# Learning, Changing Perceptions and the Anchoring of Expectations *

Shreeyesh Menon †

October 22, 2025

**Abstract**

I explain the behavior of inflation, unemployment, and long-run inflation expectations in the post-war U.S. by estimating a forward-looking model in which private agents learn about structural fundamentals and the policymakers' stabilization preferences in real-time. Learning is structural: agents understand that aggregate economic dynamics result from their optimizing behavior under imperfect knowledge. Monetary policy is conducted optimally but private agents suspect that the policymakers' stabilization preferences are evolving, which they learn from observed policy behavior. This gives rise to a nonlinear filtering problem. The model provides a novel, information-theoretic explanation of how systematic monetary policy anchors expectations when agents are learning: an increasing emphasis on real-side stabilization has made the Fed's policy behavior more predictable, stabilizing long-run inflation expectations while at the same time rendering short-run expectations more susceptible to supply shocks. The model offers a new explanation for the recent post-Covid inflation surge and the "costless disinflation" that followed, shedding light on why it differed markedly from the crisis of the 1970s and 1980s.

**Keywords:** Inflation Stabilization, Monetary Policy, Interest Rates, Lucas Critique, New Keynesian
**JEL Codes:** E120, E510, E520, E580

*I thank Saroj Bhattarai, Oli Coibion, Stefano Eusepi, Oliver Pfauti and Arpita Chatterjee for their guidance and advice. This paper has also benefited greatly from discussions with Larry Christiano and Aeimit Lakdawala.
†The University of Texas at Austin, Department of Economics, 2225 Speedway, 78712 Austin TX, shreeyesh-menon@gmail.com

# 1 Introduction

The post-pandemic surge in inflation—which saw U.S. CPI inflation rise to a 40-year high of 9.1% in June 2022—caught both the private sector and policymakers off-guard. As inflation remained elevated, comparisons were drawn to the "Great Inflation" of the 1970s–80s. Both periods were accompanied by a sharp rise in oil prices and supply disruptions, yet they yielded very different macroeconomic outcomes: a protracted inflationary spiral culminating in a painful disinflation in the 1980s versus a relatively swift "soft landing" that has characterized the US economy's recovery from the pandemic shock. A particularly striking feature of the recent surge has been the stability of long-run inflation expectations - even as private agents expected inflation to remain elevated in the short-run, their long-run expectations remained remarkably well-anchored (as seen in Figure 1).

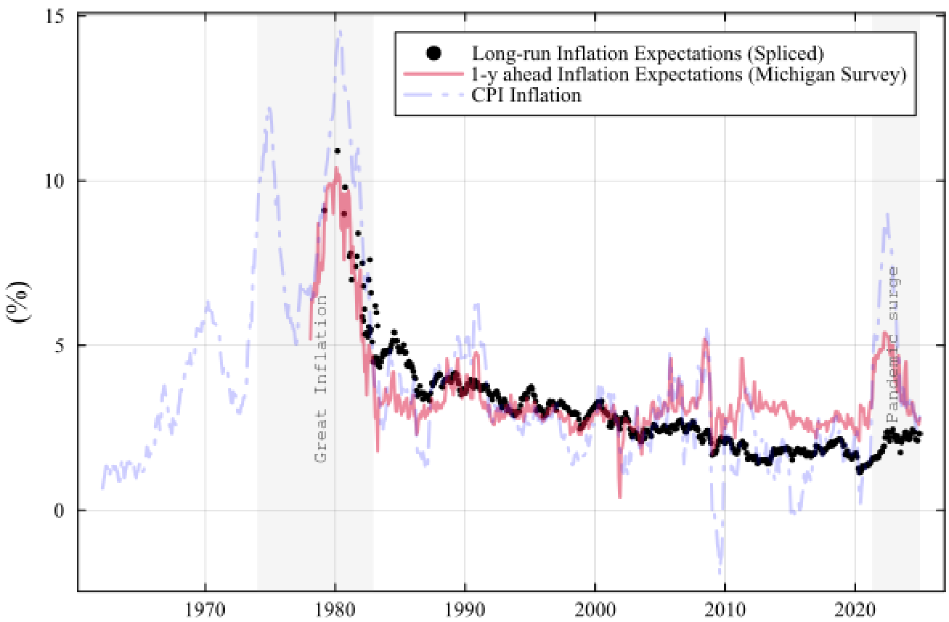



Figure 1: **Growing discord between short-run and long-run inflation expectations**: Evolution of one-year ahead inflation expectations and long-run inflation expectations from surveys *During the Great Inflation, both long-run and short-run inflation expectations were elevated to nearly the same degree and tracked each other closely. However, in recent years, short-run expectations have remained volatile yet the long-run expectations have remained much more firmly anchored.*
Long-run Inflation Expectations series is constructed by splicing together 5-year ahead inflation expectations from Michigan Survey before 1982 and 10-year ahead inflation expectations from the Cleveland Fed afterwards (due to a shorter sample).

To explain these divergent outcomes, I develop a structural model with three key features. First, neither the private agents—households and firms nor central bank policymakers possess full information - their behavior is shaped by their *perceptions* regarding the "fundamental" state of the economy; which are formed based on interpreting macroeconomic outcomes through the lens of a forward-looking structural model; thus they are perpetually *learning*. Second, monetary policy is conducted optimally under discretion, with policymakers minimizing a loss function reflecting a dual mandate, weighing between stabilizing inflation around a target and unemployment around its *natural* level. Third, agents suspect that the central bank's stabilization preferences may evolve over time, and they update their beliefs about these preferences based on observed policy behavior. Expectations are thus shaped by beliefs about both the structural features of the economy and the time-varying objectives of policymakers. Anchoring or de-anchoring of expectations thus results endogenously from the learning process. I estimate the model using monthly U.S. data on inflation, unemployment, and the federal funds rate over the postwar period, together with 10-year-ahead inflation expectations from the Survey of Professional Forecasters (SPF).

I find that a forward-looking New-Keynesian model augmented with learning is able to account for macroeconomic dynamics in the postwar U.S. remarkably well. Through the lens of the model, private agents' perceptions regarding the Federal Reserve's systematic conduct of monetary policy have changed drastically over the forty years separating the pandemic surge and the Great Inflation. In the 1970s and 1980s, private agents perceived the Fed as placing little weight on keeping the unemployment rate close to its *natural* level, allowing substantial unemployment-gap volatility. Policy appeared primarily oriented towards maintaining inflation near an implicit and unobserved target. A prolonged period of accommodative policy by the Fed - especially a tendency to deliberately inflate during recessions resulted in de-anchoring of long-run inflation expectations as agents learned. Both short-run and long-run inflation expectations rose in unison. Over the years following the Volcker disinflation, policy behavior has signaled an increasing emphasis on keeping the unemployment gap closed over and beyond a concern for inflation stabilization. This perception has reined in the degree to which agents update their beliefs about the Fed's target based on observed policy behavior, leading to long-run inflation expectations acquiring more inertia and being better anchored.

This mechanism is key to understanding the seemingly costless disinflation or the "soft landing" that followed the recent inflation surge. Even as policymakers demonstrated an unwillingness to respond to the inflation crisis for over a year (prompting concerns that the Fed was falling "behind the curve" for instance), private agents were slower to revise their long-run inflation expectations. The delayed response was rather interpreted as a greater emphasis on unemployment-gap stabilization - which would cause agents to expect inflation to stay elevated in the short-run. Thus under learning, short-run and long-run inflation stabilization are in tension. This mechanism is found to explain the peculiar discord between the behavior of short-run and the long-run inflation expectations over the years following the Volcker disinflation that is often cited as evidence for "anchored" long-run beliefs.

The central bank's conduct of monetary policy is guided by the changing economic goals of the policymakers. In the model, monetary policy does not conform to any *instrument rule*, but is the result of an optimal policy problem under discretion given the policymakers' beliefs and policy preferences.[1]. Their policy decisions *reveal* information regarding their policy objectives. Hence, there is a non-trivial role for a "learning-channel" of monetary policy transmission in this environment, which operates by revealing information regarding the policymakers' stabilization preferences to the agents. Through this channel, policy influences agents expectations over all future horizons: there is *forward guidance* embedded into policy itself. When private agents observe discrepancies in policy behavior relative to their ex-ante expectations, they attribute part of it to be resulting from idiosyncratic policy errors which will get corrected in the future (policy falling "behind the curve"), and the rest to shifts in the policymakers' stabilization preferences and hence indicative of how policy will be conducted in the future (in this case, the agents are behind the curve and need to learn). Anchoring or de-anchoring of private agents expectations is an endogenous result of this learning process.

The literature on learning in macroeconomics highlights how agents update their beliefs in response to data *in real-time*, emphasizing the feedback from macroeconomic outcomes to agents' beliefs and decisions, something that full-information rational expectations abstracts from completely. However, much of the existing literature focuses on adaptive learning, where agents estimate reduced-form forecasting rules based on past data. In this setting, agents do not internalize the general equilibrium consequences of their beliefs, treating aggregate dynamics as exogenous to their individual behavior. This paper models *structural* learning approach (see Williams (2003)), in which agents form expectations using a forward-looking model that accounts for the feedback between their beliefs and aggregate outcomes. While knowledge is imperfect, expectations remain disciplined by rational forward-looking behavior, ensuring that beliefs are consistent with the underlying structural dynamics implied by optimization.

Importantly, macroeconomic shocks by themselves do not cause agents' expectations to de-anchor so long as policy responds in the way that the agents expect. When agents reason structurally, they know that under appropriate response of policy, the economy *can* return to the same long-run equilibrium. It is the interaction between macroeconomic surprises and the policy re-

[1]Instrument-rules such as the Taylor-rule are opaque regarding the trade-offs that policymakers actually face while deliberating about the conduct of monetary policy. It also causes an inconsistent asymmetry regarding how policy behavior is modeled, departing from the forward-looking optimizing framework modeling household and firm behavior. This critique is outlined in Svensson (2003)

sponse that determines whether expectations are anchored and whether they remain anchored, rather than macroeconomic shocks in isolation.

The model also sheds light on the state-dependent nature of agents' inference: informative signals about structural parameters arrive only in particular states of the world, often in discrete "lumps". Further, agents face the same kind of econometric challenges while reasoning in real-time that researchers face ex-post. For instance, agents revise their beliefs about the weight policymakers place on unemployment-gap stabilization primarily during episodes when large and persistent cost-push shocks create visible trade-offs between inflation and real activity. Similarly, learning about the slope of the structural Phillips curve is exceptionally slow due to a poor signal-to-noise ratio: unemployment gaps are typically small, and their relationship with inflation is obscured by overlapping supply shocks. Meaningful information arriving almost exclusively during demand-driven recessions. The very arrival of information is state-dependent, which adds a key source of nonlinearity that models assuming full-information would entirely miss.

**Related literature:** The literature on learning in macroeconomics departs from the standard full-information benchmark and seeks to model how economic agents acquire information and form expectations. The literature has largely focused on adaptive learning (see Evans and Honkapohja (2001) for overview and applications) where agents use simple forecasting rules, typically reduced-form VARs to form expectations. Adaptive learning by private agents has been proposed as an explanation of the observed persistence in macroeconomic series that does not rely on ad-hoc frictions such as indexation to past prices and habit formation in consumption (see Milani (2007) and Erceg and Levin (2003)).

This paper is an empirical application of learning to study macroeconomic behavior in the post-war U.S., and is closely related to the literature examining how private agents' and policymakers' learning contributed to the Great Inflation of the 1970s and 1980s (e.g., Bullard and Eusepi (2005); Primiceri (2006); Sargent, Williams and Zha (2006),Orphanides and Williams (2005)). More broadly, it connects to the literature on how the private sector learns from monetary policy behavior. For instance, Melosi (2016) examines the signaling role of policy in a DSGE framework, where monetary policy is informative about aggregate shocks. By contrast, in this paper, the only source of information asymmetry arises from the private sector's inability to observe the central bank's stabilization preferences. Other related work has explored how agents infer policy targets from macroeconomic data (e.g., Kozicki and Tinsley (2005); Erceg and Levin (2003); Orphanides and Williams (2006)). However, much of this literature relies on adaptive learning, in which agents form beliefs using reduced-form forecasting rules based on historical correlations. In contrast, the learning behavior in this paper is grounded in a structural, forward-looking framework rooted in New Keynesian principles, where agents understand and internalize the effects of their expectations on macroeconomic outcomes.

The causes of the Great Inflation and the subsequent Great Moderation have been the subject of long-standing debate. One school attributes the volatility of the 1970s–80s era to "bad luck": a sequence of large, adverse non-policy shocks (e.g., Sims and Zha (2006); Bernanke and Mihov (1998)). Under this view, the structure of the economy and policy rules remained largely stable; it was the volatility of exogenous shocks that changed. This view implies that monetary policy made little fundamental progress—if similar shocks were to recur, so would similar outcomes. However, I find that how agents perceive the Fed's stabilization policy based on observed policy behavior has changed drastically which has had a huge bearing on the macroeconomic outcomes ever since the Great Moderation and beyond.

An alternative view emphasizes policy errors. Clarida, Gali and Gertler (2000), Taylor (1993) and Lubik and Schorfheide (2004) argue that the shift to systematic anti-inflation policy by the Fed under the chairmanship of Paul Volcker was central to the subsequent stability. DeLong (1996) and Romer and Romer (2002) provide narrative evidence that policymakers in the 1970s were misled by a perceived long-run tradeoff between inflation and unemployment. Some papers study whether these policy mis-steps by the Fed were a result of "wrong" kind of incentives. For example Christiano and Gust (2000) invokes the idea that the Fed fell into an "expectations trap", lacking the incentives to take decisive action to rein in inflation during the 70s. At least from the private agents' perspective, I find that policy errors were made. The model I present does not take a stance on the *source* of these errors, but rather, the focus here is on the *consequences*: how these errors shaped the agents' views regarding the Fed's incentives and led to inflation through the expectations channel.

Lack of Fed credibility has been proposed as another explanation for the Great Inflation. King and Lu (2022) and Debortoli and Lakdawala (2016) find that lack of commitment to low inflation in 70s made the disinflation much more costly. A related strand of literature has studied the mechanisms through which long-run inflation expectations get *anchored*. Carvalho, Eusepi, Moench and Preston (2023) and Gati (2023) describe anchoring in terms of how agents weight recent inflation data when updating their beliefs about the long-run mean of inflation based on past forecast errors (forecast-switching). In this paper, anchoring directly results from agents learning about the central bank's stabilization preferences based on the *policy response* to inflation rather than the behavior of inflation itself.

This paper contributes to the debate by offering a framework that disentangles these three explanations and sheds light on how each of these contributed to shaping the two prominent inflationary episodes in the post-war period in the U.S.

**Outline:** In Section 2, I motivate the agents' perceived structural model describing the economy as perceived by private agents which they use to reason about the macroeconomic environment that they face. In Section 3, I describe how agents recursively update their beliefs regarding the policy-invariant structural variables in their model conditional on macroeconomic observations. In Section 4, I describe the conduct of monetary policy from the perspective of the agents and describe how they update beliefs regarding the policymakers' stabilization preferences conditional on observed nominal interest rates. In Section 5, I describe the estimation methodology and the data. In Section 6, I discuss how the agents' beliefs have evolved during the postwar period in the U.S. under learning followed by concluding remarks.

# 2 A forward looking model under imperfect knowledge

Here I begin by describing the information structure of the economy, defining the set of signals that agents observe at any time, based on which they form their beliefs and make decisions. Then, I derive the agents' perceived law of motion describing the structural dynamics of the macroeconomic aggregates under imperfect knowledge.

## 2.1 Information structure and learning

Time is discrete ($t = 0, 1, 2, 3, \ldots$). Under the information structure in the model, neither the latent structural parameters or the structural shocks are directly observed by the agents. The only relevant signals available to them comes in the form of the realizations of the aggregate inflation rate, unemployment rate and the nominal interest rate. At the beginning of each period $t$, firms and households make their decisions conditional on the history of signals observed until that point. The period-$t$ inflation $\pi_t$ and unemployment rate $u_t$ then realize and are observed by the agents. The central bank then sets the interest rate $i_{t+1}$ in anticipation of future outcomes. The agents interpret the policy decision and form beliefs regarding the policymakers' stabilization preferences. Thus, at the end of period-$t$, $\pi_t$, $u_t$ and $i_{t+1}$ are realized and observed by all agents.

The entire history of aggregate signals observed by agents up to (and including) period $t_0$ is denoted by:

$$\mathcal{H}^{t_0} = \{i_{t+1}\}_{t=-\infty}^{t_0} \cup \{z_t\}_{t=-\infty}^{t_0}$$

where $z_t = [\pi_t, u_t]'$ is the vector of realizations of inflation and unemployment, and $i_{t+1}$ denotes the interest-rate policy set in period-$t$.

## 2.2 The agents' perceived model of aggregate dynamics

Following New Keynesian principles, I derive the log-linearized equations describing the structural dynamics of the economy from the perspective of the agents, based on a model of optimizing behavior by firms and households under imperfect knowledge. I assume that all private agents firms and households have common beliefs regarding the policy-invariant latent structural drivers of the economy, formed conditional on the same data and model.[2] I denote the private agents expectations conditional on $t-1$ history $\mathcal{H}^{t-1}$ as $E^P_{t-1}$.

