Monetary Policy under Uncertain Expectations in an Emerging Economy[*]

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Abstract

Monetary policy reforms in emerging market economies are often shaped by histories of high inflation, which give rise to persistent concerns about the anchoring of private-sector expectations. Against this background, we study optimal monetary policy under Knightian uncertainty about private-sector expectations. We embed near-rational expectations (NRE) into a small open economy New Keynesian model and characterize robustly optimal monetary policy when the central bank is uncertain about private-sector belief distortions. Applying the framework to Mexico's post–Peso Crisis monetary policy reforms during 1998-2007, we estimate both NRE and rational-expectations (RE) versions of the model. The estimated NRE model implies a substantial concern for robustness and substantially outperforms the RE benchmark in predicting actual monetary policy behavior during this period. Concern for robustness reshapes policy responses, leading the central bank to adopt a more aggressive stance toward stabilizing domestic inflation while tolerating larger adjustments in the nominal exchange rate. At the same time, monetary policy exhibits endogenous history dependence and generates persistent inflation dynamics even in the absence of backward-looking price setting.

JEL Classification: E52, E71, F41, F47.

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1 Introduction

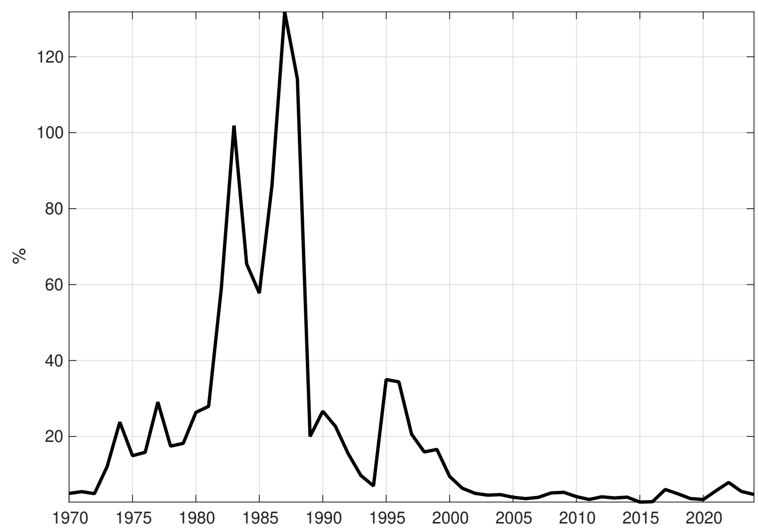
Stabilizing inflation is a core responsibility of central banks worldwide, with the anchoring of inflation expectations playing a central role in this objective. Emerging market economies (EMEs), however, often operate in economic environments that differ markedly from those of advanced economies (AEs), reflecting histories of high inflation, macroeconomic instability, and weaker institutional credibility. Against this backdrop, monetary policy regime shifts in EMEs tend to occur in the aftermath of crisis episodes—such as in Mexico (1994), Thailand (1997), Russia (1998), Brazil (1999), and Argentina (2002)—that compel policymakers to reform their monetary frameworks in an effort to restore macroeconomic stability.

One of the central challenges faced by policymakers during such transitions is how to anchor private-sector inflation expectations. In these reform episodes, the post-crisis policy regime represents a sharp break from the past. Even when a central bank adopts an inflation-stabilizing monetary framework similar to those in AEs, it may lack full confidence about the nature of the expectations it needs to stabilize. In particular, a history of high inflation raises concerns that private-sector beliefs may not be fully aligned with full-information rational expectations (RE), even after credibility-enhancing reforms are implemented. Consistent with this concern, Jacome et al. (2025) document that inflation-targeting central banks in countries with high-inflation histories respond more aggressively to deviations of inflation expectations from the target, even as institutional credibility improves over time. As a result, a persistent tension can arise between institutional reform and inherited expectations, suggesting that concerns about expectation anchoring continue to shape monetary policy responses in post-crisis environments.

In this paper, we develop a framework to study the conduct of monetary policy during periods of monetary regime transition, when central banks face challenges in stabilizing inflation and inflation expectations. Specifically, we analyze the uncertainty surrounding the anchoring of inflation expectations faced by central banks through the lens of Knightian uncertainty, or ambiguity (Gilboa and Schmeidler, 1989). We study an optimal policy problem in a small open economy New Keynesian (SOE-NK) framework, which allows monetary policy to operate in an environment where external conditions and exchange rate movements interact with domestic inflation dynamics. The policymaker is uncertain about the probabilistic nature of private agents' belief formation. While private agents may form near-rational expectations (NRE) centered around the rational-expectations (RE) benchmark, the central bank faces ambiguity regarding the private-sector belief distortions. In this environment, the policymaker exhibits ambiguity aversion and seeks a robustly optimal monetary policy that minimizes losses under worst-case expectations, following the approach of Woodford (2010). The remainder of the model environment follows the standard SOE-NK setup (Gali and Monacelli, 2005) and incorporates a lagged domestic inflation term and a cost-push shock in the aggregate supply relation.

We apply this framework to an analysis of Mexico's monetary policy reforms following the 1994

Figure 1: Annual Inflation Rate, Mexico: 1970-2024



Source: International Financial Statistics database, International Monetary Fund. Indicator code: FP.CPI.TOTL.ZG.

Peso Crisis, treating Mexico as a canonical case study of post-crisis monetary regime transition in EMEs. As illustrated in Figure 1, Mexico experienced prolonged episodes of high and volatile inflation from the 1970s through the mid-1990s, reflecting chronic macroeconomic instability before the crisis. The Peso Crisis made clear that these structural vulnerabilities had reached a point at which a fundamental policy reform was required. In response, Mexico overhauled its monetary framework, shifting from fiscal dominance to monetary dominance and formally adopting an inflation-targeting regime in 2001 (Meza, 2019). While Mexico is a single-country case, its reform episode captures key features of successful monetary transitions in EMEs.

To evaluate the quantitative implications of the framework, we estimate the models using macro–international aggregates during Mexico's policy transition, employing a Bayesian approach. To identify and quantify the shocks driving inflation dynamics, it is not sufficient to rely on inflation alone. In an open-economy setting, exchange rate movements provide additional information that helps discipline the identification of aggregate demand forces, such as natural-rate shocks driven by productivity or foreign demand, when the output gap is unobserved. Accordingly, the observables are CPI inflation and nominal exchange rate depreciation vis-à-vis the United States.

The policy rate is not used as an observable. Instead, we assess external validity by comparing the model-implied optimal policy rate with the actual policy rate. Our analysis delivers the following main findings that highlight the quantitative relevance of a concern for robustness in post-crisis monetary policy. First, the estimated NRE model implies a substantial degree of concern for robustness on the part of the central bank, suggesting that ambiguity about private-sector expectations plays a quantitatively important role in policy design. Second, the NRE model significantly outperforms the RE model in terms of in-sample fit for the observables, as measured by the log marginal data density. Third, the monetary policy rate implied by the NRE model closely tracks Mexico's observed policy rate, providing strong external validation of the framework. In contrast, the policy rate implied by the RE model fails to match the observed policy behavior. Importantly, the RE model does not satisfy external validity even when augmented with backward-looking price-setting behavior. This result demonstrates that conventional approaches to generating inflation persistence–through mechanical indexation to lagged inflation–are not sufficient to reconcile RE models with observed monetary policy behavior in the post-crisis period.

The strong concern for robustness in the NRE model gives rise to policy transmission mechanisms that differ fundamentally from those in the RE benchmark, in line with the channels emphasized in the ambiguity-aversion literature (e.g., Woodford, 2010; Kwon and Miao, 2017). In response to a cost-push shock, the estimated NRE model prescribes a markedly more conservative response to domestic inflation–about two-thirds of the magnitude of that in the RE model–implying a more hawkish stance toward inflation stabilization. At the same time, the NRE model generates substantially larger exchange rate responses–approximately twice those under RE–implying greater tolerance for exchange rate adjustments. These asymmetric policy responses reflect the central bank's attempt to guard against worst-case distortions in inflation expectations.

The differences in policy transmission mechanisms across the two models are closely linked to the estimated structural parameters. In particular, the estimated NRE model features a substantially larger standard deviation of the cost-push shock relative to the RE model, whereas the productivity shock exhibits greater variability under RE. This reallocation of shock importance reflects the central bank's concern for robustness in the presence of uncertainty about expectation formation and underpins the asymmetric policy responses emphasized above.

Moreover, concern for robustness generates greater history dependence in inflation dynamics under NRE. Even in the absence of a backward-looking inflation term in the aggregate supply relation, the NRE model produces endogenous inflation inertia. By contrast, the RE model must rely heavily on backward-looking price-setting behavior to match the observed persistence of inflation. Quantitatively, the estimated NRE model implies that only a small fraction of firms are backward-looking, whereas the RE model requires nearly half of firms to exhibit backward-looking behavior to fit the data.

These findings directly address two central criticisms raised by Gali et al. (2005) and Rudd and Whelan (2006): the quantitatively modest role of backward-looking behavior and the ad hoc nature of inflation indexation. In the NRE framework, inflation persistence arises endogenously from the central bank's concern for robustness regarding private-sector expectations, rather than from mechanical indexation to lagged inflation. Consistent with this interpretation, the estimated results remain virtually unchanged when inflation indexation is eliminated entirely. This contrasts sharply with the RE model, in which backward-looking price-setting is essential for matching observed inflation dynamics.

Taken together, a high degree of concern for robustness with a more prominent role for cost-push shock is crucial for enabling the NRE model to generate a monetary policy rate that closely aligns with the one. These results suggest that, in the context of Mexico's post-crisis monetary reforms, policymakers' uncertainty about private-sector expectation formation—and the resulting NRE-type policy response—plays a central role in shaping post-crisis monetary policy behavior and inflation dynamics.

Related Literature. This paper is related to a growing body of literature studying the macroeconomic consequences of bounded rationality and deviations from full-information RE, particularly in the context of monetary policy design. Our primary contribution lies within the literature on robustly optimal monetary policy under ambiguity. To the best of our knowledge, this paper is the first to study robustly optimal monetary policy in an open-economy environment in which the policymaker faces ambiguity about private-sector NRE—corresponding to type-3 ambiguity in the classification of Hansen and Sargent (2012)—and to take this framework to the data. In particular, we are the first to estimate such a model using Bayesian methods, to discipline the framework quantitatively, and to apply it in an emerging-economy context to study policy predictions and conduct external validity tests of the model.

While Woodford (2010) characterizes robust monetary policy under type-3 ambiguity, the analysis is confined to a closed-economy setting. A large literature studies robust monetary policy in closed-economy New Keynesian models (see, for example, Walsh, 2004; Leitemo and Soderstrom, 2008b; Dennis, 2010; Levine and Pearlman, 2010; Gerke and Hammermann, 2016), and several papers extend robust policy analysis to open-economy environments (e.g., Dennis et al., 2009; Leitemo and Soderstrom, 2008a). However, in these open-economy contributions, robustness typically reflects the policymaker's doubts about the specification of exogenous shock processes or the underlying model, rather than uncertainty about private agents' expectations. As a result, little is known about the features of robustly optimal monetary policy in open economies when policymakers are confident about the economic structure but uncertain about private-sector expectation formation. This paper fills this gap.

Our paper also contributes to the literature on monetary policy reforms in EMEs. As noted above, recent empirical work shows that countries with histories of high inflation continue to respond aggressively to inflation-expectations gaps even after adopting inflation-targeting regimes, highlighting the persistent influence of inherited expectations in shaping policy behavior (Jacome et al., 2025). We provide a structural interpretation of this evidence by embedding policymakers' concerns about private-sector expectations into a monetary policy framework and quantifying their implications during a post-crisis policy transition.

More broadly, this paper relates to a large empirical and theoretical literature documenting systematic departures from full-information RE in expectation formation. Survey and experimental evidence show sizable deviations from RE in how private agents form forward-looking expectations, while a growing theoretical literature studies the macroeconomic and policy implications of such departures (e.g., Coibion and Gorodnichenko, 2012; Bordalo et al., 2020; Afrouzi et al., 2023;

Angeletos and Lian, 2018; Gabaix, 2020). Our quantitative analysis also connects to studies that estimate New Keynesian models incorporating belief distortions, information frictions, ambiguity aversion, limited foresight, or diagnostic expectations on the part of private agents (e.g., Ilut and Schneider, 2014; Ilut and Saijo, 2021; Bhandari et al., 2023; Gust et al., 2020; Bianchi et al., 2023; L'Huillier et al., 2023; Na and Yoo, 2025). Unlike these studies, we focus on ambiguity faced by the policymaker rather than by private agents and estimate the degree of deviation from RE in an environment in which monetary policy is designed to be robust to private-sector NRE.

Finally, this paper relates to the literature on international business cycles and open-economy monetary policy. A central theme in this literature concerns the role of international financial market frictions, and a large body of work has studied their implications for optimal policy under RE. In contrast, our analysis deliberately abstracts from such frictions. This modeling choice is not intended to downplay their relevance, but rather to isolate the role of belief distortions and policymakers' concern for robustness within a parsimonious and transparent framework. By embedding ambiguity aversion into the canonical small open economy New Keynesian model of Gali and Monacelli (2005), we ensure that the mechanisms emphasized in the paper are not driven by auxiliary frictions but instead arise directly from uncertainty about private-sector expectation formation. This minimal structure facilitates identification of the policy implications of concern for robustness and allows for a clean comparison with the RE benchmark. Importantly, our approach follows earlier quantitative studies of Mexico that also adopt a parsimonious open-economy framework to focus on specific mechanisms of interest (e.g., Aguiar and Gopinath, 2007; Boz et al., 2011).

Moreover, our empirical analysis focuses on the period from 1998 to 2007, spanning the post–Peso Crisis years up to the eve of the Global Financial Crisis, a relatively tranquil period for the Mexican economy. During this interval, financial frictions were less likely to be the primary drivers of business cycle fluctuations, making it a suitable laboratory for studying how monetary policy design responds to uncertainty about expectation formation. While incorporating richer financial structures remains an important avenue for future research, our results demonstrate that belief distortions alone can account for salient features of post-crisis monetary policy behavior.

The paper is structured as follows. Section 2 develops a SOE-NK model with the private-sector NRE and the corresponding robustly optimal monetary policy problem faced by the central bank. Section 3 presents an empirical analysis, estimating both the NRE and RE models for Mexico and examining the results and underlying mechanisms. Section 4 provides several discussions. Section 5 concludes.

2 The Model

In this section, we introduce the distorted expectations of private agents into the SOE-NK model and investigate robustly optimal monetary policy in the environment. We begin by describing the model structure.

2.1 A Small Open Economy New Keynesian Environment

The key distinction of our model is that the private agents' beliefs may be distorted. We denote expectations under distorted beliefs by $\hat{\mathbb{E}}[\cdot]$ (defined in Section 2.2). Aside from this feature, the environment closely follows the canonical SOE-NK framework (e.g. Gali and Monacelli, 2005). The economy is infinitesimally small and exports domestic goods while importing foreign goods. Domestic firms use labor as the sole input, set prices in domestic currency, and face Calvo–Yun–style price rigidity. We also allow for backward-looking behavior in price setting, following Gali and Gertler (1999). In each period, a fraction of firms sets prices in a backward-looking manner as a function of lagged inflation. International financial markets are complete.

The log-linearized model is summarized by a set of linear equations describing domestic aggregate demand and supply, the links between domestic and international prices and quantities, as well as exogenous shock processes. Aggregate demand of the economy can be represented by the following equation:

$$x_t = \hat{\mathbb{E}}_t x_{t+1} - \frac{1}{\tau}\left(i_t - \hat{\mathbb{E}}_t \pi_{H,t+1} - \bar{rr}_t\right), \tag{2.1}$$

where x_t is the domestic output gap defined as the difference between actual output and its natural level under flexible prices, and $\pi_{H,t}$ is the net inflation rate of domestically produced goods (domestic inflation). The variable i_t is the short-term nominal interest rate, which serves as the central bank's policy instrument. The parameter τ governs the slope of aggregate demand and is defined as follows:

$$\tau \equiv \frac{\sigma}{1 + \alpha(\omega - 1)}, \tag{2.2}$$

where $\sigma > 0$ governs the elasticity of intertemporal substitution in the private agents' utility, $\alpha \in [0, 1]$ governs the degree of home bias $(1 - \alpha)$, and ω governs the effect of changes in the terms of trade (defined below) on output. The variable $\bar{rr}_t$ is the natural real interest rate,

$$\bar{rr}_t = \rho + \Lambda_{r,a} a_t + \Lambda_{r,y^*} y_t^*, \tag{2.3}$$

where a_t denotes the domestic productivity shock and y_t^* is the world output shock. Parameter $\rho = -\log \beta$ is the steady-state real rate, and $\Lambda_{r,a}$ and Λ_{r,y^*} are coefficients that are functions of the structural parameters.

