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Average is Good Enough: Average-inflation Targeting and the ELB

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Abstract

The Great Recession and current pandemic have focused attention on the constraint on nominal interest rates from the effective lower bound. This has renewed interest in monetary policies that embed makeup strategies, such as price-level or average-inflation targeting. This paper examines the properties of average-inflation targeting in a two-agent New Keynesian (TANK) model in which a fraction of firms have adaptive expectations. We examine the optimal degree of history dependence under average-inflation targeting and find it to be relatively short for business cycle shocks of standard magnitude and duration. In this case, we show that the properties of the economy are quantitatively similar to those under a price-level target.

Topics: Monetary policy framework; Business fluctuations and cycles; Economic models
JEL codes: E31, E32, E52

Résumé

La Grande Récession et la pandémie qui sévit présentement ont attiré l'attention sur la contrainte qu'impose la valeur plancher des taux d'intérêt nominaux. Ainsi, on note un intérêt ravivé pour les politiques monétaires comprenant des stratégies de rattrapage, telles que le ciblage du niveau des prix ou de l'inflation moyenne. L'étude traite des propriétés du ciblage de l'inflation moyenne dans un modèle de type nouveau keynésien à deux agents dans lequel une fraction des entreprises a des attentes adaptatives. Nous étudions le degré optimal de dépendance à l'égard du passé en régime de ciblage de l'inflation moyenne, et constatons qu'il est assez faible lors de chocs liés aux cycles économiques dont l'ampleur et la durée sont normales. Dans ce cas, nous montrons que, en termes quantitatifs, les propriétés de l'économie sont comparables à celles en régime de ciblage du niveau des prix.

Sujets : Cadre de la politique monétaire; Cycles et fluctuations économiques; Modèles économiques
Codes JEL : E31, E32, E52

I. INTRODUCTION

The Great Recession brought greater focus on the constraint that the effective lower bound (ELB) imposes on monetary policy. The current pandemic has sharpened this issue further, as the Federal Reserve once again lowered the federal funds rate to the ELB recently. The decline in the equilibrium real interest rate consistent with full employment and price stability implies a high risk that monetary policy will return to the ELB frequently in the future is high. To address this risk, central banks are now reconsidering their monetary policy frameworks. For instance, in November 2018, the Federal Reserve announced that it would review its strategies, communications, and tools. In particular, policy regimes embedding makeup strategies, such as price-level or average-inflation targeting, are generating renewed interests. These regimes imply that past policy misses must be offset in the future. If these policy responses are credible, the public will then expect them, leading to movements in inflation expectations that facilitate the desired adjustments in the stance of monetary policy.

In this paper, we reconsider the implications of average-inflation targeting in a New Keynesian framework that accounts for the presence of the ELB. We focus on this form of makeup strategy because its minimal departure from current inflation targeting regimes makes it easier to communicate to the public. Given that the benefits of makeup strategies largely derive from their forward-looking nature and the associated effects on expectations, we examine an environment where this channel is appropriately constrained by the presence of two realistic features. In particular, our baseline economy includes a subset of households

that do not participate in financial markets (see, e.g., Bilbiie (2019)) and in which some firms have adaptive expectations, as in Galí and Gertler (2012).[1]

We focus on average-inflation targeting in the form of implementable rules in economies subject to business cycle shocks of standard magnitude and duration; thus we abstract from more persistent shocks that could lead to long-lasting periods at the ELB, such as that following the 2007 financial crisis. We assume that the policy is credible, so that policymakers are able to commit to a specific rule. In implementing a policy of average-inflation targeting, one important consideration is the size of the time window used to calculate the average inflation rate. In other words, we examine how much history dependence should be embedded in the rule for the policy to be effective. Given the shocks and the frequency, depth, and the average duration of ELB episodes, the degree of history dependence could become very large, making it difficult to distinguish from a price-level targeting rule. In our analysis, we determine the optimal degree of history dependence by maximizing households' welfare subject to the constraints in the economic environment, including the ELB. Depending on the environment, the optimal degree of history dependence incorporates a trade-off between allowing some drift in the price level and providing greater price stability to help manage expectations during ELB episodes.

Overall, for typical-sized shocks, we find that the degree of history dependence is relatively low in our baseline economy. In economies where the ELB binds roughly 10 percent of the time and ELB episodes last four quarters, on average, it is optimal for the central bank to target an average inflation rate calculated over a window of slightly less than two years. In this case, we show that average-inflation targeting leads to outcomes that are very close to

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[1]See also Del Negro et al. (2013) and MacKay et al. (2013) on the strength of forward guidance in standard DSGE models.

those generated by price-level targeting, with the volatility of inflation and output, as well as welfare, being quantitatively similar under these two policies.

