Better On Average? Average Inflation Targeting with Unconventional Monetary Policy

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Abstract

This paper incorporates the term structure and the Fed's new average inflation targeting (AIT) framework into the DSGE model of Sims and Wu (2020) with an occasionally binding zero-lower bound. When agents know the Fed's exact policy rule, AIT stabilizes inflation and household utility compared to standard inflation targeting. Inflation is most stable, and household utility is highest, when the average window is 8 and 16 quarters, respectively. The Fed has not revealed their lag structure of AIT, and this imperfect information affects the model's results. If agents don't know the exact details of the policy, inflation is most stable when the Fed averages inflation over longer periods. Outcomes are always better when the Fed reveals the specific details about the policy.

Keywords: Average Inflation Targeting, Unconventional Monetary Policy, Zero-Lower Bound, Imperfect Information

JEL Classification: E31, E52, E61

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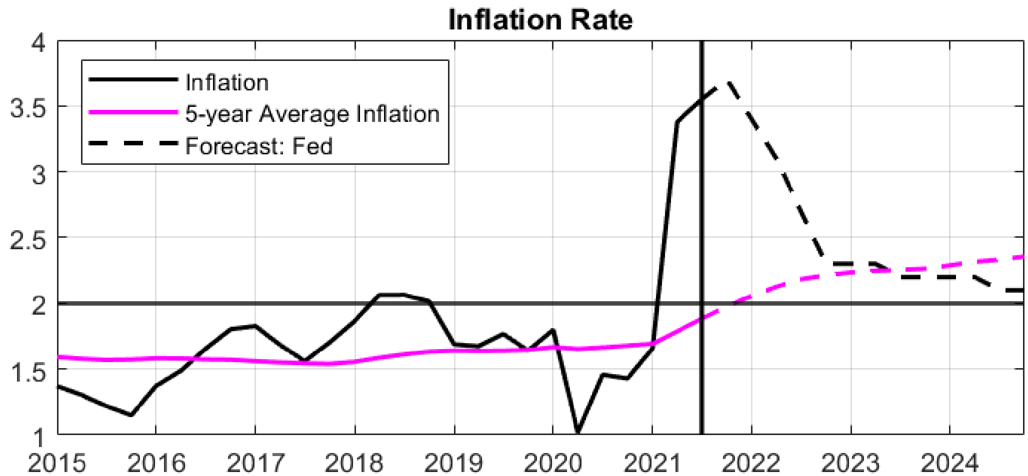

Figure 1: U.S. core Personal Consumption Expenditures inflation since 2015. The inflation projection is the median forecast from the Fed's September 2021 Summary of Economic Projections.

1 Introduction

Since the 2008 Financial Crisis, monetary policy has faced a host of new challenges. The Federal Reserve lowered interest rates to their zero-lower bound in 2008, forcing it to utilize non-interest rate policies, such as quantitative easing, forward guidance, and targeted asset purchases. These "unconventional" policies allowed the Fed to influence economic outcomes when the interest rate is limited. While these were viewed as "break glass in case of emergency" policies, the economic shock associated with the recent COVID-19 pandemic forced the Fed to lower interest rates again to their lower bound and again utilize these policies. What's more, the estimated decline in the natural rate of interest[1] indicates unconventional policy will likely continue to be a piece of the monetary policy equation moving forward. Thus, these are now an important component of the Fed's policy toolkit.

Meanwhile, inflation persistently undershot the Fed's stated 2% goal from 2008-2020. (see Figure 1), and many began to view 2% as the Fed's ceiling for inflation, rather than a symmetric target. These lowered inflation expectations push nominal interest rates down

[1]See Laubach and Williams (2003) and Del Negro et al. (2017).

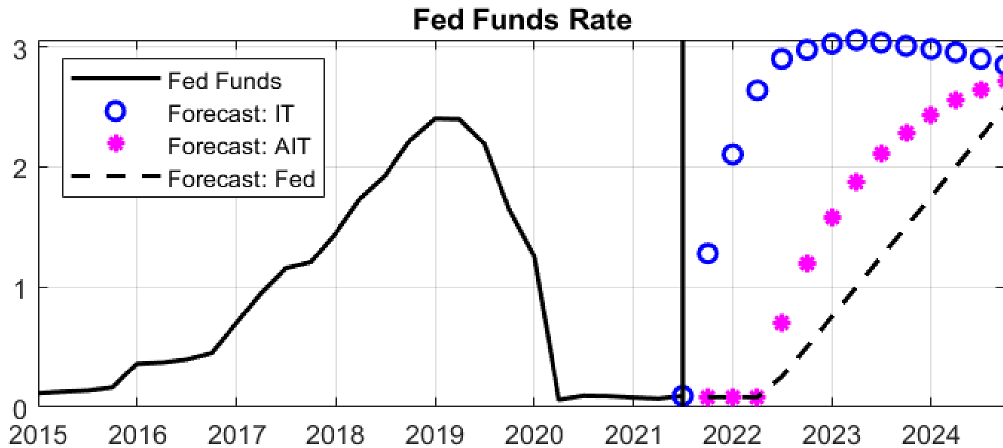

Figure 2: The fed funds rate since 2015. The Fed projection is the median forecast from the Fed's September 2021 Summary of Economic Projections. The IT forecast uses a standard inflation targeting Taylor Rule while the AIT forecast uses a 5-year average inflation targeting Taylor Rule.

