INTERNATIONAL MONETARY FUND

How Costly Will Reining in Inflation be?

It Depends on How Rational We Are

Jorge Alvarez and Allan Gloe Dizioli

WP/23/21

2023
FEB

WORKING PAPER

WP/23/21

IMF Working Paper
Research Department

How Costly Will Reining in Inflation Be? It Depends on How Rational We Are

Prepared by Jorge Alvarez and Allan Gloe Dizioli

Authorized for distribution by Benjamin Hunt
February 2023

ABSTRACT: We document that past highly inflationary episodes are often characterized by a steeper inflation-slack relationship. We show that model-generated data from a standard small Dynamic Stochastic General Equilibrium (DSGE) model can replicate this empirical finding when estimated with different expectation formation processes. When inflation becomes de-anchored and expectations drift, we can observe high inflation even with a mildly positive output gap in response to cost-push shocks. The results imply that we should not use an unconditioned (not controlling for expectations change) Phillips curve estimated in normal times to predict the cost of reining in inflation. Our optimal policy exercises prescribe early monetary policy tightening and then easing in the context of positive output gaps and inflation far above the central bank target.

RECOMMENDED CITATION: Alvarez, Jorge, and Allan Dizioli. 2023. "How Costly Will Reining in Inflation be? It Depends on How Rational We Are." IMF Working Paper 22/21, International Monetary Fund, Washington, DC.

JEL Classification Numbers:	E2, E30, E52, E37, J6
Keywords:	DSGE; inflation dynamics; optimal monetary policy; forecasting and simulation; bayesian estimation
Author's E-Mail Address:	adizioli@imf.org, jalvarez@imf.org

WORKING PAPERS

How Costly Will Reining in Inflation Be?

It Depends on How Rational We Are

Prepared by Alvarez, Jorge, and Allan Gloe Dizioli[1]

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[1] We would like to thank John Bluedorn, Daniel Leigh, Jesper Linde, Roland Meeks, Rafael Portillo, and Holly Wang for their helpful guidance and comments.

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I. INTRODUCTION

After a decade of low inflation following the Great Financial Crisis, there was a sense that relatively stable inflation and well-anchored inflation expectations ("the great moderation") would be the new normal in most countries. The pandemic shock and its repercussions accompanied a surge in global inflation not seen since the 1980s. As inflation spiked and remained high for several months, inflation expectations also started to drift higher. Both empirical and structural models that embed the low Phillips curve slope observed in recent times suggest that the costs of bringing down inflation might be large.

However, these models have been challenged by pandemic developments. Forecasts that used pre-pandemic Phillips curve estimates, for instance, predicted a much smaller rise in core inflation than has in fact materialized. This is suggestive of both a steeper Phillips curve and falls in potential output (see Gopinath (2022)). Harding, Linde, and Trabandt (2022) argue that a nonlinear Phillips curve can rationalize this steepening relationship, implying a more severe trade-off between inflation and output stabilization when inflation is high.

We propose a different mechanism that can rationalize steepening inflation-slack relationships during highly inflationary periods: shifts in expectation formation processes. More concretely, we study how inflation expectations formation mechanisms that can be triggered by highly inflationary episodes can result in steeper inflation-slack curves, with important implications for monetary policy.

We explore the role of expectations formation using a canonical economic model of firm price setting and labor markets under different expectation formation processes. We follow a growing literature trying to better model expectations formation to match the inertia of macroeconomic variables, deviating from the standard rational expectations (RE) assumption. In particular, economic agents are assumed to be oblivious to the underlying model driving all the macroeconomic variables. Instead, they form expectations based on a simple statistical model with a smaller set of observed variables rather than the full information set. These agents update their beliefs about the underlying economic relations when new data becomes available using an adaptive learning (AL) approach.

The paper proceeds in two stages. First, we present cross-country stylized facts about inflation, inflation expectations and inflation-unemployment relationships. Across countries, we find that the more anchored inflation is, the flatter the relationship between inflation and unemployment gap tends to be. That is, small inflation movements occur along relatively large movements in unemployment gaps. We then narrow our focus into specific highly inflationary episodes in a subset of economies. We show that the slope of inflation-unemployment gap relationship can be steeper during highly inflationary episodes – during which inflation expectations can become de-anchored – than during "normal times". That is, large inflationary fluctuations can occur during these times, without large changes in unemployment gaps. This has important implications for the current inflationary environment. Costs of reigning in inflation could be lower than implied by empirical relationships estimated during periods of low inflation, especially if a central bank manages to re-anchor expectations.

We also document that this point may not hold during inflationary episodes caused by external shocks in emerging markets. In particular, the change in the slope of the inflation-unemployment gap relationship during an inflationary episode is different when large external shocks are at play in a small open economy setting. In this case, following a large currency depreciation, the relationship can be flatter during an inflationary episode. This would imply a steeper cost of bringing down inflation in such situations.

Second, we model an advanced and an emerging economy under different expectation formation assumptions. There are two key results of our modelling analysis. In the context of a positive output gap and rising inflation, we show that the central bank's optimal monetary policy implies an interest rate path that is steeper under AL expectations than under RE. This is because the latter expectations have a credible anchor and a self-enforcing tendency. Expectations in the AL model are always more inertial and take longer to go back to target once they start drifting away from the target. More aggressive policy actions are therefore needed to anchor inflation and inflation expectations. An additional key result is about the cost of bringing inflation down in that setting. The model is able to qualitatively replicate the observed inflation-unemployment relationships in simulated data. The results imply a more benign inflation-slack trade-off in highly inflationary episodes driven by cost-push shocks and adaptive learning expectations.

Our paper also discusses the implication for optimal monetary policy (one that minimizes a welfare loss function) when private agents form their expectations based on the AL model. When inflationary shocks are present and the output gap is positive, it is optimal for monetary policy to respond sooner, more strongly and then ease. The goal is to avoid high inflation becoming entrenched under AL. In such cases where expectations are more backward-looking, more aggressive policy actions are needed to anchor expectations.

The rest of the paper is organized as follows. Section 2 discusses the related literature, Section 3 presents empirical stylized facts, Section 4 introduces the model focusing on the expectation formation mechanism, and Section 5 discusses data and estimation. Section 6 presents the model results, conducts conditional forecasting scenarios, discusses optimal monetary policy, and expands the model to an open economy setting. Section 7 concludes the paper.

II. Literature Review

Our modelling of adaptive learning expectations and estimation strategy mostly builds on the work by Slobodyan and Wouters (2012) and Slobodyan and Wouters (2012b). We extend their work in three dimensions. First, we use state-dependent conditional forecasting for our scenario analysis. Second, we apply optimal-control monetary policy on the model and compare the policy responses from an estimated reaction function. Third, we estimate a different benchmark model to replicate stylized facts on inflation-unemployment relationships.

The formation of agent's expectations in the model situates our paper in the adaptive learning literature first advocated by Evans and Honkapohja (2001). The main idea from the learning literature is to replace the expected terms in intertemporal optimal conditions with an ad-hoc forecasting model that agents use to form expectations and update in every period using observed data, see also (Cho and Kasa (2015)) and (Eusepi and others (2019)). Our contribution to this literature is two-fold: first we discuss the introduction of optimal monetary policy in a model where expectations could de-anchor and point out the mechanism through which monetary policy can affect expectations. Second, we estimate the model for an emerging economy (Mexico) to compare how learning mechanisms differ in this economy type and what are the implications for macroeconomic dynamics and monetary policy.

From the vast literature that covers the impact of central bank credibility on inflation, our paper is most closely related to Erceg and Levin (2003). They develop a model in which agents learn about the central bank's inflation target by observing policy decisions and show that inflation and output responses can be highly persistent. We also show that inflation becomes more inertial with adaptive learning and less anchored inflation expectations.

The illustration of how an adaptive learning model can generate steeper inflation-slack relationships during highly inflationary periods provides an alternative mechanism to research rationalizing steeper inflation-slack relationships using nonlinear Philips curves as in Harding, Linde, and Trabandt (2022). Moreover, the result on adaptive learning models outperforming the standard rational expectations model for both the closed economy model (US) and the open economy (Mexico) is similar to what Milani (2007) and Eusepi, Giannoni, and Preston (2018) show for the US. Unlike these papers, we estimate the model for an emerging economy and consider time varying beliefs. In addition to better model performance, the adaptive learning model implies that forecast errors are correlated with forecast revisions, a feature of expectations documented empirically by Coibion and Gorodnichenko (2015).

We find that inflation expectations are less well-anchored in Mexico than in the US, which warrants more aggressive monetary policy reactions in response to shocks. This is consistent with the finding that advanced economies tend to have better anchoring of long-term inflation expectations than emerging market economies (IMF (2016), Ha, Kose, and Ohnsorge (2019), Kamber, Mohanty, and Morley (2020), Bems and others (2021), among others). If, as our empirical results show, inflation expectations are more 'adaptive' in certain economies, it raises the question of whether recent global factors that have put upward pressure on inflation (such as elevated commodity price and supply-chain shortages) could lead to a sustained period of high inflation levels and inflation variability in those places going forward.

Finally, our result that optimal monetary policy should respond more to inflation under adaptive learning when inflation is away from target has similarities with Orphanides and Williams (2004). They find that, with non-rational expectations, monetary policy should respond more to inflation in order to subdue volatile expectations. However, when inflation expectations are well-anchored, monetary policy should not respond as much – a result that has similarities with Eusepi, Giannoni, and Preston (2018). They find that monetary policy cannot and should not respond strongly to inflation fluctuations.

