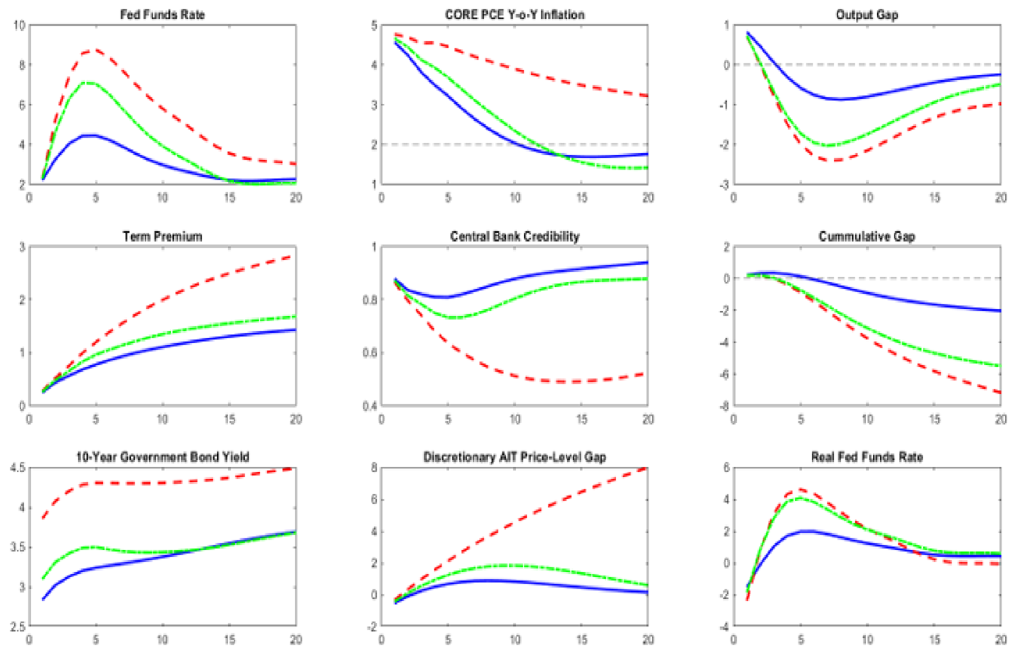
A more credible and anchored monetary system (with a higher λ_1 coefficient, meaning a greater weight on the expectations term) enables a central bank to have a larger and more immediate effect on inflation through a smaller increase in policy rates. On the other hand, if the effect of inertia is more dominant (with a lower λ_1 coefficient term, meaning a lower weight on the expectations term), longer periods of monetary policy actions and higher interest rates are required to return inflation back to target. It is important to understand that while λ_1 tends to be higher in countries with central banks that are more credible and have better-anchored expectations, no amount of perfect credibility can possibly eliminate the role of the lag effect. In other words, market participants form their expectations based on a combination of lagged effects and forward-looking expectations, and the former will *always* play a role in influencing inflation expectations. This is particularly true in countries where it is virtually impossible to control inflation very well and escape from the regular, ongoing stagflationary types of shocks that central banks face (e.g. in Colombia, India, and other countries, where weather patterns can impact crop yields and create stagflationary shocks well outside the central bank's control).

Keeping the latter point in mind, in less credible monetary policy frameworks, the weight on inflation expectations term is lower. In this first sensitivity case ($\lambda_1 = 0.6$), inflation is more persistent and dependent on its lag, which causes larger losses in central bank credibility. To bring inflation back to target, the central bank needs to increase the policy rate more and keep it higher for longer, thus causing a larger loss in output (cumulative output gap loss almost 3 times larger).

In situations where inflation inertia is even more persistent and dominant ($\lambda_1 = 0.5$), central banks need to take drastic actions to bring inflation back to the target and restore lost credibility. In this case, it takes very long for inflation to return to target (more than 10 years in our simulation), and a very big economic recession will be generated (around -10% cumulative output gap). We test different calibrations in Figure A.1.