Aggregate supply incorporates both lagged domestic inflation and forward-looking expectations as follows:

$$\pi_{H,t} = \tilde{\beta}\hat{\mathbb{E}}_t\pi_{H,t+1} + \eta\pi_{H,t-1} + \kappa x_t + u_t, \tag{2.4}$$

where the random component u_t represents an exogenous cost-push shock that affects the aggregate supply of the economy, and

$$\tilde{\beta} \equiv \frac{\zeta\beta}{[\zeta + \delta(1-\zeta(1-\beta))]},\ \eta \equiv \frac{\delta}{[\zeta + \delta(1-\zeta(1-\beta))]}, \kappa \equiv \frac{\zeta(1-\delta)\kappa_0}{[\zeta + \delta(1-\zeta(1-\beta))]}, \tag{2.5}$$

with $\beta \in (0,1)$ denoting the subjective discount factor, $\zeta \in [0,1]$ as the Calvo–Yun parameter for nominal price rigidity, $\delta \in [0,1]$ as the fraction of backward-looking firms, and $\kappa_0 > 0$ governing the slope of the aggregate supply curve, defined as follows:

$$\kappa_0 \equiv \frac{(1-\beta\zeta)(1-\zeta)(\tau+\varphi)}{\zeta}, \tag{2.6}$$

where φ denotes the inverse of the Frisch elasticity of labor supply. If the fraction of backward-looking firms, δ, equals zero, then $\tilde{\beta} = \beta$, $\eta = 0$, and $\kappa = \kappa_0$, so that the aggregate supply becomes purely forward-looking.

The log of the effective terms of trade, s_t, is defined as the difference between the log of the imported goods price and the log of the price of domestic goods, expressed as $s_t = p_{F,t} - p_{H,t}$. Complete international asset markets and the associated risk-sharing condition imply that s_t follows:

$$s_t = \tau(x_t + \tilde{y}_t - y_t^*), \tag{2.7}$$

where $\tilde{y}_t$ denotes the natural level of domestic output,

$$\tilde{y}_t = \Lambda_{y,0} + \Lambda_{y,a}a_t + \Lambda_{y,y^*}y_t^*, \tag{2.8}$$

and $\Lambda_{y,0}, \Lambda_{y,a}$ and Λ_{y,y^*} are coefficients that depend on the structural parameters.[1]

Under the law of one price, the log effective exchange rate e_t satisfies $e_t = p_{F,t} - p_t^*$ up to a first-order approximation, with p_t^* being the log of the world effective price index. Using the definition of the terms of trade, nominal exchange rate depreciation, Δe_t–defined as the percentage change in the nominal exchange rate between periods t and $t-1$–can be expressed as:

$$\Delta e_t = \pi_{H,t} + \Delta s_t - \pi_t^*, \tag{2.9}$$

where Δ denotes the first-difference operator and π_t^* is the exogenous world inflation rate. A positive (negative) value of Δe_t implies a nominal depreciation (appreciation) of the domestic currency relative to the previous period.

[1] See Table C.6 in Appendix C for a detailed description of $\Lambda_{r,a}, \Lambda_{r,y^*}, \Lambda_{y,0}, \Lambda_{y,a}$, and Λ_{y,y^*}.

The three shocks described above are assumed to follow first-order Markov processes:

$$u_{t+1} = \rho_u u_t + \sigma_u \varepsilon^u_{t+1}, \tag{2.10}$$

$$a_{t+1} = \rho_a a_t + \sigma_a \varepsilon^a_{t+1}, \tag{2.11}$$

$$y^*_{t+1} = \rho_{y^*} y^*_t + \sigma_{y^*} \varepsilon^{y^*}_{t+1}, \tag{2.12}$$

where the parameter ρ_k governs persistence, σ_k governs the standard deviation of each stochastic process, and ε^k_t is an i.i.d. standard normal innovation, for $k \in \{u, a, y^*\}$.

Having described the baseline SOE-NK structure, we next formalize how private agents' expectations deviate from the rational benchmark.

2.2 Belief Distortion

The uncertainty in the economy is generated by the set of vectors of exogenous stochastic disturbances $\{\boldsymbol{\varepsilon}_t\}^{\infty}_{t=0}$, where $\boldsymbol{\varepsilon}_t \equiv (\varepsilon^u_t, \varepsilon^a_t, \varepsilon^y_t)$. We define $\boldsymbol{\varepsilon}^t \equiv \{\boldsymbol{\varepsilon}_0, \boldsymbol{\varepsilon}_1, ..., \boldsymbol{\varepsilon}_t\}$ as the history of these periodic stochastic disturbances.

We model the probability distortion by following Hansen and Sargent (2008). Let $(\boldsymbol{\Omega}, \boldsymbol{\mathcal{F}}, \boldsymbol{\mathcal{P}})$ be a probability triple: $\boldsymbol{\Omega}$ represents the sample space, $\boldsymbol{\mathcal{F}}$ denotes its σ-field, and $\boldsymbol{\mathcal{P}}$ is the associated probability measure. The benchmark, rational expectations (RE) operator, $\mathbb{E}[\cdot]$, is induced by measure $\boldsymbol{\mathcal{P}}$, which is the rational measure for probabilities of exogenous states. However, we consider the possibility that expectations may not align with this rational measure, as they may be influenced by a potentially *different* measure $\hat{\boldsymbol{\mathcal{P}}}$.[2] Let $p(\boldsymbol{\varepsilon})$ be the unconditional probability density of random vector $\boldsymbol{\varepsilon}$ (which has the same dimension as the entries of $\boldsymbol{\varepsilon}_t$) under measure $\boldsymbol{\mathcal{P}}$. Let $\hat{p}\left(\boldsymbol{\varepsilon}|\boldsymbol{\varepsilon}^t\right)$ denote the one-step-ahead probability density for $\boldsymbol{\varepsilon}_{t+1}$, which is induced by measure $\hat{\boldsymbol{\mathcal{P}}}$, conditioned on date-$t$ information. The likelihood ratio between the two densities is

$$m_{t+1} = \frac{\hat{p}\left(\boldsymbol{\varepsilon}|\boldsymbol{\varepsilon}^t\right)}{p(\boldsymbol{\varepsilon})},$$

and m_{t+1} is nonnegative and

$$\mathbb{E}\left[m_{t+1}|\boldsymbol{\varepsilon}^t\right] = 1. \tag{2.13}$$

The one-step-ahead expectation of a random variable X_{t+1} induced by measure $\hat{\boldsymbol{\mathcal{P}}}$ is then expressed

[2] We stipulate that $\hat{\boldsymbol{\mathcal{P}}}$ must be absolutely continuous to $\boldsymbol{\mathcal{P}}$.

as follows:[3]

$$\hat{\mathbb{E}}[X_{t+1}|\boldsymbol{\varepsilon}^t] = \mathbb{E}[m_{t+1}X_{t+1}|\boldsymbol{\varepsilon}^t].$$

Henceforth, we simply express an expectation based on date-t information as the expectation with subscript t, i.e., $\hat{\mathbb{E}}_t X_{t+1} \equiv \hat{\mathbb{E}}[X_{t+1}|\boldsymbol{\varepsilon}^t]$ and $\mathbb{E}_t X_{t+1} \equiv \mathbb{E}[X_{t+1}|\boldsymbol{\varepsilon}^t]$. The operator $\hat{\mathbb{E}}[\cdot]$ describes the potentially distorted forward-looking expectations in the economy.

We use the relative entropy (Kullback-Leibler divergence) to quantify the difference between two probability measures, $\hat{\boldsymbol{\mathcal{P}}}$ and $\boldsymbol{\mathcal{P}}$. The divergence between one-period-ahead distorted belief and the rational belief is represented by the relative entropy as follows:

$$\mathcal{R}_t \equiv \mathbb{E}_t m_{t+1} \ln m_{t+1},$$

which is always nonnegative based on Gibb's inequality.

Given that policy outcomes depend on private-sector expectations, the central bank evaluates policy under uncertainty about the extent and persistence of these belief distortions.

2.3 The Robustly Optimal Monetary Policy

We now turn to the central bank's problem. The central bank sets the nominal interest rate i_t to minimize private agents' welfare loss, but–unlike in the standard RE optimal policy problem–is concerned that the expectations it seeks to anchor may be distorted. Figure 2 illustrates this informational structure: the blue sphere denotes the central bank's RE benchmark, while the surrounding orange spheres represent private agents' belief models, with their distance from the benchmark measuring relative entropy. Because private agents act on their beliefs without internalizing potential model misspecification, the central bank faces uncertainty about how those beliefs are formed and therefore designs policy with a concern for robustness (ambiguity aversion).[4]

Under this information structure, we assume that the central bank seeks to minimize private agents' welfare loss using a *paternalistic* objective in the spirit of Woodford (2010). This objective corresponds to the welfare loss under rational beliefs and reflects the central bank's concern for robustness regarding the private agents' distorted beliefs. Specifically, the central bank's welfare loss function is given by:

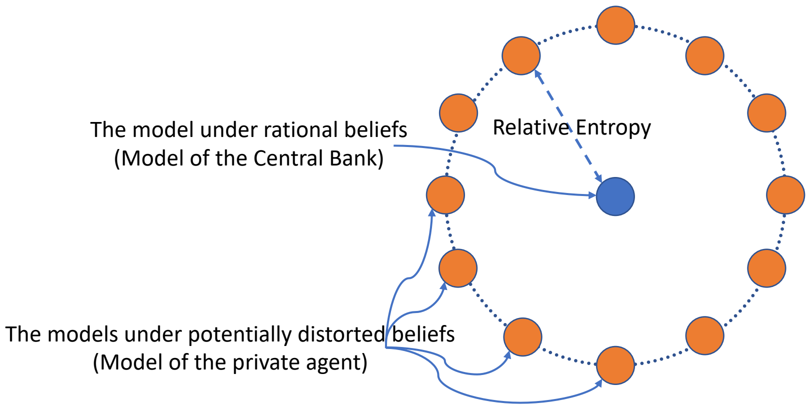
[3]Following Hansen and Sargent (2008), we set $\mathcal{M}_0 = 1$ and recursively construct $\{\mathcal{M}_t\}$ such that $\mathcal{M}_{t+1} = m_{t+1}\mathcal{M}_t$, which implies $\mathcal{M}_{t+j} = \prod_{k=1}^{j} m_{t+k}$, and it is a martingale process that satisfies $\mathbb{E}[\mathcal{M}_{t+j}|\boldsymbol{\varepsilon}^t] = \mathcal{M}_t$. Private agents' expectation $\hat{\mathbb{E}}[\cdot]$ of a random variable X_{t+j} induced by measure $\hat{\boldsymbol{\mathcal{P}}}$ conditioned on date-t information can be expressed as the expectation induced by the measure $\boldsymbol{\mathcal{P}}$ for the augmented random variable X_{t+j}:

$$\hat{\mathbb{E}}[X_{t+j}|\boldsymbol{\varepsilon}^t] = \mathbb{E}\left[\frac{\mathcal{M}_{t+j}}{\mathcal{M}_t} X_{t+j} \middle| \boldsymbol{\varepsilon}^t\right],$$

where $\frac{\mathcal{M}_{t+j}}{\mathcal{M}_t}$ represents the Radon-Nikodym derivatives, which completely summarize the belief distortions.

[4]This informational structure corresponds to *Type-3* ambiguity in Hansen and Sargent (2012).

Figure 2: Entropy Diagram



$$\mathbb{L} = \underbrace{\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \frac{1}{2} \left(\pi_{H,t}^2 + \lambda_x \left(x_t - \bar{x} \right)^2 \right)}_{\text{the welfare loss under RE}} - \underbrace{\theta \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t m_{t+1} \ln m_{t+1}}_{\text{the concern for robustness}},$$

where the first term represents the discounted lifetime welfare loss of private agents under RE, and the second term captures the central bank's concern for robustness. The parameter $\lambda_x > 0$ governs the weight on the welfare loss arising from deviations of the output gap from its target value, $\bar{x}$, and $\theta \in (0, \infty)$ reflects the degree of the central bank's concern for robustness. While the welfare loss is a convex function with respect to $\pi_{H,t}, x_t$, it is concave with respect to m_{t+1}.

Given its concern for robustness, the central bank seeks to minimize welfare loss under the *worst-case* outcomes generated by the potentially distorted belief m_{t+1}. Following the robust control framework, we assume that a hypothetical malevolent nature chooses $\{m_{t+1}\}$ to maximize the welfare loss. Taking this as given, the central bank chooses $\{\pi_t, x_t, i_t\}$ to minimize the loss. We define the central bank's robustly optimal monetary policy problem as the following game between the central bank and the malevolent nature:

Definition 2.1. *The robustly optimal monetary policy of the central bank solves the following mini-max optimization problem:*

$$\min_{\{\pi_{H,t}, x_t, i_t\}} \max_{\{m_{t+1}\}} \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \frac{1}{2} \left(\pi_{H,t}^2 + \lambda_x \left(x_t - \bar{x} \right)^2 \right) - \theta \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t m_{t+1} \ln m_{t+1}, \tag{2.14}$$

subject to equations (2.1), (2.3), (2.4), (2.10), (2.11), (2.12), and (2.13).

Note that as $\theta \to \infty$, the optimal behavior for the malevolent nature in maximizing the welfare loss is to choose $m_{t+1} = 1$, corresponding to beliefs under RE. When θ is finite, however, the optimal choice of m_{t+1} induces a departure from RE beliefs. In this sense, a higher $\tilde{\theta} \equiv \theta^{-1} \in [0, \infty)$ can be interpreted as reflecting a greater degree of concern for robustness.[5] In short, under the RE scenario, the central bank has no concern for robustness ($\tilde{\theta} = 0$), whereas under potentially distorted private-sector beliefs, the central bank has a concern for robustness ($\tilde{\theta} > 0$).

Conditionally Linear Commitment. As a benevolent planner, the central bank commits to its past policy promises, implying a history-dependent policy. The robustly optimal monetary policy problem defined in Definition 2.1 involves choosing a sequence of potentially time-varying $\{\pi_{H,t}, x_t\}_{t=0}^{\infty}$ which generally results in nonlinearity in the system. Instead, we adopt the conditionally linear commitment policy under a timeless perspective proposed by Woodford (2010). We begin by replacing the operator $\mathbb{E}_0$ in (2.14) with $\mathbb{E}_{-1}$, corresponding to expectations formed before the realization of the state in period 0. Rather than assuming that the policymaker selects a sequence $\{\pi_{H,t}, x_t\}$ for all $t \geq 0$, we focus on the choice of the sequence for $t \geq 1$, taking the initial commitment $\{\pi_{H,0}, x_0\}$ as given. We assume that the initial commitment takes a linear form:

$$\begin{bmatrix} \pi_{H,0} \\ x_0 \end{bmatrix} = \mathbf{\Phi}_{-1} + \mathbf{\Gamma}_{-1}\boldsymbol{\varepsilon}_0,$$

where $\mathbf{\Phi}_{-1} \equiv [\Phi_{\pi_H,-1}, \Phi_{x,-1}]'$ and $\mathbf{\Gamma}_{-1} \equiv \begin{bmatrix} \Gamma_{\pi_H,u,-1} & \Gamma_{\pi_H,a,-1} & \Gamma_{\pi_H,y^*,-1} \\ \Gamma_{x,u,-1} & \Gamma_{x,a,-1} & \Gamma_{x,y^*,-1} \end{bmatrix}$ characterize the initial commitment. We then focus on the following conditionally linear rule:

$$\begin{bmatrix} \pi_{H,t+1} \\ x_{t+1} \end{bmatrix} = \mathbf{\Phi}_t + \mathbf{\Gamma}_t\boldsymbol{\varepsilon}_{t+1}, \ t \geq 0, \tag{2.15}$$

where $\mathbf{\Phi}_t \equiv [\Phi_{\pi_H,t}, \Phi_{x,t}]'$ is stochastic and $\mathbf{\Gamma}_t \equiv \begin{bmatrix} \Gamma_{\pi_H,u,t} & \Gamma_{\pi_H,a,t} & \Gamma_{\pi_H,y^*,t} \\ \Gamma_{x,u,t} & \Gamma_{x,a,t} & \Gamma_{x,y^*,t} \end{bmatrix}$ is deterministic. For any initial commitment $\{\mathbf{\Phi}_{-1}, \mathbf{\Gamma}_{-1}\}$, the central bank chooses $\{\mathbf{\Phi}_t, \mathbf{\Gamma}_t\}_{t=0}^{\infty}$. The initial commitment is self-consistent if

$$\mathbf{\Phi}_{-1} \overset{d}{=} \mathbf{\Phi}_t \sim \mathbf{\Phi},$$
$$\mathbf{\Gamma}_{-1} = \mathbf{\Gamma}_t = \mathbf{\Gamma},$$

for all $t \geq 0$. This implies that $\mathbf{\Phi}_{-1}$ and $\{\mathbf{\Phi}_t\}_{t=0}^{\infty}$ follow the same unconditional distribution, and $\mathbf{\Gamma}_{-1}$ and $\{\mathbf{\Gamma}_t\}_{t=0}^{\infty}$ are the same deterministic matrices. Consequently, the initial commitment $\{\mathbf{\Phi}_{-1}, \mathbf{\Gamma}_{-1}\}$ is self-consistent, and the robustly optimal policy has a time-invariant linear form.