III. STYLIZED FACTS

This section documents empirical observations about the behavior of inflation across countries and its relationship with economic slack. For this, an unbalanced cross-country database of wages, inflation, and inflation expectations are used, covering 31 advanced economies and 14 emerging economies going back to the 1960s.[1] It first documents the cross-country corre-

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[1] This database is described in detail in the online annex of IMF (2022). Advanced Economies include AUS, AUT, BEL, CAN, CHE, CZE, DEU, DNK, ESP, EST, FIN, FRA, GBR, GRC, HKG, IRL, ITA, JPN, KOR, LTU, LVA, NLD, NOR, NZL, PRT, SGP, SVK, SVN, SWE, TWN, and USA (ISO codes). Emerging Market Economies include ARG, BGR, BRA, COL, HUN, MEX, PER, PHL, POL, ROU, RUS, THA, TUR, and UKR.

lation between broad measures of inflation-anchoring and inflationary responsiveness to slack conditions. It then looks at how this responsiveness changes within countries during highly inflationary episodes.

Cross-country relationship between inflation anchoring and responsiveness to economic slack

We document the cross-country correlation between two main objects. The first is the degree to which inflation expectations respond to past inflation outcomes. This can serve as a proxy indicator of the degree of inflation anchoring, as we would expect inflation expectations to be relatively unresponsive to inflation surprises. Motivated by our expectations modelling strategy, the measure used is constructed by regressing 12-month ahead inflation expectations[2] on realized inflation in the previous two quarters.[3] The coefficient on the previous quarter is estimated for each country in the sample, with a greater magnitude indicating a greater degree of inflation pass-through to expectations. As the availability of inflation expectations measures is limited, particularly in the years before the mid-1990s, we also conduct the same estimation using current inflation as a dependent variable. By regressing current inflation on two inflation lags, we obtain a more widely available measure of inflation persistence that is also related to the inflation anchoring concept. In both approaches, decade fixed effects are included to control for long-running differences in inflation levels.

The second object of interest is the relationship between realized inflation and the unemployment gap. The latter is estimated for each country by regressing year-on-year inflation on a simple unemployment gap constructed using an HP filter with a parameter of 1,600.

Figure 1a plots the relationship between the inflation-unemployment gap slope on the x-axis and the anchoring measures on the y-axis. This shows that countries with a higher inflation pass-through to expectations exhibit, on average, more responsiveness of inflation to economic slack. Similarly, Figure 1b shows that countries with more persistent inflation are also associated with a steeper inflation-unemployment gap relationship.

The steeper inflation-slack trade-off during highly inflationary periods

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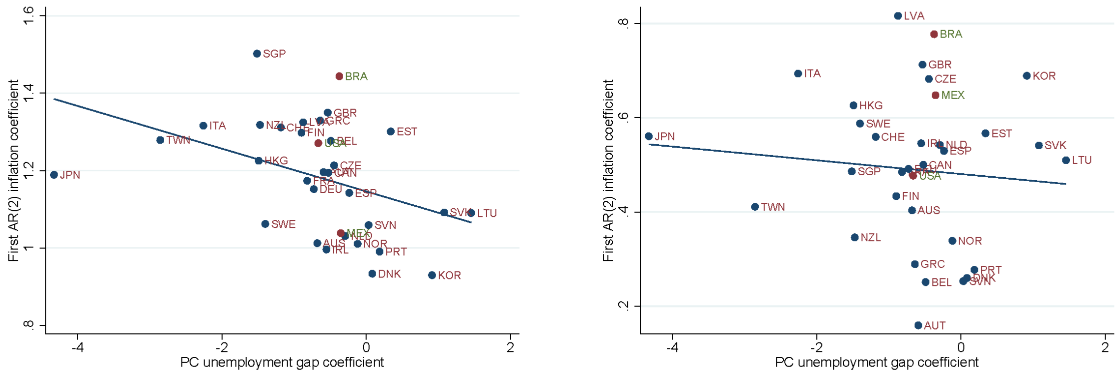
[2] Inflation expectations are sourced from Consensus Forecasts (CF). Since monthly CF surveys provide forecasts with expected current- and next-year inflation (i.e., fixed-event forecasts), the twelve-month ahead (fixed-horizon) inflation expectations are constructed as the weighted sum of monthly vintages, following the standard approach in the literature (see methodological appendix in Buono and Formai (2018) for a discussion).

[3] The specification $E_t(\ pi_{t+4}) = \gamma_1 \pi_{t-1} + \gamma_2 \pi_{t-2} + \phi_d + \epsilon_{it}$ is estimated country by country for the sample. We focus on γ_1 as the pass-through measure.

Figure 1. Relationship between inflation pass-through and the inflation-unemployment gap slope



(a) Pass-through to inflation expectations

(b) Pass-through to current inflation

Notes: Left chart shows in the y-axis coefficients on lagged inflation from country-specific regressions with 12-month ahead inflation expectations as a dependent variable and two inflation lags as independent variables along with decade fixed effects. The right chart shows a similar measure using current inflation instead of inflation as a dependent variable. The x-axis in both charts depicts coefficients on the unemployment gap from regressions with inflation as a dependent variable and decade fixed effects. Cross-country fitted linear relationship depicted by the blue line. Data labels refer to ISO country codes.

The relationships above can be partly driven by differences in cross-country variation in inflationary regimes and institutional settings. Indeed, the literature has highlighted that the relationship between slack and inflation can change over time due in part to these factors. We address these concerns by focusing on within-country variation, highlighting episodes where de-anchoring is more likely.

Specifically, we explore how the slope of the inflation-unemployment curve is empirically different during highly inflationary periods. We first identify highly inflationary episodes within each economy using the following simple algorithm:

1. We first identify quarters where inflation deviations from the five-year moving average correspond to a z-score above 1.96 of deviations observed during the preceding five years.
2. Among consecutive inflationary quarters of inflation, the highest inflation quarter is identified as the local inflation peak.

3. When two or more peaks are identified within 8-quarters, the highest inflation quarter is taken as the sole peak for that episode.
4. We define a highly inflationary episode as covering 8-quarters before and after a peak.

Figure 2 shows the resulting classification of highly inflationary episodes for the case of the United States.[4] The inflationary peaks identified are 1966Q4, 1970Q1, 1974Q4, 1980Q2, 2008Q3, and 2021Q4, each marking a period of substantial inflation volatility.

Figure 3 illustrates the US relationship between inflation and the unemployment gap observed, both within (blue dots) and outside (red dots) of highly inflationary episodes. The left chart illustrates this relationship in levels. The right chart illustrates both inflation and the unemployment gap as deviations from the mean observed during highly inflationary episodes (for the blue dots) and the deviation from the decade mean for non-inflationary episodes observations (for the red dots). As expected, we observe a negative relationship between inflation and the unemployment gap across all cases, but the slope differs depending on the episode type. The unconditioned slope linking inflation to the unemployment gap appears steeper during highly inflationary episodes. This steepening does not appear to be unique to the US, as the pattern is similar when looking at highly-inflationary episodes across the post-2000 sample of advanced economies (Figure 4a).

The steepening pattern does not hold when looking at emerging market economies (Figure 4b), where inflationary episodes show more heterogeneity. This heterogeneity is evident both in the larger range of peak inflation observed, as well as the sources of such inflationary episodes. In particular, inflationary episodes sometimes (but not always) originate in external shocks that coincide with large foreign exchange rate depreciations. The contrast of inflationary cases in Brazil and Mexico in the 2000s provide an illustration of such heterogeneity. In Mexico, gasoline price liberalization produced a cost-push shock that elevated prices in 2017. Then, as shown in Figure 6a, the inflation-unemployment behavior produced a steeper relationship relative to non-highly inflationary periods. In contrast, inflationary episodes in Brazil during that period, shown in Figures 5b and 6b, where accompanied by large depreciations of the currency stemming from idiosyncratic factors. The first one with a peak in 2003Q2 coincided with substantial political change leading to currency sell-off (see Barbosa-Filho (2008) for a more in-depth discussion of the episode). The second one, with a peak in 2015Q4, was associated with a commodity price shock interacting with domestic policy changes. The nature of

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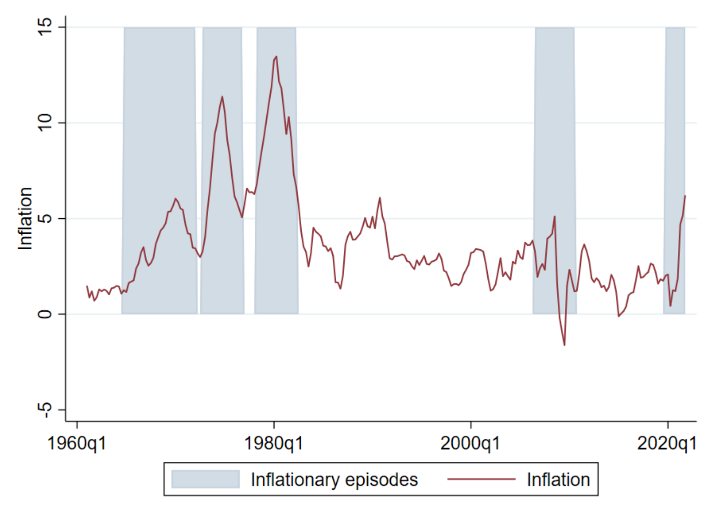
[4] United States data from 1960.

these shocks produced volatility that broke the negatively sloped inflation-unemployment gap curve observed in other cases. The curve looks flatter during highly inflationary episodes in post-2000 Brazil.

In the next sections, we describe a model that can replicate these stylized facts. In particular, our model shows that inflationary episodes caused by cost-push shocks are associated with a steeper inflation-slack relationship if expectations are less-anchored. Moreover, a standard small open-economy model can show that the opposite can be true if the inflationary episode is generated by exchange rate shocks.