The optimal degree of history dependence in our baseline economy is robust to a few variations in the economic environment. In particular, we show that when the economy is subject to demand shocks, it remains roughly the same if all firms have forward-looking expectations or if there are no hand-to-mouth households. In contrast, the optimal window length declines substantially to about two quarters when the economy is only subject to cost-push shocks and firms have adaptive expectations, consistent with findings in Néssen and Vestin (2005). With adaptive expectations, a cost-push shock that increases inflation leads to greater volatility and lower welfare under average-inflation targeting with a long averaging window. This reflects the fact that the policy promises to disinflate the economy without the full stabilizing benefits from lower expected inflation that would arise when all firms form expectations in a forward-looking manner. The optimal average-inflation targeting policy in this case dictates a short window and more drift in the price level. The optimal degree of history dependence is more robust in the case of demand shocks, since they do not entail trade-offs between inflation and output stability.

Our work adds to an important literature on the benefits of makeup strategies at the ELB. For instance, Eggertsson and Woodford (2003) show that the optimal policy at the ELB can be well approximated by a price-level targeting rule, because it introduces history dependence to policy. Reifschneider and Williams (2000) introduce a rule that keeps track of policy shortfalls at the ELB, thus bringing about additional accommodation by keeping policy "lower for longer." It is more directly related to the work of Néssen and Vestin (2005) that compares average-inflation targeting to inflation and price-level targeting. We complement this analysis by focusing on the properties of average-inflation targeting taking

the ELB into account and by calculating the optimal window's length. In addition, our work complements a recent paper by Mertens and Williams (2019) that looks at makeup strategies, including average-inflation targeting, to tackle the ELB constraint. In addition to considering the Reifschneider and Williams (2000) proposed rule tracking policy shortfalls (i.e., a so-called *shadow-rate* rule, since it tracks the policy rate that would prevail absent the ELB), Mertens and Williams (2019) also consider a static average-inflation targeting approach. This approach dictates a higher inflation rate during expansions to compensate for lower inflation at the ELB, to generate a specified average inflation rate over the cycle. In addition to a shadow-rate rule, Kiley and Roberts (2017) also examine a policy rule that sets the change in the nominal interest rate as a function of inflation deviations from target and the output gap, such that during ELB episodes policymakers keep the policy rate at the lower bound until inflation rises above target or output rises above potential. Our paper also relates to Svensson (2020), who discusses the properties of a central bank's loss function that includes an average inflation rate as one of its arguments, focusing one an averaging period of fivea years. We complement this work by partly examining the optimal degree of history dependence.

Recently, Bernanke (2017) argued in favor of temporary price-level targeting when monetary policy reaches the ELB. This policy would make up inflation shortfalls from target with above target inflation before lifting the policy rate form the ELB, thus implicitly targeting an average inflation rate during the ELB period. Using the Federal Reserve's FRB/US model to compare the performance of different policy rules, Bernanke et al. (2019) find that temporary price-level targeting with a one- or three-year window lowers the volatility of output and inflation compared to other makeup strategies, such as the shadow-rate rules

proposed by Reifschneider and Williams (2000) and Kiley and Roberts (2017). Using a similar framework, Hebden and López-Salido (2018) obtain broadly similar results, while also emphasizing that these policies entail risks of large overshoots of the natural rate of unemployment, particularly if the Phillips curve is flat. In contrast, we focus on the costs and benefits of introducing average-inflation targeting at and away from the ELB in small-scale DSGE models.

The remainder of the paper is organized as follows. The next section introduces the economic environment and monetary policy rules considered in our analysis before discussing the calibration of the economy. We then present our main results, focusing on the properties of flexible average-inflation targeting under alternative versions of the model. This last section concludes.

II. Model

To examine the effects of different monetary policies, we consider a model that explicitly takes into account the presence of the ELB. In the spirit of Galí and Gertler (2012), Galí et al. (2007), and Bilbiie (2019), we model an economy in which a fraction of households are "hand-to-mouth," in the sense that they fully consume what they earn, and where a fraction of firms have adaptive expectations. These ingredients have been shown to be empirically important for capturing movements in inflation. Given that makeup strategies like average-inflation targeting and price-level targeting work by influencing expectations, the presence of these features may mute their effectiveness and importantly impact the degree of history dependence of average-inflation targeting. The economy faces demand shocks, in the form of shocks to the natural rate of interest, and cost-push shocks.

III. Model

Given the potential merits of average-inflation targeting, we analyze the properties of this monetary policy rule in a canonical new Keynesian model with Calvo pricing and the following two additions: (i) backward-looking price-setting firms following Galí and Gertler (2012), and (ii) hand-to-mouth consumers following the Bilbiie (2019) TANK model. We will start with the household's optimization problem.