### 2.2.1 Aggregate demand: Households' consumption smoothing problem

Consider the problem of a representative household who derive utility from consumption and save in nominal bonds $B_t$ in every period $t$ conditional on their beliefs formed based on observed history $\mathcal{H}^{t-1}$:

$$\max \; E^P\left[\sum_{k=0}^{\infty} \beta^k \frac{C_{t+k}^{1-\sigma}}{1-\sigma}\right] \tag{1}$$

where $C_t$ is consumption, $\beta$ is a discount factor, $\sigma > 0$ is the inverse of the intertemporal elasticity of substitution

The household's budget constraint in nominal terms is:

$$P_tC_t + B_t = (1 + i_{t-1})B_{t-1} + W_t + T_t + \Pi_t \tag{2}$$

where $P_t$ is the aggregate price level, $B_t$ are nominal bond holdings, $i_{t-1}$ is the nominal interest rate in period $t-1$, $W_t$ denotes their nominal wage-income, $T_t$ denote lump-sum government transfers and $\Pi_t$ denotes profits from the ownership of firms.

[2] I abstract from heterogeneity in agents' belief-formation process.

In this setting, the only dynamic decision that the representative household makes is the savings decision, which leads to the following Euler equation:

$$C_t^{-\sigma} = \beta E_{t-1}^P \left[ C_{t+1}^{-\sigma} \frac{1+i_t}{1+\pi_{t+1}} | \mathcal{H}^{t-1} \right] \tag{3}$$

where $1 + \pi_{t+1} = P_{t+1}/P_t$ is the aggregate inflation rate.

Since there is no investment or government expenditure in the model, all output is consumed every period $Y_t = C_t$, log-linearizing around the steady state, we get the aggregate-demand IS-curve:

$$\hat{y}_t = E_{t-1}^P[\hat{y}_{t+1}] - \frac{1}{\sigma}(i_t - E_{t-1}^P[\pi_{t+1}] - \rho) \tag{4}$$

where $\hat{y}_t$ denotes the log-deviation of output from its steady-state. $\rho = -\log \beta$. Defining the *ex-ante* real interest rate as $r_t = i_t - E_{t-1}^P[\pi_{t+1}]$, the IS curve may be more compactly written as:

$$\hat{y}_t = E_{t-1}^P[\hat{y}_{t+1}] - \frac{1}{\sigma}(r_t - \rho) \tag{5}$$

At some hypothetical real interest rate, output would continue along the trend path, $y_t^n$ (or the "natural" rate of output) absent cyclical fluctuations. We call this the natural rate of interest and denote it by $r_t^n$.

$$\hat{y}_t^n = E_{t-1}^P[\hat{y}_{t+1}^n] - \frac{1}{\sigma}(r_t^n - \rho) \tag{6}$$

Subtracting Equation 6 from Equation 5 yields:

$$\hat{y}_t - \hat{y}_t^n = E_{t-1}^P[\hat{y}_{t+1} - \hat{y}_{t+1}^n] - \frac{1}{\sigma}(r_t - r_t^n) \tag{7}$$

Denoting $\hat{y}_t - \hat{y}_t^n$ as output gap $\tilde{y}_t$, we may re-write the dynamic IS curve in terms of output gap as:

$$\tilde{y}_t = E_{t-1}^P[\tilde{y}_{t+1}] - \frac{1}{\sigma}(i_t - E_{t-1}^P[\pi_{t+1}] - r_t^n) \tag{8}$$

#### 2.2.2 Aggregate supply: Firms' pricing problem

**Firm price-setting under dispersed information** Every period $t$, all firms automatically adjust their prices by the perceived trend inflation rate conditional on their $t-1$ information set, given by $\pi^{*P}_{t-1}$.[3] The perceived level of trend inflation does not enter firms' pricing problem since all firms have the same beliefs and adjust to the same perceived trend rate every period. However, relative price adjustments are subject to Calvo frictions. Only a constant fraction $(1-\theta)$ of firms are able to adjust their price every period (adjustment frequency $\theta$ is common knowledge). All firms set prices in order to earn a constant markup over their nominal marginal cost. The steady-state relative price of each firm is 1. For concision, we express their optimal price setting problem in terms of log-deviations from steady-state.

In the absence of Calvo frictions, log-deviations in their optimal reset are equal to the sum of log-deviations in the aggregate price-level, denoted as $\hat{p}_t$ and log-deviations in their real marginal cost, $mc_t(j)$.

$$\hat{p}^*_t(j) = \hat{p}_t + \hat{mc}_t(j)$$

Consider the problem of price-setting by monopolistic firms in the standard New-Keynesian setting, where they solve for their optimal reset price while subject to Calvo frictions. Due to these frictions, the firm must set prices so as to receive a constant markup *in expectation*.

$$\hat{p}^*_t(j) = (1-\beta\theta)E^j\Big[\sum_{k=0}^{\infty}(\beta\theta)^k(\hat{p}_{t+k} + \hat{mc}_{t+k}(j))|\mathcal{H}_{t-1}\Big] \tag{9}$$

where $E^j[\cdot]$ denotes the expectation operator conditional on firm $j$'s information set.

Additionally, each firm observes its own real marginal cost $\hat{mc}_t(j)$ at the beginning of the period. $\hat{mc}_t(j)$ is composed of an economy-wide component $\hat{mc}_t$ plus an idiosyncratic firm-specific *i.i.d* (across firms and across time) component, $\varepsilon_t(j)$ with *large* variance.[4]

[3] This assumption permits the model to be log-linearized around the zero inflation steady state despite non-zero trend inflation. Inflation here refers to inflation beyond this "normal" level.

[4] This assumption is motivated by the observation that firm-specific price changes are much more volatile as compared to fluctuations in the aggregate price-level. This modeling framework is based on Nimark (2008).

$$\hat{mc}_t(j) = \hat{mc}_t + \varepsilon_t(j) \quad \varepsilon_t(j) \sim N(0, \sigma_\varepsilon^2)\;\forall\, j \in (0,1) \tag{10}$$

Under knowledge that it can only reset with probability $1-\theta$ any period in the future would, the optimal price is given by:

$$\hat{p}_t^*(j) = (1-\beta\theta)E^j\Big[\sum_{k=0}^{\infty}(\beta\theta)^k(\hat{p}_{t+k} + \hat{mc}_{t+k}(j))|\mathcal{H}_{t-1} \cup \hat{mc}_t(j)\Big] \tag{11}$$

**Dispersed information assumption**: The firm is atomistic, its own marginal cost reveals negligible information about innovations to the economy-wide real marginal costs or changes in the price level $p_t$. Thus, their expectations regarding these are unchanged from those formed based on $\mathcal{H}^{t-1}$ and common across firms. We denote these common expectations, as $E_{t-1}^P$. Hence:

$$E^j[\hat{p}_t + \hat{mc}_t(j)|\mathcal{H}^{t-1} \cup \hat{mc}_t(j)] = E_{t-1}^P\hat{p}_t + \hat{mc}_t(j) \tag{12}$$

$$E^j[\hat{p}_{t+k} + \hat{mc}_{t+k}|\mathcal{H}^{t-1} \cup \hat{mc}_t(j)] \approx E_{t-1}^P\hat{p}_{t+k} + E_{t-1}^P\hat{mc}_{t+k}\;\forall\, k \geq 0 \tag{13}$$

Log-deviations in firm j's optimal reset price may be written as:

$$\hat{p}_t^*(j) = (1-\beta\theta)(E_{t-1}^P\hat{p}_t + \hat{mc}_t(j)) + \beta\theta E_{t-1}^P\hat{p}_{t+1}^* \tag{14}$$

All firms face the same price-setting problem, just observe a different marginal cost signal. Aggregating across all firms yields:

$$\hat{p}_t^* = (1-\beta\theta)(E_{t-1}^P\hat{p}_t + \hat{mc}_t) + \beta\theta E_{t-1}^P\hat{p}_{t+1}^* \tag{15}$$

Under a Calvo-probability of price adjustment of $(1-\theta)$, evolution of the aggregate price index satisfies:

$$\hat{p}_t = \theta\hat{p}_{t-1} + (1-\theta)\hat{p}_t^* \tag{16}$$

Combining Equation 15 and Equation 16 yields the aggregate supply condition in terms of inflation $\pi_t = p_t - p_{t-1}$:

$$\pi_t = \beta E^P_{t-1}\pi_{t+1} + \frac{(1-\theta)(1-\beta\theta)}{\theta}\hat{mc}_t + \frac{(1-\theta)^2(1-\beta\theta)}{\theta}(E^P_{t-1}\hat{mc}_t - \hat{mc}_t) \tag{17}$$

The expectational errors manifest due to the fact that the economy-wide real marginal cost is not perfectly forecast-able. If the firms' private signal revealed $\hat{mc}_t$ perfectly, we would go back to the standard New-Keynesian Phillips curve formulation and the expectational error term goes away. Also, it must be noted that the smaller the degree of price-stickiness ($\theta$), the larger the contribution of these errors to actual inflation.

**Pro-cyclicality of marginal cost** The economy-wide real marginal cost $mc_t$ is unobservable. Agents can only infer it from aggregate realizations. The structural dynamics driving the economy-wide component of real-marginal costs are unknown, but agents perceive a pro-cyclical relationship: when output is above the flex-price level, it puts upward pressure on real marginal costs across all firms. Variation in $\hat{mc}_t$ above and beyond this pro-cyclical channel are attributed to economy-wide supply shocks, $s_t$. Hence, they perceive the following structural relationship:

$$\hat{mc}_t = \gamma\tilde{y}_t + s_t$$

where $s_t$ denotes the supply shock, assumed to follow a mean-zero stationary process and independent of the unemployment-gap $\tilde{y}_t$. $\gamma > 0$ represents the link between economy-wide real marginal cost and the cyclical fluctuations in unemployment. It is assumed to be constant, but unknown.

The agents' reasoning motivates the following forward-looking Phillips curve:

$$\pi_t = \beta E^P_{t-1}[\pi_{t+1}] + \psi\tilde{y}_t + \xi_t \tag{18}$$

where (i) $E^P_{t-1}[\pi_{t+1}]$ denotes the private-sector's expectation of inflation in period $t+1$ conditional on history of signals $\mathcal{H}^{t-1}$ (ii) $\psi$ represents the sensitivity of inflation to current output-gap. Agents assume $\kappa$ is constant but unknown and hence learn about it every period. (iii) $\xi_t$ is a cost-push shock composed of the supply-shock $s_t$ and the expectational error.

The $\psi\tilde{y}_t$ term describes the contemporaneous link between inflation and the "real" side of the economy. The output gap, $\tilde{y}_t$ contemporaneously affects inflation through the slope parameter $\psi$. The relationship implies that output, when above its natural level ("potential") exerts inflationary pressure on the economy.

The cost-push shock $\xi_t$ captures the component of inflationary pressures arising from factors over and beyond real economic activity. Agents allow for the possibility that the cost-push shocks have a persistent component. Hence they decompose the cost-push shock, $\xi_t$ to into a *persistent* AR(1) component denoted by $\xi_t^P$, with large persistence $\rho$ and a *transitory* i.i.d normal component $\xi_t^T$.

$$\xi_t = \xi_t^P + \xi_t^T, \quad \xi_t^T \sim iid\, N(0, \sigma_{\xi,T}^2)$$

The persistent component is perceived to evolve as:

$$\xi_t^P = \rho \xi_{t-1}^P + \varepsilon_t^P, \quad \varepsilon_t^P \sim iid\, N(0, \sigma_{\xi,P}^2)$$

Only the persistent component $\xi_t^P$ affects future outcomes. Agents must learn about this shock to form expectations about the future. $\xi_t^T$ is irrelevant for dynamics and just functions as noise.

**Natural rate hypothesis:** Agents in the model a-priori assume that monetary policy cannot systematically drive real variables once prices and expectations fully adjust. Under the natural rate hypothesis, the output and the real interest rate attain their natural levels in the long-run, beyond the control of monetary policy. This is equivalent to agents assuming that the discount-factor $\beta \to 1$ so that expectations-augmented Phillips curve is vertical in the long-run.[5] Agents reason that in the long run, monetary policy can only create inflation, not drive output gaps.

### 2.2.3 Measuring real-economic activity

According to the structural model, real economic activity, as measured by the output gap forms the important structural link between aggregate inflation and interest rates. However, it is not directly observable. It must be inferred based on real time indicators of economic activity. I assume that the only real indicator in this economy, informing agents about the state of aggregate demand is the unemployment rate. This is because unemployment rate is a more salient variable than output or GDP and is directly part of the dual mandate that most modern central banks in the world, including the Fed follow. For this reason, it is useful to re-frame the model in terms of unemployment gaps, defined as the difference between the realized unemployment rate and the one that would prevail under flexible prices, or the "natural" rate of unemployment.

Agents posit a linear relationship between the output gap and the unemployment gap[6] defined as the difference between the unemployment rate and the natural rate of unemployment (empir-

[5]Since otherwise, the long-run unemployment-gap must be non-zero from Equation 20.

[6]This relationship is sometimes referred to as Okun's law. Ball et al. (2017) find that it has been relatively stable across time.

ically, the "trend" component of unemployment rate): $x_t = u_t - u_t^n$, we have

$$\tilde{y}_t = -\eta x_t$$

where $\eta$ is referred to as the Okun's law coefficient.

This yields the following dynamic IS-curve representing the law of motion of the unemployment-gap:

$$x_t = E_{t-1}^P x_{t+1} + \tau(i_t - E_{t-1}^P \pi_{t+1} - r_t^n) \tag{19}$$

where $\tau = 1/(\sigma\eta)$ represents the ratio of the intertemporal elasticity of substitution and the Okun's law coefficient. $\tau$ is assumed to be constant and known to all agents.

Similarly, the expectations-augmented Phillips curve in terms of unemployment gap becomes:

$$\pi_t = E_{t-1}^P[\pi_{t+1}] - \kappa x_t + \xi_t \tag{20}$$

where $\kappa = \psi\eta$ is assumed to be a constant that the agents learn about.

# 3 Learning: Latent structure of the economy

Every period, conditional on the observed unemployment rate $u_t$, all agents infer the contemporaneous unemployment gap and the natural rate of interest. Then they conditionally update their beliefs about the slope of the Phillips curve $\kappa$, and the persistent supply shock $\xi_t^p$ based on the observed aggregate inflation rate $\pi_t$. Thus, they update their beliefs about all the variables describing the latent structure of the economy in their model, every period. The rest of the section discusses the mechanics of this part of their learning behavior.

## 3.1 Learning and the Anticipated Utility assumption

This paper takes the anticipated utility approach to learning described in Kreps (1998). Under this assumption, agents form "certainty-equivalent" estimates of the relevant state-variables every period and treat their best estimates as if they were constants known with certainty when making decisions. Agents disregard the possibility of updating their current estimates in the future. This assumption is widely used in the literature on learning in macroeconomics (see Evans and Honkapohja (2001)). It allows us to surmount the computational challenges associated with solving the dynamic problem in the full Bayesian setting. Cogley and Sargent (2008) demonstrate how the anticipated utility assumption provides an excellent approximation to Bayesian decision-making in a wide class of problems.

## 3.2 Inferring the unemployment gap $x_t$

Conditional on the observed unemployment rate $u_t$, agents update their estimate of the natural rate $u_t^n$ according to the univariate smoothing algorithm:

$$u_t^n = u_{t-1}^n + g_u(u_t - u_{t-1}^n) \tag{21}$$

The natural rate is inferred from a backward-looking filter based on the unemployment rate, putting more weight on recent observations. The gain coefficient $g_u$ determines the degree to which shifts in the unemployment rate are attributed to shifts in the natural rate of unemployment. $g_u$ is constant and known to all agents.

From the natural rate hypothesis, $\lim_{h\to\infty} x_{t+h} = 0$. Hence, the unemployment rate is always expected to converge to the natural rate $u_t^n$ in the long-run equilibrium, consistent with the update-rule Equation 21.[7]

Agents' estimate of the contemporaneous unemployment gap is:

$$x_t = u_t - u_t^n$$

I abstract from issues of real-time mis-measurement and data revisions. I do however find that the agents' real-time measure inferred from data lines up quite well with series that are revised retroactively (the CFNAI index as an example, see Appendix D) suggesting that these issues are not of large consequence over the sample period.

[7] Staiger, Stock and Watson (1997) and Orphanides and van Norden (2002) show that such univariate algorithms deliver estimates that are essentially indistinguishable from the ones derived under more sophisticated procedures. Similarly, Kamber, Morley and Wong (2018) demonstrate that economic slack-measures derived from similar univariate procedures can be robust to revisions and are found to be in line with more refined measures of real-time economic activity (such as the Chicago Fed National Economic Activity Index).

### 3.3 Recursive updating

**Agents' perceived model of aggregate dynamics:** The equations describing the aggregate laws of motion of the economy from the perspective of the private agents are:

$$x_t = E^P_{t-1}[x_{t+1}] + \tau(i_t - E^P_{t-1}[\pi_{t+1}] - r^n_t)$$

$$\pi_t = E^P_{t-1}[\pi_{t+1}] - \kappa x_t + \xi^P_t + \xi^T_t, \quad \xi^T_t \sim iid\, N(0, \sigma^2_{\xi,T})$$

$$\xi^P_t = \rho \xi^P_{t-1} + \varepsilon^P_t \ , \quad \varepsilon^P_t \sim iid\, N(0, \sigma^2_{\xi,P})$$

Conditional on the observed aggregate inflation rate $\pi_t$ and the unemployment gap $x_t$ inferred from $u_t$ based on the de-trending procedure, agents update their beliefs regarding $\kappa$, $\xi^p_t$ and $r^n_t$ recursively every period treating $[\sigma^2_{\xi,T}, \sigma^2_{\xi,P}, \tau, \rho]$ as known constants.