Figure 2. Highly inflationary cases: United States

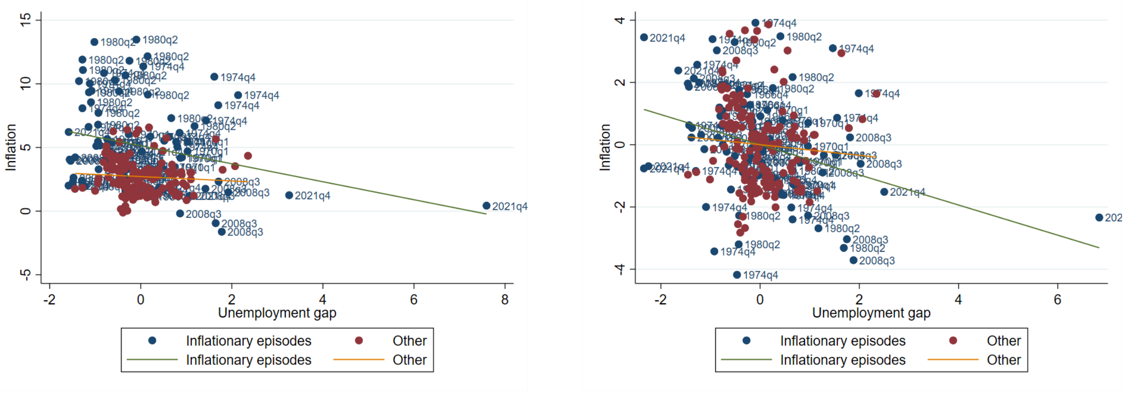


Notes: Quarters belonging to a highly-inflationary episode are shown in shaded blue.

IV. Model environment

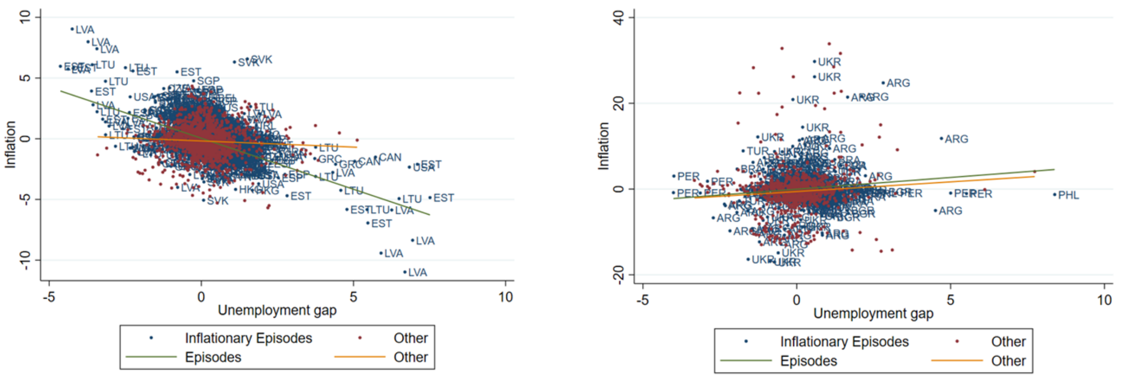
Our model is based on Galí, Smets, and Wouters (2012). The main feature of this model is the existence of a union that decides both the wage and household labor supply decisions. In

Figure 3. Highly inflationary cases vs other: United States


(a) Raw numbers **(b)** Deviations from episode mean

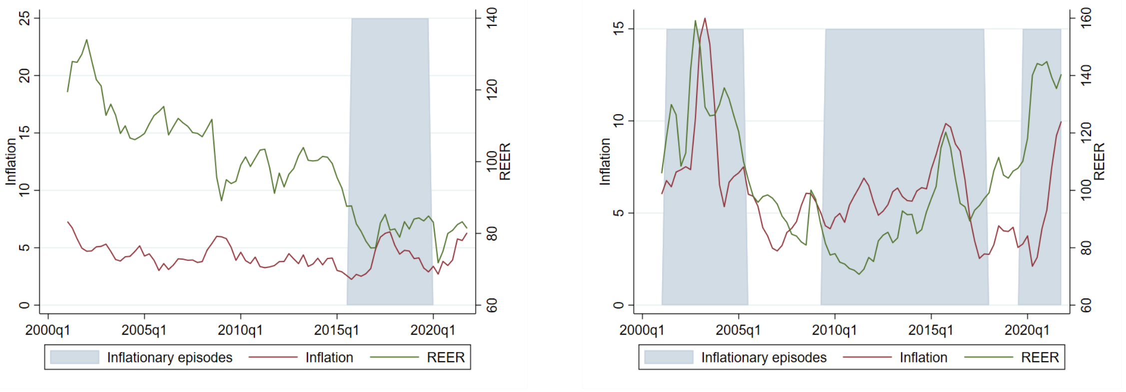
Notes: Quarters belonging to a highly-inflationary episode (eight quarters before and after an inflation peak) are shown in blue. All other quarters are shown in red. US sample from 1960 to 2021. Date labels correspond to date of inflation peak of an episode. Left chart shows the absolute inflation and unemployment gap observed in a quarter. Right chart shows the same in deviations from the episode mean (for blue dots) or decade means (for red dots). Linear fitted lines shown.

Figure 4. Highly inflationary cases: Advanced Economies vs Emerging Markets


(a) Advanced Economies **(b)** Emerging Market Economies

Notes: Quarters belonging to a highly-inflationary episode (eight quarters before and after an inflation peak) are shown in blue. All other quarters are shown in red. Sample covers 2000 to 2021. Inflation and unemployment gaps shown as deviations from the episode mean (for blue dots) or decade means (for red dots). Linear fitted lines shown. Advanced Economies include AUS, AUT, BEL, CAN, CHE, CZE, DEU, DNK, ESP, EST, FIN, FRA, GBR, GRC, HKG, IRL, ITA, JPN, KOR, LTU, LVA, NLD, NOR, NZL, PRT, SGP, SVK, SVN, SWE, TWN, and USA (ISO codes). Emerging Market Economies include ARG, BGR, BRA, COL, HUN, MEX, PER, PHL, POL, ROU, RUS, THA, TUR, and UKR.

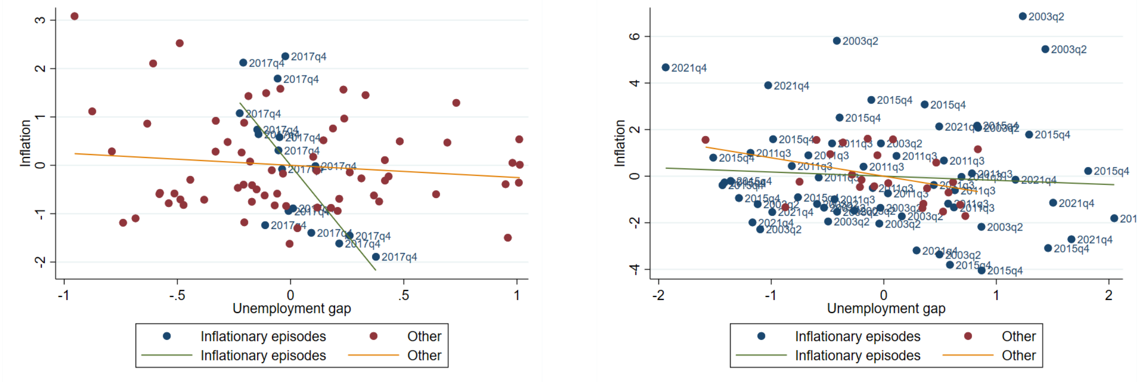
Figure 5. Highly inflationary cases: Mexico and Brazil



(a) Mexico **(b)** Brazil

Notes: Quarters belonging to a highly-inflationary episode are shown in shaded blue. REER refers to the real exchange rate. For Mexico, Great Financial Crisis episode with a peak in 2008Q4 is excluded.

Figure 6. Highly inflationary cases vs other: Mexico and Brazil



(a) Mexico **(b)** Brazil

Notes: Quarters belonging to a highly-inflationary episode (eight quarters before and after an inflation peak) are shown in blue. All other quarters are shown in red. Period from 1997 to 2021. Date labels correspond to date of inflation peak of an episode. Deviations from the episode mean (for blue dots) or decade means (for red dots) shown. Fitted linear relationships shown.