via the Fisher equation, increasing the frequency of the zero-lower bound and the need for unconventional policy. The Fed noted this challenge when reevaluating its policy framework, committing to an average inflation targeting (AIT) framework rather than targeting single period inflation. Instead of letting "bygones be bygones" regarding past undershooting, the Fed would now employ a makeup strategy, whereby past undershooting would be met with future overshooting. This, the Fed believed, would push inflation expectations closer to 2%, increasing nominal interest rates and decreasing the frequency with which unconventional policies are used. Since the economic reopening in late 2020, however, inflation has increased drastically to a 30-year high. Under the new framework, the Fed projects they will not begin raising rates until mid-2022, with rates settling at a lower long-run level (2.5%). Figure 2 compares the forecasted response of the fed funds rate under an inflation targeting Taylor Rule, a 5-year average inflation targeting Taylor Rule, and the median FOMC forecast. Under standard inflation targeting, the Taylor Rule would prescribe a tighter policy faster, while the 5-year AIT Taylor Rule prescribes a slower response and more closely matches the FOMC projections. This paper attempts to answer how this average inflation targeting will fare over time, and whether it leads to better outcomes than standard inflation targeting.

Research into average inflation targeting is largely just beginning. Nessen and Vestin (2005) are the first to consider how average inflation targeting can differ from traditional inflation targeting. They find a price level target strictly dominates both average inflation targeting and standard inflation targeting in a pure forward-looking model. However, when backward-looking elements are introduced, average inflation targeting can improve outcomes compared to both price level targeting and standard inflation targeting. Both Amano et al. (2020) and Budianto et al. (2020) extend this specification by incorporating the zero-lower bound into their analysis. Both find that average inflation targeting improves policy, even with a zero-lower bound, and the degree of history dependence is key to the policy's effectiveness. Importantly, neither Amano et al. nor Budianto et al. consider the effect of unconventional monetary policy or financial frictions when evaluating average inflation targeting. Jia and Wu (2021) incorporate the time inconsistency of the policy, finding that AIT shifts the Phillips Curve and incentivizes the central bank to deviate from its stated policy. In turn, uncertainty can actually aid the central bank stabilize inflation and output. Meanwhile, empirical research has shown mixed effects of the introduction average inflation targeting. Coibion et al. (2020) showed that most of the public had not known about the shift in the Fed's policy strategy, and Candia et al. (2021) found that, while many still had not known of the policy, their inflation expectations had begun to shift upwards.

In this paper, I evaluate the effectiveness of average inflation targeting in improving economic outcomes and decreasing the need for unconventional policy. I do this by incorporating imperfect information about average inflation targeting (AIT) into a DSGE model with an occasionally binding zero-lower bound and unconventional monetary policy. The model has an environment based on Sims and Wu (2021) and allows the central bank to set monetary policy using a simple interest rate rule, augmented for AIT, when interest rates are above the lower bound. However, when interest rates become constrained, the central bank can switch its policy instrument, using a policy rule for its balance sheet, similar to the Fed's quantitative easing. Unconventional policy works by reducing financial frictions caused by the financial intermediary's agency problem, allowing for greater firm investment and smoothed credit shocks. Additionally, average inflation targeting works as a trade-off between less stimulative policy contemporaneously and more stimulative policy in the future. Put simply, the effectiveness of average inflation targeting depends on its influence on expectations: if it can raise expectations enough to compensate for slower policy responses, it will be more effective than standard inflation targeting. However, under imperfect information, agents cannot directly observe the central bank's averaging window. Instead, agents must form an expectation on the averaging window based on past policy, updating as more information becomes available.

Results show that average inflation targeting does, indeed, lead to a slower policy to shocks, so output and inflation decline more than the baseline case. However, these larger declines are met with greater increases in output and inflation in the future. Taken as a whole, simulations show that modest average inflation targeting can improve economic outcomes compared to the baseline under both full and imperfect information. These modest averaging windows more effectively stabilize inflation and decrease the zero-lower bound frequency, two of the Fed's stated goals for the framework. However, the central bank does run the risk of "over-averaging," where they target average inflation over too long a period, leading to slower policy responses and greater instability. Overall, inflation is best stabilized by targeting inflation over 8 quarters under full information, while household welfare is maximized by targeting average inflation over longer periods. However, the success of the policy is dependant on the central bank's ability to transparently commit to an averaging rule, as the most effective policy under imperfect information leads to consistently worse outcomes than the least effective policy under full information.