**Learning the natural rate of interest $r^n_t$:** Conditional on the inferred unemployment-gap $x_t$, the contemporaneous estimate of the natural rate of interest $r^n_{t|t}$[8] is given by the dynamic IS curve (Equation 19):

$$r^n_{t|t} = \tau^{-1}(E^P_{t-1} x_{t+1} - x_t) + i_t - E^P_{t-1}\pi_{t+1}$$

Further, agents assume that $r^n_t$ follows a Martingale, so that $r^n_{t+1|t} = r^n_{t|t}$

**Learning $\xi^P_t$ and $\kappa$:** Given the unemployment-gap $x_t$, beliefs about the persistent component of the cost-push shock ($\xi^P_{t|t}$) and the slope of the Phillips curve ($\kappa_{t|t}$) are recursively updated every period based on observed aggregate inflation rate $\pi_t$.

Agents face a signal-extraction problem in real time: they cannot immediately distinguish whether an inflation surprise was driven by the unemployment-gap (due to mis-perception of the slope $\kappa$), persistent supply shocks—relevant for expectations—or transitory supply shocks, which are irrelevant for expectations. Accordingly, agents revise their beliefs about $\xi_t$ and $\kappa$ according to

[8] As we shall see, $r^n_{t|t}$ is irrelevant for expectations since stabilizing against demand shocks is costless and poses no policy trade-off.

the following equations:

The observation equation, relating aggregate inflation to $\xi_t$ and $\kappa$ in the agents' perceived model is given by:

$$\pi_t - E^P_{t-1}\pi_{t+1} = \begin{pmatrix} -x_t & 1 \end{pmatrix} \begin{pmatrix} \kappa \\ \xi^P_t \end{pmatrix} + \xi^T_t, \quad \xi^T_t \sim N(0, \sigma^2_{\xi,T}).$$

The state-transition equation specifying the agents' prior regarding how the state variables $\kappa$ and $\xi^p_t$ evolve over time is given by:

$$\begin{pmatrix} \kappa \\ \xi^P_t \end{pmatrix} = \begin{pmatrix} 1 & 0 \\ 0 & \rho \end{pmatrix} \begin{pmatrix} \kappa \\ \xi^P_{t-1} \end{pmatrix} + \begin{pmatrix} 0 \\ \epsilon^P_t \end{pmatrix}, \qquad \epsilon^P_t \sim N(0, \sigma^2_{\xi,P})$$

Note that the state-transition equation reflects the agents' prior that the true slope $\kappa$ is time-invariant.

# 4 Learning: Policymakers' stabilization preferences

Given their beliefs regarding the latent structural variables - the slope of the Phillips curve $\kappa_{t|t}$, the persistent supply shock $\xi^p_{t|t}$ and the natural rate of interest $r^n_{t|t}$, the agents interpret the period-$t$ policy decision $i_{t+1}$ and learn about the policymakers' stabilization preferences underlying policy behavior. The next subsection describes the policymakers' optimal policy problem under a dual mandate.

## 4.1 Monetary policy

The private-agents assume that the central bank conducts monetary policy optimally under discretion, having the same beliefs about the policy-invariant latent structural variables as them formed based on the same economic model and data. The central bank has a dual mandate characterized by the following loss function[9]:

$$\mathcal{L}_t = \sum_{j=1}^{\infty} [(\pi_{t+j|t} - \pi_t^*)^2 + \lambda_t x_{t+j|t}^2] \tag{22}$$

where $\pi_{t+j|t}$ and $x_{t+j|t}$ denote the central bank's forecasts of inflation and the unemployment gap for period $t + j$ formed in period-$t$ after the contemporaneous $\pi_t, x_t$ have been realized. Here, $\pi_t^*$ and $\lambda_t$ represent the policymakers' period-$t$ stabilization preferences: their inflation target and the relative weight they place on unemployment-gap stabilization. Private agents do not observe these and assume that they are subject to slow innovations over time. Their beliefs regarding these parameters conditional on $\mathcal{H}^t$ are denoted by $\pi_t^{*P}$ and $\lambda_t^P$.

The central bank in its period-$t$ decision cycle chooses the one-period ahead unemployment gap plan $x_{t+1|t}$. Private agents' period-$t$ expectations regarding future inflation and unemployment gaps formed prior to observing the policy decision (denoted by $E_t^{P-}\pi_{t+j}$ and $E_t^{P-}x_{t+j}$ ) are observed by the central bank. [10] Every period, the central bank chooses $x_{t+1|t}$ which solves its period-$t$ static optimization problem taking the observed private-sector expectations as given, conditional on the following structural constraint implied by the Phillips curve:

$$\pi_{t+1|t} = E_t^{P-}\pi_{t+2} - \kappa_{t|t} x_{t+1|t} + \xi_{t+1|t} \tag{23}$$

The optimal unemployment gap plan $x_{t+1|t}$ is given by the targeting rule:

$$x_{t+1|t} = \frac{\kappa_{t|t}}{\lambda_t}(\pi_{t+1|t} - \pi_t^*) \tag{24}$$

Equation 24 describes the textbook "lean against the wind" policy solution where the central bank reacts by creating a positive unemployment gap if it expects inflation to be above its target in the following period.

Using Equation 23 and Equation 24, the central bank's one-period ahead inflation and unemployment gap plan must satisfy:

[9] I assume that the central bank's policy preferences are not fundamentally incompatible. Hence policymakers have no incentive to sustain a level of unemployment below the natural rate.

[10] $E_t^{P-}$ denote expectations formed after the realization of the contemporaneous aggregates $z_t = [\pi_t, u_t]$ but before the period-$t$ policy decision, and are thus formed conditional on beliefs $\kappa_{t|t}, \xi_{t|t}^P, \pi_{t-1}^{*P}, \lambda_{t-1}^P$.

$$\pi_{t+1|t} = \pi_t^* + \frac{\lambda_t}{\lambda_t + \kappa_{t|t}^2}(E_t^{P-}\pi_{t+2} + \xi_{t+1|t} - \pi_t^*) \tag{25}$$

$$x_{t+1|t} = \frac{\kappa_{t|t}}{\lambda_t + \kappa_{t|t}^2}(E_t^{P-}\pi_{t+2} + \xi_{t+1|t} - \pi_t^*) \tag{26}$$

Equation 25 shows that when $\lambda_t > 0$, the central bank allows inflation to rise above its target when faced with a persistent cost-push shock. Deviations of inflation from the target, arising from private agents' inflation expectations and persistent cost-push shocks are accommodated to an extent. The larger $\lambda_t$ is, the greater the accommodation, with $\lambda_t \to \infty$ characterized by a situation where the central bank can no longer push back against private agents' expectations anymore. This represents an "expectations-trap" in the sense of Christiano and Gust (2000) that policymakers fall into where any real-side adjustment is deemed too costly. In the same vein, Equation 26 shows that the extent of unemployment gap adjustments that policymakers will engage in, is decreasing in $\lambda_t$.[11]

## 4.2 Private sector expectations in a learning equilibrium

Under rationality, private-agents' expectations for all future horizons must be consistent with their structural model of inflation dynamics:

$$E^P[\pi_{t+j}] = E^P[\pi_{t+j+1}] - E^P[\kappa x_{t+j}] + E^P[\xi_{t+j}] \,\forall\, j \geq 1$$

The constraint above yields the following forward looking system of equations that their expectations at any period $t$ must satisfy:

$$E_t^P\pi_{t+j} = E_t^P\pi_{t+j+1} - \kappa_{t|t}E_t^P x_{t+j} + \rho^j \xi_{t|t}^P$$

From the "lean against the wind" targeting rule, their unemployment gap expectations are:

[11]The expression $\frac{\kappa_{t|t}}{\lambda_t+\kappa_{t|t}^2}$ is bounded above by $\frac{1}{2\sqrt{\lambda_t}}$. So even though it also depends on $\kappa_t$, its limiting behavior is determined by $\lambda_t$.

$$E_t^P x_{t+j} = \frac{\kappa_{t|t}}{\lambda_t^P + \kappa_{t|t}^2}(E_t^P \pi_{t+j+1} + \rho^j \xi_{t|t}^P - \pi_t^{*P}) \tag{27}$$

Solving forward, we get an analytical expressions describing their inflation and unemployment gap expectations for all future horizons in terms of their beliefs $\kappa_{t|t}, \xi_{t|t}^p, \pi_t^{*P}, \lambda_t^P$ formed conditional on $\mathcal{H}^t$:

$$E_t^P \pi_{t+j} = \underbrace{\pi_t^{*P}}_{\text{perceived target}} + \underbrace{\frac{\lambda_t^P}{\lambda_t^P(1-\rho) + \kappa_{t|t}^2}\rho^j \xi_{t|t}^p}_{\text{cost-push inflation}} \tag{28}$$

$$E_t^P x_{t+j} = \frac{\kappa_{t|t}}{\lambda_t^P(1-\rho) + \kappa_{t|t}^2}\rho^j \xi_{t|t}^p \tag{29}$$

Their expectations reflect simple economic intuition. According to Equation 28, from the private-agents' perspective, the path of inflation is ultimately determined by two forces: (i) $\pi_t^{*P}$, representing their beliefs about the central bank's inflation target, defines the level that the agents expect inflation to converge to in the long run. Inflation expectations at all horizons move one-for-one with $\pi_t^{*P}$. Hence this belief is a crucial determinant of the low-frequency (slow-moving) dynamics of inflation; and (ii) persistent supply shocks $\xi_{t|t}^p$, which create involuntary inflation above and beyond this voluntary level in the short-run: the extent of their *pass-through* to short-run inflation expectations is *decreasing* in the perceived slope of the Phillips curve $\kappa_{t|t}$ but *increasing* in $\lambda_t^P$, the perceived weight that the central bank puts on unemployment-gap stabilization. Thus, when agents perceive the central bank to prioritize real-side stabilization ($\lambda_t^P$ is large), their short-run inflation expectations respond to persistent supply shocks strongly and causes them to depart further away from the long-run level, $\pi_t^{*P}$.

**Perceived policy rule:** The interest-rate $i_{t+1}^*$ that implements the optimal unemployment gap plan is given by the IS-curve:

$$i_{t+1}^* = \tau^{-1}(x_{t+1|t} - E_t^{P-} x_{t+2}) + E_t^{P-}\pi_{t+2} + r_{t+1|t}^n$$

where the private agents' ex-ante period-$t$ expectations $E_t^{P-}\pi_{t+j}$ and $E_t^{P-}x_{t+j}$ are given by:

$$E_t^{P-}\pi_{t+j} = \pi_{t-1}^{*P} + \frac{\lambda_{t-1}^P}{\lambda_{t-1}^P(1-\rho) + \kappa_{t|t}^2}\rho^j \xi_{t|t}^p$$

$$E_t^{P-}x_{t+j} = \frac{\kappa_{t|t}}{\lambda_{t-1}^P(1-\rho) + \kappa_{t|t}^2}\rho^j \xi_{t|t}^p$$

## 4.3 Monetary policy surprises

The agents assume that the central bank sets interest rates optimally every period up to some idiosyncratic policy error of constant variance so that[12]:

$$i_{t+1} = i^*_{t+1} + \epsilon^i_t, \quad \epsilon^i_t \sim N(0, \sigma^2_i)$$

Whenever the nominal interest rate that the central bank sets is different from what the private agents expect-given their beliefs about prevailing macroeconomic conditions—it constitutes a monetary policy surprise:

$$\underbrace{i_{t+1} - E^P[i_{t+1}|\mathcal{H}^{t-1}, z_t]}_{\text{monetary policy surprise}} = \underbrace{(i^*_{t+1} - E^P[i_{t+1}|\mathcal{H}^{t-1}, z_t])}_{\text{agents behind the curve}} + \underbrace{\epsilon^i_t}_{\text{policymakers behind the curve}}$$

where $\mathcal{H}^{t-1}$ represents the history of all observed signals up to $t-1$, and $z_t$ captures the current period realizations of inflation and unemployment rate.

Agents interpret policy surprises as stemming from two sources: an evolution in policymakers' preferences, which they must learn about ('agents behind the curve'), or a transitory policy error, which policymakers must subsequently correct ('policymakers behind the curve').

From the IS-curve and the optimal unemployment gap plan, we obtain the following expression mapping the policymakers' period-$t$ preferences to the optimal nominal interest rate:

$$i^*_{t+1}(\pi^*_t, \lambda_t) = \underbrace{-\tau^{-1} E^{P-}_t x_{t+2} + r^n_{t|t} + E^{P-}_t \pi_{t+2}}_{\text{ex-ante known}} + \underbrace{\frac{\tau^{-1}\kappa_{t|t}}{\lambda_t + \kappa^2_{t|t}}(E^{P-}_t \pi_{t+2} + \rho \xi^p_{t|t} - \pi^*_t)}_{\text{contains information about Fed objectives}}$$

When the central bank sets interest rates, it reveals information regarding its policy preferences. The second term represents the only component of systematic monetary policy that contains information regarding the "true" period-$t$ policy preferences $\pi^*_t$ and $\lambda_t$. Observe that as $\lambda_t$ increases, the term carrying information regarding the policymakers' stabilization preferences shrinks.

[12]The source of this error could be motivated as coming from cognitive noise in decision-making. It could also be thought of as a "control error". The main idea being that the private agents allow for idiosyncratic deviations from optimal policy arising from factors unrelated to changes in the policymakers' stabilization preferences.

In the limiting case of $\lambda_t \to \infty$, this term shrinks to zero and interest rates carry no information: the "learning channel" of policy completely dies out. When agents perceive the central bank to have such preferences, they expect the unemployment gap to be zero at all future horizons and the central bank is seen to implement a Wicksellian policy: with the the ex-ante real interest rate $i^*_{t+1} - E^{P-}_t \pi_{t+2}$ tracking the perceived natural rate of interest $r^n_{t|t}$ closely. In this case, policymakers are expected to tolerate arbitrary deviations in inflation: there is no inflation-target and the level of inflation is indeterminate, leading to self-fulfilling dynamics. On the other hand, when $\lambda^P_t \to 0$, agents' always expect the central bank to bring inflation back to its target $\pi^*_t$ regardless of the unemployment gap costs. Hence their inflation expectations at all horizons are equal to the perceived inflation target, irrespective of supply shocks $\xi^p_{t|t}$. Policy is seen oriented only towards keeping inflation close to target. Interest rates provide a strong signal regarding the inflation target. Note that policy response to $E^{P-}_t x_{t+2}$ and $r^n_{t|t}$ does not depend on $\lambda_t$ - since they don't pose a policy trade-off (often referred to as the "divine coincidence").

## 4.4 The nonlinear filter

The observed nominal interest rate functions as a noisy signal about the central bank's preferences $[\pi^*_t, \lambda_t]$, which describe the relevant state that the agents learn about:

$$i_{t+1} = i^*_{t+1}(\pi^*_t, \lambda_t) + \epsilon^i_t, \quad \epsilon^i_t \sim N(0, \sigma^2_i)$$

Linearizing around agents' prior estimates $\pi^P_{t-1}, \lambda^P_{t-1}$ assuming $\pi^*_t \approx \pi^P_{t-1}, \lambda_t \approx \lambda^P_{t-1}$[13]

$$i^*_{t+1}(\pi^*_t, \lambda_t) \approx i^*_{t+1}(\pi^{*P}_{t-1}, \lambda^P_{t-1}) + \frac{\partial i^*_{t+1}}{\partial \pi^*_t}|_{\pi^{*P}_{t-1}, \lambda^P_{t-1}} (\pi^*_t - \pi^{*P}_{t-1}) + \frac{\partial i^*_{t+1}}{\partial \lambda_t}|_{\pi^{*P}_{t-1}, \lambda^P_{t-1}} (\lambda_t - \lambda^P_{t-1})$$

The approximation above (called the Extended Kalman Filter) yields an expression for $i^*_{t+1}$ that is linear in the latent states $\pi^*_t$ and $\lambda_t$ much like the simple Kalman filter. The key difference is that the coefficients mapping the observable $i^*_{t+1}$ to the latent states are not constant, but state-

[13] This assumption is important for the filtering problem to be well-specified. Since interest-rate dynamics would be state-dependent due to the nonlinearity of $i^*_{t+1}$, large discrepancies can cause the filter to diverge. The assumption implicitly implies that under their own beliefs, agents track changes in the policymakers' preferences efficiently at all times. In subsection F.2, I report evidence in support of this assumption based on the Fed's Greenbook forecasts.

dependent. They are determined by the partial derivatives of the interest rate rule with respect to the $\pi_t^*$ and $\lambda_t$ evaluated at the agents' prior estimates $\pi_{t-1}^{*P}$ and $\lambda_{t-1}^P$. These determine how "informative" interest rates are perceived to be regarding the underlying stabilization preferences of the policymakers.

The agents perceive that $\log \pi_t^*$ and $\log \lambda_t$ evolve exogenously as independent random walks, so that:

$$\begin{pmatrix} \log\ \pi_t^* \\ \log\ \lambda_t \end{pmatrix} = \begin{pmatrix} \log\ \pi_{t-1}^* \\ \log\ \lambda_{t-1} \end{pmatrix} + \begin{pmatrix} \epsilon_t^{\pi^*} \\ \epsilon_t^{\lambda} \end{pmatrix}, \qquad \begin{pmatrix} \epsilon_t^{\pi^*} \\ \epsilon_t^{\lambda} \end{pmatrix} \sim N(\mathbf{0}, \begin{pmatrix} \sigma_{\pi^*}^2 & 0 \\ 0 & \sigma_{\lambda}^2 \end{pmatrix})$$

Every period, agents update their beliefs $\pi_t^{*P}$ and $\lambda_t^P$ based on their best-estimates as:

$$\pi_t^{*P} = \pi_{t|t}^*, \quad \lambda_t^P = \lambda_{t|t}$$

## 4.5 What anchors long-run beliefs?

Anchoring reflects the entrenchment of expectations, where beliefs about the future remain resilient to surprises. The following quote by Ben Bernanke summarizes what anchoring means in the context of monetary policy:

> "...I use the term "anchored" to mean relatively insensitive to incoming data. So, for example, if the public experiences a spell of inflation higher than their long-run expectation, but their long-run expectation of inflation changes little as a result, then inflation expectations are well anchored..." —Bernanke (2007)

According to Equation 28, agents' long-run inflation expectations are completely pinned down by their beliefs regarding the central bank's inflation target. For inflation expectations to be "well-anchored" according to this definition, agents should not revise their beliefs regarding the target by much even as they anticipate inflation to remain elevated in the short-run on account of persistent supply shocks. In the model, revisions to agents' long-run inflation expectations occur only in response to interest rate surprises. The degree of *pass-through* from these surprises to their perceived inflation target depends on how informative they perceive policy actions to be, about the underlying shifts in the central bank's inflation objective $\pi_t^*$.