particular, each household has a simple consumption/saving decision to make based on the following problem:

$$\max_{C_t, B_{t+1}} E_0 \sum_{t=0}^{\infty} \beta^t \left[log(C_t) - \int_0^1 \frac{l_{t,j}^{1+\vartheta}}{1+\vartheta} dj \right], \tag{1}$$

subject to the budget constraint,

$$P_t C_t + B_{t+1} \leq B_t R_{t-1} + \int_0^1 W_{t,j} l_{t,j} dj + \pi_t, \qquad \text{for all } t \tag{2}$$

where P_t, is the price of consumption, B_t is savings, R_t is the real gross interest rates, $W_{t,j}$ for labor type $j \in (0,1)$ is the wage level chosen by the union, $l_{t,j}$ is the value implied by the demand curve for labor and π_t are profits net of lump sum government taxes. After linearizing the Euler equation around the efficient steady state, we obtain the familiar IS curve to be later estimated:

$$\hat{y}_t = E_t[\hat{y}_{t+1} - (\hat{i}_t - \hat{\pi}_{t+1})] + shk_t^y, \tag{3}$$

where $\hat{x}$ is the output gap, and $\hat{i}_t$ and $\hat{\pi}_{t+1}$ are the interest rate and price deviations from steady state, respectively. The shock term, shk^y follows an $AR(1)$ process:

$$shk_t^y = \rho_y shk_{t+1}^y + \varepsilon_t^y, \tag{4}$$

The labor market is operated by perfectly competitive labor contractors that choose N_t and $l_{t,j}$ to maximize profits:

$$\max_{N_t, l_{t,j}} W_t N_t - \int_0^1 W_{t,j} l_{t,j} dj, \quad \text{subject to} \quad N_t = \left[\int_0^1 l_{t,j}^{\frac{\zeta-1}{\zeta}} dj \right]^{\frac{\zeta}{\zeta-1}}, \tag{5}$$

with labor demand:

$$l_{t,j} = N_t \left(\frac{W_t}{W_{t,j}} \right)^{\zeta}, \tag{6}$$

Given this labor demand, each union of type j negotiates wages to maximize the objectives of its members. In order to capture fluctuation in unemployment, we assume Calvo-style frictions to produce wage stickiness. Thus, we assume that there is a fraction $1 - \tau$ of firms that can optimize wages in the current period. For the non-optimizing unions, we assume that they set $W_{t,j} = W_{t-1,j}$. Meanwhile, the optimizing unions set $W_{t,j}$ to maximize the present value of the members' objectives:

$$\max_{W_t} E_t \sum_{i=0}^{\infty} (\beta\tau)^i \left[v_{t+i} W_t l_{t+i}^t - \frac{{l_{t+i}^t}^{1+\vartheta}}{1+\vartheta} \right], \qquad \text{subject to} \qquad l_t^{t+i} = N_{t+i} \left(\frac{W_{t+i}}{W_t} \right)^{\zeta}, \tag{7}$$

In this notation, l_t^{t+i} is employment at time $t+i$ supplied by workers with the wage set in time t. v_{t+i} is household marginal utility of money at time $t+i$.

The solution to this problem is the wage Phillips curve that is used in the simulations we use in the next section.

$$\pi_{w,t} = \kappa_1 y_t - \kappa_2 \hat{\bar{w}}_t + \beta \pi_{w,t+1} + \varepsilon_{pi_w,t}, \tag{8}$$

where $\pi_{w,t}$ is nominal wage inflation, that is $\pi_{w,t} = \hat{\bar{w}}_t - \widehat{\bar{w}_{t-1}} + \hat{\pi}_t$. Real wages are measured as deviations from technological growth, that is $\bar{w} = w_t - a_t$, and y_t is output gap.

On the production side, we also assume Calvo price-setting frictions. The final good firms are perfectly competitive and maximize profits:

$$\max_{Y_t} P_t Y_t - \int_0^1 P_{i,t} Y_{i,t} dj, \qquad \text{subject to} \qquad Y_t = \left[\int_0^1 Y_{i,t}^{\frac{\epsilon-1}{\epsilon}} dj \right]^{\frac{\epsilon}{\epsilon-1}}. \tag{9}$$

The solution to this problem delivers the familiar demand curve for the i^{th} intermediate good monopolist:

$$Y_{i,t} = Y_t \left(\frac{P_t}{P_{i,t}} \right)^{\epsilon}. \tag{10}$$

In this simple model, the production function of the intermediate firm is just $Y_{i,t} = N_{i,t}$. Finally, we assume that at every period there is a fraction of firms $1 - \theta$ that can re-optimize their prices while a fraction θ index their prices to past inflation $P_{i,t} = P_{i,t-1}$. The optimizing intermediate good firms then choose a price to solve the following problem:

$$\max_{P_t} E_t \sum_{j=0}^{\infty} (\beta\theta)^j \left[v_{t+j} P_t Y_{i,t+j} - P_{t+j} Y_{i,t+j} s_{t+j} \right], \qquad \text{subject to} \quad Y_{i,t} = Y_t \left(\frac{P_t}{P_{i,t}} \right)^{\epsilon}, \tag{11}$$

After log-linearizing the solution to this problem around the steady state, one obtains the NK Phillips curve:

$$\pi_t = \kappa_p \hat{w}_t + \beta \pi_{t+1} + \beta_l \pi_{t-1} + \varepsilon_{pi,t}, \tag{12}$$

We close the model with a standard monetary policy reaction function that features interest rate smoothing and estimated responses to inflation and output deviations:

$$\hat{i}_t = \rho \widehat{i_{t-1}} + (1-\rho)[\rho_\pi \widehat{\pi_{t+1}} + \rho_y y_t] + \varepsilon_{i,t}, \tag{13}$$

where $\hat{i}_t$ is the nominal 1-year ahead policy rate as deviation from the neutral rate and ε_i are monetary policy shocks.

A. Expectation formation processes

This section zooms in on the role that expectation formation processes play in shaping macroeconomic dynamics. The strategy is to estimate the model described in IV under different expectation formation processes.

Monetary policy in the RE version of similar models has been studied extensively, for example in Svensson (1999) and Clarida, Gali, and Gertler (1999). This section compares the model dynamics under the standard RE formation process with the one implied by limited rationality models. The rational expectations model assumes that households use all the information available in the model, including all parameters and variables, to form their expectations. In other words, rational expectations forecasts are the conditional expectation under the true distribution expectations $E_t[y_{t+1}] = y_{t+1}$. The limited rationality model we use is the adaptive learning expectations as developed in Slobodyan and Wouters (2012b) and Slobodyan and Wouters (2012). In this model, households use and update statistical models with a smaller set of variables at every period. Households learn from mistakes and use their forecasts errors to update parameter values with a Kalman filter.

Households use a limited information set, X_j, and form their expectations linearly with:

$$y^j_{t+1} = X^j_t \beta^j_t, \tag{14}$$

for all the variables j that appear with leads in our equilibrium equations. In the terminology of the learning literature, this linear equation is called the Perceived Law of Motion (PLM). While any kind of linear model would work in this framework, the one with the best out-of-sample forecast performance is a simple univariate $AR(2)$ model. That is, the information set X_j contains a constant and two lags of y^j_{t+1}. With this model, the leading variables of the model can be cast in a seemingly unrelated regression equations (SURE) format:

$$\begin{pmatrix} Y^1_t \\ Y^2_t \\ Y^3_t \\ \vdots \\ Y^m_t \end{pmatrix} = \begin{pmatrix} X^1_t & 0 & \dots & 0 \\ 0 & X^2_t & \dots & 0 \\ 0 & 0 & X^3_t & 0 \\ \vdots & \vdots & \vdots & \vdots \\ 0 & 0 & 0 & X^m_t \end{pmatrix} \begin{pmatrix} \beta^1_t \\ \beta^2_t \\ \beta^3_t \\ \vdots \\ \beta^m_t \end{pmatrix} + \begin{pmatrix} \eta^1_t \\ \eta^2_t \\ \eta^3_t \\ \vdots \\ \eta^m_t \end{pmatrix} \tag{15}$$

Where η are the errors with a non-diagonal variance-covariance matrix Σ. In every period, the learning update to the B vector (the stacked vector containing the β for all models) is done with a Kalman filter mechanism:

$$B_{t|t} = B_{t|t-1} + P_{t|t-1}X_{t-1}\left[\Sigma + X'_{t-1}P_{t|t-1}X_{t-1}\right]^{-1}\left(y^j_{t+1} - X^j_t B_{t|t-1}\right), \tag{16}$$

with the transition equation

$$B_{t+1|t} = \bar{B} + F\left(B_{t|t} - \bar{B}\right), \tag{17}$$

where F is a diagonal matrix with $\rho \leq 1$ on the main diagonal. Finally, the corresponding covariance matrix and its transition are given by:

$$P_{t|t} = P_{t|t-1} - P_{t|t-1}X_{t-1}\left[\Sigma + X'_{t-1}P_{t|t-1}X_{t-1}\right]^{-1}\left(X'_{t-1}P_{t|t-1}\right), \tag{18}$$

and

$$P_{t+1|t} = FP_{t|t}F' + V. \tag{19}$$

Once the coefficients for the believes are updated, $B_{t|t-1}$, the households form their expectations for the lead variables as in (14). If we replace these lead variables in the model solution, we obtain a time-dependent backward-looking representation of the model:

$$\begin{bmatrix} y_t \\ \omega_t \end{bmatrix} = \alpha_t + T_t \begin{bmatrix} y_{t-1} \\ \omega_{t-1} \end{bmatrix} + R_t\epsilon_t, \tag{20}$$

where y_t includes the model variables and ω_t are the shocks.

Differently from the rational expectations solution, the matrices α_t, T_t and R_t are time dependent. They depend on the parameters that define policy function and on the forecast model summarized by the vector B_t. The system described in (20) is the Actual Law of Motion (ALM) of the model.

V. Data and Model Estimation

The model described in Section 3 is estimated with quarterly macroeconomic data from 2008Q1 to 2019Q4 for Mexico and the US. The set of variables included in the estimation are the output gap, the real wage gap, annualized quarterly price inflation deviation from target[5], the real

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[5] For the US, we use the core personal consumption expenditures (PCE). For Mexico, we use core CPI.

exchange rate gap and the policy rate. The specific variables used are described in the appendix.

As previously documented in Howard, Rich, and Tracy (2022), measures of average wage per worker in the US suffered from changes in workforce composition. Lower wage workers suffer larger employment losses than high wage workers. That created an artificial increase in average wage through this composition effect. The same qualitative change in workforce composition happened in Mexico. Since our model does not have enough structure to explain this workforce composition change, we use the composition-constant real wage calculated by Howard, Rich, and Tracy (2022) for the US and use the same logic to create a composition-constant real wage for Mexico. The adjustment at this aggregate level does not completely correct for the workforce composition change, but it lessen its effect on the real average wage series that we use.