III.1. **Households.** There are a continuum of households between 0 and 1, where a fraction $(1 - \lambda)$ of households are savers (S) and a fraction λ live hand-to-mouth (H). For household $j \in \{S, H\}$ the household maximizes its lifetime utility

$$E_0 \sum_{t=0}^{\infty} U(C_t^j, N_t^j) \tag{1}$$

where the period utility function for household j is

$$U(C_t^j, N_t^j) = \frac{C_t^{j \, 1-\sigma} - 1}{1 - \sigma} - \frac{N_t^{j \, 1+\psi}}{1 + \psi}. \tag{2}$$

Here C_t^j is the composite consumption good consumed by household j, N_t^j is employment, ψ is the elasticity of labor supply and σ is the risk aversion parameter. The consumption good C_t^j is defined as

$$C_t^j \equiv \left(\int_0^1 C_t^j(i)^{1 - \frac{1}{\epsilon}} di \right)^{\frac{\epsilon}{\epsilon - 1}} \tag{3}$$

where the consumption good $C_t^j(i)$ is the amount of good i consumed by household j. The elasticity of substitution between different goods is ϵ.

III.1.1. **Savers**. Savers maximize their lifetime utility (1) subject to the following budget constraint each period:

$$\int_0^1 P_t(i)C_t^S(i)di + Q_tB_t \leq B_{t-1} + P_tW_tN_t^S + D_t \tag{4}$$

where $P_t(i)$ is the price of good i, B_t is a one-period discount bond with a price $Q_t = 1/R_t$. W_t is real wages and is common across both types of households. Lastly, savers own the firms and receive profits D_t each period.

The above optimization problem for savers implies the following first-order conditions for their consumption C_t^S and labor supply decision N_t^S

$$1/R_t = \beta E_t \left(\left(\frac{C_t^S}{C_{t+1}^S} \right)^\sigma \frac{P_t}{P_{t+1}} \right) \tag{5}$$

$$(N_t^S)^\psi = C_t^{S-\sigma}W_t. \tag{6}$$

III.1.2. *Hand-to-Mouth Households.* Hand-to-mouth households are liquidity constrained. As such, they consume their entire income every period and don't purchase bonds. These households maximize their lifetime utility given in equation (1) subject to the following budget constraint each period:

$$\int_0^1 P_t(i)C_t^H(i)di = P_tW_tN_t^H. \tag{7}$$

The above problem for hand-to-mouth consumers implies the following first-order condition for their labor supply N_t^H:

$$(N_t^H)^\psi = C_t^{H-\sigma}W_t. \tag{8}$$

Hand-to-mouth households' consumption is determined by their budget constraint

$$C_t^H = W_tN_t^H. \tag{9}$$

III.1.3. *Aggregate IS curve.* To derive the aggregate IS curve, we first take a log-linear approximation of the equilibrium equations, expressing lowercase variables as deviations from their respective steady state. Substituting the wage schedule $w_t = (\sigma + \psi)c_t$ into the hand-to-mouth household budget constraint, we can derive hand-to-mouth consumption as a function of aggregate output y_t

$$c_t^H = \chi y_t, \qquad \text{where } \chi \equiv 1 + \psi. \tag{10}$$

With a mass of hand-to-mouth consumers λ, we can solve for the saver's consumption

$$c_t^S = \frac{(1 - \lambda\chi)}{(1 - \lambda)}y_t. \tag{11}$$

Given the previous two equations, can aggregate across households to obtain the aggregate IS equation:

$$x_t = E_t x_{t+1} - \frac{1}{\sigma}\frac{(1 - \lambda)}{(1 - \lambda\chi)}(r_t - E_t \pi_{t+1} - r_t^n) \tag{12}$$

where x_t is the output gap defined as output deviations from the natural level of output, y_t^n, and where the natural rate of interest, r_t^n, is determined exogenously as

$$r_t^n = (1 - \rho^{r^n})\bar{r^n} + \rho^{r^n} r_{t-1}^n + \sigma^{r^n} \epsilon_t^{r^n}, \tag{13}$$

with an autocorrelation coefficient ρ^{r^n} and σ^{r^n} representing the standard deviation of the innovation $\epsilon_t^{r^n}$.

III.2. **Firms.** There is a continuum of unit mass firms, with individual firms denoted by i. Only a fraction $(1 - \theta)$ of firms are able to adjust their price each quarter. Therefore, the aggregate price level is equal to

$$P_t = P_{t-1}^\theta \bar{P}_t^{*(1-\theta)} \tag{14}$$

where $\bar{P}_t^*$ is the reset price index, determined by all firms who reset their prices in that period. Following Gali and Gertler (1999), we assume that a fraction of these firms that reset their price, $\omega \in [0,1)$, are backwards looking, setting prices based a rule-of-thumb rather than setting prices optimally based on expectations. Therefore, the reset price index equals

$$\bar{P}_t^* = P_t^{f(1-\omega)} P_t^{b\omega} \tag{15}$$

where P_t^f is the optimal price charged by forward-looking price-setting firms and P_t^b the price charged by rule-of-thumb price setters. All firms produce output $Y_t(i)$ according to the following production function

$$Y_t(i) = N_t(i) \tag{16}$$

where we assume constant returns to scale, with labor as the only input. We have abstracted away from discussing technology shocks in our analysis.