2 Additional Literature

This paper lies at the intersection of two strands of literature: that on unconventional monetary policies and alternative monetary policy goals. Several empirical papers have examined the effectiveness of non-interest rate policies, such as quantitative easing and forward guidance, in replacing traditional interest rate policies. An excellent summary of the literature surrounding unconventional policy can be found in Kuttner (2018). Papers such as Gagnon et al. (2011), Krishnamurthy and Vissing-Jorgensen (2011), and Baur and Neely (2014) take an event study approach to quantifying the effects of QE, finding that QE did significantly reduce long-term interest rates. Specifically, 10-year Treasury yields declined roughly 150 basis points in response to announcements of QE. Quantitative easing has also been shown to have effects on real outcomes as well. Rodnyansky and Darmouni (2017) and Luck and Zimmerman (2017) found that QE1 and QE3 led to increased bank lending, while Foley-Fischer, Ramcharan, and Yu (2016) found that firms issued more long-term debt in response to QE, leading to greater capital spending and employment. Finally, Engen, Laubach, and Reifschneider (2015) and Wu and Xia (2016) found that unconventional policies had similar effects on the overall economy to that of a 300 basis point decline in the fed funds rate.

Unconventional monetary policy has also presented new challenges for modelers. Indeed, the Fed's use of non-interest rate instruments has necessitated modelers expand the sphere of policy and its transmission in macroeconomic models. Gertler and Karadi (2011, 2013), Carlstrom et al. (2017) and Sims and Wu (2020, 2021) incorporate quantitative easing into a DSGE model by segmenting financial markets and incorporating financial frictions. These models allow quantitative easing to work slightly differently than traditional interest rate policy, as asset purchases ease financing constraints on firms and reduce the effect of financial frictions on banks. Other papers have begun to incorporate the idea that unconventional policy may have limited effectiveness as it is used more frequently. McMahon et al. (2018) find that inflation can become indeterminate when the central bank expends its balance sheet without restricting the composition of its assets, and Karadi and Nakov (2020) find QE loses its effectiveness to offset nonfinancial shocks as bank balance sheets become unconstrained.

While much has been made about the Fed's shift to average inflation targeting, commitment and transparency are key determinants to the success of a shift in policy strategy. Erceg and Levin (2003) showed that the dynamics of inflation during the Volcker disinflation could largely be accounted for with rational, optimizing agents by incorporating imperfect information surrounding the inflation target. Ireland (2007) extends this imperfect information framework to estimate the Fed's true inflation target from the 1950's to early 2000's, finding the target increased as high as 8% in the 1970s before settling at roughly 2.5% in the 2000s. Finally, De Michelis and Iacoviello (2016) examine the interaction of imperfect information and the zero-lower bound, applied to the introduction of Abenomics in Japan. They find information availability plays an even larger role in policy effectiveness when the interest rate is constrained by the zero-lower bound, as inflation and output are only half as responsive to changes in the inflation target under imperfect information.

3 Model

The model has an environment based on Sims and Wu (2021) containing both forward- and backward-looking elements with 6 types of agents: households, firms, financial intermediaries, the labor market, the fiscal authority, and the central bank. Households consume, hold short-term deposits, and a fraction of households supply labor through the labor union while the remainder are intermediaries. The labor union purchases differentiated labor from the household and sells it as final labor to firms. There are 4 types of firms: retail, wholesale, capital producing, and final goods firms which transform capital and labor into final output. Wholesale firms must finance a portion of new projects by issuing long-term bonds. The financial intermediary can lend by holding these long-term bonds, but are subject to a value constraint. The fiscal authority finances its spending by levying lump-sum taxes on the household, collecting transfers from the central bank, and issuing long-term bonds. Finally, the central bank sets monetary policy according to two Taylor-type rules: one for interest rate policy when above the zero-lower bound, and one for bond-purchasing policy when against the zero-lower bound.

3.1 Households

There are two types of members within each household: workers and intermediaries. A fixed fraction of households are financial intermediaries, and each period intermediaries stochastically exit and become workers. Households all have the same lifetime utility function and maximize:

$$\mathbb{E}_t \sum_{j=0}^{\infty} \beta^j \left[ln(C_{t+j} - bC_{t+j-1}) - \frac{\xi L_{t+j}^{1+\eta}}{1+\eta} \right] \tag{3.1.1}$$

where $\beta \in (0,1)$ is the discount factor, $b \in [0,1)$ is the habit formation parameter, η is the inverse Frisch elasticity, ξ is a scaling parameter, C_t is consumption, and L_t is the labor supplied. Households also face the following budget constraint when making their purchasing decisions:

$$P_t C_t + D_t - D_{t-1} \leq MRS_t L_t + DIV_t - P_t X - P_t T_t + (R_{t-1}^d - 1)D_{t-1} \tag{3.1.2}$$

where P_t is the price level, D_{t-1} is the nominal level of deposits a household has entering period t, R_{t-1}^d is the interest rate paid on those deposits, MRS_t is the compensation a household receives for their labor supplied. DIV_t are dividends received from ownership of nonfinancial firms, X is startup capital for new intermediaries, and T_t are lump-sum taxes.