There are many possible filters to calculate the output gap and to detrend real wage from its labor productivity trend, we use standard filters, such as the HP filter and a linear filter[6]. We use the methodology developed in Sun and Tsang (2019) to make our filter selection. The results presented in the next section use the HP filter. This was chosen because the model has better in-sample fit (Table 3) and, in general, better out-of-sample forecast performance for wages and prices (Table 4).

The model is estimated using the Bayesian likelihood methods with standard priors as in Smets and Wouters (2007). Some parameters have weak identification and are calibrated using standard values in the literature. Those parameters that are related to the steady state values of the observed variables of the model are also calibrated.

In Table 3, we report the in-sample forecast performance of the model for the US. The AL model outperforms the RE model, particularly when the linear filter is used. The AL model with the HP filter has the best fit overall.

Table 1. In-Sample Forecast Performance for RE and AL Models

Log marginal likelihood	**RE**	**AL**
Linear Filter	-391.09	-341.38
HP Filter	-342.81	-334.14

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[6] Other filters can also be used and this is an area of robustness to be further explored.

In Table 4, we compare the out-of-sample forecast performance of the model in terms of root mean squared errors. We normalize all the results in terms of the RMSE of the adaptive learning model with linear filter. We report results at different forecast horizons for the real wage gap, and inflation. Even though the RE model performs better in forecasting near-term inflation, the AL model outperforms in forecasting 4-quarters ahead. The AL approach also shows better forecasts for the real wage gap at any forecast horizon. Part of the explanation for this better performance might be the high persistence of this variable. As forecast horizon lengthens, the forecast performance for the real wage gap of both models deteriorates, with RE deteriorating at a faster speed.

Table 2. Out-of-Sample Forecast Performance for RE and AL Models

	Real Wage Gap		**Inflation**	
Linear Filter	**RE**	**AL**	**RE**	**AL**
1-quarter ahead RMSE	3	1	0.7	1
4-quarter ahead RMSE	2.2	1	0.7	1
8-quarter ahead RMSE	1.7	1	0.9	1
HP Filter	**RE**	**AL**	**RE**	**AL**
1-quarter ahead RMSE	0.4	0.6	0.4	2.4
4-quarter ahead RMSE	2.6	2.1	1.1	1.1
8-quarter ahead RMSE	2.6	2.2	0.8	0.7

VI. Model simulation results

A. The inflation-slack curve through the lens of the model

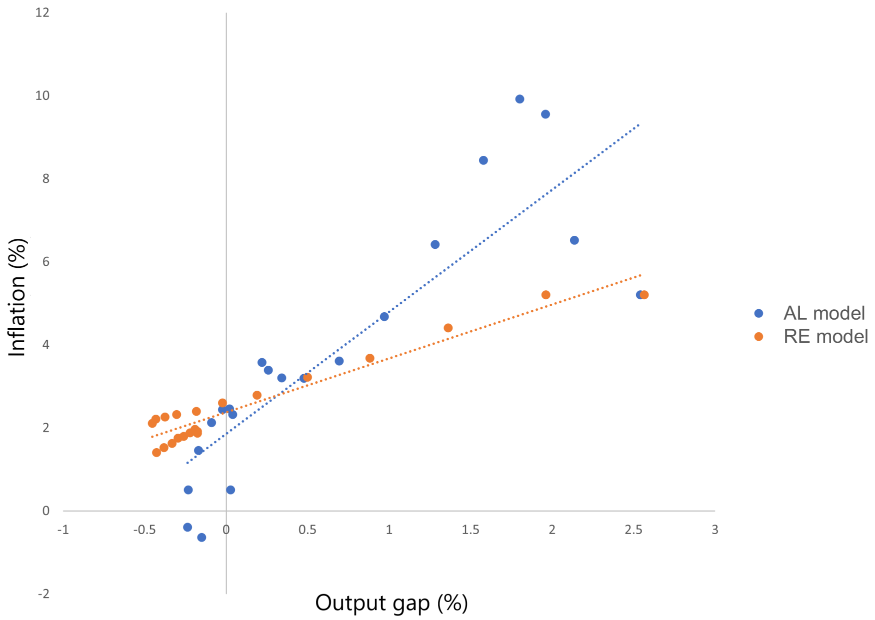
Section III provided empirical evidence that the slope of observed inflation-slack relationships can change rapidly during highly inflationary episodes. The case could be made that expectation formation processes are more likely to change during these extraordinary periods. In this subsection, we show that our model can replicate changing inflation-slack relationships by changing expectations formation processes under certain conditions.

In order to do that, we simulate data from our models assuming that inflation cost-push shocks drive inflation to a level considerably higher than the inflation target. Specifically, we assume that an inflation shock hits the economy and takes inflation to a level comparable to what the US is currently experiencing. We do so in both a model with rational expectations and a model with adaptive expectations. The inflation output is consistent with the criteria used to identify highly inflationary episodes in the preceding section. Using this simulated data, we graph inflation and output gap outcomes for both models. We find patterns similar to those presented in Section III.

If an inflationary episode is generated by cost-push shocks, as our shock decomposition demonstrates, then the slope of the inflation-slack curve is steeper under adaptive expectations than under rational expectations. Figure 7 shows that the two models have small deviations when inflation is close to target. However, as we deviate from target, inflation picks up considerably faster in the adaptive expectations model. That is, when inflation is far from target, inflation expectations become more important to determine the level of inflation and they deviate by more from target under adaptive expectations. The model then generates a steeper inflation-slack curve in a more de-anchored expectation formation process, similarly to what we observe in the data. It is important to highlight that the steeper curve is not driven by how slack impacts inflation. It is just a result of how inflation expectations are formed.

Our model provides a theoretical explanation linking the de-anchoring of expectations to the steepening of the inflation-slack curve during highly inflationary episodes. This result has also important policy implications. If inflation increases to a level substantially higher than target and expectations remain anchored, then the cost of disinflation would be substantially higher (we would be in the orange line of Figure 7). However, this simple analysis of inflation-slack curves could be deceiving, as our model suggests that the reason inflation outcomes are high even though output gap deviations were not that positive is because of de-anchored expectations. It is important to highlight that this does not mean that inflation de-anchoring is a desirable outcome, as inflation will more quickly go back to target if it is anchored around the target (as subsection VI.B shows). Moreover, if the central bank manages to anchor expectations back to a rational expectation regime, we would see disinflation at an even smaller output cost.

Figure 7. Model generated data implies that the inflation-slack curve is steeper under adaptive expectations



Notes: Output from model simulations of an cost-push shock under both rational (RE) and fully adaptive learning expectations (AL). Linear fitted lines shown.

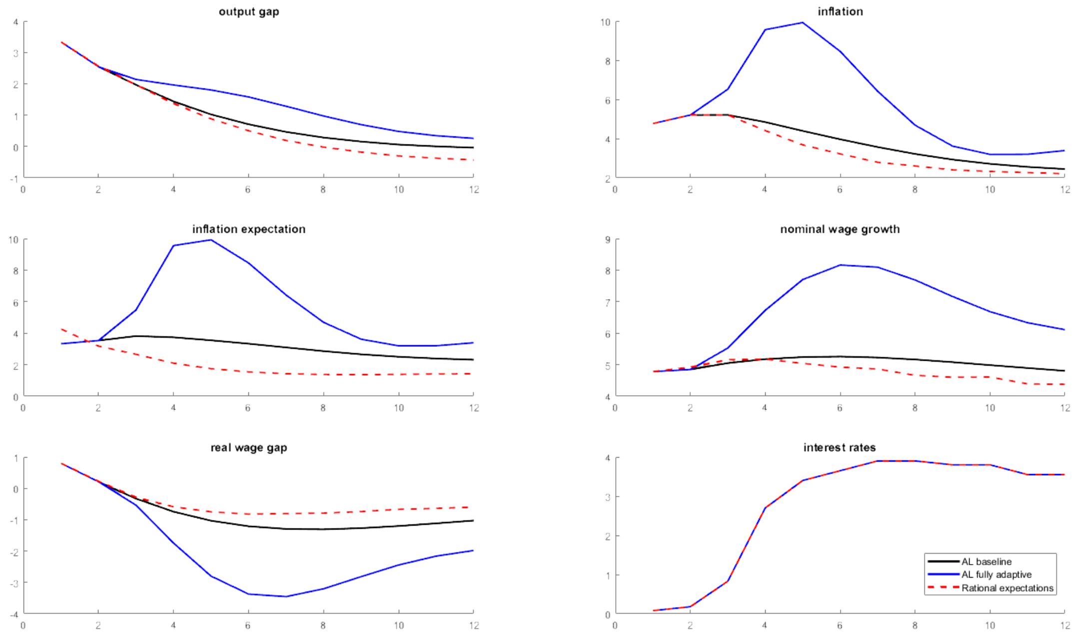
B. Adaptive learning expectations could lengthen the high inflation episode

This section produces conditional forecasting scenarios for the US to isolate the role of different expectation formation processes in the current inflationary environment. The scenarios described in Figure 8 share a common set of shocks. In particular, it is assumed that: 1) inflation shocks explain most of the current inflation and die at a root of 0.8 per quarter with no new shocks to inflation; and 2) interest rates are exogenously at a level consistent with market expectations.

With these shocks, the output gap smoothly converges to zero and inflation comes down to the Federal Reserves target of 2 percent if expectations for wages and prices are rational (Figure 8, dashed red lines). In contrast, if wage and price expectations are fully adaptive, there is a fast, near-term acceleration in wage and price inflation because businesses and households expect them to be identical to their most recent realizations, which have been higher than usual (Figure 8, blue lines). Moreover, the economy is still facing large cost-push shocks that exacerbate price pressures and mostly offset the near-term disinflationary effects of falling real wages (since wage growth does not keep up fully with price inflation). As shocks dissipate and the real wage gap becomes even more negative, price inflation quickly declines after five quarters. However, price inflation remains 1.5 percentage points over target even 12 quarters later under AL expectations formation. This is in spite of inflation coming down and no further shocks being assumed. To bring inflation down more quickly under such expectations formation, monetary policy would need to tighten more sharply.