III.2.1. *Forward-looking Firms.* A fraction of firms $(1 - \omega)$ are forward looking and choose P_t^f to maximizes their profit

$$\max_{P_t^f} \sum_{k=0}^{\infty} \theta^k E_t(\Lambda_{t,t+k}(\frac{1}{P_{t+k}}) \left((1+\tau)P_t^f Y_{t+k|t} - \Phi_{t+k}(Y_{t+k|t}) \right), \tag{17}$$

given the conditional demand

$$Y_{t+k|t} = \left(\frac{P_t^f}{P_{t+k}} \right)^{-\epsilon} C_{t+k}. \tag{18}$$

The stochastic discount factor is $\Lambda_{t,t+k} = \beta^k U_{c,t+k}^S / U_{c,t}^S$, and $\Phi_t(\cdot)$ refers to the nominal cost function. τ is a tax on production to invoke an efficient equilibrium and is set equal to $(\epsilon - 1)^{-1}$. It is assumed that the tax on production is returned back to the firm as a lump

sum. The first-order condition for the forward-looking firm's optimal price P_t^f is

$$\sum_{k=0}^{\infty} \theta^k E_t(\Lambda_{t,t+k} Y_{t+k|t}(\frac{1}{P_{t+k}}) \left((1+\tau) P_t^f - \frac{\epsilon}{\epsilon - 1} \Phi'_{t+k}(Y_{t+k|t}) \right) = 0. \tag{19}$$

III.2.2. *Backward-Looking Firms.* Backward-looking firms set their prices equal to the previous period's reset price, adjusted by last period's inflation, according to the following rule of thumb

$$P_t^b = P_{t-1}^{\bar{*}} \Pi_{t-1} \tag{20}$$

where $\Pi_{t-1} \equiv \frac{P_{t-1}}{P_{t-2}}$.

III.3. **The Phillips Curve.** The inclusion of an additional subset of firms that are backward looking implies a hybrid Phillips curve (Galí and Gertler (1999)). After log-linearizing equations (14), (15), (19), and (20), we derive the following Phillips curve with backward-looking firms

$$\pi_t = \chi^f \beta E_t(\pi_{t+1}) + \chi^b \pi_{t-1} + \kappa x_t + u_t, \tag{21}$$

so that inflation, π_t, is a function of past and expected inflation with respective weights given by $\chi^b = \frac{\omega}{(\omega(1-\theta+\theta\beta)+\theta)}$ and $\chi^f = \frac{\theta}{\omega(1-\theta+\theta\beta)+\theta}$, and of the output gap, x_t, defined as output deviations from the natural level of output, y_t^*. An exogenous cost-push shock u_t is included and evolves according to the following process:

$$u_t = \rho^u u_{t-1} + \sigma^u \epsilon_t^u, \tag{22}$$

where ρ^u is the persistence and σ^u is the standard deviation of the innovation ϵ_t^u.

The slope of the Phillips curve is given by

$$\kappa = \frac{(1-\omega)(1-\theta)(1-\theta\beta)}{(\omega(1-\theta+\theta\beta)+\theta)}(\sigma+\psi), \tag{23}$$

so that the slope collapses to the typical expression, $\frac{(1-\theta)(1-\theta\beta)}{\theta}(\sigma + \psi)$, when all firms have forward-looking expectations ($\omega=0$).

III.4. **Monetary Policy.** We consider three alternative monetary policy frameworks, including an inflation-targeting rule

$$r_t = \bar{r} + \phi^\pi \pi_t + \phi^x x_t, \tag{24}$$

a price-level targeting rule

$$r_t = \bar{r} + \phi^p p_t + \phi^x x_t, \tag{25}$$

and an average-inflation targeting rule

$$r_t = \bar{r} + \frac{\phi^\pi}{m} \sum_{k=0}^{m} \pi_{t-k} + \phi^x x_t, \tag{26}$$

where m denotes the number of lags included when calculating average inflation. As a robustness exercise, we also consider a broader rule that includes expected inflation terms.

III.5. **Equilibrium.** Clearing in the labor market implies

$$N_t = \lambda N_t^H + (1 - \lambda) N_t^S \tag{27}$$

where aggregate employment across all i firms is given as

$$N_t = \int_0^1 N_t(i) di \tag{28}$$

Equilibrium in the goods market implies

$$Y_t = C_t = \lambda C_t^H + (1 - \lambda) C_t^S. \tag{29}$$

Table 1 provides a summary of the model's equilibrium conditions.