3.2 Labor Market

The labor market consists of two portions: labor unions who purchase labor from households, and labor packers who sell final labor to firms. The labor union, indexed by $h \in [0,1]$, is given by the demand curve:

$$L_{d,t}(h) = \left(\frac{W_t(h)}{W_t}\right)^{-\epsilon_w} L_{d,t} \tag{3.2.1}$$

where $W_t(h)$ is the wage paid for union h's labor and ϵ_w is the elasticity of substitution. The aggregate wage is then simply:

$$W_t^{1-\epsilon_w} = \int_0^1 W_t(h)^{1-\epsilon_w} dh \tag{3.2.2}$$

Unions are subject to Calvo-style nominal wage rigidity, so each period unions face a $1-\phi_w$ probability they can adjust their wage, with $\phi_w \in [0,1]$. When wages are not updated, they can be indexed to inflation with the weight $\gamma_w \in [0,1]$. Profit for a labor union is a function of the labor markup they receive by repackaging labor:

$$DIV_{L,t}(h) = W_t(h)^{1-\epsilon_w} W_t^{\epsilon_w} L_{d,t} - MRS_t W_t(h)^{-\epsilon_w} W_t^{\epsilon_w} L_{d,t} \tag{3.2.3}$$

Labor unions, taking this into account, would optimally set the real wage, $w_t^* = \frac{W_t^*}{P_t}$, at:

$$w_t^* = \frac{\epsilon_w}{\epsilon_w - 1} \frac{f_{1,t}}{f_{2,t}} \tag{3.2.4}$$

$$f_{1,t} = mrs_t w_t^{\epsilon_w} L_{d,t} + \phi_w \, \mathbb{E}_t \, \Lambda_t \left(\frac{\Pi_{t+1}}{\Pi_t^{\gamma_w}}\right)^{\epsilon_w} f_{1,t+1} \tag{3.2.5}$$

$$f_{2,t} = w_t^{\epsilon_w} L_{d,t} + \phi_w \, \mathbb{E}_t \, \Lambda_t \left(\frac{\Pi_{t+1}}{\Pi_t^{\gamma_w}}\right)^{\epsilon_w - 1} f_{2,t+1} \tag{3.2.6}$$

Integrating the union labor demand curve across h gives the aggregate labor demand curve:

$$L_t = L_{d,t} v_t^w \tag{3.2.7}$$

where v_t^w is the wage dispersion:

$$v_t^w = \int_0^1 \left(\frac{w_t(h)}{w_t}\right)^{-\epsilon_w} dh \tag{3.2.8}$$

which, combined with the optimal wage, w^*, gives the expression for the aggregate wage:

$$w_t^{1-\epsilon_w} = (1-\phi_w)(w_t^*)^{1-\epsilon_w} + \phi_w \Pi_{t-1}^{\gamma_w(1-\epsilon_w)} \Pi_t^{\epsilon_w - 1} w_{t-1}^{1-\epsilon_w} \tag{3.2.9}$$

3.3 Production Firms

There are four types of firms in the economy: wholesale, retail, capital producing, and final goods. Wholesale firms use capital and labor to create output, $Y_{m,t}$, capital producing firms create physical capital, $\hat{I}_t$, and retail firms repackage and sell wholesale output.

Retail firms face the demand curve:

$$Y_t(f) = \left(\frac{P_t(f)}{P_t}\right)^{\epsilon_p} Y_t \tag{3.3.1}$$

where $P_t(f)$ is the price of the retail output. The price of final output is then given by:

$$P_t^{1-\epsilon_p} = \int_0^1 P_t(f)^{1-\epsilon_p} df \tag{3.3.2}$$

where ϵ_p is the elasticity of substitution. Similar to labor unions, retailers face a Calvo-style price rigidity, so firms face a probability $1-\phi_p$ of being able to adjust their price each period and can index their price to inflation with weight γ_p. Taking this into account, firms maximize their dividends:

$$DIV_{R,t}(f) = P_t(f)^{1-\epsilon_p} P_t^{\epsilon_p} Y_t - P_{m,t} P_t(f)^{-\epsilon_p} P_t^{\epsilon_p} Y_t \tag{3.3.3}$$

Retailers attempt to optimally set prices at:

$$p_t^* = \frac{\epsilon_p}{\epsilon - 1} \frac{x_{1,t}}{x_2, t} \tag{3.3.4}$$

$$x_{1,t} = p_{m,t} Y_t + \phi_p \, \mathbb{E}_t \, \Lambda_t \left(\frac{\Pi_{t+1}}{\Pi_t^{\gamma_p}}\right)^{\epsilon_p} x_{1,t+1} \tag{3.3.5}$$

$$x_{2,t} = Y_t + \phi_p \mathbb{E}_t \Lambda_t \left(\frac{\Pi_{t+1}}{\Pi_t^{\gamma_p}} \right)^{\epsilon_{p-1}} x_{2,t+1} \tag{3.3.6}$$

Aggregating across all retail firms gives the aggregate price index:

$$1 = (1 - \phi_p)(p_t^*)^{1-\epsilon_p} + \phi_p \Pi_{t-1}^{\gamma_p(1-\epsilon_p)} \Pi_t^{\epsilon_p - 1} \tag{3.3.7}$$