To compute the equilibrium under the robustly optimal policy, we employ the solution method proposed by Kwon and Miao (2019). The system of equations for the linearized equilibrium of our

[5] We begin by using the parameter θ as in the equation (2.14), following the convention in the ambiguity aversion literature. From this point onward, we use the transformed parameter $\tilde{\theta}$ to associate a higher value of the parameter with a greater degree of concern for robustness.

model can be rewritten in the following form:

$$\begin{bmatrix} \boldsymbol{X}_{t+1} \\ \hat{\mathbb{E}}_t \boldsymbol{Y}_{t+1} \end{bmatrix} = \boldsymbol{A} \begin{bmatrix} \boldsymbol{X}_t \\ \boldsymbol{Y}_t \end{bmatrix} + \boldsymbol{B} i_t + \boldsymbol{C} \boldsymbol{\varepsilon}_{t+1},$$

where $\boldsymbol{X}_t \equiv [1, \pi_{H,t-1}, u_t, a_t, y_t^*]'$ and $\boldsymbol{Y}_t \equiv [\pi_{H,t}, x_t]'$. The mini-max problem in (2.14) can be rewritten as the problem of choosing $\{\boldsymbol{\Phi}_t, \boldsymbol{\Gamma}_t\}_{t \geq 0}$, $\{\boldsymbol{X}_t, m_t\}_{t \geq 1}$, and $\{i_t\}_{t \geq 0}$ for a given initial commitment $\{\boldsymbol{\Phi}_{-1}, \boldsymbol{\Gamma}_{-1}\}$. The Lagrangian of the central bank's problem is then given by:

$$\mathcal{L} = \mathbb{E}_{-1} \sum_{t=0}^{\infty} \beta^t \Bigg\{ \frac{1}{2} \left(\pi_{H,t}^2 + \lambda_x (x_t - \bar{x})^2 \right) - \tilde{\theta}^{-1} m_{t+1} \ln m_{t+1} + \phi_t (\mathbb{E}_t m_{t+1} - 1)$$
$$+ [\boldsymbol{\mu}'_{X,t+1}, \boldsymbol{\mu}'_{Y,t}] \left(\begin{bmatrix} \boldsymbol{X}_{t+1} \\ \mathbb{E}_t m_{t+1} \boldsymbol{Y}_{t+1} \end{bmatrix} - \boldsymbol{A} \begin{bmatrix} \boldsymbol{X}_t \\ \boldsymbol{Y}_t \end{bmatrix} - \boldsymbol{B} i_t - \boldsymbol{C} \boldsymbol{\varepsilon}_{t+1} \right) \Bigg\}, \tag{2.16}$$

where $\beta^t \phi_t$ is the Lagrange multiplier associated with constraint (2.13) and $\beta^t [\boldsymbol{\mu}_{X,t+1}, \boldsymbol{\mu}_{Y,t}]$ are vectors of Lagrange multipliers associated with the system of equations (2.1), (2.3), (2.4), (2.10), (2.11), and (2.12).

Solving this problem proceeds in several steps. First, the hypothetical malevolent nature chooses m_{t+1} to maximize the loss, yielding the worst-case belief m_{t+1}. Next, the policymaker chooses $\{\boldsymbol{X}_t, \boldsymbol{\Phi}_t, \boldsymbol{\Gamma}_t, i_t\}$ after substituting the solution of m_{t+1} into the Lagrangian. Because we focus on self-consistent policy, we additionally impose $\boldsymbol{\Gamma}_t = \boldsymbol{\Gamma}$. To obtain the solution for $\boldsymbol{\Gamma}$, we begin with an initial guess for $\boldsymbol{\Gamma}$ and solve the first-order conditions, except for the first-order condition for i_t. The solution is then used to update $\boldsymbol{\Gamma}$ from the first-order condition for i_t. This process is repeated until convergence in $\boldsymbol{\Gamma}$ is achieved. We solve the resulting system of linear difference equations using the method of Klein (2000). From the solution, we obtain the following state-space representation:

$$\begin{bmatrix} \boldsymbol{\varepsilon}_{t+1} \\ \boldsymbol{X}_{t+1} \\ \boldsymbol{\Phi}_t \end{bmatrix} = \boldsymbol{H} \begin{bmatrix} \boldsymbol{\varepsilon}_t \\ \boldsymbol{X}_t \\ \boldsymbol{\Phi}_{t-1} \end{bmatrix} + \begin{bmatrix} \boldsymbol{I} \\ \boldsymbol{C}_X \\ \boldsymbol{0} \end{bmatrix} \boldsymbol{\varepsilon}_{t+1}, \tag{2.17}$$

and

$$\begin{bmatrix} i_t \\ \boldsymbol{\mu}_{Y,t} \\ \boldsymbol{\mu}_{X,t} \\ \mathbb{E}_t \boldsymbol{\mu}_{X,t+1} \end{bmatrix} = \boldsymbol{G} \begin{bmatrix} \boldsymbol{\varepsilon}_t \\ \boldsymbol{X}_t \\ \boldsymbol{\Phi}_{t-1} \end{bmatrix}, \tag{2.18}$$

where $\boldsymbol{I}$ is an identity matrix, $\boldsymbol{C}_X$ is a partition of $\boldsymbol{C}$, $\boldsymbol{0}$ is a zero matrix, and the matrices $\boldsymbol{H}$ and $\boldsymbol{G}$ govern the evolution of state variables and the policy rules for non-predetermined variables, respectively.

Finally, the worst-case beliefs, one-period-ahead expectations of variables under the worst-case beliefs, and the relative entropy in the worst-case scenario are given by

$$m_{t+1} = \exp\left(-\frac{1}{2}\tilde{\theta}^2 \boldsymbol{\mu}'_{Y,t}\boldsymbol{\Gamma}\boldsymbol{\Gamma}'\boldsymbol{\mu}_{Y,t} + \tilde{\theta}\boldsymbol{\mu}'_{Y,t}\boldsymbol{\Gamma}\boldsymbol{\varepsilon}_{t+1}\right), \tag{2.19}$$

$$\mathbb{E}_t m_{t+1}\boldsymbol{Y}_{t+1} = \boldsymbol{\Phi}_t + \tilde{\theta}\boldsymbol{\Gamma}\boldsymbol{\Gamma}'\boldsymbol{\mu}_{Y,t}, \tag{2.20}$$

$$\mathbb{E}_t m_{t+1}\ln m_{t+1} = \frac{1}{2}\tilde{\theta}^2 \boldsymbol{\mu}'_{Y,t}\boldsymbol{\Gamma}\boldsymbol{\Gamma}'\boldsymbol{\mu}_{Y,t}. \tag{2.21}$$

For brevity, we relegate the details of the matrices $\boldsymbol{A}, \boldsymbol{B}, \boldsymbol{C}$, along with their partitions, to Appendix A.2.

3 Empirical Analysis

In this section, we bring the theoretical framework in Section 2 to the data by estimating the model using the Mexican inflation rate and the nominal exchange rate. We consider two specifications: an NRE model in which the central bank's concern for robustness, $\tilde{\theta}$, is estimated, and an RE model in which $\tilde{\theta} = 0$.

Our empirical analysis proceeds in two steps. First, following standard practice, we evaluate each model's fit to key unconditional second moments of the observables and the log marginal data density. Second, we conduct an external-validity exercise by comparing the model-implied policy rate with the actual policy rate, as the policy rate is not included among the observables used in estimation. Together, these exercises address (i) what the data reveal about the magnitude of the central bank's concern for robustness, $\tilde{\theta}$; (ii) how the NRE and RE models differ in their empirical predictions; and (iii) how well each model performs when evaluated against both standard business-cycle moments and the path of observed policy rates.

We present the estimation procedure and results below.

Data. We use CPI inflation, π_t, and nominal exchange rate depreciation vis-à-vis the U.S. dollar, Δe_t, as observables. In the model, CPI inflation satisfies (to a first-order approximation)

$$\pi_t = \pi_{H,t} + \alpha\Delta s_t, \tag{3.1}$$

while nominal depreciation is given by (2.9). We set world inflation π_t^* to zero. The world output process y_t^* is treated as exogenous and calibrated using U.S. output over the sample period, yielding $(\rho_{y^*}, \sigma_{y^*})$. Given the observables $\{\pi_t, \Delta e_t\}$, equations (3.1) and (2.9) discipline the joint dynamics of domestic inflation $\pi_{H,t}$ and terms-of-trade changes Δs_t, while the remaining equilibrium conditions pin down the implied output gap and policy rate.

To construct the observables, we use quarterly CPI price indices and nominal exchange rates (vis-á-vis the US dollar). The time spans of the CPI inflation rate and the depreciation rate are Q1:1998-Q4:2007.[6]

[6] We intentionally disregard the periods after the 2008 global financial crisis, because our model does not have

The Linear State Space System for Estimation. We reproduce the system that governs equilibrium solution of the model. We denote $\boldsymbol{\xi}_t \equiv [\boldsymbol{\varepsilon}_t', \boldsymbol{X}_t', \boldsymbol{\Phi}_{t-1}']'$ and $\boldsymbol{\chi}_t \equiv [i_t, \boldsymbol{\mu}_{Y,t}', \boldsymbol{\mu}_{X,t}', \mathbb{E}_t\boldsymbol{\mu}_{X,t+1}']'$. Because the measurement equations for π_t and Δe_t involve lagged model variables, we use $[\boldsymbol{\xi}_t', \boldsymbol{\xi}_{t-1}']'$ as the state variables in the measurement system for estimation. The resulting measurement equation, allowing for measurement errors, is:

$$\begin{bmatrix} \pi_t \\ \Delta e_t \end{bmatrix} = \tilde{\boldsymbol{G}} \begin{bmatrix} \boldsymbol{\xi}_t \\ \boldsymbol{\xi}_{t-1} \end{bmatrix} + \begin{bmatrix} \sigma_\pi^{me} & 0 \\ 0 & \sigma_{\Delta e}^{me} \end{bmatrix} \cdot \begin{bmatrix} \epsilon_t^{me,\pi} \\ \epsilon_t^{me,\Delta e} \end{bmatrix}, \tag{3.2}$$

where $[\epsilon_t^{me,\pi}, \epsilon_t^{me,\Delta e}]'$ are orthogonal standard normal random variables, and $[\sigma_\pi^{me}, \sigma_{\Delta e}^{me}]'$ are the standard deviations of the measurement errors of the observables for the observables π_t and Δe_t, respectively.

The corresponding transition equation for estimation is:

$$\begin{bmatrix} \boldsymbol{\xi}_{t+1} \\ \boldsymbol{\xi}_t \end{bmatrix} = \tilde{\boldsymbol{H}} \begin{bmatrix} \boldsymbol{\xi}_t \\ \boldsymbol{\xi}_{t-1} \end{bmatrix} + \boldsymbol{\nu}_{t+1}. \tag{3.3}$$

Equations (3.2) and (3.3) together define the linear state-space system used for estimation. The details of $\tilde{\boldsymbol{G}}$, $\tilde{\boldsymbol{H}}$, and $\boldsymbol{\nu}_{t+1}$ are presented in Appendix B.

Pre-Set Parameters. The parameter σ, representing the curvature of the household utility function, is set to 1, following standard values in the literature. The Calvo-Yun nominal price rigidity parameter for domestic producers, ζ, is set to 0.75, indicating an average price adjustment interval of one year, which is also standard in the literature. For the rest of the world's output, we use the overlapping U.S. output series for Mexico, performing an AR(1) regression. This results in a persistence parameter, ρ_{y^*}, of 0.84, and a standard deviation, σ_{y^*}, of 0.0045. The discount factor, β, is set to 0.975 to match the 10% annual country interest rate for emerging market countries (Uribe and Schmitt-Grohé, 2017). The home-bias related parameter, α, is calibrated to 0.279 to match the average import-to-GDP ratio of 27.9% over the sample period. We list the pre-set parameters in Table C.7.

Estimated Parameters. We estimate the remaining eight structural parameters $\boldsymbol{\Theta} \equiv [\tilde{\theta}, \delta, \omega, \varphi, \rho_u, \sigma_u, \rho_a, \sigma_a]'$ and standard deviations of the measurement errors $[\sigma_\pi^{me}, \sigma_{\Delta e}^{me}]'$ using the likelihood-based Bayesian method.

The prior for $\tilde{\theta}$ is uniform on $[0, 10^4]$, reflecting an agnostic view over a wide range; the posterior distribution is well away from the RE boundary. For parameter δ, which governs the fraction of backward-looking firms, we assume a Beta (2,3) distribution as the prior. For parameters ω and φ, we assume Gamma (2,2) distributions as the prior.[7] The prior distribution of the persistence

a zero lower bound restriction. The CPI price indices are seasonally adjusted by using the program package X13-ARIMA-SEATS.

[7] Rather than estimating the shape parameters τ, $\tilde{\beta}$, η and κ directly, we estimate δ, ω and φ, as they jointly affect the shape parameters through the parametric relationships (2.2), (2.5), and (2.6). In Table 2, we report the implied

Table 1: Posterior Distributions

	NRE		RE		NRE_0		RE_0	
Parameters	Mean	[5%, 95%]	Mean	[5%, 95%]	Mean	[5%, 95%]	Mean	[5%, 95%]
$\tilde{\theta}$	1807	[896, 3190]	-	-	1594	[831, 2708]	-	-
δ	0.10	[0.023, 0.21]	0.49	[0.14, 0.78]	-	-	-	-
ω	8.27	[6.16, 11.3]	4.31	[1.17, 7.62]	8.11	[5.99, 11.1]	6.47	[4.46, 9.14]
φ	1.97	[0.48, 4.80]	2.95	[0.33, 7.94]	1.35	[0.31, 3.44]	0.66	[0.10, 1.68]
ρ_u	0.32	[0.09, 0.59]	0.60	[0.12, 0.92]	0.38	[0.15, 0.62]	0.86	[0.75, 0.95]
σ_u	0.030	[0.016, 0.057]	0.013	[0.008, 0.023]	0.029	[0.016, 0.056]	0.013	[0.008, 0.022]
ρ_a	0.88	[0.77, 0.96]	0.88	[0.78, 0.96]	0.88	[0.77, 0.96]	0.87	[0.73, 0.96]
σ_a	0.031	[0.018, 0.049]	0.044	[0.027, 0.066]	0.027	[0.015, 0.044]	0.043	[0.029, 0.064]
Log MDD	209.57		192.07		212.82		192.00	

Note. The labels 'NRE' and RE' refer to the baseline models in section 2. The labels 'NRE_0' and 'RE_0' refer to the NRE and RE models, which are estimated by imposing no backward-looking firms, i.e., $\delta = 0$. The posterior mean, median, 5th percentile, and 95th percentile were computed over one million draws from the MCMC chain.

Table 2: Implied Parameters Shaping Aggregate Demand and Supply

	NRE	RE	NRE_0	RE_0
τ	0.36	0.60	0.37	0.43
η	0.11	0.38	0	0
$\tilde{\beta}$	0.86	0.60	0.975	0.975
κ	0.16	0.08	0.15	0.09

Note. The for NRE and RE models, parameter values are obtained from the posterior means of δ, ω, and φ, together with other remaining calibrated parameters. In contrast, NRE_0 and RE_0 models impose $\delta = 0$ by construction.

of each shock process is assumed to follow a Beta (2,3) distribution. The prior distribution for 100 times of the standard deviation of each shock process is assumed to follow a Gamma (0.25,2) distribution. Finally, for the standard deviations of the measurement errors of the observables, we impose uniform distributions with the maximum support to be 25% of the standard deviation of each observable as the prior. We use the random-walk Metropolis-Hastings algorithm with a 25 percent acceptance rate to generate 1 million draws of MCMC chains, which we then use to assess the posterior distributions. We place the details of the prior distributions of the eight structural parameters in Table C.8.