Figure A.1: Different Calibrations of λ_1 in the Philips Curve

$(\lambda_1 = 0.7)$ ---, $(\lambda_1 = 0.6)$ ---, $(\lambda_1 = 0.5)$ ---



Source: Authors'calculations

Sensitivity Analysis 2. Effects of Long-Term Interest Rates on Output Gap

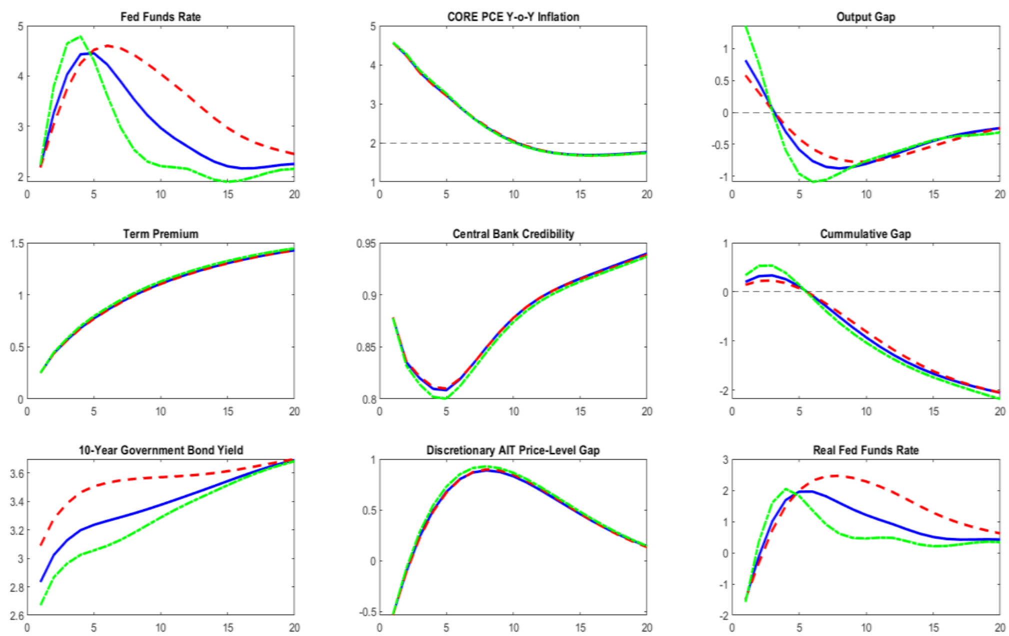
$$\hat{y}_t = \beta_1 * \hat{y}_{t-1} + \beta_2 * \hat{y}_{t+1} - \beta_3 * \hat{r}_{t-1} + \beta_4 * \hat{\varphi}_t^{10YR} + \varepsilon_t^{\hat{y}}$$

Sensitivity Analysis 2 examines the impact of the effectiveness of the interest rate transmission mechanism on the output gap. In economies where the mechanism on output works better (when the value of β_3 is higher, such as $\beta_3 = 0.4$), central banks do not need to increase policy rate as much or keep rates higher for longer. This situation allows policymakers to manage output-inflation tradeoff more efficiently. When the mechanism is less effective ($\beta_3 = 0.1$), policy rates have to be kept higher for longer, resulting in losses of efficiency in the output-inflation tradeoff.

In Figure A.2, we test these different parameter values for β_3.

Figure A.2: Different Calibrations of β_3 in the Output Gap Equation

($\beta_3 = 0.2$) ---, ($\beta_3 = 0.4$) ---, ($\beta_3 = 0.1$) ---



Source: Authors' calculations

We highly recommend modelers that are interested in developing their own country models to conduct similar types of analysis with most, if not all, parameters in their model to: first, better understand the economic concepts behind each parameter; second, get a grasp of the different ranges for certain parameters, and why some ranges are more plausible than others; and third, achieve a better understanding of the uncertainty embedded in the model. A thorough understanding of these elements are critical for applying these types of macroeconomic models and conducting useful macroeconomic analysis in real-time, when there is a high degree of uncertainty in the economy.

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