IV. Calibration

Table 2 summarizes the calibration of the benchmark model with backward-looking firms and hand-to-mouth consumers. Starting with the household, we assume an elasticity of labor supply, ψ, of 1 and a constant risk aversion parameter, σ, of 1, implying logarithmic preference. The household's discount factor β will be set equal to 0.994, implying a steady-state interest rate of 2.4percent. With limited asset market participation, there is one additional parameter λ, which determines the fraction of hand-to-mouth consumers. In our calibration, we assume 20percent of the population lives hand-to-mouth with $\lambda = 0.2$.

For the firms, we set the probability that a firm is unable to adjust prices each quarter, θ, to 0.7, which implies that prices are fixed on average for four quarters. The elasticity of substitution across goods, ϵ, will be set equal to 5, implying a markup of 1.25. With backward-looking firms, we set $\omega = 0.75$. Under this calibration the coefficients for lagged inflation (χ^b) and expected inflation next quarter (χ^f) in equation (21) are 0.52 and 0.48 respectively.

As for the calibration for the three policy rules, we consider an average-inflation targeting policy rule with up to 15 lags. For each policy, we set the weights on the target (ϕ^π and ϕ^P) equal to 1.5, where we assume no interest rate smoothing nor any weight on the output gap. Lastly, there are two shocks in the model; a demand shock and a cost-push shock. Following Guerrieri and Iacoviello (2014), each shock will follow an AR(1) process with a persistence of 0.6 and standard deviation of 0.0067.

V. Results

In this section, we examine the performance of average-inflation targeting relative to a simple Taylor rule or policies that target either the current or expected inflation rate or the

price level. As a reference point, we also compute the optimal policy under commitment. Using model simulations, we first examine the optimal degree of history dependence under average-inflation targeting in our benchmark economy and a few alternative specifications: (i) Ricardian households and all firms set expectations in a forward-looking manner (the standard New Keynesian framework), (ii) Ricardian households and a fraction of firms have backward-looking expectations (the Gali-Gertler framework), and (iii) hand-to-mouth consumers and all firms set expectations in a forward-looking manner (a TANK framework). We solve the model numerically using the algorithm developed in Guerrieri and Iacoviello (2015), which uses a first-order perturbation approach applied in a piecewise fashion to environments with occasionally binding constraints.

To compare our results with the literature, we first focus on cost-push shocks, abstracting from the ELB. We then introduce the ELB constraint and focus on demand shocks, as they are more relevant for the challenges that the constraint imposes on monetary policy.[2] We contrast the impact of the policies on household welfare and on the volatility of the economy. Throughout, we examine the extent to which average-inflation targeting, under the optimal degree of history dependence, can approximate the properties of the economy under price-level targeting.

V.1. **The Optimal Degree of History Dependence.** We first look at the optimal degree of history dependence under average-inflation targeting under commitment for our benchmark economy and the alternative models. For this analysis, we assume that the coefficients on inflation and the output gap in the interest-rate rules remain fixed. We calculate the optimal degree of history dependence by varying the window's length, k, in the average-inflation

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[2]While a negative cost-push shock could move the policy rate to the ELB, it would be accompanied by higher output.

targeting rule to maximize households' welfare. We conduct this exercise by simulating the economy for 10,000 periods.

Table 3 reports the optimal averaging window length, assuming that interest rates are above the ELB and that only cost-push shocks impact the economy. We find that the optimal degree of history dependence in the benchmark economy is only two quarters. The size of the averaging window is robust to abstracting from the presence of hand-to-mouth consumers. However, this small degree of history dependence is largely due to the presence of firms with backward-looking expectations. It is instead optimal to include eight quarters when calculating the average inflation rate when all firms have forward-looking expectations. As shown in the literature (e.g., Néssen and Vestin (2005)), makeup strategies, including average-inflation targeting, can be costly in responding to cost-push shocks under adaptive expectations. For instance, following a positive cost-push shock that increases inflation, average-inflation targeting with a long averaging window promises to disinflate the economy without the full stabilizing benefits from lower expected inflation that would arise when all firms form expectations in a forward-looking manner. As a result, the policy increases output volatility, which is costly in terms of welfare. The optimized average-inflation targeting policy in this case dictates a short window and more drift in the price level.

However, this intuition doesn't carry through to demand shocks. The top panel of Table 4 shows that the optimal window length of roughly five quarters is stable across all model variations, including environments where some firms have adaptive expectations. By inducing history dependence, makeup strategies are closer to the optimal monetary policy under commitment in the canonical baseline New Keynesian framework, which displays policy persistence (Woodford (1999)). Since demand shocks do not entail a trade-off between inflation

and output stabilization, the size of the averaging window is robust to adaptive expectations. It is similarly robust to varying the degree of hand-to-mouth households.