Wholesale firms produce output with a Cobb-Douglas production function:

$$Y_{m,t} = A_t (u_t K_t)^{\alpha} L_{d,t}^{1-\alpha} \tag{3.3.8}$$

where $Y_{m,t}$ is output, $L_{d,t}$ is the labor input, α is the capital share. A_t is exogenous productivity which follows a stochastic process, u_t is capital utilization, and the capital stock, K_t, accumulates with a normal law of motion:

$$K_{t+1} = \hat{I}_t + (1 - \delta(u_t))K_t \tag{3.3.9}$$

Wholesale firms must finance a constant portion, $\psi \in [0, 1]$, of their new capital purchases, $\hat{I}_t$, bought at price P_t^k.[2] To do this, similar to Carlstrom et al. (2017), firms must issue perpetual bonds. This creates the "loan in advance" constraint:

$$\psi P_t^k \hat{I}_t \leq Q_t CF_{m,t} = Q_t(F_{m,t} - \kappa F_{m,t-1}) \tag{3.3.10}$$

where $CF_{m,t}$ is the new nominal bond issuance, and $F_{m,t}$ is the total outstanding liability due in period t. These wholesale firms incorporate the loan in advance constraint and attempt to maximize dividends:

$$DIV_{m,t} = P_{m,t} A_t (u_t K_t)^{\alpha} L_{d,t}^{1-\alpha} - W_t L_{d,t} - P_t^k \hat{I}_t - F_{m,t-1} + Q_t(F_{m,t} - \kappa F_{m,t-1}) \tag{3.3.11}$$

[2]While this fraction, ψ, is currently exogenous, future drafts of this paper will focus on endogenizing this so firms could attempt to take advantage of QE and good credit conditions

Finally, capital producing firms produce new capital via:

$$\hat{I}_t = \left[1 - S\left(\frac{I_t}{I_{t-1}}\right)\right] I_t \tag{3.3.12}$$

from unused output, I_t, with the adjustment cost $S(\frac{I_t}{I_{t-1}})$. They maximize dividends given by:

$$DIV_{k,t} = P_t^k \left[1 - S\left(\frac{I_t}{I_{t-1}}\right)\right] I_t - P_t I_t \tag{3.3.13}$$

3.4 Long Term Bonds

Both the fiscal authority and wholesale firm can finance their endeavours by issuing long-term bonds. Similar to Woodford (2001), these bonds are modeled as perpetuities with a constant decaying coupon payment, where the decay parameter is given by $\kappa \in [0, 1]$. New nominal bond issuances for the government are given by CB_t and issuances for firms are given by $CF_{m,t}$. Both follow a similar form where the total liability due in period t is based on previous issuances:

$$B_t = CB_{t-1} + \kappa CB_{t-2} + \kappa^2 CB_{t-3} + \ldots \tag{3.4.1}$$

Iterating forward gives:

$$CB_t = B_t - \kappa B_{t-1} \tag{3.4.2}$$

New government bond issuances are sold at the price $Q_{B,t}$, while new corporate bond issuances sell at price $Q_{F,t}$. Taken as a whole, the value of outstanding government and private bonds are given by

$$Q_{B,t}B_t = Q_{B,t}CB_{t-1} + \kappa Q_{B,t}CB_{t-2} + \kappa^2 Q_{B,t}CB_{t-3} + \ldots \tag{3.4.3}$$

$$Q_{F,t}F_t = Q_{F,t}CF_{t-1} + \kappa Q_{F,t}CF_{t-2} + \kappa^2 Q_{F,t}CF_{t-3} + \ldots \tag{3.4.4}$$

The interest rates on bonds, i_t^F and i_t^B, are the realized holding period returns:

$$i_t^B = \frac{1 + \kappa Q_{B,t}}{Q_{B,t-1}} \tag{3.4.5}$$

$$i_t^F = \frac{1 + \kappa Q_{F,t}}{Q_{F,t-1}} \tag{3.4.6}$$

The term premium, modeled similar to Carlstrom et al. (2017), is the difference between the realized interest rate on government debt, i_t^B, and the yield implied by the expectations hypothesis of the term structure as the sum of short rates over the life of the bond. The price and yield of the hypothetical expectations hypothesis bond are then:

$$Q_t^{EH} = \mathbb{E}_{\mathrm{t}} \frac{1 + \kappa}{i_{SS}^d} Q_{t+1}^{EH} \tag{3.4.7}$$

$$i_t^{EH} = \frac{1}{q_t^{EH}} + \kappa \tag{3.4.8}$$

In turn, the term premium and risk premium are:

$$tp_t = i_t^B - i_t^{EH} \tag{3.4.9}$$

$$rp_t = i_t^F - i_t^B \tag{3.4.10}$$

3.5 Financial Intermediaries

Financial intermediaries in this model are based on those in Gertler and Karadi (2013). They finance their lending to firms and government, as well as their reserve holdings, by absorbing household savings. In doing so, intermediaries also engage in maturity transformation, holding short-term liabilities in the form of deposits while holding long-term assets in the form of government and corporate bonds. Each period, a fraction $1 - \sigma$, with $\sigma \in [0, 1]$, of intermediaries stochastically exit, returning their net worth to households. These intermediaries are then replaced by new ones, beginning with the startup capital X from the household owner.