Under our estimated adaptive learning model, the paths of inflation, wage growth, and the output gap lie between those for rational and fully adaptive expectations (black line in Figure 8). Even so, while the output gap mostly closes, inflation is still about a half-percentage point above after eight quarters.

Figure 8. Inflation is stickier when expectations are adaptive learning



Notes: Near term scenarios with set interest rate path under different expectation formation assumptions.

We can also show analytically why inflation inertia is higher under adaptive expectations. For that, let's first rewrite the NK phillips curve.

$$E_t[\pi_t] = \kappa_p E_t[\hat{w}_{t+1}] + (1-\beta)\pi_{t-1} + \beta E_t[\pi_{t+1}], \tag{21}$$

In the adaptive learning model, expectations evolve according to a moving $AR(2)$ specification process. That's it:

$$E_t[\pi_{t+1}] = \beta_t^1 \pi_{t-1} + \beta_t^2 \pi_{t-2}, \tag{22}$$

for simplicity, and without loss of generality, let's assume that $\beta_t^1 = 1$ and $\beta_t^2 = 0$ for all t. This case is what one can call fully adaptive expectations. We can then rewrite the NK PC equation 12 as:

$$\pi_t - \pi_{t-1} = \kappa_p \hat{w}_t + \varepsilon_t^{\pi}, \tag{23}$$

in this case the central bank can only affect the inflation change through its effect on the current real wage gap.

In the RE setting, if we assume that $\beta < 1$, then we have a similar NK phillips curve to the adaptive expectations case. If we subtract $\pi t - 1$ from both sides of equation 24, then:

$$E_t[\pi_t] - \pi_{t-1} = \Delta\pi_t = \kappa_p E_t[\hat{w}_{t+1}] + \beta(E_t[\pi_{t+1}] - \pi_{t-1}), \tag{24}$$

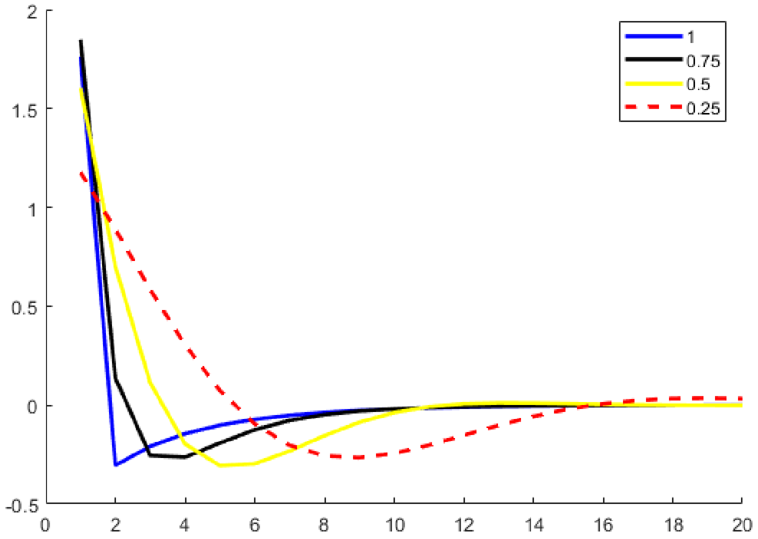
We can then take the derivative of $\Delta\pi_t$ with respect to β to assess the speed of inflation decline when β moves away from 0.

$$\frac{\partial \Delta\pi_t}{\partial \beta} = E_t[\pi_{t+1}] - \pi_{t-1}, \tag{25}$$

after an inflation shock hits, there is a period that inflation starts falling, so $E_t[\pi_{t+1}] - \pi_{t-1} < 0$. That is, in the RE setting, the larger the coefficient on expected inflation, the faster inflation will fall in the RE model compared to the AL model. This can be seeing when we plot inflation IRF functions to inflation shocks assuming different values for β (Figure 9).

Finally, if we assume pure forward looking expectations, $\beta = 1$, then we can rewrite the NK PC (equation 12) as a forward sum of the real wage gap:

Figure 9. Inflation converges more quickly to target with more forward-looking inflation in the RE model



Notes: Inflation impulse response function to shock to inflation under different β parameters.

$$\pi_t = \kappa_p \sum_{j=0}^{\infty} \beta^j E_t[\hat{w}_{t+j}] + \varepsilon_t^{\pi}, \tag{26}$$

Note that monetary policy is more powerful because it can also control future deviations of the wage gap and can then affect the change in inflation.

In all cases, the dynamics of real wages are critical to the evolution of wage and price inflation since they can affect price pressures. For simplicity, wages are the only determinant of marginal costs in the model. Because of this, the model can also illustrate the likelihood of a wage-price spiral dynamic taking hold. This modeling choice not only allows the assessment of the likelihood of wage-price spirals in the simulated scenarios but also show that wages can be an important anchor to inflation when cost-push shocks hit the economy. When inflationary, cost-push shocks occur, the negative real wage gap characterizing the current circumstances helps to anchor inflation, even in the case of fully adaptive expectations. In a model where the price Phillip's curve only includes the output gap, as in Cochrane (2022), the only way to lower inflation is with a negative output gap. This model shows a situation where a positive output gap and a negative real wage gaps is possible. In this scenario, the central bank is able to anchor inflation even with a positive output gap and fully adaptive expectations.

Given the negative inflation outlook under AL expectations, we can then ask what a central bank minimizing a welfare function would do in this scenario, which is addressed in the next section.

C. Optimal monetary policy discussion

In this section, we use the same strategy as in Alichi and others (2015) and instead of using the estimated monetary policy function as in equation (13), we assume that the central bank chooses a path for interest rate so as to minimize the following welfare loss function:

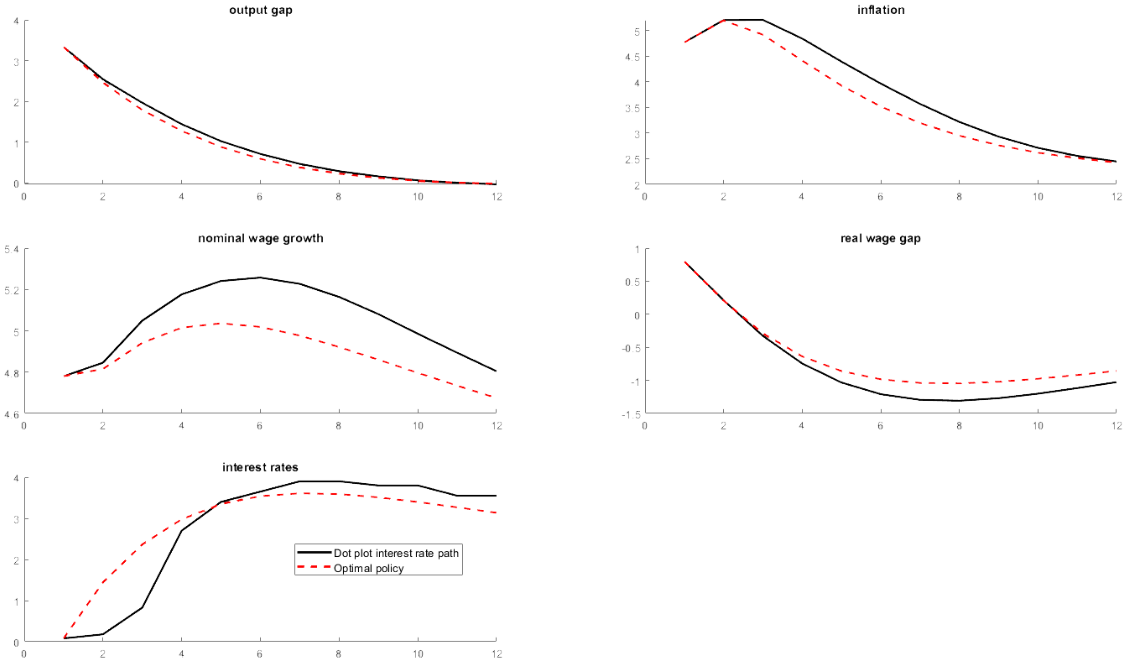
$$\min_{\hat{\imath}_t} E_t \sum_{t=0}^{\infty} \beta^t \left(0.75(\hat{\imath}_t - \hat{\imath}_{t-1}) + \hat{y}_t^2 + \hat{\pi}_t^2\right), \tag{27}$$

note that we assume equal weights for output gap $\hat{y}$ and inflation deviations from target $\hat{\pi}$. We also assume a role for interest rate smoothing. Thus, we define the optimal monetary policy path as the interest rate path that minimizes this function. In this section simulations, we further assume that the central bank has full knowledge of the current shocks hitting the economy, know all the future shocks that will hit the economy and also have full knowledge of how their actions impact expectations.

In our model, the central bank has three channels to influence inflation. The standard direct channel in which a tighter policy cools off demand, lowering the output gap and hence inflation. The other two channels operate through inflation expectations. By tightening policy, the central bank lowers current inflation that enters in the $AR(2)$ inflation expectations equation, lowering next period expectations. Finally, the central bank can affect households' learning process (the coefficients in the $AR(2)$ equation). By seeing less inflation this period than they have expected, households update their model of how past inflation matters for future inflation. The combined effect of these three channels can be seeing in Figure 10.