In contrast, the optimal degree of history dependence importantly hinges on the inflation weight in the interest-rate rule. Figure 1 shows that the optimal size of the averaging window is inversely related to that weight.[3]

Average-inflation targeting and the ELB. We now introduce the ELB in our analysis. We concentrate on demand shocks, since cost-push shocks do not capture the challenges imposed by a weak economy with low inflation at the ELB.

The bottom panel of Table 4 reports that taking into account the ELB increases the optimal degree of history dependence, with the magnitude of this effect being slightly more pronounced when all firms have forward-looking expectations. Across the different model specifications, the optimal size of the averaging window is between six and seven quarters. In the presence of the ELB, a higher degree of history dependence is welfare enhancing, since it introduces needed policy accommodation through expectations of a lower-for-longer policy stance. While the monetary policy rules in our baseline model do not directly respond to economic activity, assuming that policymakers put some weight (i.e., $\phi^x = 0.5$) on the output gap does not change the width of the optimal window, as shown in Table 5.

To highlight this channel, we compare the behavior of the economy under average-inflation targeting and a few alternative policies following a negative demand shock that pushes the economy to the ELB. In particular, we consider a simple Taylor rule, price-level targeting, and the optimal policy under commitment. As shown in Figure 2, output and inflation decline substantially more when monetary policy is governed by the Taylor rule. The policy rate lifts

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[3]Note that there is a unique stable local equilibrium even when the weight on inflation is less than 1, as long as there is a sufficient degree of history dependence.

off from the ELB after four quarters, as output recovers and the disinflationary pressures diminish. In contrast, the movements in output and inflation are much more muted under the optimal policy. Output declines less than half as much and inflation falls only slightly before overshooting the target for several quarters. Compared to price-level targeting or the optimized average-inflation targeting rule, the optimal policy lowers the policy rate sooner and for a prolonged period. The economy's response under the price-level targeting rule is qualitatively similar to that under the optimal policy, although output and inflation decline more. average-inflation targeting with an optimal window length of six quarters leads to output and inflation outcomes that are close to those under price-level targeting.

The similarity between these two policies can also be seen more comprehensively in Figure 3, which reports the volatility of inflation and output against the volatility of the interest rate, thus facilitating comparison across policies. Using the benchmark economy, we derive this figure by varying the weight on inflation (or the price level) in the interest-rate rules. The figure shows that the standard deviation of inflation and output decline, because monetary policy becomes more responsive to price pressures and interest rates become more volatile. The decline in both inflation and output volatility reflects the absence of stabilization trade-offs under demand shocks. Importantly, the figure shows that the properties of price-level targeting can be well approximated by average-inflation targeting with a relatively short averaging window. For a given volatility of interest rates, the volatility of inflation and output under average-inflation targeting or price-level targeting are quantitatively similar and substantially lower than under the Taylor rule. In addition, as shown in Table 6, welfare is only slightly lower under average-inflation targeting than price-level targeting.

VI. Conclusion

In this paper, we reconsidered the implications of average-inflation targeting in a New Keynesian framework that accounts for the presence of the ELB. Given that the benefits of makeup strategies largely derive from their forward-looking nature and the associated effects on expectations, we examined an environment in which this channel is constrained by adaptive expectations and financial market imperfections. We focused on average-inflation targeting in the form of implementable rules and found that the degree of history dependence is relatively low in our baseline economy. In most cases, it is optimal for the central bank to target an average inflation rate calculated over a window of slightly less than two years, yielding outcomes that are very close to those generated by price-level targeting.

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Table 1. Summary of equilibrium conditions