Table 1 reports posterior distributions and log marginal data densities for the baseline NRE and RE models, as well as the corresponding versions that impose $\delta = 0$ (NRE_0 and RE_0). The NRE estimates imply a sizable degree of concern for robustness: the posterior mean of $\tilde{\theta}$ is 1807 with a 90% credible interval of [896, 3190], placing it far from the RE limit of zero. The two models also differ sharply in the extent of backward-looking price setting. Under NRE, the posterior mean of δ is 0.10, whereas the RE model has $\delta = 0.49$. Consistent with this contrast, imposing $\delta = 0$ leaves the NRE posterior largely unchanged (NRE_0 versus NRE), while it induces sizable shifts in

shape parameters from the posterior mean estimates.

Table 3: Second Moments: Data and Models

Moments	Data	NRE	RE	NRE_0	RE_0
$\sigma(\pi_t)$	1.09	0.81	1.23	0.83	1.22
$\sigma(\Delta e_t)$	3.12	3.30	3.10	3.28	2.94
$\rho(\pi_t, \Delta e_t)$	0.28	0.23	0.31	0.26	0.39
$\rho(\pi_t, \pi_{t-1})$	0.92	0.65	0.37	0.69	0.23
$\rho(\pi_t, \pi_{t-2})$	0.80	0.44	0.09	0.49	0.07
$\rho(\Delta e_t, \Delta e_{t-1})$	0.13	-0.09	0.05	-0.06	-0.02
$\rho(\Delta e_t, \Delta e_{t-2})$	0.07	-0.10	-0.03	-0.08	-0.03

Note. The second moments of the models are computed using the posterior means of the parameters for each model.

key parameters under RE (RE_0 versus RE), indicating that the RE benchmark relies more heavily on the backward-looking channel.

Beyond $\tilde{\theta}$ and δ, several parameters differ meaningfully across the NRE and RE models. The open-economy parameter ω is substantially larger under NRE (8.27) than under RE (4.31), implying a stronger role for terms-of-trade movements in shaping domestic dynamics. The posterior mean of φ is 1.97 under NRE and 2.95 under RE. The estimated cost-push shock is less persistent but more volatile under NRE ($\rho_u = 0.32$, $\sigma_u = 0.030$) than under RE ($\rho_u = 0.60$, $\sigma_u = 0.013$). The persistence of the productivity shock is similar across models ($\rho_a = 0.88$ in both), while its volatility is smaller under NRE ($\sigma_a = 0.031$) than under RE ($\sigma_a = 0.044$).

Furthermore, in terms of in-sample fit, the NRE specification overwhelmingly outperforms the RE benchmark. The difference in log marginal data density is economically large (209.57 vs. 192.07), corresponding to decisive Bayesian evidence in favor of NRE. Importantly, this ordering is preserved—and even strengthened—when backward-looking price setting is eliminated (212.82 for NRE_0 vs. 192.00 for RE_0), indicating that the superior performance of NRE does not hinge on mechanical inflation persistence but instead reflects the central bank's concern for robustness.

Table 2 reports the implied parameters governing the shapes of aggregate demand (τ) and aggregate supply (η, $\tilde{\beta}$, κ), constructed from the posterior means of δ, ω, and φ in Table 1 using the parametric relationships in (2.2), (2.5), and (2.6). Two main patterns emerge. First, the implied slopes differ markedly between the NRE and RE models. The NRE model features a steeper aggregate demand curve, with a lower value of τ (0.36 versus 0.60), and a substantially more forward-looking aggregate supply relation. In particular, the weight on lagged inflation is much smaller under NRE ($\eta = 0.11$) than under RE ($\eta = 0.38$), while the forward-looking component is correspondingly larger ($\tilde{\beta} = 0.86$ versus 0.60). At the same time, the slope of aggregate supply with respect to the output gap is steeper under NRE ($\kappa = 0.16$) than under RE ($\kappa = 0.08$). Second, imposing $\delta = 0$ leaves the implied parameters under NRE largely unchanged, whereas it induces substantial shifts under RE—most notably in τ.

3.1 Predictions of the Estimated Models

We now discuss the predictions of the estimated models, focusing on their in-sample performance in matching the second moments of the observables and their out-of-sample performance (external validity), as measured by the model-implied monetary policy rates and their alignment with the actual policy rate.

Second Moments. Table 3 presents the empirical and theoretical second-order moments for CPI inflation and nominal exchange rate depreciation, comparing the observables with the predictions of the models. The results indicate that both the NRE and RE models perform similarly in terms of fitting the unconditional standard deviations and cross-correlations. However, the NRE model is more successful in predicting inflation persistence, as reflected in the higher autocorrelations of inflation ($\rho(\pi_t, \pi_{t-1})$ and $\rho(\pi_t, \pi_{t-2})$) relative to the RE model, even though aggregate supply in the NRE model is significantly more forward-looking, as indicated by the estimates of δ, η, and $\tilde{\beta}$ in Tables 1 and 2. While nominal exchange rate depreciation exhibits little persistence in the data and is reasonably captured by both models, the key quantitative distinction between the models in Table 3 arises from their implications for inflation dynamics.

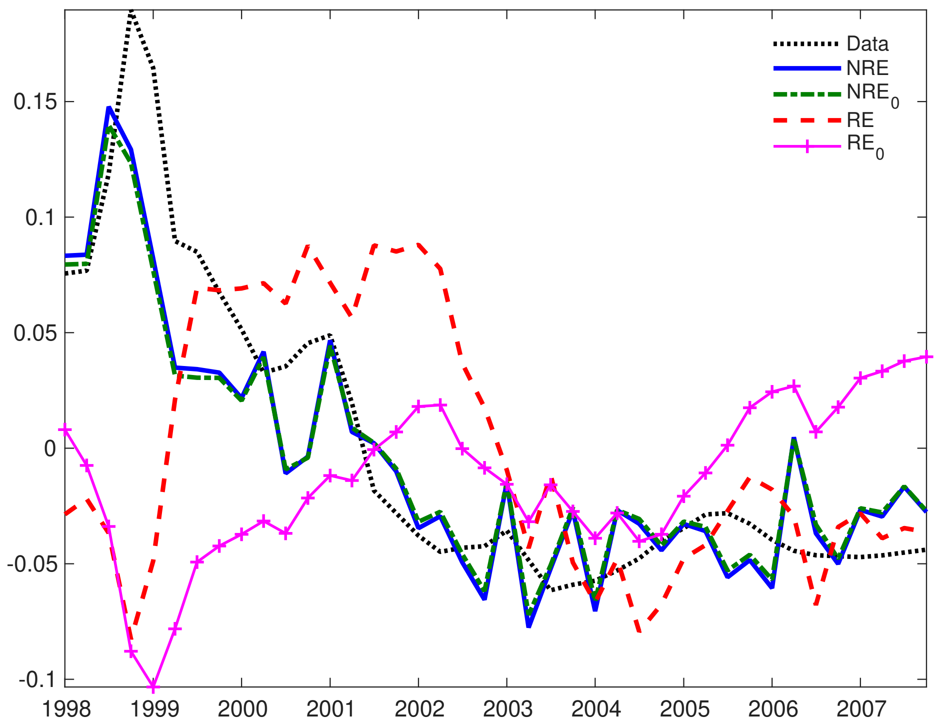
The results from the NRE_0 and RE_0 models further reinforce this conclusion. The NRE_0 specification—despite completely shutting down the backward-looking component in the aggregate supply relation—continues to generate inflation persistence comparable to, and even slightly stronger than, that of the baseline NRE model. By contrast, the RE_0 model performs markedly worse than the RE benchmark in matching observed inflation persistence. Combined with the evidence from Tables 1 and 2, which show no meaningful differences in estimated parameters between the NRE and NRE_0 models, these results indicate that the NRE framework does not rely on backward-looking price indexation to fit the data.

This finding is important in light of long-standing critiques of lagged inflation terms in New Keynesian models, which—while often improving empirical fit—are frequently viewed as ad hoc (Gali et al., 2005). In the NRE model, inflation persistence arises endogenously from the interaction between the central bank's concern for robustness and private-sector expectations, rather than from mechanical indexation to past inflation. In contrast, the RE model depends heavily on backward-looking pricing behavior to reproduce inflation persistence. Thus, the NRE framework provides a quantitatively successful and conceptually disciplined alternative to backward-looking inflation mechanisms.

Prediction on Monetary Policy Rates. We now examine how closely the optimal monetary policy rates generated by the estimated models resemble the actual data.[8] Using the estimated models and observables, we extract the historical paths of exogenous shocks through the Kalman

[8] We use the Mexican overnight interbank rate as a proxy for the actual monetary policy rate. All series are on a quarterly frequency and have been demeaned.

Figure 3: Monetary Policy Rates: Data and Model Predictions



Note. The black dotted line denotes the monetary policy rate in the data. The blue solid line (labeled NRE) and the red dashed line (labeled RE) show the policy rate paths predicted by the estimated NRE and RE models, respectively. The green dash–dotted line (labeled NRE_0) and the magenta line with crosses (labeled RE_0) show the predicted policy rate paths from the estimated NRE and RE models without backward-looking firms (i.e., $\delta = 0$), respectively. All series are demeaned and annualized. The RMSEs for NRE, RE, NRE_0, and RE_0 are 0.0295, 0.0788, 0.0301, and 0.0910, respectively.

smoother and feed them into the models to obtain the monetary policy rates implied endogenously by each model. Because the monetary policy rate is not used as an observable in estimation, this comparison provides an out-of-sample evaluation of model fit and serves as an external-validity check of the framework.

Figure 3 plots the actual monetary policy rate in Mexico together with the policy rate paths implied by the models. The NRE model clearly outperforms the RE benchmark in terms of predictive accuracy. Over the entire sample, the policy rate implied by the NRE model closely tracks the actual data, whereas the RE model exhibits substantial deviations. Quantitatively, the RMSE of the policy rate path is 0.0295 under NRE, compared with 0.0788 under RE, corresponding to a reduction of approximately 63%.

The contrast becomes even sharper when backward-looking price setting is shut down. The NRE_0 model performs almost identically to the baseline NRE model, whereas the RE_0 model deteriorates further relative to the RE benchmark. The RMSE of the policy rate path is 0.0301 under NRE_0, compared with 0.0910 under RE_0, implying a reduction of approximately 67%.

Table 4: The Optimal Policy Coefficients in the Estimated Models

	NRE	RE	NRE_0	RE_0
$\Gamma_{\pi_H,u}$	0.0088	0.0143	0.0087	0.0141
$\Gamma_{x,u}$	-0.1152	-0.0493	-0.1138	-0.0541

Note. The optimal policy coefficients are computed using the posterior means of parameters of the models.

3.2 Inspecting Mechanism

In this section, we investigate the mechanisms underlying the models' empirical predictions and clarify their economic interpretation. To begin, we note that even under a concern for robustness, optimal monetary policy retains a sharp focus on specific sources of distortion. In particular, robustness does not alter which shocks generate policy trade-offs; rather, it reshapes how the central bank responds to those trade-offs once they arise. To formalize this insight, we begin by establishing a lemma that characterizes the normative structure of the robustly optimal policy.

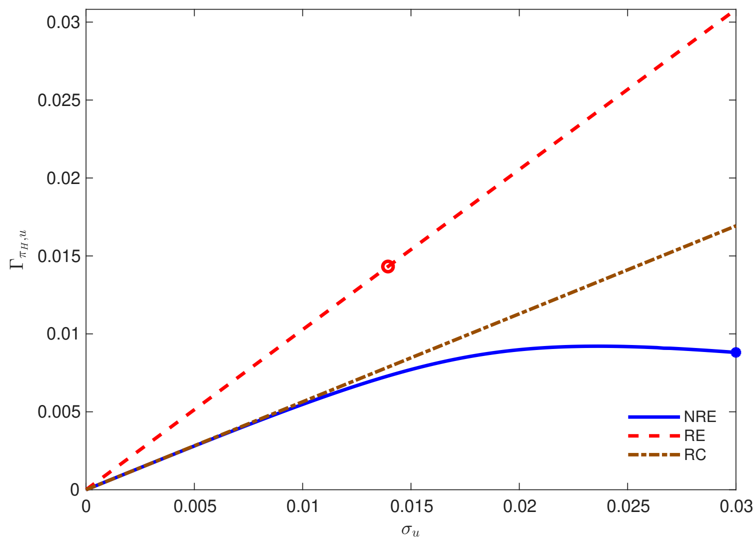
Lemma 3.1. *For any $\tilde{\theta} \in \mathbb{R}_+$, the robustly optimal monetary policy calls for zero domestic inflation and a zero output gap in response to domestic productivity shocks a_t and world output shocks y_t^*, i.e., $\Gamma_{\pi_H,a} = \Gamma_{x,a} = \Gamma_{\pi_H,y^*} = \Gamma_{x,y^*} = 0$.*

Lemma 3.1 implies that, regardless of the degree of concern for robustness, only the cost-push shock u_t affects domestic inflation $\pi_{H,t}$ and the output gap x_t under the optimal policy. Domestic productivity shocks a_t and world output shocks y_t^* influence the natural real interest rate $\bar{rr}_t$ (equation 2.3), but their effects on aggregate demand are fully offset by policy, even in the presence of distorted private-sector expectations. As a result, there is no trade-off between stabilizing domestic inflation and the output gap–the *divine coincidence*. These shocks nevertheless affect the economy through the natural level of output $\tilde{y}_t$, thereby influencing terms-of-trade and nominal exchange rate dynamics (equations 2.7 and 2.9).

Optimal Policy Coefficients. Guided by Lemma 3.1, we focus on the optimal policy responses to the cost-push shock, summarized by $\Gamma_{\pi_H,u}$ and $\Gamma_{x,u}$. Table 4 reveals a stark contrast between the NRE and RE models. Under NRE, the central bank responds much more conservatively–implying the adoption of a more hawkish stance toward stabilization–to inflation, with $\Gamma_{\pi_H,u} = 0.0088$, roughly two-thirds of its RE counterpart of 0.0143, while tolerating a substantially larger adjustment in the output gap, $\Gamma_{x,u} = -0.1152$, roughly twice its RE counterpart of -0.0493. This asymmetry already suggests a fundamental reallocation of policy stabilization effort under robustness.

Figure 4 illustrates the economic mechanism underlying these differences. In the RE model, the optimal inflation response $\Gamma_{\pi_H,u}$ increases linearly with the size of the cost-push shock σ_u, reflecting the principle of *certainty equivalence*. This principle breaks down under NRE. Relative to the RE counterfactual (RC) that shares the same parameter estimates but sets $\tilde{\theta} = 0$, the NRE policy exhibits a concave response: as σ_u increases, $\Gamma_{\pi_H,u}$ rises less than proportionally and eventually

Figure 4: Robustly Optimal Policy Coefficient $\Gamma_{\pi_H,u}$: Graphical Illustration



Note. The blue solid and red dashed lines depict the optimal policy coefficient $\Gamma_{\pi_H,u}$ as a function of the standard deviation of the cost-push shock, σ_u, with all other parameters fixed at their posterior means from the estimated NRE and RE models, respectively. The circle on each linee indicates the posterior mean of σ_u for the corresponding model. The brown dash-dot line depicts $\Gamma_{\pi_H,u}$ under the RE counterfactual (RC), which uses the estimated NRE model parameters but sets $\tilde{\theta} = 0$.

declines. This pattern indicates that a central bank concerned with robustness becomes increasingly reluctant to scale up its inflation response in the presence of large shocks.

Consequently, the NRE model reallocates stabilization toward inflation and away from the output gap. As documented in Table 1, this behavior is driven jointly by a high estimated concern for robustness ($\tilde{\theta}$) and a large estimated volatility of cost-push shocks (σ_u), leading the central bank to adopt a markedly more hawkish inflation stabilization stance than under RE.

This reallocation has direct implications for exchange-rate dynamics. Because nominal depreciation responds to both domestic inflation and movements in the output gap (equations 2.7 and 2.9), the initial response of Δe_t closely mirrors $\Gamma_{x,u}$. Quantitatively, the larger magnitude of $\Gamma_{x,u}$ relative to $\Gamma_{\pi_H,u}$, combined with the conservative inflation response under NRE, implies that exchange-rate adjustment operates primarily through the output-gap channel.

Table 4 further demonstrates that the NRE_0 model delivers policy coefficients nearly identical to those of the baseline NRE model. This stability underscores that the robustness channel, rather than backward-looking pricing, is the primary driver of optimal policy behavior in the NRE framework. By contrast, the RE_0 model exhibits a noticeably larger output-gap response than the RE benchmark, indicating that backward-looking components play a quantitatively important role in sustaining the policy stance under RE.