**Anchoring is state-dependent**

The perceived informativeness of the observed interest rate signal about the states $\pi_t^*$ and $\lambda_t$ is described by the Jacobian (first-order partial derivatives) of the interest-rate rule with respect to these state variables, evaluated at their ex-ante beliefs $\pi_{t-1}^{*P}$ and $\lambda_{t-1}^P$:

$$\frac{\partial i_{t+1}^*}{\partial \pi_t^*}|_{(\pi_{t-1}^{*P}\lambda_{t-1}^P)} = -\frac{\tau^{-1}\kappa_{t|t}}{\lambda_{t-1}^P + \kappa_{t|t}^2} \tag{30}$$

$$\frac{\partial i_{t+1}^*}{\partial \lambda_t}|_{(\pi_{t-1}^{*P},t\lambda_{t-1}^P)} = -\frac{\tau^{-1}\kappa_{t|t}}{(\lambda_{t-1}^P + \kappa_{t|t}^2)[\lambda_{t-1}^P(1-\rho) + \kappa_{t|t}^2]}\rho\xi_{t|t}^P \tag{31}$$

Naturally, if the Jacobian with respect to a particular state variable is of large magnitude, interest rates are perceived to be highly responsive to changes in that state and hence, agents put more weight on the signal while updating their beliefs.

Equation 30 implies that interest rates fall in response to an increase in the policymakers' inflation target. Thus when interest rates undershoot expectations, agents respond by revising their beliefs regarding the inflation target upwards. However, the magnitude of the updates would be decreasing in $\lambda_{t-1}^P$. The magnitude of the term $\frac{\kappa_{t|t}}{\lambda_{t-1}^P+\kappa_{t|t}^2}$ is an important determinant of the degree of anchoring of long-run inflation expectations since they determine how much weight the agents put on a given interest rate surprise and revise their beliefs about the inflation target. Hence, I call its reciprocal the "anchoring coefficient" (large value corresponds to more anchored long-run inflation expectations). When this term is large, long-run expectations remain more firmly "anchored". $\lambda_t$ may also be interpreted as policymakers' adherence to the natural-rate theory under which they treat departures of the unemployment rate from its natural rate as costly. A smaller value of $\lambda_t$ implies that the natural rate of unemployment is less relevant to policy design.

According to Equation 31, the degree to which interest rates respond to supply shocks is decreasing in $\lambda_t$. If interest rates are seen to rise more strongly in response to a persistent supply shock than the agents expect based on their ex-ante beliefs, they infer that $\lambda_t$ is smaller and their beliefs $\lambda_t^P$ get revised downward. Note that $\lambda_t$ is irrelevant to policy in the absence of policy trade-offs and hence meaningful updates to $\lambda_t^P$ only occur when agents perceive their economic environment to be characterized by persistent supply shocks posing such trade-offs.

# 5 Estimation

To characterize the path of beliefs and expectations, we must pin down the vector of parameters:

$$\Phi = [\tau, g_u, \sigma^2_{\xi,P}/\sigma^2_{\xi,T}, \sigma^2_i, \sigma^2_{\pi^*}, \sigma^2_\lambda]$$

These parameters govern how private agents update beliefs in equilibrium conditional on their observations. Given a vector of parameters $\Phi$ and a history of realizations $\mathcal{H}^t$, the path of private-sector beliefs regarding the state variables $\{\kappa_t, \xi^P_t, u^n_t, r^n_t\}$ as well as the central bank's policy preferences $\{\pi^*_t, \lambda_t\}$ are determined under the learning scheme described in the previous sections.

I set the parameter $\rho$ governing the persistence of the persistent component of the supply shocks as perceived by the agents to $0.99$, so that it is meaningfully distinct from the transitory i.i.d component so that it doesn't pose identification problems. It also captures a particularly low-frequency component of the supply shocks which would be the most relevant for forming expectations.

## 5.1 Data

The learning algorithm is implemented with monthly data on Headline CPI Inflation (CPIAUCSL), Unemployment rate (UNRATE) and the Effective Fed Funds rate (FEDFUNDS) from 1958:01-2024:12 (available from FRED St Louis) as observations. For the zero-lower bound period, the Wu-Xia shadow interest rate is used as the measure of the nominal interest rate instead of the effective Fed funds rate. The initial beliefs are set to have large variance in order to allow them to adjust freely in response to data. I allow 48 periods (4 years) for the filter to converge to steady-state and the estimates from this period are discarded.

To estimate the vector of parameters governing learning, $\Phi$, I use survey data on long-run inflation expectations from the Survey of Professional Forecasters (SPF)—specifically, the cross-sectional mean of the 10-year-ahead CPI inflation forecasts—as a proxy for private agents' beliefs about the Federal Reserve's inflation target.[14] The SPF series is available at a quarterly

[14] Short-run inflation forecasts depend upon a combination of $\pi^{*P}_t$, $\lambda^P_t$ and $\xi^p_{t|t}$, which makes these parameters harder to identify if those are used for estimation. Long-run inflation expectations have the advantage that they isolate movements due $\pi^{*P}_t$ alone as beliefs regarding the other parameters play a negligible role at longer horizons.

frequency over the period 1991–2024. The implicit assumption here is that professional forecasters' long-run inflation expectations are broadly representative of those held by firms and households. Given the low volatility of long-run inflation expectations during this period, this assumption is reasonable: discrepancies between types are unlikely to be large.

Although alternative measures covering a longer sample period exist such as the Michigan Survey of Consumers and Cleveland Fed's 10-year ahead inflation expectations series[15], they are not used in the baseline estimation. However, they are employed in an out-of-sample validation test (see Appendix A) to assess the robustness of the results. Not explicitly including long-run inflation expectations data for the Great Inflation period allows us to check if the structural dynamics captured by the model can provide a consistent explanation for their behavior during this period without explicitly being fit to the data.

## 5.2 Estimation results

The goal of estimation is to pin down the vector $\Phi$ that generates a path of long-run expectations closest to the observed survey measure under the agents' learning mechanism given their observations. A least-squares minimum-distance estimator is used, matching the path of model-implied private-sector beliefs regarding the inflation target $\pi_t^{*P}$ with the observations from the SPF. The minimum-distance estimate $\Phi^*$ is the solution of the resulting minimization problem:

$$\Phi^* = \underset{\Phi}{\text{argmin}} \sum_{t=1991:01}^{2024:12} ([\pi_t^{*P}|\mathcal{H}^t, \Phi] - \pi_t^{10y,SPF})^2$$

I discard values of $\Phi$ that generate explosive paths for beliefs. This problem arises because beliefs are a non-differentiable function of $\Phi$: even small perturbations in the parameters can induce large changes in the updating process across all variables, setting off some beliefs on divergent paths.[16]

The point-estimate of $\Phi^*$ along with 95% credibility intervals generated using Sequential Monte Carlo (SMC) sampling are shown in Table 1. The point-estimate implies that the variance of innovations in the policy preference parameters is very small compared with the idiosyncratic policy errors. The innovations to persistent cost-push shocks are also approximately $10^3$ times

15

16 This also makes the use of gradient-based optimization algorithms infeasible. I use the Nelder-Mead direct search method that does not require the computation of gradients or derivatives of the objective function.

smaller than i.i.d. innovations.

Appendix B compares the agents' ex-ante forecasts of inflation, unemployment rate and the nominal interest rate informed by their model with the actual realizations to assess the fit. The agents' perceived model is able to track the target variables closely and learning performs satisfactorily in the sense of making small forecast errors.

Table 1: Estimated parameters of the baseline model

| **Parameter** | **Description** | **Estimate (95% CI)** |
|---|---|---|
| $\tau$ | Ratio of IES to Okun's law coefficient | $0.647\ (0.430,\ 1.184)$ |
| $g_u$ | Gain for updating $u_t^n$ | $0.329\ (0.209,\ 0.351)$ |
| $\sigma_i^2$ | Variance of idiosyncratic monetary policy errors | $0.488\ (0.389,\ 1.334)$ |
| $\sigma_{\pi^*}^2$ | Variance of innovations to (log)inflation target | $6.696\ (5.186,\ 7.772) \times 10^{-4}$ |
| $\sigma_\lambda^2$ | Variance of innovations to (log)weight on unemployment-stabilization | $6.802\ (3.611,\ 9.173) \times 10^{-5}$ |
| $\frac{\sigma_{\varepsilon^t}^2}{\sigma_{\varepsilon^p}^2}$ | Ratio of the variance of innovations to the transitory component of cost-push shocks to that of the persistent component | $911.901\ (196.125,\ 5176.436)$ |

Note: Confidence intervals are constructed using Sequential Monte Carlo sampling. The likelihood function is not differentiable in the parameters $\Phi$, so asymptotic standard errors cannot be used.

# 6 Evolution of the agents' beliefs

This section discusses time-paths of private-sector agents' beliefs regarding the structural variables describing the economy as implied by the point estimates given in Table 1. The section also provides context on how beliefs evolved and their bearing on the macroeconomic outcomes in the post-war period.

## 6.1 The Fed's inflation target

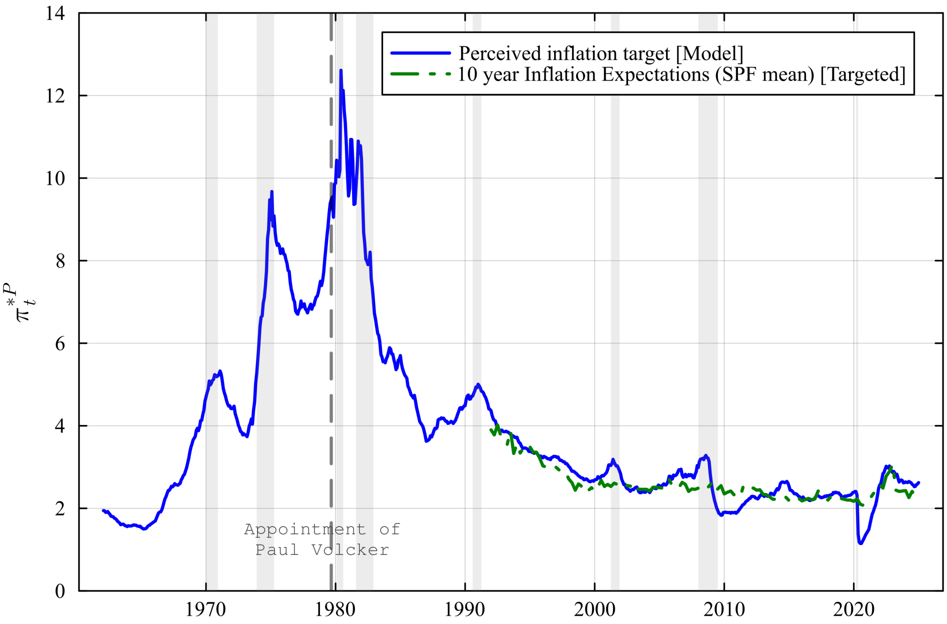



Figure 2: **Perception of the Fed's inflation target** $\pi_t^*$: Private agents' beliefs regarding the Fed's inflation target as implied by the model *(solid)* vs SPF 10-year inflation expectations *(dashed)* which serves as the empirical proxy
*During the Great inflation, private-sector beliefs about the inflation target exhibit sharp upward revisions. This is not the case during the recent post-pandemic surge.*
Note: Shaded regions indicate NBER recessions
SPF 10-year ahead inflation expectations begins in 1991:Q1

Figure 2 illustrates the model-implied path of the agents' perceptions regarding the Fed's inflation target. This is in contrast with papers such as Bhattarai, Lee and Park (2016) that rely on identifying the inflation target from low-frequency movements in inflation.

According to the model, the private agents perceive the Fed's inflation target to be close to 2% in the early 1960s. In the latter half of the decade, the perceived target begins to rise, reaching around 4% by 1970.[17]

From the eyes of the private sector, the 70s would be a period of great volatility in the Fed's inflation target. Their beliefs are sharply revised upwards on two occasions, each coinciding with an NBER recession—one during the beginning of the decade and the other around the time of the OPEC Embargo and the oil crisis of 1974. From the lens of the model, the private

[17] Hence I find that the anchor had begun to loosen in the late 1960s, before the appointment of Arthur Burns (in 1970), similar to Reis (2021). In December 1965 a policy-tightening provoked an unprecedented backlash against Fed Chair Martin, marking what many observers regard as the beginning of a prolonged era of accommodative monetary policy.

agents saw that the Fed had an *incentive* to inflate the economy, over and beyond any supply disturbances creating policy trade-offs. From their point of view, the Fed displayed a tendency to deliberately inflate the economy during recessions, operating with a higher inflation target, followed by dis-inflationary pursuits soon after. The Volcker-era, beginning with the chairmanship of Paul Volcker in 1979 is often cited as watershed moment in the Fed's eventual "conquest" of inflation. In October 1979, the Fed announced "new operating procedures" aimed at reining in inflation. But these do not immediately effect a disinflation (as also noted by Goodfriend and King (2005)). A recession follows and the perceived target shoots up yet again. It is not until 1982 that we see the perverse dynamics reverse course. The following years see a sharp decline in the perceived inflation target which coincides with a deep recession. By the mid 1980s, agents perceive the Fed's inflation target to be below 5% after nearly a decade. Thus the U.S. economy enters the "Great Moderation". Beliefs regarding the Fed's target are on a steady downward trajectory in the two decades that follow, under the chairmanship of Alan Greenspan (1987-2006). Only during the Great Financial crisis and the recent COVID-pandemic do we see the agents' perceptions exhibiting some modest revisions (interestingly, breaking away from the SPF series).

The model generates an uptick in the perceived target during the post-pandemic episode that is seen in the SPF data as well, showing that there was some endogenous feedback from the post-pandemic policy to private agents' inflation expectations, causing the perceived target to be revised upwards, peaking at 3%. This is remarkable considering that CPI inflation itself reached a peak of 9.1% in June 2022. The same learning mechanism that drove the perceived target as high as 12% during the 80s remained largely muted during the recent surge. As we shall see, the reason has to do with changes in the agents' perceptions about the relative weight the Fed attaches to real-side stabilization.

Figure 3 further illustrates how the link between realized inflation and long-run inflation expectations has weakened following the Volcker disinflation. Upto the mid-1980s, the perceived inflation target moved closely with actual inflation. Afterwards however, while CPI inflation continued to fluctuate, agents' beliefs about the target moved very slowly. In the mid-1980s, even as inflation fell below 2.5% for the first time in nearly two decades, the perceived target hovered near 4%. Hence, for a time, agents viewed the benign inflation as a temporary reprieve driven by the macroeconomic environment soon to be undone by policy.

While I argue that the conduct of policy created the perception among private agents that the inflation target had risen substantially during the 1970s, the model does not take a stand on what would cause the policymakers to acquire a taste for such exorbitant levels of inflation. Narrative evidence offered by Romer and Romer (2002), DeLong (1996) provide some valuable clues: inflation was deliberately pursued under the false notion that unemployment could be driven lower by inflationary surprises. This behavior would be broadly consistent with the policymakers' implied target rising during recessions. Under this explanation, the policymakers did not view the natural rate of unemployment as a constraint on policy design, instead viewing the Phillips curve as offering an exploitable long-run trade-off between inflation and unemployment. The results in the next subsection are consistent with the idea that the conduct of policy had signaled little concern for keeping the unemployment gap closed during this episode.

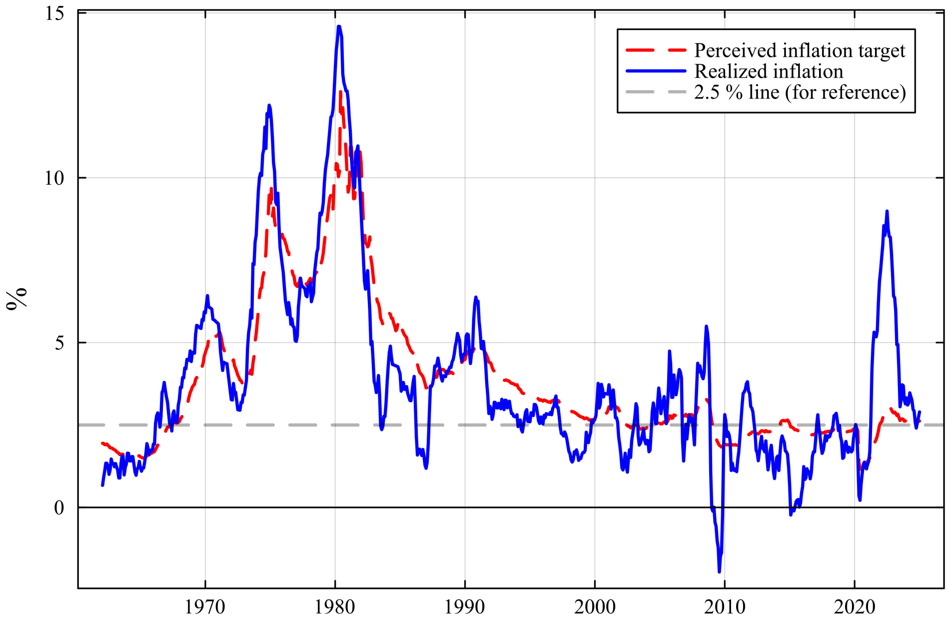



Figure 3: **Weakening link between the long-run and the short-run:** Realized CPI inflation *(solid)* vs Model-implied private-sector beliefs about the inflation target *(dashed)*
*Co-movement between current CPI Inflation and the private-sector's beliefs regarding the long-run inflation target has weakened considerably since the Volcker disinflation.*

## 6.2 The Fed's weight on unemployment gap stabilization

Figure 4 plots the evolution of the private sector's estimates of $\lambda_t$: the relative weight the Fed puts on closing the unemployment-gap. The estimates suggest that, during the early 1960s, the private sector attributed relatively little concern from the Fed towards closing the gap.