Summary	Nonlinearized
FOC C_t^S	$1/R_t = \beta E_t \left(\left(\frac{C_t^S}{C_{t+1}^S} \right)^\sigma \frac{P_t}{P_{t+1}} \right)$
FOC N_t^S	$(N_t^S)^\psi = C_t^{S-\sigma} W_t$
Budget constraint S	$C_t^S = W_t N_t^S + D_t$
FOC N_t^H	$(N_t^H)^\psi = C_t^{H-\sigma} W_t$
Budget constraint H	$C_t^H = W_t N_t^H$
Labour market clearing	$N_t = \lambda N_t^H + (1-\lambda) N_t^S$
Goods market clearing	$C_t = Y_t$
Aggregate consumption	$C_t = \lambda C_t^H + (1-\lambda) C_t^S$
Firm production	$Y_t = N_t$
Marginal costs	$\Phi_t = P_t W_t$
FOC for p_t^f	$\sum_{k=0}^{\infty} \theta^k E_t (\Lambda_{t,t+k} Y_{t+k\mid t} (\frac{1}{P_{t+k}}) \left((1+\tau) P_t^f - \frac{\epsilon}{\epsilon-1} \Phi'_{t+k}(Y_{t+k\mid t}) \right) = 0$
Rule-of-thumb price setters	$P_t^b = \bar{P}_{t-1}^* \Pi_{t-1}$
Aggregate price level	$P_t = P_{t-1}{}^\theta \bar{P}_t^{*(1-\theta)}$
Reset price	$\bar{P}_t^* = P_t^{f(1-\omega)} P_t^{b\omega}$
Aggregate IS curve	$\frac{1}{1+(r_t - r_t^n)} = \beta E_t \left(\left(\frac{X_t}{X_{t+1}} \right)^{\sigma \frac{(1-\lambda\chi)}{(1-\lambda)}} \frac{P_t}{P_{t+1}} \right)$
Phillips curve	$\Pi_t = E_t(\Pi_{t+1}^{\chi^f \beta}) \Pi_{t-1}{}^{\chi^b} X_t{}^\kappa u_t$
Monetary policy rule	*varied*

TABLE 3. The Optimal Degree of History Dependence: Cost-Push Shocks

Model	Optimal Width
Benchmark Model $(\omega = 0.75, \lambda^H = 0.2)$	2
Hand-to-Mouth Consumer $(\omega = 0, \lambda^H = 0.2)$	8
Backwards Looking Firms $(\omega = 0.75, \lambda^H = 0)$	2
Baseline New Keynesian $(\omega = 0, \lambda^H = 0)$	7

Table 4. The Optimal Degree of History Dependence: Demand Shocks

| Model	Optimal Width
Without Zero Lower Bound	
Benchmark Model ($\omega = 0.75, \lambda^H = 0.2$)	5
Hand-to-Mouth Consumer ($\omega = 0, \lambda^H = 0.2$)	4
Backwards Looking Firms ($\omega = 0.75, \lambda^H = 0$)	5
Baseline New Keynesian ($\omega = 0, \lambda^H = 0$)	5
With Zero Lower Bound	
Benchmark Model ($\omega = 0.75, \lambda^H = 0.2$)	6
Hand-to-Mouth Consumer ($\omega = 0, \lambda^H = 0.2$)	7
Backwards Looking Firms ($\omega = 0.75, \lambda^H = 0$)	6
Baseline New Keynesian ($\omega = 0, \lambda^H = 0$)	7

TABLE 5. The Optimal Degree of History Dependence: Demand Shocks and

Output Gaps

Model	Optimal Width Weight on Output Gap, $\phi^x = 0$	Optimal Width Weight on Output Gap, $\phi^x = 0.5$
Benchmark Model ($\omega = 0.75, \lambda^H = 0.2$)	6	6
Hand-to-Mouth Consumer ($\omega = 0, \lambda^H = 0.2$)	7	7
Backwards Looking Firms ($\omega = 0.75, \lambda^H = 0$)	6	6
Baseline New Keynesian ($\omega = 0, \lambda^H = 0$)	7	7

Table 6. Welfare

Model	Optimal window (quarters)
Benchmark model ($\omega = 0.75, \lambda^H = 0.2$)	2
Hand-to-mouth consumers ($\omega = 0, \lambda^H = 0.2$)	8
Backward-looking firms ($\omega = 0.75, \lambda^H = 0$)	2
Baseline New Keynesian ($\omega = 0, \lambda^H = 0$)	7