The following proposition shows how the degree of concern for robustness affects the optimal dynamics of the domestic inflation rate:

Proposition 3.2. *Consider $\delta = 0$. In equilibrium with the robustly optimal monetary policy, the dynamics of domestic inflation is determined by the following equation:*

$$\pi_{H,t} = \rho_{\pi_H} \pi_{H,t-1} + \Gamma_{\pi_H,u} \varepsilon_t^u - \rho_{\pi_H}(1-\rho_u)\sigma_u \sum_{j=0}^{\infty} \rho_u^j \varepsilon_{t-j-1}^u, \tag{3.4}$$

where $\rho_{\pi_H} \in (0,1)$ increases as $\tilde{\theta}$ increases.

Proposition 3.2 isolates the effect of robustness on endogenous inflation persistence by imposing $\delta = 0$. As the concern for robustness increases, the autoregressive coefficient ρ_{π_H} rises, strengthening the dependence of current inflation on its own past. Moreover, when the cost-push shock is persistent ($\rho_u > 0$), this increase in ρ_{π_H} amplifies the contribution of past cost-push shocks to current inflation through the moving-average component of (3.4). Taken together, these effects imply that heightened concern for robustness induces more history-dependent inflation dynamics relative to the RE benchmark. This insight echoes the conclusions of Woodford (2010), which are derived in a closed-economy setting. Proposition 3.2 extends this logic by highlighting how shock persistence amplifies history dependence under robust monetary policy.

These results imply that inflation inertia in the NRE model emerges *endogenously* from robust monetary policy, even in the absence of backward-looking price setting, as also reflected in the model's fit to inflation autocorrelations in Table 3. This mechanism is conceptually distinct from the traditional backward-looking channel: while the latter generates inertia mechanically through firms' pricing rules, robustness gives rise to persistence through a breakdown of certainty equivalence in policy design. The small posterior estimates of δ in the NRE model further indicate that backward-looking behavior is not the dominant source of inflation persistence in this environment.

Shock Decompositions. The sharply different policy stances and transmission mechanisms implied by the NRE and RE models lead them to interpret the data differently when identifying the sources of macroeconomic fluctuations. To clarify the mechanisms underlying these contrasting policy implications, we examine shock decompositions. This analysis reveals systematic differences in how the two frameworks attribute fluctuations in observables to underlying shocks, with particularly pronounced contrasts in the role assigned to cost-push disturbances.

Table 5 reports the unconditional variance decompositions of the two observables. Across all models, world output shocks play only a negligible role in explaining fluctuations in either variable. Under the NRE model, cost-push shocks dominate fluctuations in both variables, accounting for 75.4% of inflation variance and 78.7% of exchange-rate variance. By contrast, the RE model assigns a much smaller role to cost-push shocks—especially for depreciation—while attributing the bulk of exchange-rate fluctuations to productivity shocks (72.5%). This contrast becomes even sharper when backward-looking pricing is shut down. The NRE$_0$ model delivers decompositions almost identical to the baseline NRE model, whereas the RE$_0$ model shifts further toward a TFP-driven interpretation, with productivity shocks explaining 88.7% of exchange-rate variance.

Table 5: Decomposition of Unconditional Variances

Model	NRE			RE			NRE_0			RE_0		
Series/shock	Cost	TFP	World	Cost	TFP	World	Cost	TFP	World	Cost	TFP	World
CPI Inflation	75.4	21.7	0.45	62.1	36.1	0.38	77.3	19.7	0.52	58.0	40.2	0.43
Depreciation Rate	78.7	16.7	0.34	24.1	72.5	0.77	79.4	15.9	0.42	7.90	88.7	0.94

Note. The labels "Cost", "TFP", and "World" refer to the cost-push shock, domestic productivity shock, and world output shock, respectively. The variance decompositions are performed using the posterior means of parameters of the models. Shares are in percent. The sum of the contributions from each shock does not equal 100, and the remaining portions are due to measurement errors.

These differences in variance attribution have direct implications for the interpretation of monetary policy dynamics. To illustrate this link, we decompose the model-implied policy rates using the estimated shock histories. Figure 5 shows that the divergence between the NRE and RE models extends beyond overall fit to the underlying sources of policy-rate movements. In the NRE model, cost-push shocks emerge as the primary driver of the historical dynamics of the policy rate. In contrast, the RE model assigns a much more limited role to cost-push shocks and instead attributes policy movements largely to productivity shocks. This pattern persists when backward-looking pricing is removed. The NRE_0 model closely mirrors the NRE benchmark, while the RE_0 model exhibits a stark reallocation toward productivity-driven policy dynamics. As a result, the RE_0 model fails to reproduce the observed path of the policy rate.

Viewed through this lens, these decompositions reveal that the key distinction between the two frameworks lies in how policy-relevant shocks are interpreted. Under NRE, the central bank's concern for robustness leads policy dynamics to be driven primarily by cost-push disturbances, consistent with the observed behavior of the policy rate during Mexico's post-crisis transition. By contrast, the RE framework interprets policy movements largely through productivity shocks, a mapping that fails to reproduce the data even when backward-looking pricing is introduced. From this perspective, the success of the NRE model reflects not an auxiliary role for backward-looking behavior, but a fundamentally different reading of the shocks that matter for policy, shaped by optimal policy design under a concern for robustness.

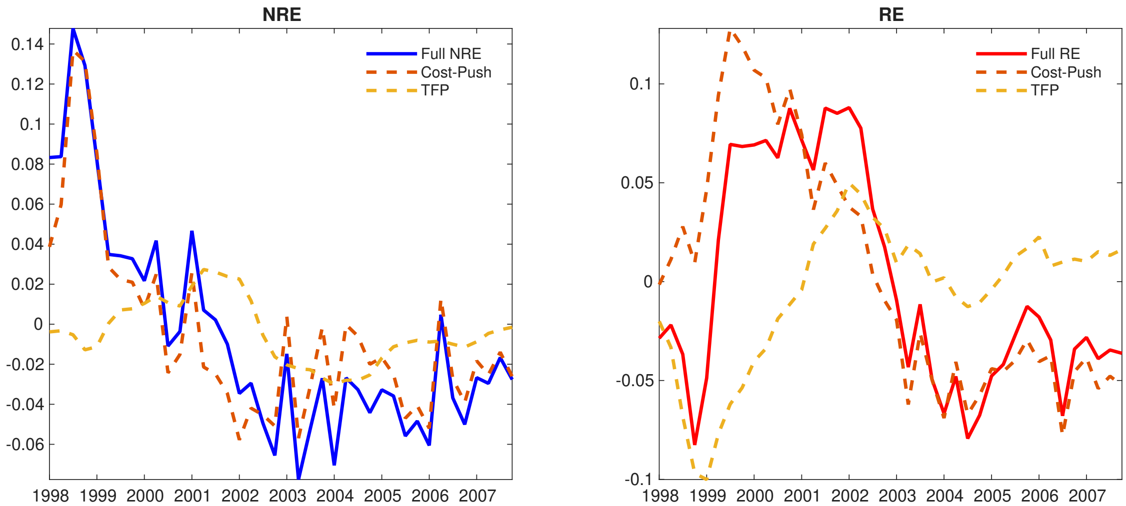
4 Discussion

Sensitivity Checks of the Main Results. We re-estimate the NRE and NRE_0 models in Section 3 by imposing a wider prior for $\tilde{\theta}$, specifically uniform distributions over the ranges $[0, 10^6]$ and $[0, 10^{18}]$. The corresponding posterior distributions for the NRE models are reported in Table C.9 in Appendix C. We find no statistically meaningful differences in the posterior distributions of the NRE and NRE_0 models compared to those in Table 1, and the main results in Section 3 remain unchanged.

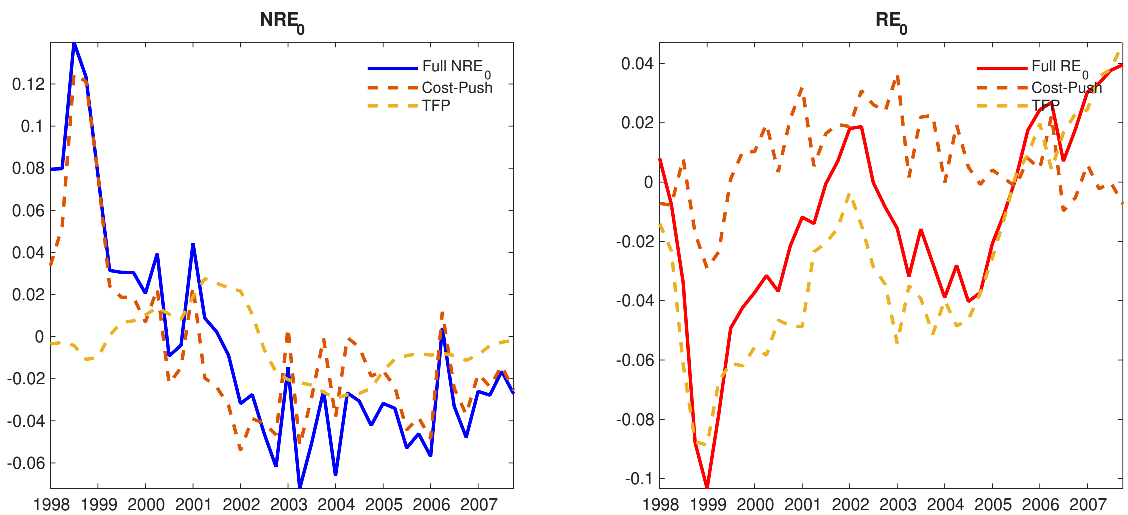
We also repeat the exercise in Section 3 using extended samples that begin closer to the Mexican

Figure 5: Monetary Policy Rates in the Models Conditional on Shocks

(a) Baseline



(b) No Backward-Looking ($\delta = 0$)



Note. The blue and red solid lines in panel (a) represent the monetary policy rates predicted by the NRE and RE models, respectively, while the blue and red solid lines in panel (b) represent the policy rates predicted by the NRE_0 and RE_0 models, respectively. These series are identical to those shown in Figure 3. The dashed lines labeled 'Cost-Push' and 'TFP' correspond to predictions conditional only on the cost-push shock and domestic productivity shock, respectively. The world output shock is quantitatively negligible.

Peso Crisis, starting in 1Q 1996 and 1Q 1997. The results remain robust: the NRE models exhibit a substantial degree of concern for robustness (high values of $\tilde{\theta}$), rely only minimally on the backward-looking term in the Phillips curve, and deliver strong external-validity performance in predicting the monetary policy rate. By contrast, the RE models rely heavily on the backward-looking term and still fall short in predictive performance. The corresponding results are reported in Table C.10 and Figure C.6 in Appendix C.

We also conduct the same exercise for an advanced economy, where we presume that the central bank faced significantly lower levels of Knightian uncertainty due to its long-standing experience with policy commitment and well-anchored inflation expectations, as well as the absence of abrupt policy regime shifts such as those observed in Mexico. Using Canadian data (2Q 1991 to 4Q 2007), we obtain results consistent with this presumption. The NRE models feature much lower values of $\tilde{\theta}$—closer to zero (compared to the case of Mexico)—regardless of whether a backward-looking term is included in aggregate supply. Moreover, the NRE and RE models yield similar parameter estimates and comparable predictive performance for the monetary policy rate, suggesting that the degree of uncertainty faced by the central bank is relatively low and that the RE environment provides a good approximation. The corresponding results are reported in Table C.11 and Figure C.7 in Appendix C.

External Validation and Roles of Parameters. The success of the NRE model in externally validating the predictions of monetary policy rates in Figure 3 is primarily attributable to the central bank's concern for robustness rather than to other structural parameters. In Figure C.8 in Appendix C, we plot the monetary policy rates implied by the RE counterfactual, which uses the estimated NRE model parameters while setting $\tilde{\theta} = 0$. The RE counterfactual generates a policy-rate path similar to that of the RE model, implying a comparable lack of external-validity performance.

Financial Frictions and Expectation-Based Mechanisms. Our findings also inform the broader debate on the role of financial frictions in emerging-market monetary policy. While a large literature has emphasized the role of monetary policy in the presence of various forms of financial frictions–including sovereign default risk (e.g. Na et al., 2018), sudden stops and external financing constraints (e.g. Braggion et al., 2009; Devereux et al., 2019), and currency risk premia (e.g. Itskhoki and Mukhin, 2023)–our results indicate that even in the absence of such wedges, belief distortions combined with policymakers' concern for robustness can generate quantitatively meaningful policy dynamics.

Importantly, this does not imply that financial frictions are unimportant. Rather, it suggests that part of what is often attributed to financial wedges may, in certain environments, reflect uncertainty about private-sector expectation formation. For policy analysis, this distinction matters: it shifts the focus from correcting external financing distortions to stabilizing expectations and managing robustness concerns within the domestic policy framework.

5 Conclusion

This paper studies robustly optimal monetary policy in a small open economy when the central bank faces uncertainty about private agents' forward-looking expectations. We introduce near-rational expectations (NRE) into an otherwise standard open-economy New Keynesian framework and model the policymaker's concern for robustness as ambiguity about belief distortions. Within this environment, optimal policy departs sharply from the rational-expectations (RE) benchmark: greater concern for robustness leads the central bank to respond more conservatively to domestic inflation in the presence of cost-push shocks, while tolerating larger adjustments in the output gap and the nominal exchange rate. Moreover, the robustly optimal monetary policy exhibits endogenous history dependence and generates persistent inflation dynamics even in the absence of backward-looking price setting.

We take the model to the data by estimating both NRE and RE versions using Mexican macroeconomic time series during the post–Peso Crisis transition. The estimated NRE model implies a substantial degree of concern for robustness on the part of the central bank and delivers a markedly different policy configuration from the RE benchmark. In particular, the NRE model assigns a central role to the interaction between a concern for robustness and cost-push shocks in shaping inflation, exchange-rate movements, and policy-rate dynamics, whereas the RE model relies heavily on backward-looking pricing behavior and productivity shocks. These differences are not merely quantitative: the NRE framework substantially outperforms the RE benchmark in external validity, closely tracking the observed path of Mexico's policy interest rate despite not using it as an observable in estimation.

Beyond its empirical performance, the analysis highlights a novel policy mechanism with broader relevance for emerging market economies. When central banks face uncertainty about the formation of private-sector expectations—particularly in the aftermath of crisis-driven regime transitions—robust policy design reshapes both shock transmission and the interpretation of inflation persistence. In our framework, inflation inertia emerges endogenously from optimal policy responses under ambiguity, rather than from mechanical backward-looking behavior. This distinction suggests that observed inflation persistence in post-crisis environments need not reflect intrinsic structural rigidities, but may instead arise from deliberate policy choices aimed at guarding against worst-case distortions in expectations.

Taken together, our results underscore the importance of incorporating policymakers' uncertainty about private-sector expectations into open-economy monetary models. Even within a parsimonious structural framework, accounting for robustness concerns yields qualitatively different policy prescriptions and empirical implications. We view this approach as a promising avenue for understanding monetary policy design in economies undergoing institutional transitions, where anchoring private-sector expectations remains a central—and inherently uncertain—policy challenge.

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Monetary Policy under Uncertain Expectations in an Emerging Economy

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Appendix: For Online Publication

A Details in Section 2

A.1 The Aggregate Supply with Lagged Domestic Inflation

The households' log-linearized optimal choices of consumption and labor are the same to the ones in Gali and Monacelli (2005) under distorted beliefs:

$$\sigma c_t + \varphi n_t = w_t - p_t, \tag{A.1}$$

$$c_t = \hat{\mathbb{E}}_t[c_{t+1}] - \frac{1}{\sigma}\left(r_t - \hat{\mathbb{E}}_t[\pi_{t+1}] - \rho\right). \tag{A.2}$$

The firms also have the same production technology as the ones in Gali and Monacelli (2005): $Y_t(j) = A_t N_t(j)$. Now, following Gali and Gertler (1999), we assume that a fraction $1-\delta$ of the firms, which we refer to as forward-looking, behave like the firms in Calvo-Yun model, i.e., they set prices optimally, given the constraints on the timing of adjustments and using all the available information in order to forecast future marginal costs. The remaining firms of measure δ, which we refer to as backward-looking, instead use a simple rule of thumb that is based on the recent history of aggregate price behavior.