After a slow and steady rise following the Volcker disinflation, perceptions regarding $\lambda$ were sharply revised upwards following the Global Financial Crisis and again in the aftermath of the

COVID-19 pandemic: the emphasis of policy has shifted. This development has had important implications for the anchoring of expectations. Concisely, a large $\lambda$ implies that the Fed "ties its hands"; unemployment gaps are perceived as costly and hence policy emphasizes keeping the gap closed - policy behavior that is conducive to the stability of inflation in the long-run. A large $\lambda_t$ also has the effect of making future unemployment gaps more predictable (since they are closer to zero) and less responsive to supply shocks, ultimately reducing real-side volatility.

These findings are consistent with recent empirical literature using high-frequency identification utilizing changes in asset prices around Fed policy announcements to study how the private sector learns about the Fed's "policy rule" (e.g., Bauer and Swanson (2023), Bauer, Pflueger and Sunderam (2024), Pflueger (2025),). These studies find that monetary policy in the recent period, following 2000, has been perceived to be increasingly responsive to output. A rise in $\lambda_t$, and the greater predictability of unemployment-gaps also complements earlier findings that output-gap volatility in the U.S. has declined significantly since the Volcker disinflation (see Blanchard and Simon (2001); McConnell and Perez-Quiros (2000)), underscoring the role of systematic monetary policy in engineering output-stability.

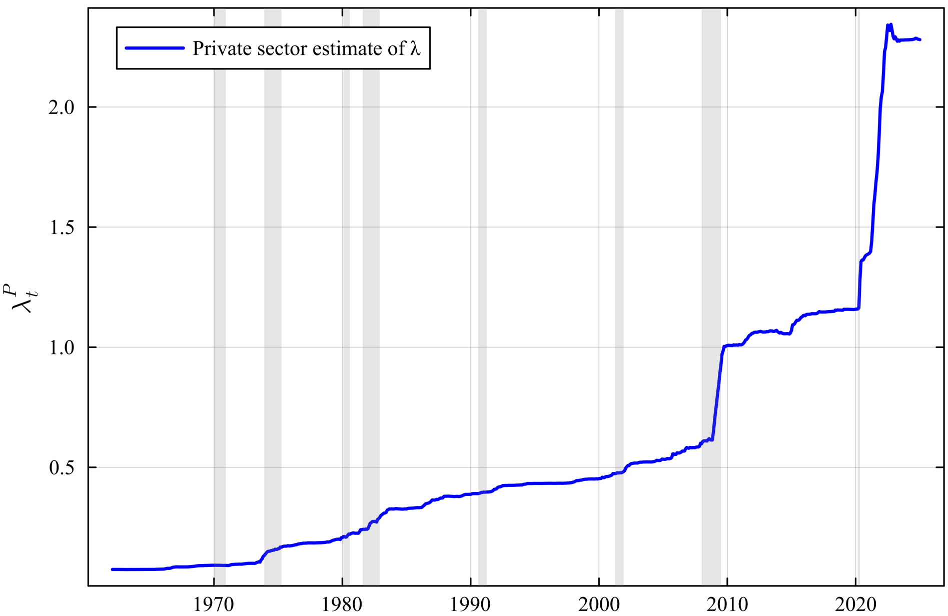



Figure 4: **Beliefs regarding the Fed's weight on unemployment-gap stabilization:** Evolution of the Private sector estimate of $\lambda_t$
*The private sector perceives the Fed to put more emphasis on stabilizing the unemployment-gap*
*Note: Shaded regions indicate NBER recessions*

### 6.3 The slope of the expectations-augmented Phillips Curve

The parameter $\kappa$, represents the sensitivity of aggregate inflation to contemporaneous unemployment gap. Hence, it serves as the connective tissue between the real and nominal side of the economy and is a key parameter that agents must learn. Figure 5 plots the evolution of the agents' beliefs regarding the slope of the expectational Phillips curve under their learning mechanism. Under the agents' prior, $\kappa$ is time-invariant. However, their real-time estimates under learning exhibit significant time-variation over the sample period.

Since $\kappa$ is not subject to innovations, the steady-state filter would be a decreasing-gain one. As new data is observed and beliefs are updated, each additional observation carries marginally less information and their beliefs should stabilize near a constant value. But it does not appear that any such convergence has attained within the sample period spanning about 60 years.

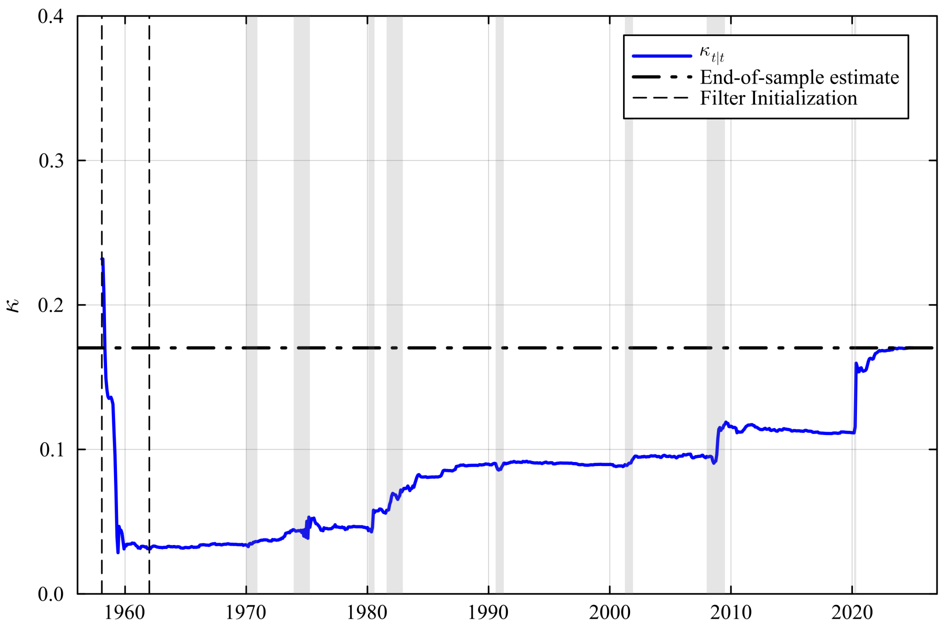



Figure 5: **Slope of the expectations-augmented Phillips curve:** Filtered (*solid*) estimates of the slope of the Phillips curve.
*From the private agents' perspective, the Phillips curve is steeper now than it was during the Great Inflation period. Even though the agents learn under the assumption that the true structural Phillips curve has a time-invariant slope, their beliefs are subject to constant revisions owing to the identification problems posed by the information structure of the economy.*
Note: Shaded regions indicate NBER recessions

To understand why this is the case, let's revisit the observation equation through which agents update their beliefs regarding $\kappa$ and $\xi_t^p$:

$$\pi_t - E^P_{t-1}\pi_{t+1} = -\kappa x_t + \xi^p_t + \xi^t_t$$

Note that current inflation, $\pi_t$ delivers information about $\kappa$ only through the unemployment gap $x_t$. It is not surprising then, that we see the bulk of the large updates in agents' estimates of $\kappa$ around recessions (corresponding to large variations in $x_t$). During "normal" times, the unemployment gap is small and it is hence evident that learning would slow down (since inflation carries little information regarding the true $\kappa$). In totality, the signal informing the agents about $\kappa$ gets drowned out due to (i) the unemployment gap $x_t$ being of small magnitude most of the time (Figure 14 in Appendix D plots the evolution of the variable) and (ii) the presence of cost-push shocks confounding the estimation. The second of these reasons is a familiar one: Supply shocks are known to confound the estimation of the Phillips curve and the literature has often relied on adding oil prices or similar variables as proxies. Inferring the slope of the structural Phillips curve has been among the most enduring and difficult problems in macroeconomics. It is hence no surprise that the agents in the model are not immune to the fundamental econometric challenges that it poses. Models assuming full-information mask such issues entirely.

The agents perceive the slope to be relatively "flat" during the 1970s. This belief would be reinforced by the experience of high inflation in the face of rising unemployment experienced during this period. The perception of a flat Phillips curve is one of the primary reasons cited by Primiceri (2006) and Sargent, Williams and Zha (2006) for the policymakers' aversion to act decisively against inflation during this period. The agents revise their beliefs over time and see the slope become steeper over time.[18] In the post-pandemic period, the large decline in inflation from its highs with little rise in unemployment leads the agents to update their beliefs about $\kappa$ upwards. Overall, the results suggest that real-time identification of the Phillips curve is quite poor and agents' estimates would take an unreasonably long time to converge to a constant.

However, estimates during the entire sample period remain within a plausible range (between 0.05-0.20) and the model does not need to rely on an excessively flat Phillips curve to rationalize the outcomes of the past 20 years. The estimates also shine a light on why recent literature has invoked specifications involving a nonlinear Phillips curve to explain the behavior of inflation during the post-pandemic surge (see Harding, Lindé and Trabandt (2023) Benigno and Eggertsson (2024))[19]. Though the model considered here does not nest such nonlinearities, agents' perceptions regarding the true slope do change substantially during the pandemic-recession.

[18]This is in contrast with the literature finding a flattening Phillips curve over time. However, the estimates are not directly comparable to the one here since the empirical specification used is very different.

[19]However, Beaudry, Hou and Portier (2025)) find limited evidence in favor of nonlinear Phillips curve specifications once inflation expectations are explicitly taken into account.

They perceive the slope to be much steeper now. Whether this represents a change in the true underlying structural slope is yet an open question outside the scope of this paper.

## 6.4 Anchoring Coefficient

In subsection 4.5, we derived a quantity measuring the responsiveness of interest rates to changes in the target and denoted its reciprocal as the "anchoring coefficient", $\zeta_t = \frac{\lambda^P_{t-1}+\kappa^2_{t|t}}{\kappa_{t|t}}$. I plot the evolution of $\zeta_t$ in Figure 6.

From the private agents' vantage point, the policy environment has changed drastically in the 40 years separating the Great Inflation and the post-pandemic surge. The degree of anchoring of long-run inflation expectations has steadily increased over the past 40 years - even more so since the GFC and the pandemic. According to the model, long-run inflation expectations are more entrenched at this juncture than any other time in the post-war history of the United States. This yielded in large part due to the steady increase in $\lambda_t$ over this period. The rise in this coefficient is precisely what gave the Fed room to continue to "look-through" supply shocks, adopting a wait-and-see approach without triggering large revisions in the perceived inflation target. Beliefs about the inflation target are quite unresponsive to interest rates. While this makes de-anchoring due to perceived mistakes unlikely, it also hampers the Fed's ability to guide these beliefs back to target *if* they were to change. An implication of the model is that the steadfast disinflation of the 80s would be much less likely given the circumstances now.

## 6.5 "Bad luck" vs "bad policy" revisited

The following section contributes to the debate regarding whether the economic outcomes of the post-Volcker period were a result of luck (favorable economic environment, benign shocks) or systematic policy (shifts in the Fed's implied policy objectives). I discuss how evolving perceptions regarding structural shocks and the Fed's systematic monetary policy contributed to shaping macroeconomic outcomes in the post-war period in the U.S.

### 6.5.1 The role of policy in shaping agents' expectations

To assess the role of the Fed's systematic monetary policy, it is useful to consider the perceived real rate gap, defined as the difference between the ex-ante real interest rate and the perceived

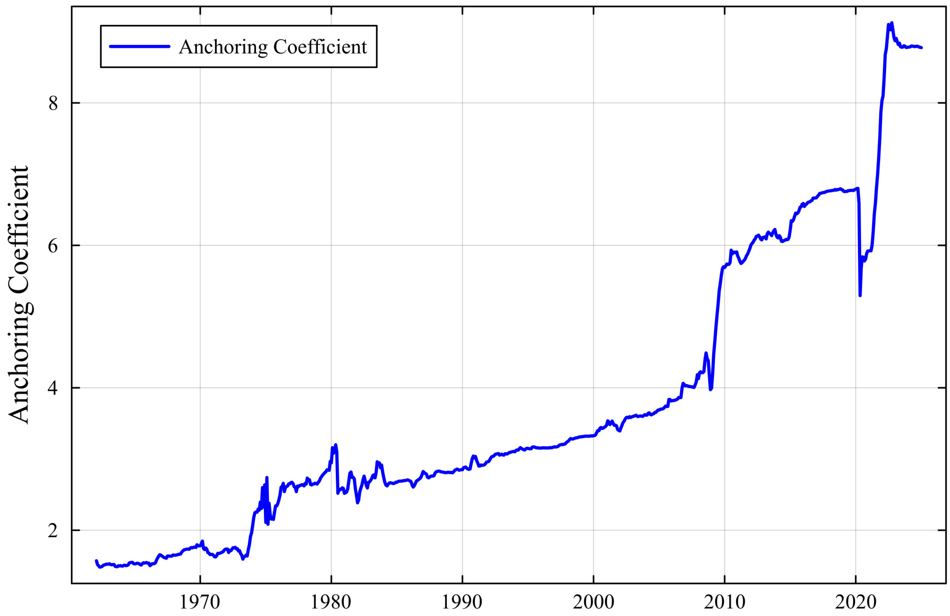



Figure 6: **Evolution of the anchoring coefficient** ($\frac{\lambda^P_{t-1}+\kappa^2_{t|t}}{\kappa_{t|t}}$): The coefficient measuring the "anchoring" of long-run inflation expectations has risen drastically
*Even as the perceived slope of the Phillips curve has risen, the rise in the perceived weight on unemployment gap stabilization $\lambda^P_t$ has outpaced it and made the coefficient larger.*

natural rate of interest, $r^n_{t|t}$. A positive real rate gap implies that the policy exerts upwards pressure on the unemployment gap and thereby indicating a contractionary policy stance. Conversely, a negative real rate gap reflects an expansionary stance of policy.

Figure 7 illustrates agents' perceptions of the real rate gap and the persistent supply shocks in the economy. As we can see, the late 60s are characterized by moderate supply shocks. But the real rate gap tends to stay negative throughout the latter half of the decade.[20] The mid 1970s see a much worse version of the same problem with mounting supply shocks and an expansionary Fed policy. Naturally, since policy was seen as tolerant of unemployment gaps at the time, such behavior only points to the Fed having a high implied inflation target. Long-run inflation expectations shot up.

"Forever inflation" took hold with no resolve from policymakers to combat it. It is not until 1980, under the chairmanship of Paul Volcker that we see a sustained positive real rate gap leading to the eventual "conquest over inflation". From the model's perspective, two aspects of policy behavior in the post-Volcker period were important for the onset of the "Great Moderation": (i)

[20]Some narrative evidence from this period finds that Chairman Martin's initial anti-inflation stance clashed with expansionary fiscal policy by the Congress. This ended up eroding the postwar monetary discipline of the Fed, with focus shifting from inflation stabilization to policy accommodation.

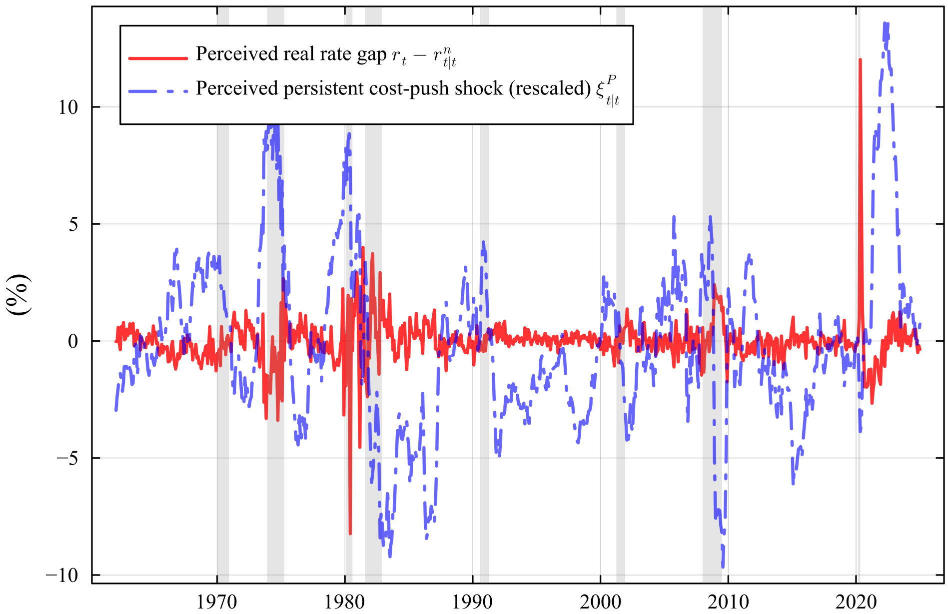



Figure 7: **Policy response to inflationary shocks:** The perceived real rate gap $r_t - r^n_{t|t}$ *(solid)* vs filtered estimates of persistent supply shocks $\xi^p_{t|t}$ *(dashed)*
*Supply-side shocks in the 70s and 80s were met with accommodative policy by the Fed. Policy was perceived to be similarly accommodative at the beginning of the post-pandemic surge.*Note: Shaded regions indicate NBER recessions

a positive real rate gap was maintained for a prolonged period signaling a lower inflation target and (ii) muted response of policy to persistent shocks in the Phillips curve signaling a steadily increasing weight on real-side stabilization represented by $\lambda_t$. These gradually led the agents to believe in a low, stable inflation target. Note that without (ii), the anchoring would be fragile and long-run beliefs would have been similarly volatile, shooting up at any hint that Fed policy was “too loose”.