FIGURE 1. The Optimal Window Length and the Weight on Inflation in the Rule

Inflation

Output

Price Level

Interest Rate
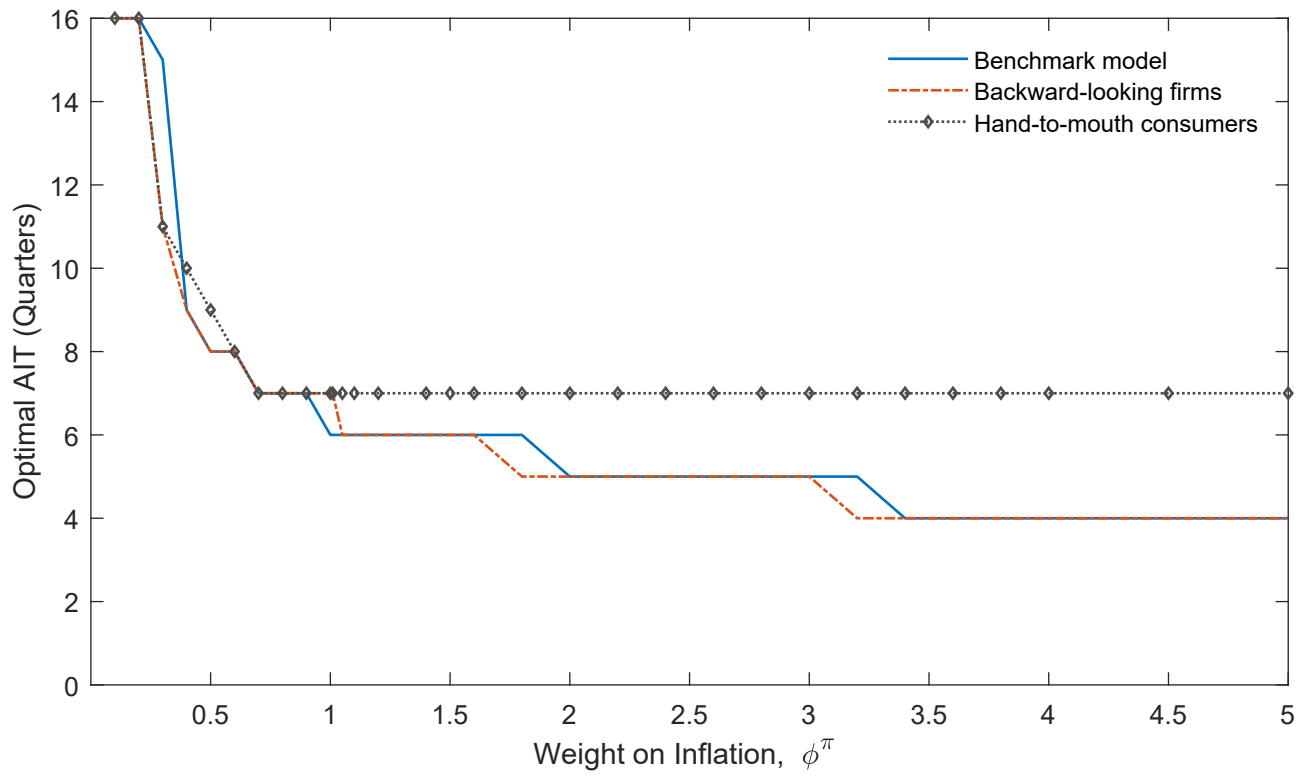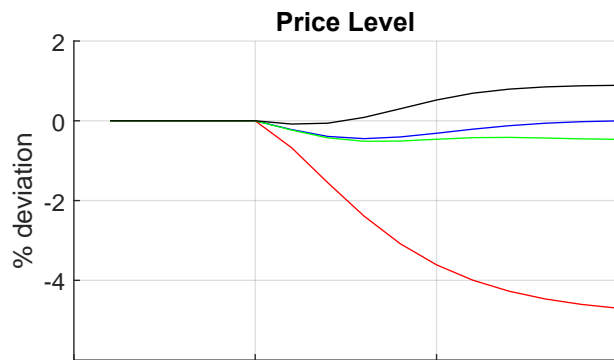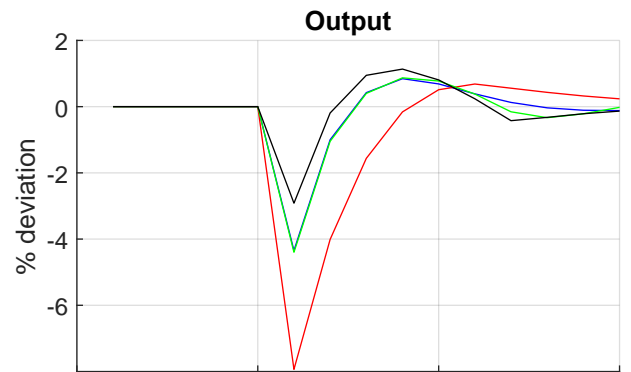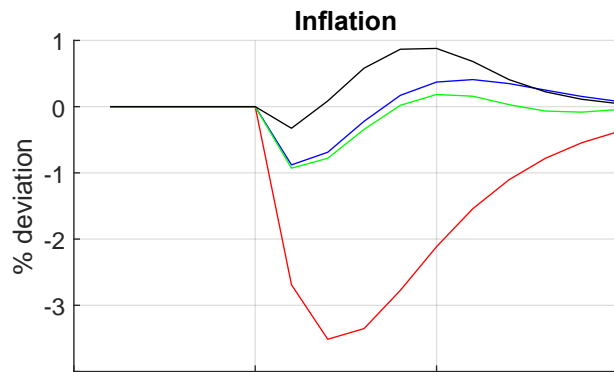
——— Price-level targeting ——— Inflation targeting ——— Optimized average-inflation targeting ——— Optimal policy under commitment

FIGURE 3. Output and Inflation Volatility under Alternative Policies