Intermediaries, indexed by z, hold long-term bonds issued by both the government and wholesale firms, as well as interest-bearing reserves, $RE_{z,t}$. They finance these holdings through their net worth, $N_{z,t}$, and by issuing deposits, $D_{z,t}$:

$$Q_{F,t}F_{z,t} + Q_{B,t}B_{z,t} + RE_{z,t} = D_{z,t} + N_{z,t} \tag{3.5.1}$$

Surviving intermediaries' net worth is given by:

$$\begin{aligned} N_{z,t} = (i_t^F - i_{t-1}^d)Q_{F,t-1}F_{z,t-1} + (i_t^B - i_{t-1}^d)Q_{B,t-1}B_{z,t-1} \\ + (i_{t-1}^{RE} - i_{t-1}^d)RE_{z,t-1} + i_{t-1}^d N_{z,t-1} \end{aligned} \tag{3.5.2}$$

where i_{t-1}^{re} is the interest rate on reserves, set by the central bank. i_{t-1}^d is the equilibrium deposit rate, and interest rates in (3.5.2) are given by their net interest margin. Intermediaries attempt to maximize their terminal wealth, discounted by the stochastic discount factor, Λ_t:

$$V_{z,t} = \max(1-\sigma)\,\mathbb{E}_{\mathrm{t}} \sum_{j=1}^{\infty} \sigma^{j-1}\Lambda_t n_{z,t+j}$$

with $n_{z,t} = N_{z,t}/P_t$. The financial intermediary faces two constraints. The first is a standard reserve requirement:

$$RE_{z,t} \geq \tau D_{z,t} \tag{3.5.3}$$

While the reserve requirement is an important piece in the intermediary's maximization, it rarely binds, consistent with the Fed's recent ample reserve regime.[3] Second, intermediaries face a value constraint similar to that in Gertler and Karadi (2013). This constraint allows intermediaries to abscond with a portion of their assets at the end of a period instead of

[3] For a summary of how an ample reserve regime differs from a scarce reserve regime, see the explanation in Ihrig et al. (2020)

continuing as an intermediary. When an intermediary absconds, depositors can only recover a portion of the intermediary's assets, while the intermediary retains the rest. Thus, for a depositor to lend to an intermediary, it must not be optimal for the intermediary to abscond and enter bankruptcy:

$$V_{z,t} \geq \theta_t(Q_{F,t}F_{z,t} + \Delta Q_{B,t}B_{z,t}) \tag{3.5.4}$$

Intuitively, the value constraint says that the value of continuing as an intermediary ($V_{z,t}$) must outweigh the value of the funds it can retain if it enters bankruptcy ($\theta_t[Q_t f_{z,t} + \Delta Q_{B,t} b_{z,t}]$). Once the intermediary enters bankruptcy, it keeps a fraction θ_t of its private bonds and $\theta_t \Delta$ of its government bonds, with $\Delta \in [0, 1]$. θ_t can thus be considered a credit wedge that arises from an agency problem in when an intermediary enters bankruptcy. Moreover, θ_t follows an AR(1) type process, and shocks can be considered a credit shock: when θ_t suddenly increases, depositors can recover fewer assets, so the agency problem worsens. In turn, interest rate spreads must increase for intermediaries to be willing to continue.

Taken as a whole, intermediaries have the optimality conditions:

$$\mathbb{E}_{\mathrm{t}}\, \Lambda_t \Omega_{t+1} \Pi_{t+1}^{-1}(i_{t+1}^{B} - i_t^{d}) = \frac{\lambda_t}{1+\lambda_t}\theta_t \Delta \tag{3.5.5}$$

$$\mathbb{E}_{\mathrm{t}}\, \Lambda_t \Omega_{t+1} \Pi_{t+1}^{-1}(i_{t+1}^{F} - i_t^{d}) = \frac{\lambda_t}{1+\lambda_t}\theta_t \tag{3.5.6}$$

$$\mathbb{E}_{\mathrm{t}}\, \Lambda_t \Omega_{t+1} \Pi_{t+1}^{-1}(i_{t+1}^{RE} - i_t^{d}) = -\frac{\omega_t}{1+\lambda_t} \tag{3.5.7}$$

where $\lambda_t \geq 0$ is the multiplier on the value constraint, ω_t is the multiplier on the reserve requirement, and:

$$\Omega_t = 1 - \sigma + \sigma(1+\lambda_t)\,\mathbb{E}_{\mathrm{t}}\left[\Lambda_{t,t+1}\Omega_{t+1}\Pi_{t+1}^{-1}\right] i_t^{D} - \frac{\sigma \omega_t RE_t}{N_t} \tag{3.5.8}$$

When the value constraint (3.5.4) binds, an intermediary's leverage ratio is given by:

$$\phi_t = \frac{Q_{F,t}F_{z,t} + \Delta Q_{B,t}B_{z,t}}{N_{z,t}} \tag{3.5.9}$$

This leverage ratio is lower than would be optimal for the intermediary, giving rise to excess returns on holding long-term bonds. However, when neither constraint binds ($\lambda_t = \omega_t = 0$), the credit spreads decrease to zero ($i^F_{t+1} = i^B_{t+1} = i^{RE}_t = i^D_t$).