Turning to the post-pandemic period, the agents see the mistakes of the 70s being repeated: persistent supply shocks are at the door and the Fed is nowhere close to contain the imminent crisis. Yet, we see long-run inflation expectations remain largely stable. After a period of “looking through” the shocks, the Fed quickly catches up and the agents see the real-rate gap close as the Fed begins its cycle of rate hikes. From the model’s perspective, even as the agents perceived the policymakers to be making a similar kind of mistake in the recent period, their expectations responded differently - they did not interpret it as coming from a shift in the inflation target this time: in large part due to a change in their perceptions regarding $\lambda_t$. Disciplined Fed policy has shaped agents’ beliefs in a way that prevented the inflationary spiral of the 70s. Disciplined policy of the past continues to bear fruit.

### 6.5.2 Supply shocks: The structural drivers of policy trade-offs

As the only variable driving a trade-off between inflation and unemployment gap stabilization, persistent supply shocks cause all "involuntary" inflation, over and beyond the Fed's targeted level. Agents' beliefs about these shocks are an important determinant of their short-run inflation expectations and hence of inflation dynamics themselves.

Figure 8 plots the time-series of the agents' beliefs (real-time as well as smoothed) regarding persistent supply shocks in the Phillips curve. One fact that emerges is that the agents perceived large persistent supply shocks, both during the Great Inflation of the 70s-80s and in the more recent inflation surge. Moreover, the shocks were of roughly similar magnitude across the two episodes if not larger during the recent episode. Hence, the going by the size of the shocks alone, one would find it hard to explain why the inflation crisis was much more benign this time.

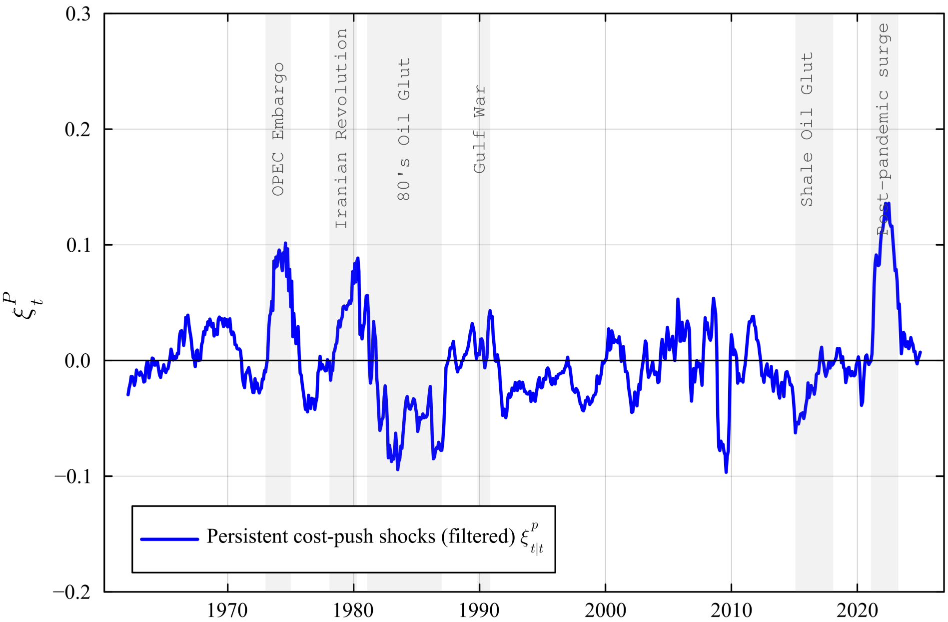



Figure 8: **Structural shocks that drive inflation:** Private agents' estimates of the persistent component of the cost-push process $\xi_t^P$: Filtered *(solid)* vs smoothed *(dashed)*
*The magnitude of persistent cost-push shocks perceived by the agents during the post-COVID period were similar to those during the 70s-80s Great Inflation period.*

The perceived supply shocks line up well with documented episodes of oil price surges. There is ample evidence in the literature that fluctuations in relative prices of energy goods are significant drivers of inflation (see Afrouzi, Bhattarai and Wu (2024), Gagliardone and Gertler (2023) for recent papers examining link between crude oil prices and the post-pandemic inflation surge). Interestingly, the last time that the agents perceived inflationary supply shocks was during the recovery from the Great Financial Crisis (GFC). This is consistent with evidence that oil price shocks in the aftermath of the crisis propped up inflation expectations accounting for the "missing deflation" (Coibion and Gorodnichenko (2015)). According to the model, even as the agents' long-run inflation expectations remain stable during this period, their short-run expectations are quite responsive to inflationary supply shocks during this period.

To aid interpretation of these "persistent supply shocks", in Figure 9 I plot the series against food and energy price inflation derived as the difference between Headline CPI and Core CPI. The series are de-meaned and re-scaled for comparison. The two series display significant co-movement. Since Core CPI is not a series that the model has "seen" (only Headline CPI data is used during estimation), it is remarkable that such a link emerges.

The post-pandemic episode was characterized by structural shifts over and above oil price surges, such as sectoral shocks shifting consumption between goods and services (see Guerrieri et al. (2021)) structural changes in the labor market (Blanchard and Bernanke (2023), Ball et al. (2022)), increasing attention to inflation (Pfauti (2023)) to name a few. However, shocks to relative food and energy prices appear to explain a large part of the variation in these persistent supply shocks perceived by the agents. This is intuitive considering how *salient* these prices are (as also argued by Coibion and Gorodnichenko (2015)). It makes sense that firms and households' perceptions about inflation in the short run would respond to these prices given their pervasive impact on the rest of the economy (as argued in Afrouzi et al. (2024) using a model of input-output linkages). Hence, the model adds support to the literature emphasizing the importance of relative price disturbances in driving aggregate inflation dynamics.

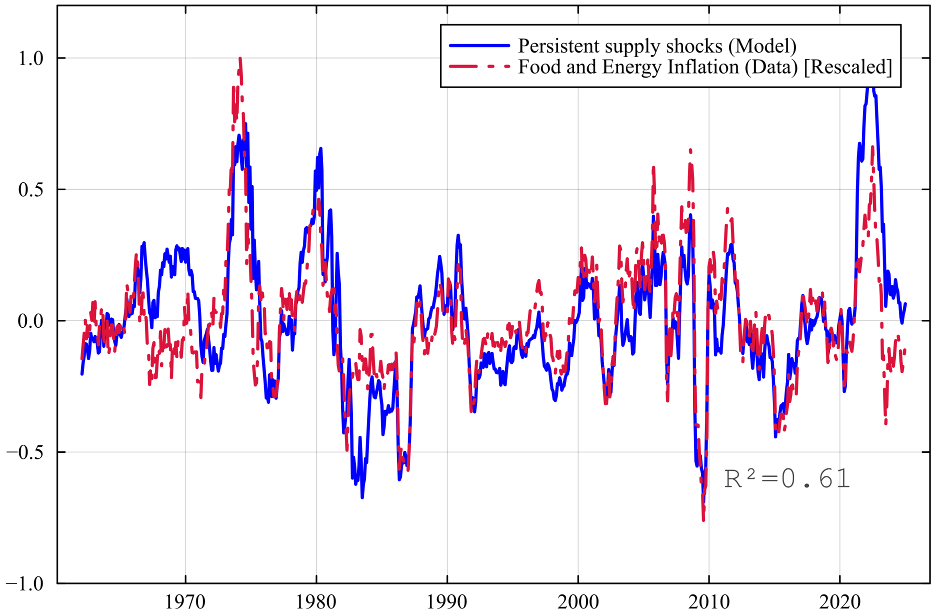



Figure 9: **Do relative prices drive inflation expectations?:** Persistent supply shocks perceived by the agents (smoothed estimate) vs relative price inflation in food and energy (Untargeted)
*Note: Measure of Food and Energy inflation constructed as difference between headline and core CPI inflation*

# 7 Conclusions

The rational expectations revolution—spearheaded by the work of Lucas and Sargent—marked a profound shift in macroeconomic thought. New Keynesian macroeconomics incorporated this transformation by explicitly modeling how aggregate outcomes emerge from the optimizing behavior of individual agents. The model developed in this paper extends the forward-looking New Keynesian framework to an environment of imperfect knowledge, in which agents form and update beliefs about the economy using a structural model. In doing so, it describes postwar U.S. macroeconomic dynamics from the perspective of agents operating within a New Keynesian economy, learning about its structural drivers in real-time.

A central implication of the model is that, because expectations play a pivotal role in shaping macroeconomic outcomes, the function of monetary policy extends beyond mechanical stabilization. Policy actions not only influence current economic conditions but also actively shape agents' expectations—a point first emphasized by Kydland and Prescott (1977). The learning mechanism embedded in the model illustrates how the anchoring of expectations emerges endogenously from the systematic conduct of monetary policy. The evolution of postwar U.S.

macroeconomic dynamics is thus closely linked to how Federal Reserve policymakers have signaled their underlying stabilization objectives. The model provides a structural interpretation of how monetary policy contributes to the anchoring of expectations, highlighting its dual role as both a stabilizing instrument and a signal relaying information and affecting expectations.

Perceived changes in the Federal Reserve's policy priorities — specifically, a heightened emphasis on unemployment stabilization has contributed to the anchoring of the long-run inflation expectations, cushioning the long-run anchor against perceived policy mistakes; while simultaneously amplifying the inflationary impact of persistent supply shocks. From the lens of the model, these perceptions were the principal reason that the Fed could "look-through" supply shocks without de-anchoring long-run expectations. Beliefs shaped by the disciplined conduct of monetary policy over the forty years following the Volcker disinflation have contributed greatly to the "soft-landing" that we saw recently. While recent work (e.g., Coibion and Gorodnichenko (2025)) has warned of inflationary risks resulting from de-anchoring of expectations from inflationary pressures in the short-run, the model presented here paints a less grim picture while recognizing the risks that an indecisive policy response to supply shocks could pose in the future.

This work also highlights the explanatory power of the textbook New-Keynesian model when augmented with imperfect information and learning. The model reconciles the empirically observed persistence in macroeconomic aggregates, delivering an excellent fit to macroeconomic data without resorting to backward-looking mechanisms such as indexation to past prices, habit formation in consumption or interest rate smoothing. Finally, the model highlights the *state-dependent* nature of agents' learning: the rate at which information arrives is neither uniform over time nor identical across structural parameters. One key parameter for which this distinction is particularly relevant is the slope of the expectations-augmented Phillips curve, which remains poorly identified under learning. This finding suggests that the full-information assumption commonly imposed in macroeconomic models may be far less innocuous than often presumed.

# References

**Afrouzi, Hassan, Saroj Bhattarai, and Edson Wu**, "Relative-price changes as aggregate supply shocks revisited: Theory and evidence," *Journal of Monetary Economics*, 2024, *148*, 103650. Inflation in the COVID Era and Beyond. 37, 38

**Ball, Laurence, Daniel Leigh, and Prakash Loungani**, "Okun's Law: Fit at 50?," *Journal of*

*Money, Credit and Banking*, 2017, *49* (7), 1413–1441. 13

**Ball, Laurence M, Daniel Leigh, and Prachi Mishra**, "Understanding U.S. Inflation During the COVID Era," Working Paper 30613, National Bureau of Economic Research October 2022. 38

**Bauer, Michael D. and Eric T. Swanson**, "A Reassessment of Monetary Policy Surprises and High-Frequency Identification," *NBER Macroeconomics Annual*, 2023, *37* (1), 87–155. 31

**Bauer, Michael D, Carolin E Pflueger, and Adi Sunderam**, "Perceptions About Monetary Policy*," *The Quarterly Journal of Economics*, 06 2024, *139* (4), 2227–2278. 31

**Beaudry, Paul, Chenyu Hou, and Franck Portier**, "On the Fragility of the Nonlinear Phillips Curve View of Recent Inflation," Working Paper 33522, National Bureau of Economic Research February 2025. 33

**Benigno, Pierpaolo and Gauti B. Eggertsson**, "The Slanted-L Phillips Curve," *AEA Papers and Proceedings*, May 2024, *114*, 84–89. 33

**Bernanke, Ben S. and Ilian Mihov**, "Measuring Monetary Policy*," *The Quarterly Journal of Economics*, 08 1998, *113* (3), 869–902. 6

**Bhattarai, Saroj, Jae Won Lee, and Woong Yong Park**, "Policy Regimes, Policy Shifts, and U.S. Business Cycles," *The Review of Economics and Statistics*, 12 2016, *98* (5), 968–983. 28

**Blanchard, Olivier and John Simon**, "The Long and Large Decline in U.S. Output Volatility," *Brookings Papers on Economic Activity*, 2001, *2001* (1), 135–164. 31

**Blanchard, Olivier J and Ben S Bernanke**, "What Caused the US Pandemic-Era Inflation?," Working Paper 31417, National Bureau of Economic Research June 2023. 38

**Bullard, James and Stefano Eusepi**, "Did the great inflation occur despite policymaker commitment to a Taylor rule?," *Review of Economic Dynamics*, 2005, *8* (2), 324–359. Monetary Policy and Learning. 5

**Carvalho, Carlos, Stefano Eusepi, Emanuel Moench, and Bruce Preston**, "Anchored Inflation Expectations," *American Economic Journal: Macroeconomics*, January 2023, *15* (1), 1–47. 6

**Christiano, Lawrence and Christopher Gust**, "The expectations trap hypothesis," *Economic Perspectives*, 2000, *25* (Q II), 21–39. 6, 19

**Clarida, Richard, Jordi Gali, and Mark Gertler**, "Monetary Policy Rules and Macroeconomic Stability: Evidence and Some Theory*," *Quarterly Journal of Economics*, February 2000, *115* (1), 147–180. 6

**Cogley, Timothy and Thomas J. Sargent**, "Anticipated Utility and Rational Expectations as approximations of Bayesian decision making*," *International Economic Review*, February 2008, *49* (1), 185–221. 15

**Coibion, Olivier and Yuriy Gorodnichenko**, "Is the Phillips Curve Alive and Well after All? Inflation Expectations and the Missing Disinflation," *American Economic Journal: Macroeconomics*, January 2015, *7* (1), 197–232. 38

**— and —**, "Inflation, Expectations and Monetary Policy: What Have We Learned and to What End?," Working Paper 33858, National Bureau of Economic Research May 2025. 40

**Debortoli, Davide and Aeimit Lakdawala**, "How Credible Is the Federal Reserve? A Structural Estimation of Policy Re-Optimizations," *American Economic Journal.Macroeconomics*, 07 2016, *8* (3), 42–76. 6

**DeLong, J. Bradford**, "America's Only Peacetime Inflation: The 1970s," NBER Historical Working Papers 0084, National Bureau of Economic Research, Inc May 1996. 6, 30

**Erceg, Christopher J. and Andrew T. Levin**, "Imperfect credibility and inflation persistence," *Journal of Monetary Economics*, 2003, *50* (4), 915–944. 5, 48

**Evans, George W. and Seppo Honkapohja**, *Learning and Expectations in Macroeconomics*, Princeton University Press, 2001. 5, 15

**Gagliardone, Luca and Mark Gertler**, "Oil Prices, Monetary Policy and Inflation Surges," Working Paper 31263, National Bureau of Economic Research May 2023. 37

**Gati, Laura**, "Monetary policy & anchored expectationsâ€"An endogenous gain learning model," *Journal of Monetary Economics*, None 2023, *140* (S), 37–47. 6

**Goodfriend, Marvin and Robert G. King**, "The incredible Volcker disinflation," *Journal of Monetary Economics*, July 2005, *52* (5), 981–1015. 29

**Guerrieri, Veronica, Guido Lorenzoni, Ludwig Straub, and Ivan Werning**, "Monetary Policy in Times of Structural Reallocation," 2021. <em>Proceedings of the Jackson Hole Symposium</em>, 2021. 38

**Harding, Martín, Jesper Lindé, and Mathias Trabandt**, "Understanding post-COVID inflation dynamics," *Journal of Monetary Economics*, 2023, *140*, S101–S118. Inflation: Drivers and Dynamics 2022. 33

**Ireland, Peter N.**, "Changes in the Federal Reserve's Inflation Target: Causes and Consequences," *Journal of Money, Credit and Banking*, 2007, *39* (8), 1851–1882. 49

**Kamber, Güneş, James Morley, and Benjamin Wong**, "Intuitive and Reliable Estimates of the Output Gap from a Beveridge-Nelson Filter," *The Review of Economics and Statistics*, 07 2018, *100* (3), 550–566. 15

**King, Robert G. and Yang K. Lu**, "Evolving Reputation for Commitment: The Rise, Fall and Stabilization of US Inflation," NBER Working Papers 30763, National Bureau of Economic Research, Inc Dec 2022. 6