Every period, a fraction $1-\zeta$ of firms reset prices (as in Calvo-Yun):

$$P_{H,t} = \left[\zeta\left(P_{H,t-1}\right)^{1-\epsilon} + (1-\zeta)\left(\bar{P}^{reset}_{H,t}\right)^{1-\epsilon}\right]^{\frac{1}{1-\epsilon}},$$

and out of those that reset, some are forward-looking $(1-\delta)$ while others are backward-looking (δ):

$$\bar{P}^{reset}_{H,t} = \left[(1-\delta)\left(P^f_{H,t}\right)^{1-\epsilon} + \delta\left(P^b_{H,t}\right)^{1-\epsilon}\right]^{\frac{1}{1-\epsilon}},$$

where the backward-looking firms set:

$$P^b_{H,t} = \bar{P}^{reset}_{H,t-1} \times \Pi_{H,t-1},$$

and the forward-looking firms solve the optimal pricing problem:

$$\max_{P^f_{H,t}} \sum_{k=0}^{\infty} \zeta^k \mathbb{E}_t\left\{Q_{t,t+k}[P^f_{H,t}(j)Y_{t+k}(j) - (1-\tau_f)W_{t+k}Y_{t+k}(j)/A_{t+k}]\right\},$$

subject to

$$Y_{t+k}(j) = \left(\frac{P^f_{H,t}}{P_{H,t+k}}\right)^{-\epsilon} \left(C_{H,t+k} + \int_0^1 C^i_{H,t+k} di\right),$$

where $Q_{t,t+k}$ is the households' one-period stochastic discount factor and τ_f is the employment subsidy. The firms' optimization yields the following log-linearized equation:

$$p^f_{H,t} = (1-\beta\zeta)(\mu + mc^n_t) + \beta\zeta \mathbb{E}_t \left[p^f_{H,t+1}\right].$$

The aggregate price level can, therefore, be solved for using the solutions of $p^f_{H,t}$ and $p^b_{H,t}$ in the expression of $\bar{P}^{reset}_{H,t}$. This price level can then be used to produce the following log-linearized equation:

$$\pi_{H,t} = \frac{(1-\zeta)(1-\delta)(1-\beta\zeta)}{[\zeta + \delta\left(1-\zeta(1-\beta)\right)]}(\mu + mc_t) + \frac{\delta}{[\zeta + \delta\left(1-\zeta(1-\beta)\right)]}\pi_{H,t-1} + \frac{\beta\zeta}{[\zeta + \delta\left(1-\zeta(1-\beta)\right)]}\mathbb{E}_t\pi_{H,t+1},$$

where the coefficients are written as:

$$\tilde{\beta} \equiv \frac{\zeta}{[\zeta + \delta(1-\zeta(1-\beta))]} \cdot \beta < \beta,$$
$$\eta \equiv \frac{\delta}{[\zeta + \delta(1-\zeta(1-\beta))]} > 0.$$

Finally, using the expression for marginal cost, $\mu + mc_t = (\tau + \varphi)x_t$, the aggregate supply curve augmented with the lagged domestic inflation is given as:

$$\pi_{H,t} = \tilde{\beta}\mathbb{E}_t\left\{\pi_{H,t+1}\right\} + \eta\pi_{H,t-1} + \tilde{\kappa}x_t,$$

where

$$\tilde{\kappa} \equiv \frac{\zeta(1-\delta)\kappa_0}{[\zeta + \delta(1-\zeta(1-\beta))]} < \kappa_0.$$

A.2 Solving the LQ System with Conditionally Linear Commitment

This section describes how we solve the linear-quadratic (LQ) robust policy problem under conditionally linear commitment, following Kwon and Miao (2019). The solution proceeds in the following steps. First, a hypothetical malevolent agent chooses the worst-case distortion to maximize welfare losses, subject to a relative-entropy penalty. Second, the central bank chooses the allocation and the policy instrument, taking the worst-case distortion as given. These two problems jointly yield a stacked linear system, from which we obtain the state-space representation by applying a standard linear difference equation solver. Since the conditionally linear self-commitment is time-invariant, we update the solution iteratively until a specified convergence criterion is met.

Worst-case beliefs. The first-order condition of the Lagrangian (2.16) with respect to m_{t+1} is:

$$\tilde{\theta}^{-1}(1 + \ln m_{t+1}) - \phi_t - \boldsymbol{\mu}'_{Y,t}\boldsymbol{Y}_{t+1} = 0.$$

Using the representation $\boldsymbol{Y}_{t+1} = \boldsymbol{\Phi}_t + \boldsymbol{\Gamma}_t\boldsymbol{\varepsilon}_{t+1}$ for $t \geq 0$ and the normalization constraint (2.13), we obtain

$$m_{t+1} = \exp\left(-\frac{1}{2}\tilde{\theta}^2\boldsymbol{\mu}'_{Y,t}\boldsymbol{\Gamma}_t\boldsymbol{\Gamma}'_t\boldsymbol{\mu}_{Y,t} + \tilde{\theta}\boldsymbol{\mu}'_{Y,t}\boldsymbol{\Gamma}_t\boldsymbol{\varepsilon}_{t+1}\right). \tag{A.3}$$

This implies the following conditional moments under the worst-case beliefs:

$$\begin{aligned}
\mathbb{E}_t m_{t+1}\boldsymbol{Y}_{t+1} &= \boldsymbol{\Phi}_t + \tilde{\theta}\boldsymbol{\Gamma}_t\boldsymbol{\Gamma}'_t\boldsymbol{\mu}_{Y,t}, \\
\mathbb{E}_t m_{t+1}\ln m_{t+1} &= \frac{1}{2}\tilde{\theta}^2\boldsymbol{\mu}'_{Y,t}\boldsymbol{\Gamma}_t\boldsymbol{\Gamma}'_t\boldsymbol{\mu}_{Y,t}.
\end{aligned}$$

Central bank's problem and first-order conditions. Substituting the worst-case distortion into the objective, the period loss can be written in matrix form as

$$\begin{aligned}
L(\boldsymbol{X}_t, \boldsymbol{\Phi}_{t-1} + \boldsymbol{\Gamma}_{t-1}\boldsymbol{\varepsilon}_t, i_t) = \frac{1}{2}\begin{bmatrix} \boldsymbol{X}_t \\ \boldsymbol{\Phi}_{t-1} + \boldsymbol{\Gamma}_{t-1}\boldsymbol{\varepsilon}_t \end{bmatrix}' \boldsymbol{Q} \begin{bmatrix} \boldsymbol{X}_t \\ \boldsymbol{\Phi}_{t-1} + \boldsymbol{\Gamma}_{t-1}\boldsymbol{\varepsilon}_t \end{bmatrix} \\
+\frac{1}{2}i_t\boldsymbol{R}i_t + \begin{bmatrix} \boldsymbol{X}_t \\ \boldsymbol{\Phi}_{t-1} + \boldsymbol{\Gamma}_{t-1}\boldsymbol{\varepsilon}_t \end{bmatrix}' \boldsymbol{S}i_t,
\end{aligned}$$

where the matrix $\begin{bmatrix} \boldsymbol{Q} & \boldsymbol{S} \\ \boldsymbol{S}' & \boldsymbol{R} \end{bmatrix}$ is symmetric and positive definite.

The central bank chooses $\{\boldsymbol{X}_t, \boldsymbol{\Phi}_t, \boldsymbol{\Gamma}_t, i_t\}$ after substituting for the chosen value of m_{t+1} in the Lagrangian. The new Lagrangian is:

$$\begin{aligned}
\mathcal{L} = \mathbb{E}_{-1}\sum_{t=0}^{\infty}\beta^t\Bigg\{L(\boldsymbol{X}_t, \boldsymbol{\Phi}_{t-1} + \boldsymbol{\Gamma}_{t-1}\boldsymbol{\varepsilon}_t, i_t) - \frac{\tilde{\theta}}{2}\boldsymbol{\mu}'_{Y,t}\boldsymbol{\Gamma}_t\boldsymbol{\Gamma}'_t\boldsymbol{\mu}_{Y,t} + \\
\begin{bmatrix} \boldsymbol{\mu}_{X,t+1} \\ \boldsymbol{\mu}_{Y,t} \end{bmatrix}'\left(\begin{bmatrix} \boldsymbol{X}_{t+1} \\ \boldsymbol{\Phi}_t + \tilde{\theta}\boldsymbol{\Gamma}_t\boldsymbol{\Gamma}'_t\boldsymbol{\mu}_{Y,t} \end{bmatrix} - \boldsymbol{A}\begin{bmatrix} \boldsymbol{X}_t \\ \boldsymbol{\Phi}_{t-1} + \boldsymbol{\Gamma}_{t-1}\boldsymbol{\varepsilon}_t \end{bmatrix} - \boldsymbol{B}i_t - \boldsymbol{C}\boldsymbol{\varepsilon}_{t+1}\right)\Bigg\}.
\end{aligned} \tag{A.4}$$

The first-order necessary conditions with respect to $\{\boldsymbol{X}_t, \boldsymbol{\Phi}_t, \boldsymbol{\Gamma}_t, i_t\}$ are:

$$\begin{aligned}
\mathbf{0} &= -\boldsymbol{Q}_{XX}\boldsymbol{X}_t - \boldsymbol{Q}_{XY}(\boldsymbol{\Phi}_{t-1} + \boldsymbol{\Gamma}_{t-1}\boldsymbol{\varepsilon}_t) - \boldsymbol{S}_X i_t - \beta^{-1}\boldsymbol{\mu}_{X,t} + \boldsymbol{A}'_{XX}\mathbb{E}_t\boldsymbol{\mu}_{X,t+1} + \boldsymbol{A}'_{YX}\boldsymbol{\mu}_{Y,t}, \\
\mathbf{0} &= -\boldsymbol{R}i_t - \boldsymbol{S}'_X\boldsymbol{X}_t - \boldsymbol{S}'_Y(\boldsymbol{\Phi}_{t-1} + \boldsymbol{\Gamma}_{t-1}\boldsymbol{\varepsilon}_t) + \boldsymbol{B}'_X\mathbb{E}_t\boldsymbol{\mu}_{X,t+1} + \boldsymbol{B}'_Y\boldsymbol{\mu}_{Y,t}, \\
\mathbf{0} &= -\left(\boldsymbol{Q}_{YY}\boldsymbol{\Phi}_t + \boldsymbol{Q}'_{XY}\mathbb{E}_t\boldsymbol{X}_{t+1}\right) - \boldsymbol{S}_Y\mathbb{E}_t i_{t+1} - \beta^{-1}\boldsymbol{\mu}_{Y,t} + \mathbb{E}_t\left[\boldsymbol{A}'_{XY}\boldsymbol{\mu}_{X,t+2} + \boldsymbol{A}'_{YY}\boldsymbol{\mu}_{Y,t+1}\right], \\
\mathbf{0} &= -\beta\boldsymbol{Q}_{YY}\mathbb{E}_t\left[\boldsymbol{\Phi}_t\boldsymbol{\varepsilon}'_{t+1} + \boldsymbol{\Gamma}_t\boldsymbol{\varepsilon}_{t+1}\boldsymbol{\varepsilon}'_{t+1}\right] - \beta\boldsymbol{Q}'_{XY}\mathbb{E}_t\boldsymbol{X}_{t+1}\boldsymbol{\varepsilon}'_{t+1} \\
&\quad -\beta\boldsymbol{S}_Y\mathbb{E}_t i_{t+1}\boldsymbol{\varepsilon}'_{t+1} - \tilde{\theta}\boldsymbol{\mu}_{Y,t}\boldsymbol{\mu}'_{Y,t}\boldsymbol{\Gamma}_t + \beta\mathbb{E}_t\left[\left(\boldsymbol{A}'_{XY}\boldsymbol{\mu}_{X,t+2} + \boldsymbol{A}'_{YY}\boldsymbol{\mu}_{Y,t+1}\right)\boldsymbol{\varepsilon}'_{t+1}\right]
\end{aligned} \tag{A.5}$$

where the matrices are partitioned as $\boldsymbol{A} \equiv \begin{bmatrix} \boldsymbol{A}_{XX} & \boldsymbol{A}_{XY} \\ \boldsymbol{A}_{YX} & \boldsymbol{A}_{YY} \end{bmatrix}$, $\boldsymbol{B} \equiv [\boldsymbol{B}_X, \boldsymbol{B}_Y]'$, and $\boldsymbol{C} \equiv [\boldsymbol{C}_X, \boldsymbol{C}_Y]'$, $\boldsymbol{Q} \equiv \begin{bmatrix} \boldsymbol{Q}_{XX} & \boldsymbol{Q}_{XY} \\ \boldsymbol{Q}_{XY}' & \boldsymbol{Q}_{YY} \end{bmatrix}$, and $\boldsymbol{S} \equiv \begin{bmatrix} \boldsymbol{S}_X \\ \boldsymbol{S}_Y \end{bmatrix}$.

In addition, the first-order necessary conditions with respect to $\{\boldsymbol{\mu}_{X,t+1}, \boldsymbol{\mu}_{Y,t}\}$ deliver the law of motion of the constraints:

$$\begin{aligned} \mathbf{0} &= \boldsymbol{X}_{t+1} - \boldsymbol{A}_{XX}\boldsymbol{X}_t - \boldsymbol{A}_{XY}(\boldsymbol{\Phi}_{t-1} + \boldsymbol{\Gamma}_{t-1}\boldsymbol{\varepsilon}_t) - \boldsymbol{B}_X i_t - \boldsymbol{C}_X\boldsymbol{\varepsilon}_{t+1}, \\ \mathbf{0} &= \boldsymbol{\Phi}_t + \tilde{\theta}\boldsymbol{\Gamma}_t\boldsymbol{\Gamma}_t'\boldsymbol{\mu}_{Y,t} - \boldsymbol{A}_{YX}\boldsymbol{X}_t - \boldsymbol{A}_{YY}(\boldsymbol{\Phi}_{t-1} + \boldsymbol{\Gamma}_{t-1}\boldsymbol{\varepsilon}_t) - \boldsymbol{B}_Y i_t. \end{aligned}$$

Stacked linear system. Adding two auxiliary conditions $\mathbb{E}_t\boldsymbol{\varepsilon}_{t+1} = \mathbf{0}$ and $\mathbb{E}_t\boldsymbol{\mu}_{X,t+2} = \mathbb{E}_t\boldsymbol{\mu}_{X,t+1}$, the equilibrium conditions can be written as the stackled system

$$\boldsymbol{J}\begin{bmatrix} \mathbb{E}_t\boldsymbol{\varepsilon}_{t+1} \\ \mathbb{E}_t\boldsymbol{X}_{t+1} \\ \boldsymbol{\Phi}_t \\ \mathbb{E}_t i_{t+1} \\ \mathbb{E}_t\boldsymbol{\mu}_{Y,t+1} \\ \mathbb{E}_t\boldsymbol{\mu}_{X,t+1} \\ \mathbb{E}_t\boldsymbol{\mu}_{X,t+2} \end{bmatrix} = \boldsymbol{F}\begin{bmatrix} \boldsymbol{\varepsilon}_t \\ \boldsymbol{X}_t \\ \boldsymbol{\Phi}_{t-1} \\ i_t \\ \boldsymbol{\mu}_{Y,t} \\ \boldsymbol{\mu}_{X,t} \\ \mathbb{E}_t\boldsymbol{\mu}_{X,t+1} \end{bmatrix}, \tag{A.6}$$

where $\{\boldsymbol{\varepsilon}_t, \boldsymbol{X}_t, \boldsymbol{\Phi}_{t-1}\}$ are predetermined state variables, whereas $\{i_t, \boldsymbol{\mu}_{Y,t}, \boldsymbol{\mu}_{X,t}, \mathbb{E}_t\boldsymbol{\mu}_{X,t+1}\}$ are non-predetermined variables. The explicit expressions for $\boldsymbol{J}$ and $\boldsymbol{F}$ follow Kwon and Miao (2017) and are reported below:

$$\boldsymbol{J} = \begin{pmatrix} \boldsymbol{I} & \mathbf{0} & \mathbf{0} & \mathbf{0} & \mathbf{0} & \mathbf{0} & \mathbf{0} \\ \mathbf{0} & \mathbf{0} & \mathbf{0} & \mathbf{0} & \mathbf{0} & \boldsymbol{I} & \mathbf{0} \\ \mathbf{0} & \boldsymbol{I} & \mathbf{0} & \mathbf{0} & \mathbf{0} & \mathbf{0} & \mathbf{0} \\ \mathbf{0} & \mathbf{0} & \boldsymbol{I} & \mathbf{0} & \mathbf{0} & \mathbf{0} & \mathbf{0} \\ \mathbf{0} & \mathbf{0} & \mathbf{0} & \mathbf{0} & \mathbf{0} & \boldsymbol{A}_{XX}' & \mathbf{0} \\ \mathbf{0} & \mathbf{0} & \mathbf{0} & \mathbf{0} & \mathbf{0} & \boldsymbol{B}_X' & \mathbf{0} \\ \mathbf{0} & \boldsymbol{Q}_{XY}' & \boldsymbol{Q}_{YY} & \boldsymbol{S}_Y & -\boldsymbol{A}_{YY}' & \mathbf{0} & -\boldsymbol{A}_{XY}' \end{pmatrix},$$

$$\boldsymbol{F} = \begin{pmatrix} \mathbf{0} & \mathbf{0} & \mathbf{0} & \mathbf{0} & \mathbf{0} & \mathbf{0} & \mathbf{0} \\ \mathbf{0} & \mathbf{0} & \mathbf{0} & \mathbf{0} & \mathbf{0} & \mathbf{0} & \boldsymbol{I} \\ \boldsymbol{A}_{XY}\boldsymbol{\Gamma} & \boldsymbol{A}_{XX} & \boldsymbol{A}_{XY} & \boldsymbol{B}_X & \mathbf{0} & \mathbf{0} & \mathbf{0} \\ \boldsymbol{A}_{YY}\boldsymbol{\Gamma} & \boldsymbol{A}_{YX} & \boldsymbol{A}_{YY} & \boldsymbol{B}_Y & -\tilde{\theta}\boldsymbol{\Gamma}\boldsymbol{\Gamma}' & \mathbf{0} & \mathbf{0} \\ \boldsymbol{Q}_{XY}\boldsymbol{\Gamma} & \boldsymbol{Q}_{XX} & \boldsymbol{Q}_{XY} & \boldsymbol{S}_X & -\boldsymbol{A}_{YX}' & \beta^{-1}\boldsymbol{I} & \mathbf{0} \\ \boldsymbol{S}_Y'\boldsymbol{\Gamma} & \boldsymbol{S}_X' & \boldsymbol{S}_Y' & \boldsymbol{R} & -\boldsymbol{B}_Y' & \mathbf{0} & \mathbf{0} \\ \mathbf{0} & \mathbf{0} & \mathbf{0} & \mathbf{0} & -\beta^{-1}\boldsymbol{I} & \mathbf{0} & \mathbf{0} \end{pmatrix}.$$