The optimal policy prescribes front-loading interest rate tightening and then easing. The red dashed line in Figure 10 shows the optimal interest rate path and the black line shows the previous path. The optimal path has policy tighter by 150 basis points in 2022Q3, 30 basis points in 2022Q4 but then looser over the next two years. By the end of 2024, the policy rate is 40 basis points lower in the optimal path compared to the previous path. With the optimal policy, the output gap and inflation converge faster to zero and target, respectively. Note that it takes time for the deviation in monetary policy to influence inflation and that the difference gets higher over time. Of course, these results depend on full information by the central bank and also that the inflation shock dissipates with a half-life of 2.5 quarters.

Figure 10. The central bank should front-load tightening and then ease



Notes: Scenarios with adaptive learning expectations.

D. Extension to an open economy model

We extend the framework described above to model a small open economy. We do this to first check if findings from the previous sections apply to an open economy setting. In particular, we want study how the slope of the inflation-slack curve behaves when an inflationary episode is driven by a large exchange rate depreciation. We then also assess whether the estimated coefficients in the expected inflation equations (equation 22) differ between an advanced economy and an emerging economy. Finally, we explore whether exchange rate dynamics change when expectations are formed according to the AL model, and how much domestic inflation is explained by foreign inflation.

Relative to the equations described in Section IV, the main change is the introduction of the well-known uncovered interest parity relating domestic and foreign real interest rates:

$$z_t = E_t[z_{t+1}] - \left(\hat{i}_t - \hat{\pi}_{t+1} - (\hat{i}^F_t - \hat{\pi}^F_{t+1})\right) + \varepsilon^z_t, \tag{28}$$

where z is the de-trended real exchange rate and an increase in z means a depreciation. Notice the introduction of a new forward variable in the model that will display the same expectation formation process as in Section IV.A. $\hat{i}^F_t$ and $\hat{\pi}^F_{t+1}$ are the foreign interest rate and inflation, respectively. Moreover, the domestic IS curve for the small-open economy is also modified to include foreign spillovers:

$$\hat{x}_t = \phi^x(E_t[\hat{x}_{t+1}]) - \phi^r(\hat{i}_t - \hat{\pi}_{t+1}) + \phi^z z_t + \phi^{XF} E_t[\hat{x}^F_{t+1}] + shk^x, \tag{29}$$

where the new terms include the impact of the exchange rate, $\phi^z z_t$ and the spillovers from foreign output $\phi^{XF} E_t[\hat{x}^F_{t+1}]$. Finally, the domestic Phillips' curve equation is also expanded to include the impact of the exchange rate:

$$\pi_t = \kappa_p \hat{w}_t + (1-\beta)\pi_{t-1} + \beta\pi_{t+1} + \lambda z_t + \varepsilon_{pi,t}. \tag{30}$$

The foreign economy is modelled the same way as before, with no direct impact from the small economy. With these small modifications, we re-estimate the full model using US and Mexico data from 2008Q1 to 2019Q4[7]

Figures 11(a) and 11(b) show the shock decomposition for the US using this open macro model. The inflation shock decomposition is almost identical to the closed economy version and the interest rate decomposition is very similar, with the only exception being the positive contribution of inflation in the 2021Q4. Figure 12 describes the shock decomposition for the real exchange rate, and the US inflation and monetary policy shocks are the largest contributors to the recent real exchange rate of the Mexican Peso.

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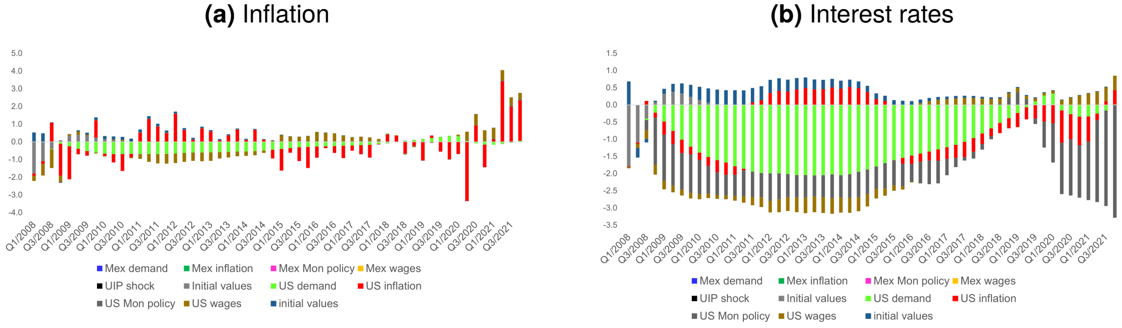
[7] We use data from Mexico because we have a larger model with many more parameters to estimate and the wage data in Brazil does not go that far back.

Figure 11. US Shock decomposition in open macro model



(a) Inflation

(b) Interest rates

Figure 12. Real exchange rate shock decomposition in open macro model

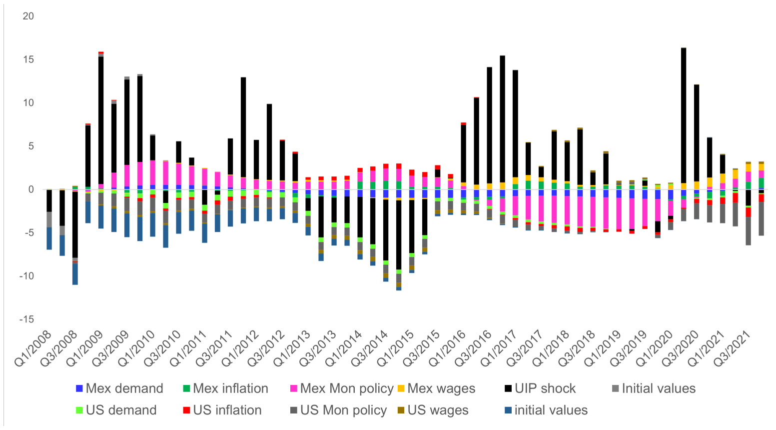
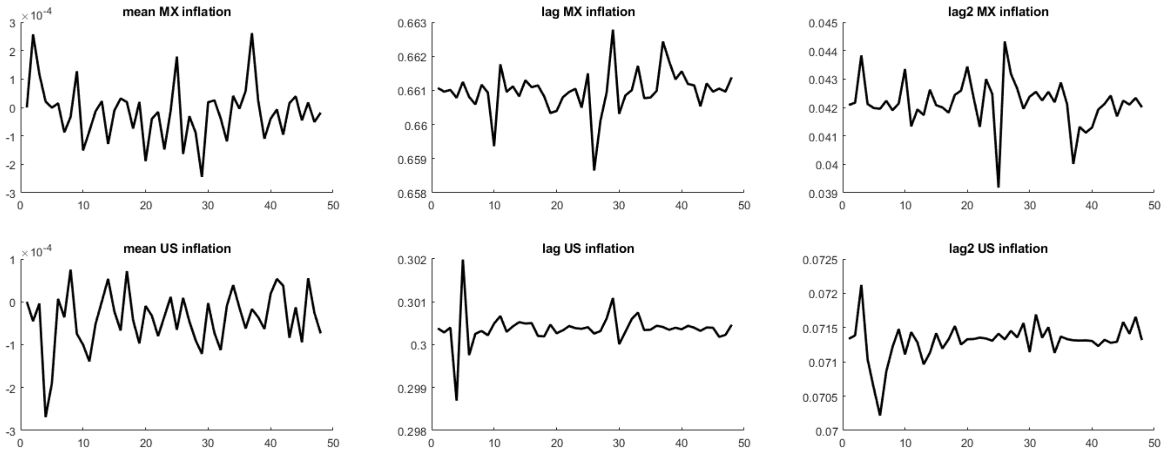


Figure 13. Expectations in Mexico appear more backward-looking than in the US



The comparison of household's beliefs about the evolution of inflation is described in Figure 13. Expectations in Mexico are indeed estimated to be more backward looking than in the US (this can be seen when adding the estimated coefficients on the first two lags of both inflation and wages). This result is achieved when we simulate all the parameters of both economies together. In fact, Mexico households' put twice as much weight on past inflation to explain future inflation than US households. With these kind of expectations, a stronger monetary policy response in necessary following an episode of cost-push shocks. This figure also shows coefficient stability over the last ten years before the pandemic. The coefficient reflecting the mean expected inflation was zero as households expected inflation to be at the central bank target.

Finally, the extended model also replicates the behavior of the inflation-slack curve after an inflationary episode caused by a large exchange rate depreciation. The open macro model extension allows us to study the case discussed in Figure 5b and 6b, where a large exchange rate depreciation coincided with the inflationary episode. This time, we generate data from the model assuming that a shock to the exchange rate depreciates the Peso by 50% in just one quarter.[8] As Figure 14 shows, the model generated data produces an inflation-slack curve with a higher slope in the RE model. The discussion in Section VI.A and Figure 14 shows that the relative slope of the inflation-slack curve depends on which shock generates the inflation episode. Moreover, it shows that it is not necessary to assume a non-linearity on how slack affects inflation to change the slope of the observed inflation-slack curve. A shift in how expectations are formed is sufficient to produce this slope change.

VII. CONCLUSION

After a long period of stable inflation and inflation expectations, the COVID-19 recovery and subsequent cost-push shocks produced a surge in global inflation not seen since the 1980s. Inflation expectations have also risen, and fears of de-anchoring have been cited as reasons to lift monetary policy rates. In this context, it is important to understand how expectations are formed, how they can affect the macroeconomic outlook, and what are the implications for monetary policy.