**Kozicki, Sharon and P.A. Tinsley**, "Permanent and transitory policy shocks in an empirical macro model with asymmetric information," *Journal of Economic Dynamics and Control*, 2005, *29* (11), 1985–2015. Expectations, learning, and monetary policy. 5

**Kreps, David M.**, "Anticipated Utility and Dynamic Choice (1997)," in Donald P. Jacobs, Ehud Kalai, Morton I. Kamien, and Nancy L. Schwartz, eds., *Frontiers of Research in Economic Theory: The Nancy L. Schwartz Memorial Lectures, 1983–1997*, Econometric Society Monographs, Cambridge: Cambridge University Press, 1998, pp. 242–274. 14

**Kydland, Finn E. and Edward C. Prescott**, "Rules Rather than Discretion: The Inconsistency of Optimal Plans," *Journal of Political Economy*, 1977, *85* (3), 473–491. 39

**Lubik, Thomas A. and Frank Schorfheide**, "Testing for Indeterminacy: An Application to U.S. Monetary Policy," *American Economic Review*, March 2004, *94* (1), 190–217. 6

**McConnell, Margaret M. and Gabriel Perez-Quiros**, "Output Fluctuations in the United States: What Has Changed Since the Early 1980's?," *The American Economic Review*, 2000, *90* (5), 1464–1476. 31

**Melosi, Leonardo**, "Signalling Effects of Monetary Policy," *The Review of Economic Studies*, 09 2016, *84* (2), 853–884. 5

**Milani, Fabio**, "Expectations, learning and macroeconomic persistence," *Journal of Monetary Economics*, 2007, *54* (7), 2065–2082. 5, 48

**Nimark, Kristoffer**, "Dynamic pricing and imperfect common knowledge," *Journal of Monetary Economics*, 2008, *55* (2), 365–382. 10

**Orphanides, Athanasios and John C. Williams**, "The decline of activist stabilization policy: Natural rate misperceptions, learning, and expectations," *Journal of Economic Dynamics and Control*, 2005, *29* (11), 1927–1950. Expectations, learning, and monetary policy. 5

_ **and** _ , "Monetary Policy with Imperfect Knowledge," *Journal of the European Economic Association*, 2006, *4* (2/3), 366–375. 5

_ **and Simon van Norden**, "The Unreliability of Output-Gap Estimates in Real Time," *The Review of Economics and Statistics*, 2002, *84* (4), 569–583. 15

**Pfauti, Oliver**, "The Inflation Attention Threshold and Inflation Surges," Papers 2308.09480, arXiv.org Aug 2023. 38

**Pflueger, Carolin**, "Back to the 1980s or not? The drivers of inflation and real risks in Treasury bonds," *Journal of Financial Economics*, 2025, *167*, 104027. 31

**Phillips, A. W.**, "The Relation Between Unemployment and the Rate of Change of Money Wage Rates in the United Kingdom, 1861–1957," *Economica*, 1958, *25* (100), 283–299. 54

**Primiceri, Giorgio E**, "Why Inflation Rose and Fell: Policy-Makers' Beliefs and U. S. Postwar Stabilization Policy*," *Quarterly Journal of Economics*, August 2006, *121* (3), 867–901. 5, 33

**Reis, Ricardo**, "Losing the Inflation Anchor," *Brookings Papers on Economic Activity*, 2021. 28

**Romer, Christina D. and David H. Romer**, "A Rehabilitation of Monetary Policy in the 1950's," *American Economic Review*, May 2002, *92* (2), 121–127. 6, 30

**Sargent, Thomas, Noah Williams, and Tao Zha**, "Shocks and Government Beliefs: The Rise and Fall of American Inflation," *American Economic Review*, September 2006, *96* (4), 1193–1224. 5, 33

**Sims, Christopher A and Tao Zha**, "Were There Regime Switches in U.S. Monetary Policy?," *American Economic Review*, February 2006, *96* (1), 54–81. 6

**Staiger, Douglas, James H. Stock, and Mark W. Watson**, "The NAIRU, Unemployment and Monetary Policy," *Journal of Economic Perspectives*, March 1997, *11* (1), 33–49. 15

**Svensson, Lars E. O.**, "What Is Wrong with Taylor Rules? Using Judgment in Monetary Policy through Targeting Rules," *Journal of Economic Literature*, June 2003, *41* (2), 426–477. 4

**Taylor, John B.**, "Discretion versus policy rules in practice," *Carnegie-Rochester Conference Series on Public Policy*, 1993, *39*, 195–214. 6

**Williams, Noah**, "Adaptive Learning and Business Cycles," *Unpublished*, 2003. 4

# 8 Appendix

## A Long-run inflation expectations

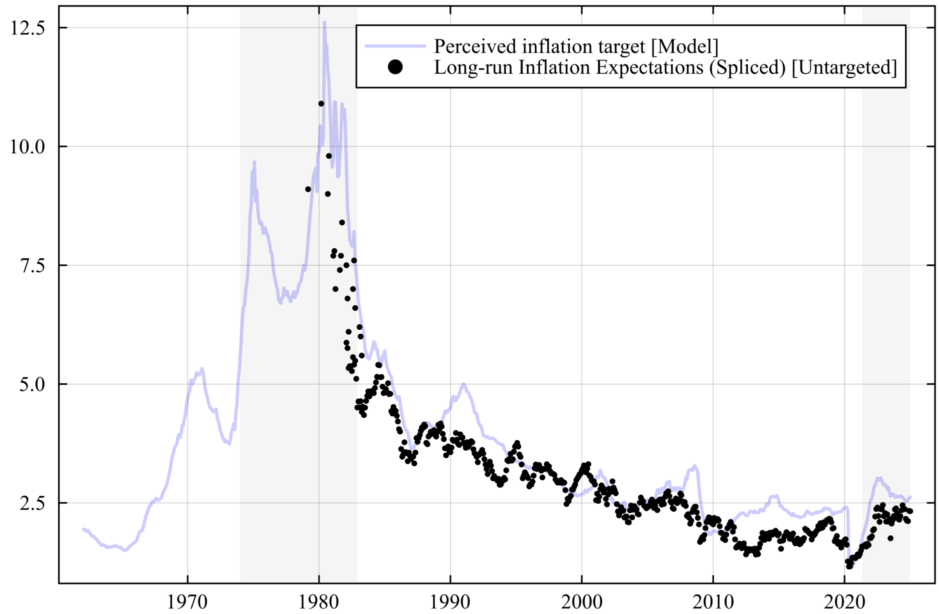
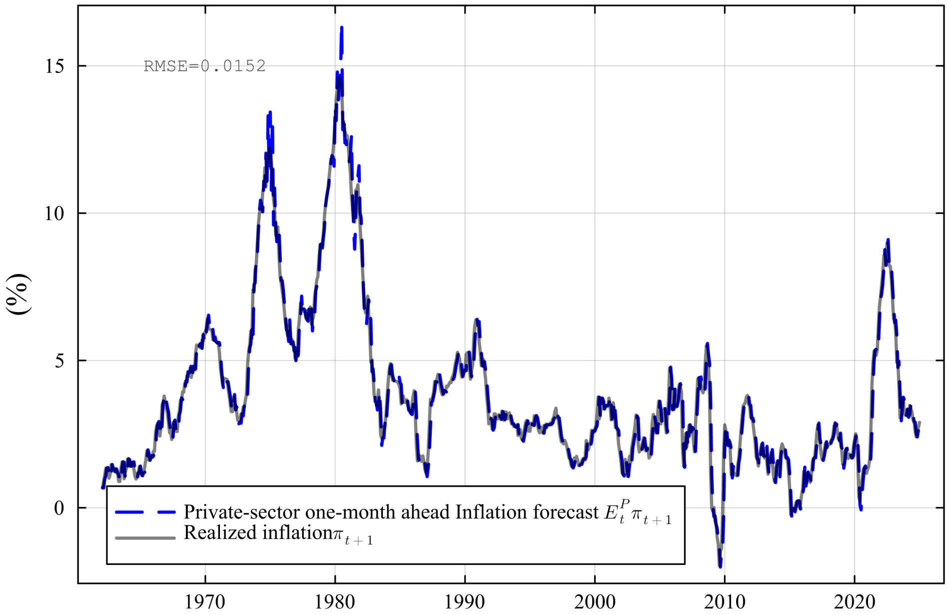


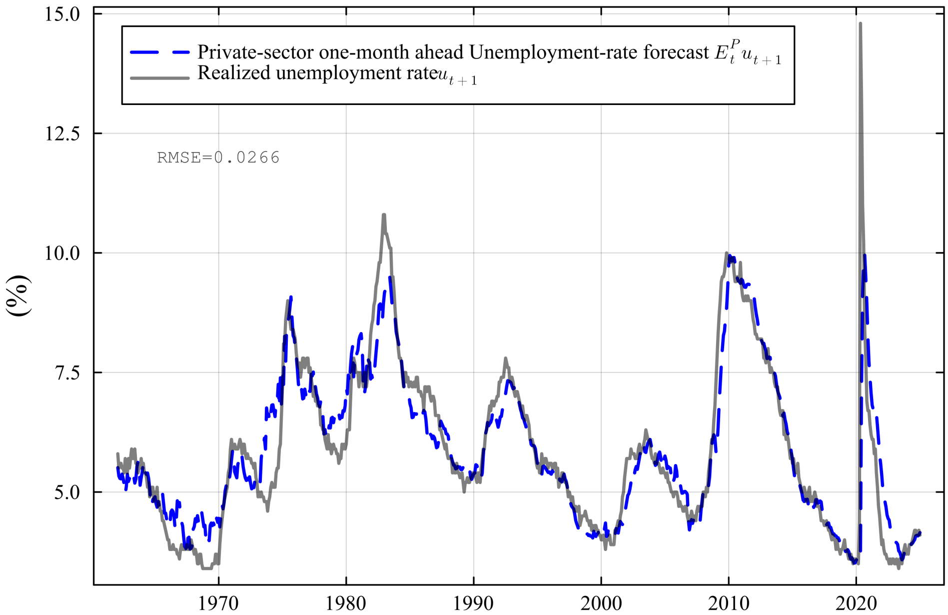

Figure 10: **Comparing with untargeted measures of long-run inflation expectations**
*Private agents' perceptions about the inflation target, as implied by the model are able to track survey-based measures of long-run inflation expectations quite well. The series is not used for estimation.*
Long-run Inflation Expectations series is constructed by splicing together 5-year ahead inflation expectations from Michigan Survey before 1982 and 10-year ahead inflation expectations from the Cleveland Fed afterwards (due to a shorter sample)

## B Forecast performance of agents' model

If the learning algorithm arising from the agents' assumed model of economic dynamics implies forecasts that are persistently off-target, it wouldn't make sense to assume that the agents would continue using it. Rational agents would abandon the model. Hence, it is useful to check how well the agents' ex-ante forecasts agree with the realizations of the inflation, unemployment rate and interest rates or in other words if the agents' assumed model remains plausible given what they observe. Figure 12 plots the agents' ex-ante expectation of the policy rate (prior to announcement) and the realized effective Fed funds rate. Similarly, in Figure 11 I plot the agents' one-period ahead forecasts of inflation and unemployment rate against their corresponding realized values.




(a) Agents' one-month ahead forecast of inflation vs realized value




(b) Agents' one-month ahead forecast of unemployment rate vs realized value

Figure 11: **Performance of agents' learning algorithm at tracking the macroeconomic targets**: Agents' 1-month ahead forecasts of inflation and unemployment rate plotted against actual realizations

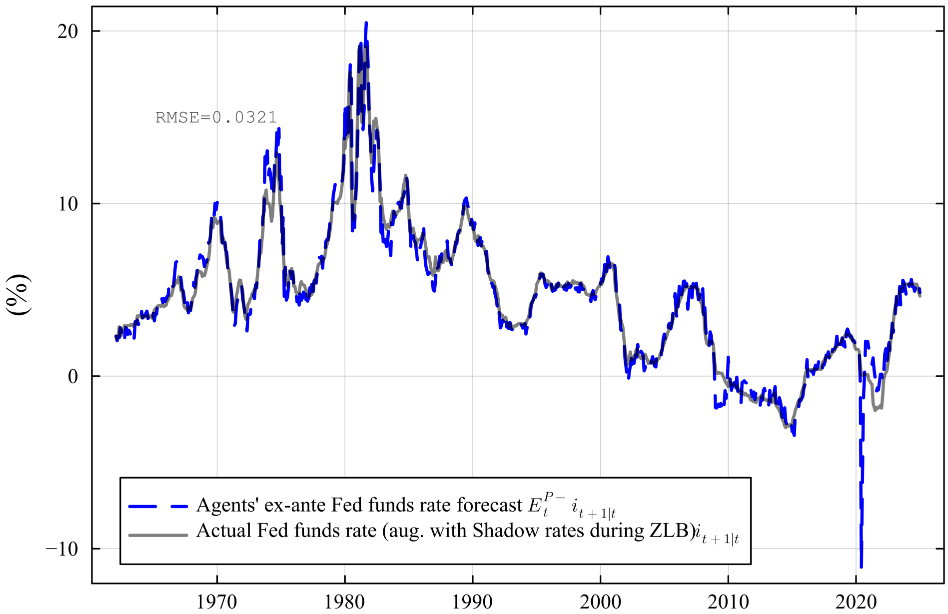


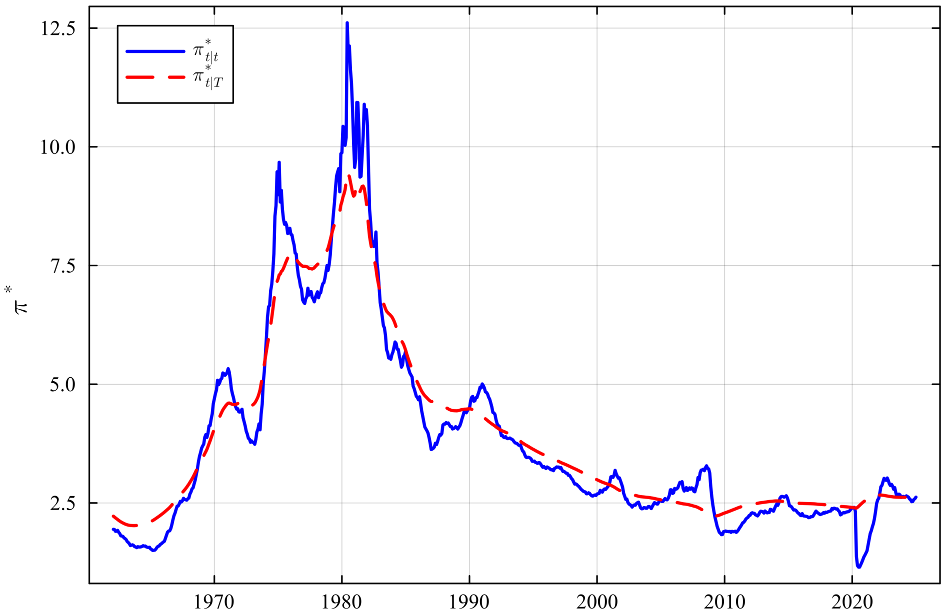

Figure 12: **How well have private agents tracked policy behavior?:** The figure compares the private agents' expected nominal interest rates based on their ex-ante beliefs with the actual Fed funds rate (augmented with the shadow rate)
*Agents' learning algorithm allows them to track policy behavior quite closely.*

The learning model generates forecasts errors of small magnitude (in the RMSE sense). Thus, their model of the economy "works" - they wouldn't find a compelling reason to abandon learning. What is also interesting is the fact that the time-series of their expectations displays a similar degree of persistence as the corresponding macroeconomic variables themselves. The fact that this happens despite their model not having mechanical sources of persistence is noteworthy. Hence, forces such as price-indexation and habit-formation in consumption do not seem to be necessary to generate persistence in the macroeconomic aggregates once the role of learning in agents' expectations-formation process is modeled, as also demonstrated in Milani (2007) and Erceg and Levin (2003).

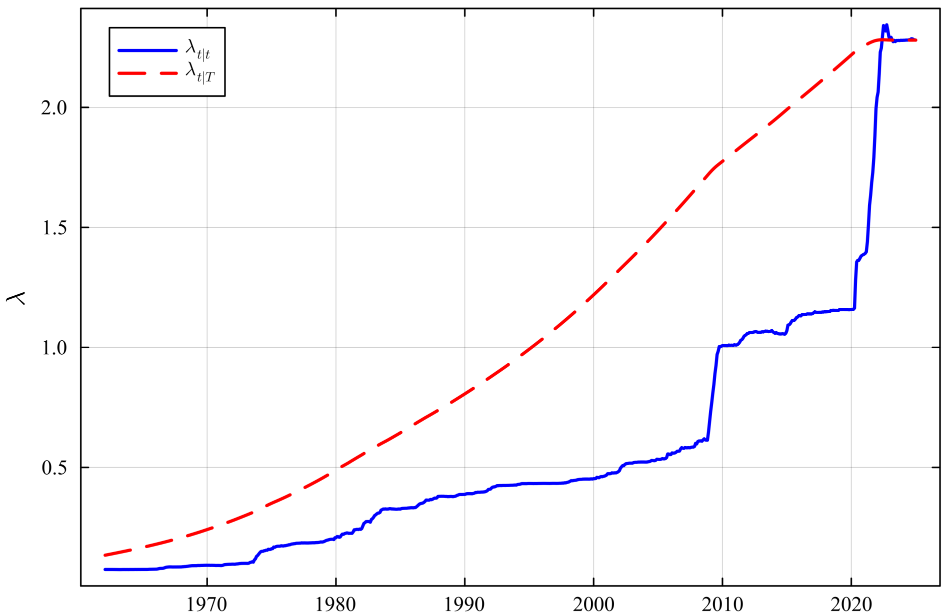
# C What were the Fed's "true" policy preferences?