In our model, the partitions of the matrices $\boldsymbol{A}$, $\boldsymbol{B}$, $\boldsymbol{C}$, $\boldsymbol{Q}$, $\boldsymbol{R}$, and $\boldsymbol{S}$ are produced below:

$$\boldsymbol{A}_{XX} = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & \rho_u & 0 & 0 \\ 0 & 0 & 0 & \rho_a & 0 \\ 0 & 0 & 0 & 0 & \rho_{y^*} \end{bmatrix}, \ \boldsymbol{A}_{XY} = \begin{bmatrix} 0 & 0 \\ 1 & 0 \\ 0 & 0 \\ 0 & 0 \\ 0 & 0 \end{bmatrix},$$

$$\boldsymbol{A}_{YX} = \begin{bmatrix} 0 & -\frac{\eta}{\tilde{\beta}} & -\frac{1}{\tilde{\beta}} & 0 & 0 \\ -\frac{\varrho}{\tau} & \frac{\eta}{\tau\tilde{\beta}} & \frac{1}{\tau\tilde{\beta}} & \Gamma(1-\rho_a) & \alpha(\Theta+\Psi)(1-\rho_{y^*}) \end{bmatrix}, \ \boldsymbol{A}_{YY} = \begin{bmatrix} \frac{1}{\tilde{\beta}} & -\frac{\tilde{\kappa}}{\tilde{\beta}} \\ -\frac{1}{\tau\tilde{\beta}} & 1+\frac{\tilde{\kappa}}{\tau\tilde{\beta}} \end{bmatrix},$$

$$\boldsymbol{B}_X = \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix}, \ \boldsymbol{B}_Y = \begin{bmatrix} 0 \\ \tau^{-1} \end{bmatrix}, \ \boldsymbol{C}_X = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ \sigma_u & 0 & 0 \\ 0 & \sigma_a & 0 \\ 0 & 0 & \sigma_{y^*} \end{bmatrix}, \ \boldsymbol{C}_Y = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix}.$$

$$\boldsymbol{Q}_{XX} = \begin{bmatrix} \lambda_x(x^*)^2 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}, \ \boldsymbol{Q}_{XY} = \begin{bmatrix} 0 & -\lambda_x x^* \\ 0 & 0 \\ 0 & 0 \\ 0 & 0 \\ 0 & 0 \end{bmatrix}, \ \boldsymbol{Q}_{YX} = \boldsymbol{Q}'_{XY}, \ \boldsymbol{Q}_{YY} = \begin{bmatrix} 1 & 0 \\ 0 & \lambda_x \end{bmatrix},$$

$$\boldsymbol{R} = [0], \ \boldsymbol{S}_X = \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix}, \ \boldsymbol{S}_Y = \begin{bmatrix} 0 \\ 0 \end{bmatrix}.$$

We solve (A.6) using Klein (2000)'s method. The solution to the aforementioned system therefore takes the state-space representation as in (2.17) and (2.18).

Updating $\boldsymbol{\Gamma}$. Under conditionally linear self-consistent commitment, $\boldsymbol{\Gamma}_t$ is time-invariant and is updated iteratively. Taking unconditional expectations in (A.5) and rearranging with respect to $\boldsymbol{\Gamma}$ yields the updating rule

$$\boldsymbol{\Gamma}^{(n)} = \beta \left(\tilde{\theta} \mathbb{E} \left[\boldsymbol{\mu}_{Y,t} \boldsymbol{\mu}'_{Y,t} \right] + \beta \boldsymbol{Q}_{YY} \right)^{-1} \left\{ \mathbb{E}[(\boldsymbol{A}'_{XY} \mu_{X,t+2} + \boldsymbol{A}'_{YY} \boldsymbol{\mu}_{Y,t+1}) \varepsilon'_{t+1}] - \boldsymbol{Q}_{XY} \boldsymbol{C}_X - \boldsymbol{S}_Y \mathbb{E}[i_t \varepsilon'_t] \right\}. \tag{A.7}$$

To compute the moments appearing in (A.7), define the auxiliary state $\tilde{\boldsymbol{X}}_t \equiv [\boldsymbol{\varepsilon}'_t, \boldsymbol{X}'_t, \boldsymbol{\Phi}'_{t-1}]'$.

From (2.17), the second moments satisfy

$$\mathbb{E}\left[\tilde{\boldsymbol{X}}_{t+1}\tilde{\boldsymbol{X}}'_{t+1}\right] = \boldsymbol{H}\left[\tilde{\boldsymbol{X}}_t\tilde{\boldsymbol{X}}'_t\right]\boldsymbol{H}' + \begin{pmatrix} \boldsymbol{I} & \boldsymbol{C}'_X & \boldsymbol{0} \\ \boldsymbol{C}_X & \boldsymbol{C}_X\boldsymbol{C}'_X & \boldsymbol{0} \\ \boldsymbol{0} & \boldsymbol{0} & \boldsymbol{0} \end{pmatrix}.$$

If the matrix $\boldsymbol{H}$ is stable, this Lyapunov equation yields $\mathbb{E}\left[\tilde{\boldsymbol{X}}_t\tilde{\boldsymbol{X}}'_t\right]$. After that, we apply (2.18) and derive

$$\boldsymbol{\mu}_{Y,t} = \boldsymbol{G}_{2,\varepsilon}\boldsymbol{\varepsilon}_t + \boldsymbol{G}_{2,X}\boldsymbol{X}_t + \boldsymbol{G}_{2,\Phi}\boldsymbol{\Phi}_{t-1} = \boldsymbol{N}_2\tilde{\boldsymbol{X}}_t,$$

where $\boldsymbol{G} \equiv [\boldsymbol{G}_{2,\varepsilon}, \boldsymbol{G}_{2,X}, \boldsymbol{G}_{2,\Phi}]$ is the second row of $\boldsymbol{G}$ in (2.18). Then we obtain

$$\mathbb{E}\left[\boldsymbol{\mu}_{Y,t}\boldsymbol{\mu}'_{Y,t}\right] = \boldsymbol{G}_2\mathbb{E}\left[\tilde{\boldsymbol{X}}_t\tilde{\boldsymbol{X}}'_t\right]\boldsymbol{G}_2,$$

$$\mathbb{E}\begin{pmatrix} i_{t+1}\boldsymbol{\varepsilon}'_{t+1} \\ \boldsymbol{\mu}_{Y,t+1}\boldsymbol{\varepsilon}'_{t+1} \\ \boldsymbol{\mu}_{X,t+1}\boldsymbol{\varepsilon}'_{t+1} \end{pmatrix} = \boldsymbol{G}\mathbb{E}\begin{pmatrix} \boldsymbol{\varepsilon}_{t+1}\boldsymbol{\varepsilon}'_{t+1} \\ \boldsymbol{X}_{t+1}\boldsymbol{\varepsilon}'_{t+1} \\ \boldsymbol{\Phi}_t\boldsymbol{\varepsilon}'_{t+1} \end{pmatrix} = \boldsymbol{G}\begin{pmatrix} \boldsymbol{I} \\ \boldsymbol{C}_X \\ \boldsymbol{0} \end{pmatrix}.$$

The updating procedure of $\boldsymbol{\Gamma}$ in (A.7) stops when $||\boldsymbol{\Gamma}^{(n-1)} - \boldsymbol{\Gamma}^{(n)}|| < \varepsilon_\Gamma$. We set $\varepsilon_\Gamma = 10^{-5}$.

A.3 Proofs

Proof of Lemma 3.1. The interest rate i_t is a choice variable of the central bank to determine the optimal path of domestic inflation $\pi_{H,t}$ and output gap x_t. At any given equilibrium path of $\{\pi_{H,t}, x_t\}$ and worst-case expectations, the corresponding path of interest rate makes the aggregate demand equation (2.1) always hold. Thus, the path of $\{\pi_{H,t}, x_t\}$ can be determined without reference to equation (2.1), as long as the zero lower bound is not binding, which is implicitly assumed in the model. Then the natural rate shocks $\{a_t, y_t^*\}$ in (2.1) do not affect the optimal paths of $\{\pi_{H,t}, x_t\}$. Thus, $\Gamma_{\pi_H,a} = \Gamma_{x,a} = \Gamma_{\pi_H,y^*} = \Gamma_{x,y^*} = 0$. □

Proof of Proposition 3.2. Proof of Proposition 3.2. Consider the case with $\delta = 0$. Given the worst-case near-rational expectations of private agents, the first-order condition of the central bank's minimization problem in (2.14) with respect to $\Phi_{\pi_H,t}$ can be written as (see Appendix A.2 in Woodford, 2010)

$$-\beta\frac{\lambda_x}{\kappa}\frac{\pi_{H,t} - u_t - \kappa\bar{x} - \beta\Phi_{\pi_H,t}}{\Xi} + \beta\mathbb{E}_t\left(\pi_{H,t+1} + \frac{\lambda_x}{\kappa^2}\frac{\pi_{H,t+1} - u_{t+1} - \kappa\bar{x} - \beta\Phi_{\pi_H,t+1}}{\Xi}\right) = 0, \quad \text{(A.8)}$$

where

$$\Xi \equiv 1 - \tilde{\theta}\beta^2\frac{\lambda_x}{\kappa^2}\Gamma^2_{\pi_H,u} > 0.$$

Under the conditionally linear commitment policy, domestic inflation satisfies

$$\pi_{H,t} = \Phi_{\pi_H,t-1} + \Gamma_{\pi_H,u}\varepsilon_t^u.$$

Substituting this relation into (A.8) and rearranging terms yields the following second-order stochastic difference equation for $\Phi_{\pi_H,t}$:

$$\mathbb{E}_t[A(L)\Phi_{\pi_H,t+1}] = (\sigma_u - \Gamma_{\pi_H,u})\varepsilon_t^u - \rho_u\left(u_t - u_{t-1}\right), \tag{A.9}$$

where L denotes the lag operator and

$$A(L) \equiv \beta - \left(1 + \beta + \frac{\kappa^2 \Xi}{\lambda_x}\right) L + L^2. \tag{A.10}$$

Factorizing the lag polynomial $A(L)$ and imposing the no-bubbles condition yields a unique stationary solution characterized by the stable root $0 < \mu < 1$ of

$$\mathbb{P}(\mu) \equiv \beta\mu^2 - \left(1 + \beta + \frac{\kappa^2 \Xi}{\lambda_x}\right) \mu + 1 = 0.$$

Accordingly, the solution for $\Phi_{\pi_H,t}$ can be written recursively as

$$\Phi_{\pi_H,t} = \mu\Phi_{\pi_H,t-1} - \mu\left[(\sigma_u - \Gamma_{\pi_H,u})\varepsilon_t^u - \rho_u\left(u_t - u_{t-1}\right)\right]. \tag{A.11}$$

Using the AR(1) process for the cost-push shock,

$$u_t = \rho_u u_{t-1} + \sigma_u \varepsilon_t^u,$$

we obtain the moving-average representation

$$u_{t-1} = \sigma_u \sum_{j=0}^{\infty} \rho_u^j \varepsilon_{t-j-1}^u,$$

which implies

$$u_t - u_{t-1} = \sigma_u\varepsilon_t^u - (1-\rho_u)\sigma_u \sum_{j=0}^{\infty} \rho_u^j \varepsilon_{t-j-1}^u.$$

Finally, setting $\rho_{\pi_H} \equiv \mu$ and using the commitment relation

$$\pi_{H,t} = \Phi_{\pi_H,t-1} + \Gamma_{\pi_H,u}\varepsilon_t^u$$

together with (A.11), we obtain

$$\pi_{H,t} = \rho_{\pi_H}\pi_{H,t-1} + \Gamma_{\pi_H,u}\varepsilon_t^u - \rho_{\pi_H}(1-\rho_u)\sigma_u \sum_{j=0}^{\infty} \rho_u^j \varepsilon_{t-j-1}^u,$$

which establishes (3.4). □

B Linear State Space System for Estimation

This section summarizes the transition and measurement equations used in Bayesian estimation.

Transition equation. Define the estimation state as

$$\begin{bmatrix} \boldsymbol{\xi}_t \\ \boldsymbol{\xi}_{t-1} \end{bmatrix} \equiv \begin{bmatrix} \boldsymbol{\varepsilon}_t \\ \boldsymbol{X}_t \\ \boldsymbol{\Phi}_{t-1} \\ \boldsymbol{\varepsilon}_{t-1} \\ \boldsymbol{X}_{t-1} \\ \boldsymbol{\Phi}_{t-2} \end{bmatrix}.$$

Using the solution matrices in (2.17), the transition equation is

$$\begin{bmatrix} \boldsymbol{\xi}_{t+1} \\ \boldsymbol{\xi}_t \end{bmatrix} = \tilde{\boldsymbol{H}} \begin{bmatrix} \boldsymbol{\xi}_t \\ \boldsymbol{\xi}_{t-1} \end{bmatrix} + \boldsymbol{\nu}_{t+1},$$

where

$$\tilde{\boldsymbol{H}} \equiv \begin{bmatrix} \boldsymbol{H} & \boldsymbol{0} \\ \boldsymbol{I} & \boldsymbol{0} \end{bmatrix}, \qquad \boldsymbol{\nu}_{t+1} \equiv \begin{bmatrix} \boldsymbol{I} \\ \boldsymbol{C}_X \\ \boldsymbol{0} \\ \boldsymbol{0} \\ \boldsymbol{0} \\ \boldsymbol{0} \end{bmatrix} \boldsymbol{\varepsilon}_{t+1}.$$

Measurement equation. We estimate the model using two observables: CPI inflation π_t and nominal depreciation Δe_t. The measurement equation is

$$\begin{bmatrix} \pi_t \\ \Delta e_t \end{bmatrix} = \tilde{\boldsymbol{G}} \begin{bmatrix} \boldsymbol{\xi}_t \\ \boldsymbol{\xi}_{t-1} \end{bmatrix} + \begin{bmatrix} \sigma_\pi^{me} & 0 \\ 0 & \sigma_{\Delta e}^{me} \end{bmatrix} \begin{bmatrix} \varepsilon_t^{me,\pi} \\ \varepsilon_t^{me,\Delta e} \end{bmatrix},$$

where $\tilde{\boldsymbol{G}}$ in our model is given by

$$\tilde{\boldsymbol{G}} = \begin{bmatrix} \Gamma_{\pi_H,u} + \alpha\tau\Gamma_{x,u} & \Gamma_{\pi_H,u} + \tau\Gamma_{x,u} \\ \Gamma_{\pi_H,a} + \alpha\tau\Gamma_{x,a} & \Gamma_{\pi_H,a} + \tau\Gamma_{x,a} \\ \Gamma_{\pi_H,y^*} + \alpha\tau\Gamma_{x,y^*} & \Gamma_{\pi_H,y^*} + \tau\Gamma_{x,y^*} \\ 0 & 0 \\ 0 & 0 \\ 0 & 0 \\ \alpha\tau\frac{1+\varphi}{\tau+\varphi} & \tau\frac{1+\varphi}{\tau+\varphi} \\ -\alpha\tau\frac{\tau+\varphi+(\omega-1)\alpha\tau}{\tau+\varphi} & -\tau\frac{\tau+\varphi+(\omega-1)\alpha\tau}{\tau+\varphi} \\ 1 & 1 \\ \alpha\tau & \tau \\ -\alpha\tau\Gamma_{x,u} & -\tau\Gamma_{x,u} \\ -\alpha\tau\Gamma_{x,a} & -\tau\Gamma_{x,a} \\ -\alpha\tau\Gamma_{x,y^*} & -\tau\Gamma_{x,y^*} \\ 0 & 0 \\ 0 & 0 \\ 0 & 0 \\ -\alpha\tau\frac{1+\varphi}{\tau+\varphi} & -\tau\frac{1+\varphi}{\tau+\varphi} \\ \alpha\tau\frac{\tau+\varphi+(\omega-1)\alpha\tau}{\tau+\varphi} & \tau\frac{\tau+\varphi+(\omega-1)\alpha\tau}{\tau+\varphi} \\ 0 & 0 \\ -\alpha\tau & -\tau \end{bmatrix}^T,$$

where T denotes the transpose of the matrix.