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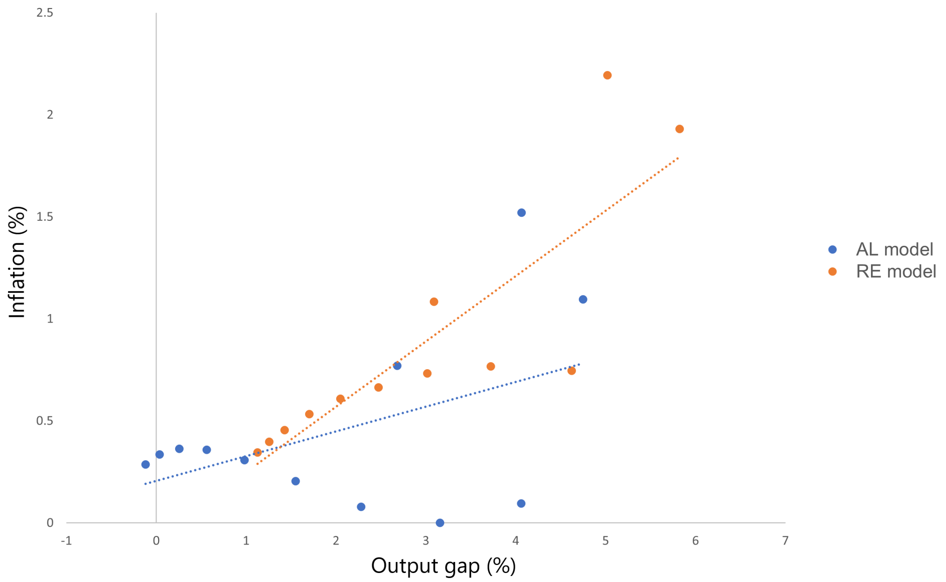
[8] We picked this size for the shock inspired by the level of depreciation experienced in Brazil during its inflationary episodes

Figure 14. Model generated data implies that the inflation-slack curve is steeper under RE if inflation is driven by exchange rate shock



Notes: Output from model simulations of an exchange rate shock under both rational (RE) and adaptive learning (AL) expectations. Linear fitted lines shown.

This paper introduced standard New Keynesian models that differ in the way that households form expectations. We moved away from the standard assumption of rational expectations and included a "limited rationality" backward-looking expectation formation process in which households learn from previous forecasting mistakes. This modelling strategy creates a new mechanism through which central banks can affect inflation. In particular, central banks affect households' expectations differently depending on the learning process at play.

The model can account for stylized facts observed during past highly inflationary episodes – including steeper inflation-slack curves. Changing slopes can therefore be rationalized as the result of shifting expectation formation processes that could be triggered by extraordinary price rises. In cases where expectations deviate from rationality and become more similar to adaptive learning, we argue that disinflation can be less costly than suggested by Phillips curves estimated during normal times that do not account for expectations formation differences.

Within the adaptive learning paradigm, we also discussed how an optimal monetary policy should be designed in an environment of high inflation and a positive output gap. Results suggest that policy should tighten sooner and more strongly than during normal times if expectations are adaptive. The optimal monetary policy response seeks to influence the learning process and avoids high-inflation beliefs leading into higher costs of disinflation.

References

Alichi, Ali, Kevin Clinton, Charles Freedman, Ondrej Kamenik, Michel Juillard, Douglas Laxton, Jarkko Turunen, and Hou Wang, 2015, "Avoiding Dark Corners: A Robust Monetary Policy Framework for the United States," *IMF Working Papers*, Vol. 2015, No. 134.

Barbosa-Filho, Nelson, 2008, "Inflation targeting in Brazil: 1999-2006," *International Review of Applied Economics*, Vol. 22, No. 2, pp. 187–200.

Bems, Rudolfs, Francesca Caselli, Francesco Grigoli, and Bertrand Gruss, 2021, "Expectations' anchoring and inflation persistence," *Journal of International Economics*, Vol. 132(c).

Buono, Ines, and Sara Formai, 2018, "New evidence on the evolution of the anchoring of inflation expectations," *Journal of Macroeconomics*, Vol. 57, No. C, pp. 39–54.

Cho, In-Koo, and Kenneth Kasa, 2015, "Learning and Model Validation," *Review of Economic Studies*, Vol. 82, No. 1, pp. 45–82.

Clarida, Richard, Jordi Gali, and Mark Gertler, 1999, "The Science of Monetary Policy: A New Keynesian Perspective," *Journal of Economic Literature*, Vol. 37, No. 4, pp. 1661–1707.

Cochrane, John, 2022, "Is the Fed Fisherian?" Available at https://johnhcochrane.blogspot.com/2022/04/is-fed-fisherian.html (2022/04/22).

Coibion, Olivier, and Yuriy Gorodnichenko, 2015, "Information Rigidity and the Expectations Formation Process: A Simple Framework and New Facts," *American Economic Review*, Vol. 105, No. 8, pp. 2644–78.

Erceg, Christopher J., and Andrew T. Levin, 2003, "Imperfect credibility and inflation persistence," *Journal of Monetary Economics*, Vol. 50, No. 4, pp. 915–944.

Eusepi, Stefano, Marc P. Giannoni, and Bruce Preston, 2018, "Some implications of learning for price stability," *European Economic Review*, Vol. 106, pp. 1–20.

Eusepi, Stefano, Emanuel Moench, Bruce Preston, and Carlos Viana de Carvalho, 2019, "Anchored Inflation Expectations," CEPR Discussion Papers 13900, C.E.P.R. Discussion Papers.

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

Galí, Jordi, Frank Smets, and Rafael Wouters, 2012, "Unemployment in an Estimated New Keynesian Model," *NBER Macroeconomics Annual*, Vol. 26, pp. 329–360.

Gopinath, Gita, 2022, "How Will the Pandemic and War Shape Future Monetary Policy?" Available at https://www.imf.org/en/News/Articles/2022/08/26/sp-gita-gopinath-remarks-at-the-jackson-hole-symposium (2022/08/26).

Ha, Jongrim, M. Ayhan Kose, and Franziska Ohnsorge, 2019, *Inflation in Emerging and Developing Economies : Evolution, Drivers and Policies* (World Bank).

Harding, Martin, Jesper Linde, and Mathias Trabandt, 2022, “Understanding Post-Covid Inflation Dynamics,” *Working Paper*.

Howard, Sean, Robert Rich, and Joseph Tracy, 2022, “Real Wages Grew During Two Years of COVID-19 After Controlling for Workforce Composition,” Available at https://www.dallasfed.org/research/economics/2022/0215/ (2022/02/15).

IMF, 2016, “Global disinflation in a era of constrained monetary policy,” *World Economic Outlook*, pp. 121–170.

———, 2022, “Wage Dynamics PostCOVID-19 and Wage-Price Spiral Risks,” *World Economic Outlook*.

Kamber, Günes, Madhusudan Mohanty, and James Morley, 2020, “What drives inflation in advanced and emerging market economies?” *BIS Papers chapters, in: Bank for International Settlements (ed.), Inflation dynamics in Asia and the Pacific*, Vol. 111, pp. 21–36.

Milani, Fabio, 2007, “Expectations, learning and macroeconomic persistence,” *Journal of Monetary Economics*, Vol. 54, pp. 2065–2082.

Orphanides, Athanasios, and John Williams, 2004, “Imperfect Knowledge, Inflation Expectations, and Monetary Policy,” in *The Inflation-Targeting Debate*, NBER Chapters (National Bureau of Economic Research, Inc).

Slobodyan, Sergey, and Raf Wouters, 2012, “Learning in a Medium-Scale DSGE Model with Expectations Based on Small Forecasting Models,” *American Economic Journal: Macroeconomics*, Vol. 4, No. 2, pp. 65–101.

———, 2012b, “Learning in an estimated medium-scale DSGE model,” *Journal of Economic Dynamics and Control*, Vol. 36, pp. 22–46.

Smets, Frank, and Rafael Wouters, 2007, “Shocks and Frictions in US Business Cycles: A Bayesian DSGE Approach,” *American Economic Review*, Vol. 97, No. 3, pp. 586–606.

Sun, Xiaojin, and Kwok Ping Tsang, 2019, “What cycles? Data detrending in DSGE models,” *Studies in Nonlinear Dynamics Econometrics*, Vol. 23, No. 3, p. 20170084.

Svensson, Lars E.O., 1999, “Inflation targeting as a monetary policy rule,” *Journal of Monetary Economics*, Vol. 43, No. 3, pp. 607–654.

Appendix A. Open economy model fit

In the main section, we showed that adaptive learning expectations performed better than rational expectations when used in the closed economy model for the USA. In this appendix, we showed that the model performance of adaptive learning expectations is even better when we consider the open macro model discussed in sub-section VI.D. In fact, the in-sample model performance of AL is much better at more than 30 points larger than RE, as can be seen in Table 3.

Table 3. In-Sample Model Performance for RE and AL in Open Macro Model

Log marginal likelihood	**RE**	**AL**
Linear Filter	-459.24	-428.20

Finally, similar to the main text, the Adaptive Learning (AL) model generally has a better out-of-sample forecast performance compared to the Rational Expectation (RE) model. In the open economy model for the Mexican variables, the AL model does a much better in forecasting output gap, especially at longer horizons. In terms of inflation, the RE has a better forecast performance at the 4-quarter ahead forecast, but it is worse forecasting the next quarter and substantially worse forecasting at the 8-quarter ahead horizon.

Table 4. Out-of-Sample Forecast Performance for RE and AL Models

	Output Gap		**Inflation**	
Linear Filter	**RE**	**AL**	**RE**	**AL**
1-quarter ahead RMSE	0.203	0.38	0.109	0.071
4-quarter ahead RMSE	3.08	2.51	0.256	0.479
8-quarter ahead RMSE	7.07	4.04	1.12	0.434

PUBLICATIONS

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