While the parameters representing the "true" policy preferences of the Fed over the post-war period remain latent (it evolves as an exogenous structural variable as far as the model is concerned), it is possible to arrive at a best-guess using the model by obtaining the smoothed (backward-looking) estimates of the time-$t$ policy preferences (Figure 13). These estimates represent the evolution of Fed's policy preferences in the post-war period from the perspective of a private agent in the model looking back at the end of the sample period (Dec 2024). The estimates suggest that the Fed's true inflation target was upwards of 8 percent during the peak of the 80s-era inflation. Notably, the estimates of the time-varying inflation target are also in line with Ireland (2007) who uses a specification that is very different from the one used here.

Taken at face value, the smoothed estimates of $\lambda$ suggest that Fed was hardly concerned with keeping the unemployment-gap closed during the 70s-80s. Over time however, the Fed has steadily emphasized closing the gap as part of its monetary policy strategy: which brings us to present-day. The estimated weight on unemployment-stabilization is almost twice as large as that on inflation-stabilization. The backward-looking estimates of $\lambda_t$ display periods of departure from the real-time ones. This is because meaningful information regarding $\lambda$ only arrives during periods where agents perceive large cost-push shocks driving policy tradeoffs (since $\lambda$ is only relevant to policy when such a trade-off exists). Thus from the private agents' perspective, though $\lambda$ has been evolving continuously, information regarding $\lambda$ only arrives in clumps during episodes involving large persistent cost-push shocks driving policy trade-offs. Not much learning regarding $\lambda$ takes place during "normal" times.




(a) $\pi_t^*$: Filtered *(solid)* vs Smoothed *(dashed)* estimates




(b) $\lambda_t$: Filtered *(solid)* vs Smoothed *(dashed)* estimates

Figure 13: **The Fed's "true" policy preferences:** Smoothed estimates of $\pi_t^*$ and $\lambda_t$

## D Perceived unemployment-gap

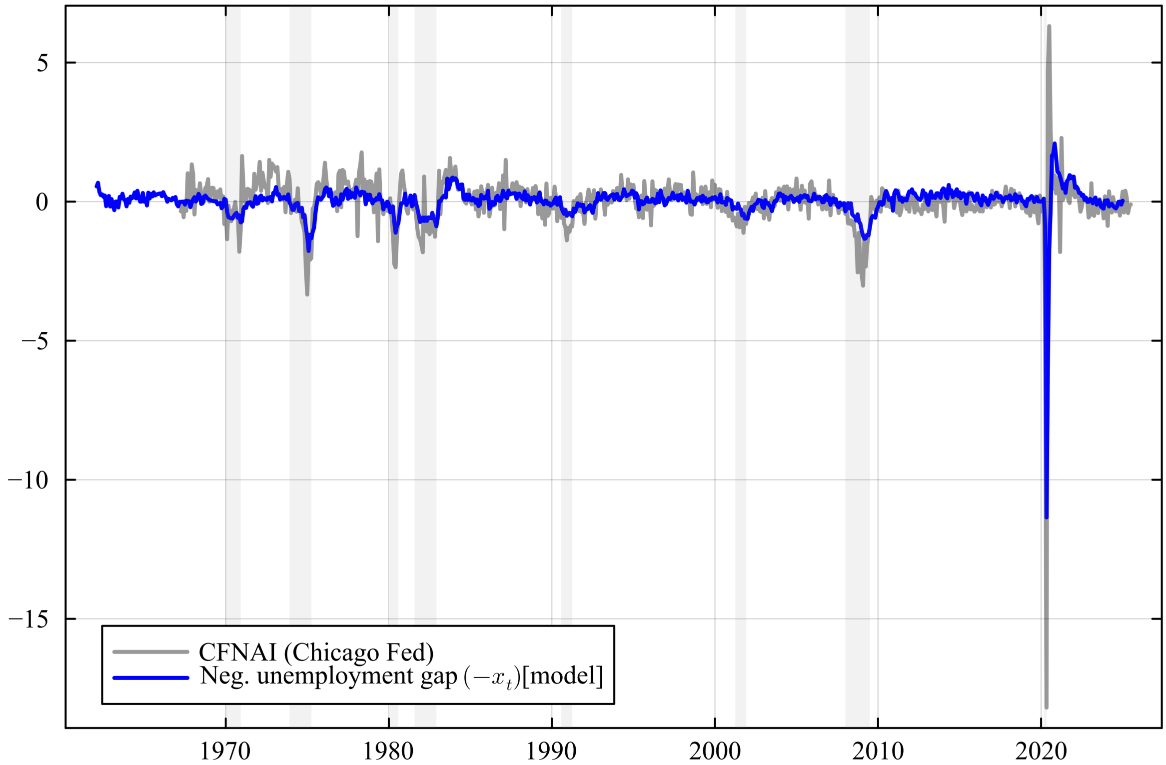



Figure 14: **Estimated unemployment-gap**: Agents' real-time estimates of the (negative of) unemployment gap compared with the CFNAI (Chicago Fed National Activity Index), a composite measure of real activity based on 81 series.
*Note: Shaded regions indicate NBER recessions*

*Source of CFNAI: Chicago Fed*

## E Perceived natural rate of interest $r^n_{t|t}$

Figure 15 plots the evolution of the natural rate of interest as inferred by agents in real-time. This is a useful measure and serves as a barometer to gauge the stance of policy.

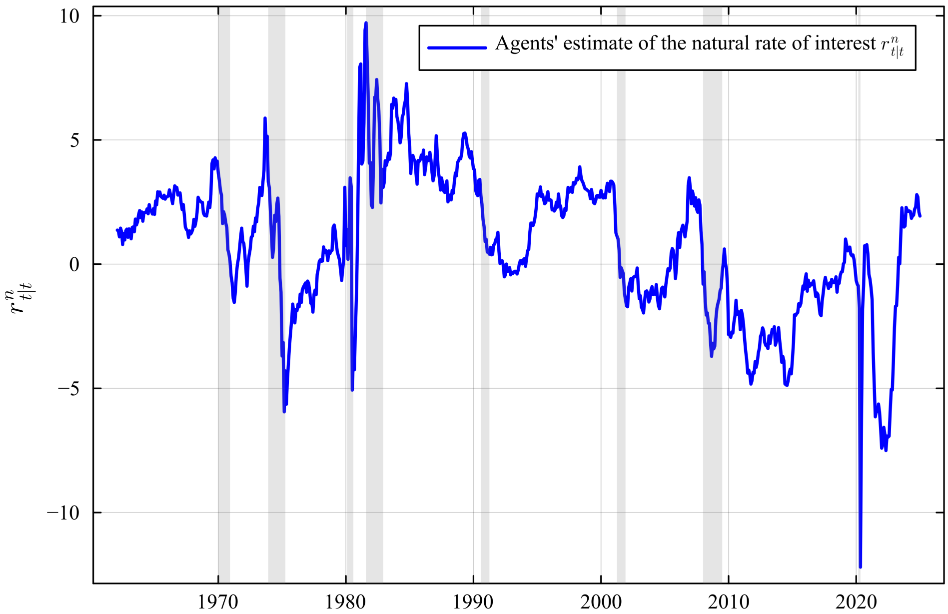



Figure 15: **Estimates of the natural rate of interest**: Model-implied path of the natural rate of interest $r_t^n$
*Note: Shaded regions indicate NBER recessions*

# F Testing the assumptions

## F.1 Has the "true" slope of the Phillips curve changed over time?

In the baseline model, we proceeded with the assumption of a time-invariant Phillips curve in order to keep the model parsimonious and avoid over-reliance on time-variation Phillips curve to explain the observations. However, one can statistically test if there has been a change in the true relationship between unemployment-gap and inflation during the pandemic (motivated by literature arguing that structural shifts in the Phillips curve during the pandemic period were an important factor driving the inflation surge).

In order to do this, we can construct an expectation-adjusted measure of inflation $\pi_t^{adj}$ as:

$$\pi_t^{adj} = \pi_t - E_{t-1}^P \pi_{t+1}$$

This expectations-adjusted measure of inflation is regressed against the unemployment-gap variable $x_t$. The OLS result would not recover the true underlying $\kappa$ since we would expect $x_t$ to be correlated with the supply shock $\xi_t$. It will only be able to recover the reduced-form relationship between inflation and unemployment gap, not any structural linkage. The results of the baseline regression show that once expectations are taken into account, the relationship between inflation and the unemployment-gap is statistically significant - implying a 1% increase in the unemployment-gap associated with a roughly 10 bp decrease in inflation. It is worth noting that the estimate is quite close to the agents' beliefs about $\kappa$ at the end of the sample shown in Figure 5 ($\approx -0.11$). However, the second column shows that the dummy representing the difference in slope during the post-2020 period is not found to be statistically significant at the 5% confidence level.

Table 2: Expectations-augmented Phillips curve: Examining change in slope

| | Model 1<br>Baseline | Model 2<br>Change in slope post-2020 |
|---|---|---|
| $\hat{x}_t$ | **-0.106**$^{**}$ | **-0.193**$^{**}$ |
| | (0.037) | (0.063) |
| $\hat{x}_t \times \mathbf{1}_{\{t>2020\}}$ | — | 0.119 |
| | | (0.067) |
| Observations | 756 | 756 |
| $R^2$ (uncentered) | 0.023 | 0.028 |
| F-stat | 8.322 | 10.42 |
| $p$-value | 0.004 | 3.44e-05 |

*Notes:* Dependent variable is $\pi_t^{\text{adj}}$. Model 2 augments Model 1 with the interaction $x_t \times \mathbf{1}_{\{t>2020\}}$, where $\mathbf{1}_{\{t>2020\}}$ equals one for dates from 2020 onward. HAC (Newey–West) robust standard errors (Bartlett kernel, maxlags = 6). $R^2$ is computed without centering because the model has no constant. Significance: $^*$ indicates that the coefficient is significant at the 5% level.

Another way to shed light on whether time-variation in the Phillips curve slope is an important feature of economic dynamics necessary to explain the data is to directly test for time-variation in the $\kappa_t$ against the null of a constant-$\kappa_t$ in the relationship:

$$\pi_t^{adj} = -\kappa_t x_t + \xi_t$$

If the data supports time-variation in $\kappa_t$, then relaxing the restriction of a constant $\kappa$ should result in a significantly better fit, as measured by log-likelihood. A likelihood-ratio (LR) test is conducted, testing the alternate hypothesis of time-variation in $\kappa$ against the null of a constant $\kappa$.

The LR test is not statistically significant with $p \approx 1.00$. This suggests that the model finds no evidence in favor of time-variation slope of the Phillips curve once expectations are accounted for. The results of the test are reported in Table 3. Re-estimating the model with a time-varying slope $\kappa$ (allowing for innovations with a reasonably small variance $10^{-3}$ over time) produces nearly identical paths of beliefs as the baseline. Overall, the results suggest that changes in the slope of the structural Phillips curve are not a necessary feature to explain post-war U.S. economic dynamics.

Table 3: Results of the Likelihood Ratio Test

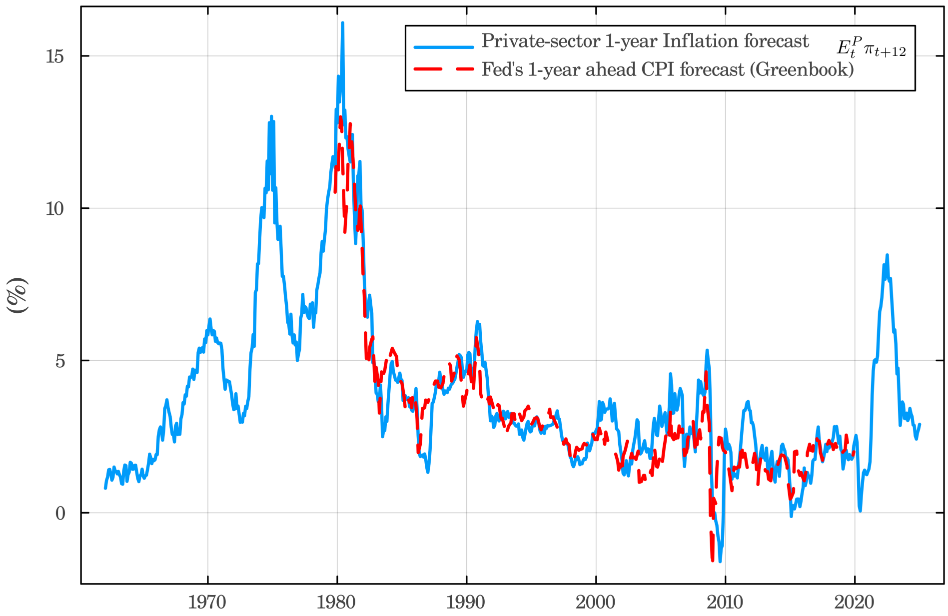
| **Model** | **Log-Likelihood** | **Parameters** | $\chi^2$ | **df** | **p-value** |
|---|---|---|---|---|---|
| Restricted (Constant $\kappa$) | -402.460 | 3 | $3.1 \times 10^{-7}$ | 1 | 1.000 |
| Full (Time-Varying $\kappa$) | -402.460 | 4 | | | |

**Note:** The restricted model assumes a constant $\kappa$ coefficient, while the full model allows it to vary over time. The constant parameter case is nested within the full time-varying parameter model. The Likelihood Ratio Test (LRT) statistic ($\chi^2$) is calculated as $2 \times (\log L_{\text{Full}} - \log L_{\text{Restricted}})$, with degrees of freedom (df) equal to the difference in the number of parameters between the two models.

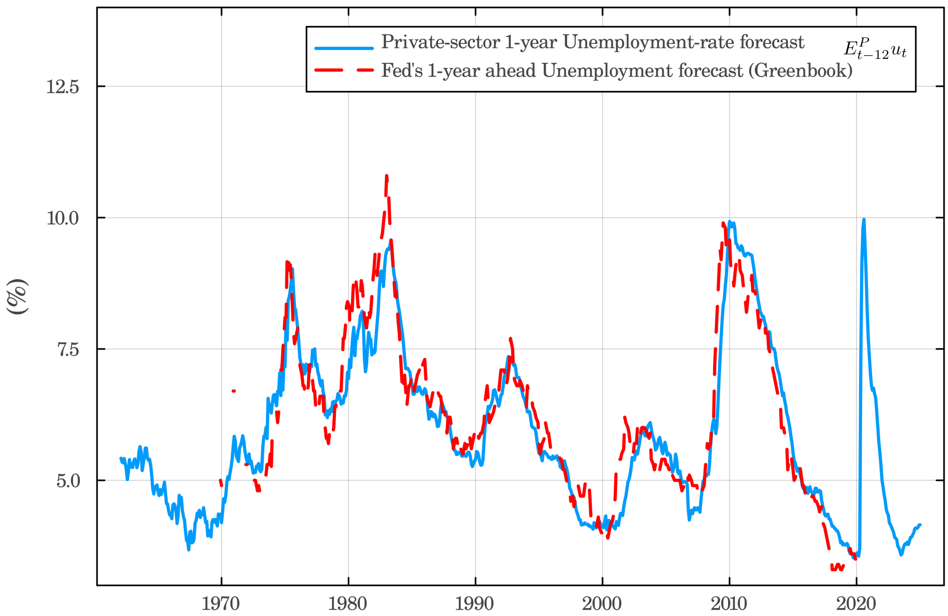
Overall, these results favor the view that time-invariant Phillips curve view adopted by the private agents in the model. Since the modeling framework in this paper explicitly accounts for endogenous formation of expectations, $\kappa$ should not be interpreted as a purely a statistical relationship between inflation and unemployment, differently from the classical Keynesian specification of the Phillips curve described by Phillips (1958).

## F.2 Is the degree of information asymmetry small or large?

This paper assumes little information asymmetry between the Fed and the private-sector: (i) their beliefs about the structural parameters and shocks in the economy are shaped by the same data and the same economic model (ii) the filtering problem assumes that private-agents are able to track the true policy preferences efficiently, meaning that their tracked estimates never stray away from the "true" underlying parameters describing the Fed policymakers' stabilization preferences. One way to test whether these assumptions hold well during the sample period is to compare the agents' forecasts as implied by the model with those from the Greenbook: the Fed's internal forecasts prepared by the staff before each FOMC meeting. If the Fed policymakers do hold significantly different beliefs compared to the private agents, then it would be reflected as a discrepancy in their forecasts.




(a) **Inflation forecasts:** Comparing the Fed's 1-year ahead Headline CPI inflation forecast from Greenbook with 1-year ahead private-agents' forecasts from the baseline model




(b) **Unemployment rate forecasts:** Comparing the Fed's 1-year ahead unemployment rate forecast from Greenbook with 1-year ahead private agents' forecasts from the baseline model

Figure 16: **Macroeconomic outlook (1 year-ahead):** The Fed's 1 year-ahead forecasts for the target variables inflation and unemployment based on the Greenbook are plotted against the corresponding forecasts of the private agents as implied by the model
*The private agents' forecasts based on the learning mechanism described in the model tracks the Greenbook forecasts quite closely. There is little indication that the Fed policymakers' beliefs regarding the future were very different from those of the agents in the model, implying that the degree of information asymmetry was probably of small order.*

To the extent that asymmetric information is large enough to drive a wedge between private agents' and the Fed's forecasts, it does not seem to be important during the sample period. Private-sector forecasts as implied by the model are very close to the corresponding internal forecasts of the Fed (as observed in the Greenbook).