C Additional Tables and Figures

Table C.6: Parameters

Parameter	Description	Remarks
β	Subjective discount factor	0.975 (MEX), 0.99 (CAN)
$\tilde{\theta}$	Central bank's degree of concern for robustness with respect to private agents' NRE	Estimated (Country- and model- specific)
ρ	Steady-state real interest rate $\beta^{-1} - 1$	0.0256 (MEX), 0.0101 (CAN)
σ	Curvature of the utility function	1
α	Degree of home bias (openness of the economy)	0.24 (MEX), 0.33 (CAN)
ϵ	Elasticity of substitution across home varieties	6
ζ	Calvo–Yun price stickiness parameter	0.75
φ	Inverse Frisch elasticity of labor supply	Estimated (Country- and model- specific)
ω	Effect of terms-of-trade movements on output	Estimated (Country- and model- specific)
Θ	Composite openness parameter $\omega - 1$	Implied (Country- and model- specific)
τ	Slope of the aggregate demand curve $\frac{\sigma}{1+\alpha(\omega-1)}$ $\frac{\sigma}{1+\alpha(\omega-1)}$	Implied (Country- and model- specific)
κ_0	Baseline slope of the aggregate supply curve $\frac{(1-\beta\zeta)(1-\zeta)(\sigma+\varphi)}{\zeta}$	Implied (Country- and model- specific)
δ	Fraction of backward-looking firms	Estimated (Country- and model- specific)
κ	Slope of the hybrid Phillips curve $\frac{\zeta(1-\delta)\kappa_0}{[\zeta+\delta(1-\zeta(1-\beta))]}$	Implied (Country- and model- specific)
$\tilde{\beta}$	Effective discount factor in the hybrid Phillips curve $\frac{\zeta\beta}{[\zeta+\delta(1-\zeta(1-\beta))]}$	Implied (Country- and model- specific)
η	Weight on lagged inflation in the hybrid Phillips curve $\frac{\delta}{[\zeta+\delta(1-\zeta(1-\beta))]}$	Implied (Country- and model- specific)
λ_x	Relative weight on output gap stabilization in the loss function $\frac{(1-\beta\zeta)(1-\zeta)(1+\varphi)}{\zeta\epsilon}$	Implied (Country- and model- specific)
$\bar{x}$	Long-run output gap target	0
$\Lambda_{y,0}$	Intercept on the natural level of output	0
$\Lambda_{y,a}$	Effect of TFP on the natural level of output $\frac{1+\varphi}{\tau+\varphi}$	Implied (Country- and model- specific)
Λ_{y,y^*}	Effect of world output on the natural level of output $-\frac{\alpha\Theta\tau}{\tau+\varphi}$	Implied (Country- and model- specific)
$\Lambda_{r,a}$	Effect of TFP on the natural interest rate $-\tau\Lambda_{y,a}(1-\rho_a)$	Implied (Country- and model- specific)
Λ_{r,y^*}	Effect of world output on the natural interest rate $-\varphi\Lambda_{y,y^*}(1-\rho_y^*)$	Implied (Country- and model- specific)
ρ_u	Persistence of cost-push shock	Estimated (Country- and model- specific)
ρ_a	Persistence of TFP shock	Estimated (Country- and model- specific)
ρ_{y^*}	Persistence of world output shock	0.84 (MEX), 0.85 (CAN)
σ_u	Standard deviation of cost-push shock	Estimated (Country- and model- specific)
σ_a	Standard deviation of TFP shock	Estimated (Country- and model- specific)
σ_{y^*}	Standard deviation of world output shock	0.0045 (MEX), 0.0042 (CAN)
σ_π^{me}	Standard deviation of measurement error in CPI inflation	Estimated (Country- and model- specific)
$\sigma_{\Delta e}^{me}$	Standard deviation of measurement error in nominal depreciation	Estimated (Country- and model- specific)

Note. "Implied" indicates that the parameter is determined as a function of calibrated and estimated parameters. "Country- and model- specific" incidates that the parameter values vary across models (NRE and RE) and countries (Mexico and Canada).

Table C.7: Pre-Set Parameters: Mexico

σ	1
ζ	0.75
ρ_{y^*}	0.84
$\sigma_{y^*} \times 100$	0.45
β	0.975
α	0.279

Note. The time unit is one quarter.

Table C.8: Prior Distributions of Parameters for Estimation

Parameter	Support	Distribution	Para (1)	Para (2)	[mean, std]
$\tilde{\theta}$	$[0, 10^4]$	Uniform	0	10^4	[5000, 2886.75]
δ	$\mathbb{R}^+$	Beta	2.0	3.0	[0.4, 0.2]
ω	$\mathbb{R}^+$	Gamma	2.0	2.0	[4.0, 2.82]
φ	$\mathbb{R}^+$	Gamma	2.0	2.0	[4.0, 2.82]
ρ_u	$[0, 1)$	Beta	2.0	3.0	[0.4, 0.2]
ρ_a	$[0, 1)$	Beta	2.0	3.0	[0.4, 0.2]
$\sigma_u \times 100$	$\mathbb{R}^+$	Gamma	0.25	2.0	[0.5, 1.0]
$\sigma_a \times 100$	$\mathbb{R}^+$	Gamma	0.25	2.0	[0.5, 1.0]

Table C.9: Posterior Distributions under Alternative Priors for $\tilde{\theta}$

	Uniform $[0, 10^6]$				Uniform $[0, 10^{18}]$			
	NRE		NRE_0		NRE		NRE_0	
Parameters	Mean	[5%, 95%]	Mean	[5%, 95%]	Mean	[5%, 95%]	Mean	[5%, 95%]
$\tilde{\theta}$	1801	[905, 3113]	1591	[825, 2685]	1789	[898, 3101]	1588	[822, 2686]
δ	0.10	[0.02, 0.22]	–	–	0.10	[0.02, 0.21]	–	–
ω	8.18	[6.17, 11.0]	8.13	[6.00, 11.2]	8.17	[6.14, 11.0]	8.07	[5.98, 11.1]
φ	1.96	[0.48, 4.88]	1.29	[0.30, 3.15]	1.87	[0.47, 4.52]	1.29	[0.30, 3.19]
ρ_u	0.32	[0.09, 0.58]	0.38	[0.15, 0.62]	0.32	[0.09, 0.57]	0.37	[0.15, 0.62]
σ_u	0.029	[0.016, 0.055]	0.028	[0.016, 0.052]	0.029	[0.016, 0.053]	0.028	[0.016, 0.052]
ρ_a	0.88	[0.77, 0.96]	0.88	[0.77, 0.96]	0.88	[0.77, 0.96]	0.88	[0.77, 0.96]
σ_a	0.031	[0.018, 0.048]	0.027	[0.015, 0.044]	0.031	[0.017, 0.049]	0.027	[0.015, 0.043]

Note. The posterior mean, median, 5th percentile, and 95th percentile were computed over one million draws from the MCMC chain.

Figure C.6: Data and Model Predictions on Monetary Policy Rates: by Sample Periods

(a) 1Q 1996–4Q 2007 (b) 1Q 1997–4Q 2007

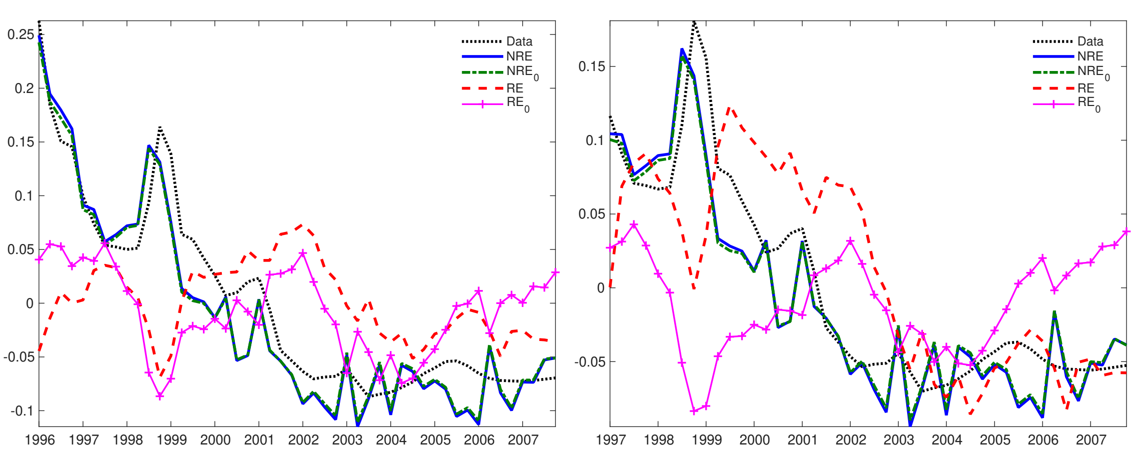


Table C.10: Posterior Distributions by Sample Period

(a) 1Q 1996–4Q 2007

	NRE		RE		NRE_0		RE_0	
Parameters	Mean	[5%, 95%]	Mean	[5%, 95%]	Mean	[5%, 95%]	Mean	[5%, 95%]
$\tilde{\theta}$	1035	[544, 1885]	–	–	959	[508, 1728]	–	–
δ	0.06	[0.01, 0.16]	0.54	[0.21, 0.87]	–	–	–	–
ω	13.7	[9.81, 18.9]	7.82	[2.12, 11.0]	13.3	[9.52, 18.4]	8.92	[7.18, 11.4]
φ	1.80	[0.68, 4.00]	0.56	[0.07, 4.00]	1.31	[0.49, 2.76]	0.14	[0.03, 0.38]
ρ_u	0.60	[0.43, 0.73]	0.86	[0.19, 0.95]	0.62	[0.45, 0.74]	0.94	[0.88, 0.97]
σ_u	0.037	[0.019, 0.069]	0.006	[0.003, 0.010]	0.033	[0.018, 0.062]	0.006	[0.004, 0.009]
ρ_a	0.96	[0.92, 0.98]	0.87	[0.72, 0.95]	0.96	[0.92, 0.98]	0.81	[0.68, 0.92]
σ_a	0.054	[0.034, 0.081]	0.040	[0.028, 0.065]	0.048	[0.030, 0.073]	0.035	[0.027, 0.048]

(b) 1Q 1997–4Q 2007

	NRE		RE		NRE_0		RE_0	
Parameters	Mean	[5%, 95%]	Mean	[5%, 95%]	Mean	[5%, 95%]	Mean	[5%, 95%]
$\tilde{\theta}$	1868	[961, 3633]	–	–	1685	[875, 3293]	–	–
δ	0.08	[0.02, 0.21]	0.73	[0.43, 0.87]	–	–	–	–
ω	11.3	[8.17, 15.7]	2.84	[0.80, 7.40]	10.8	[7.87, 15.1]	8.21	[6.02, 11.4]
φ	2.29	[0.83, 5.55]	2.06	[0.29, 7.16]	1.41	[0.50, 3.34]	0.26	[0.05, 0.75]
ρ_u	0.48	[0.26, 0.65]	0.38	[0.07, 0.88]	0.49	[0.28, 0.66]	0.91	[0.83, 0.96]
σ_u	0.035	[0.019, 0.067]	0.009	[0.006, 0.014]	0.030	[0.017, 0.058]	0.007	[0.005, 0.012]
ρ_a	0.93	[0.84, 0.97]	0.90	[0.81, 0.96]	0.93	[0.85, 0.98]	0.84	[0.70, 0.94]
σ_a	0.044	[0.028, 0.066]	0.034	[0.024, 0.054]	0.039	[0.024, 0.059]	0.038	[0.028, 0.057]

Note. The posterior mean, median, 5th percentile, and 95th percentile were computed over one million draws from the MCMC chain.

Table C.11: Posterior Distributions: Canada

	NRE		RE		NRE_0		RE_0	
Parameters	Mean	[5%, 95%]	Mean	[5%, 95%]	Mean	[5%, 95%]	Mean	[5%, 95%]
$\tilde{\theta}$	46.8	[14.4, 94.3]	–	–	35.7	[10.4, 70.4]	–	–
δ	0.05	[0.01, 0.12]	0.07	[0.016, 0.21]	–	–	–	–
ω	4.20	[3.38, 5.12]	3.36	[2.86, 3.81]	3.90	[3.13, 4.83]	3.45	[2.89, 3.98]
φ	2.29	[0.77, 5.23]	1.89	[0.51, 4.82]	1.47	[0.44, 3.44]	1.49	[0.45, 3.53]
ρ_u	0.92	[0.86, 0.96]	0.96	[0.91, 0.98]	0.92	[0.86, 0.96]	0.94	[0.89, 0.98]
σ_u	0.025	[0.014, 0.045]	0.019	[0.011, 0.034]	0.021	[0.012, 0.038]	0.020	[0.012, 0.036]
ρ_a	0.90	[0.80, 0.96]	0.94	[0.88, 0.97]	0.89	[0.79, 0.95]	0.92	[0.86, 0.97]
σ_a	0.013	[0.009, 0.017]	0.012	[0.008, 0.015]	0.011	[0.008, 0.016]	0.011	[0.008, 0.014]

Note. The posterior mean, median, 5th percentile, and 95th percentile were computed over one million draws from the MCMC chain. The sample period for the observables is 2Q 1991–4Q 2007.

Figure C.7: Data and Model Predictions on Monetary Policy Rates: Canada

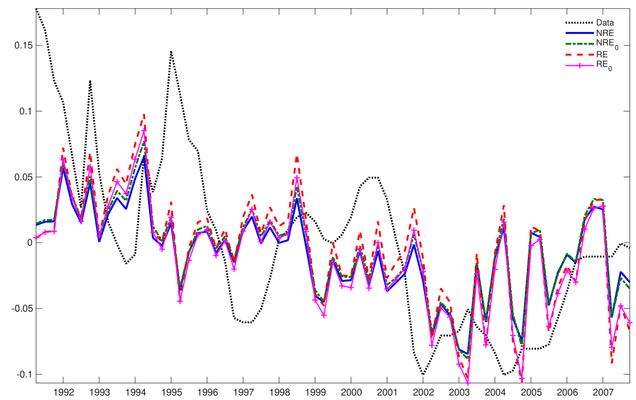
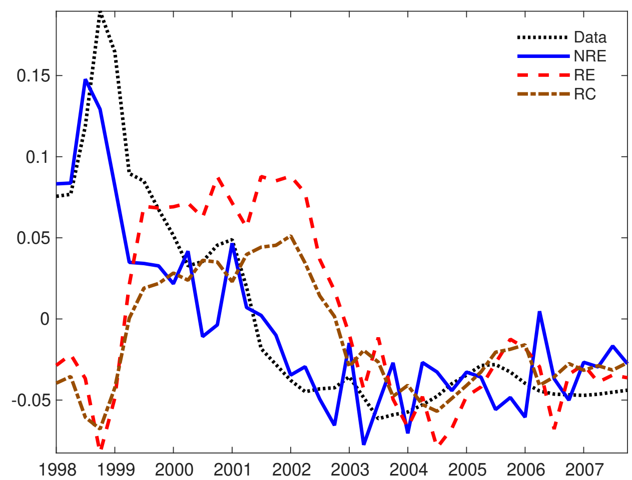


Figure C.8: Model Predictions of Monetary Policy Rates in Mexico: RE Counterfactual (RC)



Note. The brown dash–dot line depicts the model-implied monetary policy rate under the RE counterfactual ("RC"), which uses the estimated NRE model parameters while setting $\tilde{\theta} = 0$. The actual data on the monetary policy rate ("Data") and the predictions from the NRE and RE models ("NRE" and "RE," respectively) are the same as those shown in Figure 3 in Section 3.