3.6 Monetary Policy

The central bank can conduct monetary policy via interest rate and balance-sheet policies while targeting average inflation. The central bank can hold both private and government bonds, and it finances the purchases of these bonds by issuing interest-bearing reserves. The central bank balance sheet is given by:

$$Q_{F,t}F_{cb,t} + Q_{B,t}B_{cb,t} = RE_t \tag{3.6.1}$$

With standard policy, the central bank uses the short-term interest rate on reserves as its primary instrument to conduct policy, but the short-term interest rate can become constrained by the zero-lower bound. It sets policy according to a Taylor-type rule, responding to deviations of J-period average inflation from its stated inflation target, $\bar{\pi}$, as well as to the growth rate in output[4]. The $J-$period average of inflation is denoted by $\pi^J_t = \frac{1}{J}\sum_{j=0}^{J-1}\pi_{t-j}$. When the short-term interest rate is above the zero lower bound and the required reserve ratio is nonbinding, all short-term rates are equal to the desired policy rate:

$$i_t = \max\{0, i^{TR}_t\} \tag{3.6.2}$$

[4]The Taylor Rule in this model responds to output growth, rather than the output gap, for two reasons: first, because of the presence of both nominal and financial frictions, it is not clear what "potential" output should be, as most models on consider nominal frictions. Second, it is likely desireable for a central bank to focus on output growth, rather than an output gap, to resolve the imperfect knowledge problem discussed in Orphanides and Williams (2003).

$$i_t^D = i_t^{RE} = i_t^{TR} \tag{3.6.3}$$

which is set according to:

$$i_t^{TR} = \rho_{TR} i_{TR,t-1} + (1 - \rho_{TR}) \left[\phi_\pi (\pi_t^J - \bar{\pi}) + \phi_Y (Y_t - Y_{t-1}) \right] + e_{i,t} \tag{3.6.4}$$

where ρ_{TR} is the smoothing parameter, ϕ_π is the inflation feedback parameter, and ϕ_Y is the output growth feedback parameter. When the short-term interest rate becomes constrained by the zero-lower bound, the central bank then switches its policy instrument, utilizing its balance sheet in the spirit of the Fed's quantitative easing programs. It adjusts its bond holdings according to a similar Taylor-type rules[5]:

$$F_{cb,t} = \rho_F F_{cb,t-1} + (1 - \rho_F)\Psi \left[\phi_\pi (\pi_t^J - \bar{\pi}) + \phi_Y (Y_t - Y_{t-1}) \right] + e_{F,t} \tag{3.6.5}$$

$$B_{cb,t} = \rho_B B_{cb,t-1} + (1 - \rho_B)\Psi \left[\phi_\pi (\pi_t^J - \bar{\pi}) + \phi_Y (Y_t - Y_{t-1}) \right] + e_{B,t} \tag{3.6.6}$$

where ρ_B and ρ_F are the bond smoothing parameters and Ψ is a scaling parameter which maps the same inflation and output preferences to the bond-holding policy rule.

The central bank can purchase both government and corporate bonds, but corporate bond purchases have a greater effect for two reasons. First, the financial wedge allows intermediaries to abscond with more corporate bonds than government bonds, so corporate bond purchases ease this friction. Second, purchases of corporate bonds have a direct effect on the wholesale firm's loan in advance constraint: first, the central bank buys bonds from banks, decreasing bank bond holdings (F_t) and increasing reserves (RE_t). These purchases increase the demand for outstanding corporate bonds, increasing bond prices ($Q_{F,t}$), decreasing the interest rate on bonds (i_t^F) and excess returns ($i_t^F - i_t^{RE}$). These higher bond prices, in turn,

[5] In the current specification of the model, the central bank can purchase both government and private securities. While this is standard for the ECB and BOJ, the Fed only began purchasing private securities under the CARES Act authorization. Thus, it is unclear whether this will become standard policy implementation going forward. Future drafts will consider how the model changes when the central bank can only buy government securities.

ease the loan in advance constraint, allowing for a greater level of investment with the same number of bonds outstanding.

3.6.1 Policy Information

As stated in the previous section, in this model the central bank targets J-period average inflation to reflect the Federal Reserve's new operating framework. In September 2020, the Fed completed its review of its monetary policy framework, concluding that it would shift to targeting "flexible" average inflation, rather than its previous policy of single-period inflation. However, the Fed eschewed any mention of a specific averaging window, instead allowing for discretion in their new framework. In this model, I incorporate this uncertainty surrounding their averaging window similar to Erceg and Levin's (2003) strategy of incorporating a time varying inflation target. In the case of full information, the central bank commits to a specific averaging window, which agents can directly observe. However, in the case of imperfect information, agents in the model know the parameters of the policy rule $(\rho_{TR}, \phi_\pi, \phi_Y)$, but cannot directly observe the averaging window. In turn, they can only perceive innovations to the interest rate, Z_t. These innovations could be the result of a standard monetary shock, e_t, or a misperception of the averaging window, π^J. Thus, the linear combination of these innovations is:

$$Z_t = e_t - (1 - \rho_{TR})(\phi_\pi)\pi_t^J \tag{3.6.7}$$

In turn, they must solve a signal extraction problem via the Kalman filter to form an expectation of the averaging window and the future path of interest rates based on policy innovations. In state space form, these components evolve according to the system:

$$\begin{bmatrix} \pi_t^J \\ e_t \end{bmatrix} = \begin{bmatrix} \rho_{\pi^J} & 0 \\ 0 & \rho_e \end{bmatrix} \begin{bmatrix} \pi_{t-1}^J \\ e_{t-1} \end{bmatrix} + \begin{bmatrix} \epsilon_{\pi^J,t} \\ \epsilon_{e,t} \end{bmatrix} \tag{3.6.8}$$

where $\epsilon_{\pi,t}$ and $\epsilon_{e,t}$ are normal IID innovations with variances of $\sigma^2_{\pi^J}, \sigma^2_e$, respectively. The averaging window has a high autoregressive root, while the monetary shock has an autoregressive root near zero. Intuitively, this means the central bank is committed to their unobserved policy rule, and they attempt to quickly correct for monetary shocks. The properties of these components are explored in depth in Erceg and Levin (2003), Ireland (2007), and De Michelis and Iacoviello (2016).

3.6.2 Average Inflation Targeting

In announcing the new framework, the Chair Powell noted that inflation had run persistently below its stated target of 2%, and that inflation expectations had become somewhat anchored at this lower level. Therefore, the goal of average inflation targeting is not just to makeup for the past undershooting of inflation, but also to reset inflation expectations closer to the Fed's 2% target.[6] This, in turn, should push interest rates higher, away from the zero-lower bound.

Expectations play a key role in the effectiveness of average inflation targeting. Regardless of the size of the averaging window, standard average inflation targeting works as a trade-off between less responsive policy contemporaneously and more responsive policy over time. Specifically, longer averaging windows raise household, firm, and intermediary inflation expectations, as they incorporate the central bank's promise to "overshoot" in response to declines in inflation. These higher inflation expectations lead to comparatively higher wages and prices, higher long-term interest rates, and a greater overshoot in inflation and output over time. However, because policy is focused on longer-term goals and is less responsive to current shocks.

For example, a one percentage point decrease in current inflation causes the central bank to decrease rates by $(1-\rho_{TR})\phi_\pi \frac{1}{J}$ percentage points under average inflation targeting, compared to $(1-\rho_{TR})\phi_\pi$ percentage points under standard inflation targeting. As such,

[6]Coibion et al. (2020) and Naggert et al. (2021) discuss in greater detail how the announcement of AIT influenced inflation expectations.

one would expect this slower contemporaneous movement to lead to greater short-term decreases in output and inflation from demand shocks, producing greater short-term declines in utility. However, policy is accomodative for longer under AIT, holding rates $(1-\rho_{TR})\phi_\pi \frac{1}{J}$ percentage points lower for $J-$periods after the change in inflation[7]. In this way, average inflation targeting acts similar to forward guidance as a promise to hold rates lower for longer. Observing this future path of interest rates, households shift their expectations accordingly. Thus, intuitively, the effectiveness of average inflation targeting will depend on the relative effect of the shift in long-term expectations compared to the effect of smaller responses to current shocks. If re-set expectations play a larger role in determining the path of the economy, then AIT should improve policy-making compared to the baseline. However, if the dulled contemporaneous response of policy outweighs the effect of new expectations, standard inflation targeting should lead to better outcomes than average inflation targeting. Moreover, the trade-off is likely to vary across averaging windows, as long averaging windows run the risk of over-averaging inflationary signals, leading to slow and suboptimal policy.

3.7 Government

The fiscal authority purchases an exogenous amount of final output, G_t, which is financed through lump-sum taxes, transfers from the central bank, and bond issuances, $B_{G,t}$. Because of financial frictions, Ricardian equivalence does not hold. However, lump sum taxes from the household adjust each period to ensure the government's budget constraint holds. Thus, the government's budget constraint is given by:

$$P_tG_t + P_{t-1}\bar{b_G} = P_tT_t + P_tT_{cb,t} + Q_{B,t}P_t\bar{b_G}(1-\kappa\Pi_t^{-1}) \tag{3.7.1}$$

[7]Appendix 1 considers how the effectiveness of the policy changes if the central bank responds more strongly to current inflation by targeting decaying inflation, rather than an arithmetic average.

3.8 Calibration

The model is solved using a piece-wise linear approximation around a non-stochastic steady state subject to the constraint that the interest rate never dip below the zero-lower bound. The model is solved using the OccBin toolbox developed in Guerrieri and Iacoviello (2015). Calibrated values of model parameters key to the analysis are described in Table 1. The values are standard to those in the literature. The bond decay parameter, κ, is calibrated so the average bond duration is 40 quarters; ψ, the proportion of new investment funded via debt, is taken to match the observed value of private debt to GDP. The intermediary survival probability, σ, is 0.95, in line with the value used in Gertler and Karadi (2011, 2013). The steady state risk spread, $i_t^F - i_t^B$, is calibrated at 200 basis points to match the average Baa - 10-year Treasury spread from 1970-2008, while the steady state term spread spread, $i_t^B - i_t^{EH}$, is calibrated at 100 basis points, the average 10-year Treasury - fed funds spread over the same period. The discount factor, β, is calibrated at a literature-standard 0.95, implying a natural real interest rate of 2%. The Calvo parameters, ϕ_p and ϕ_w, and the indexation parameters, γ_p and γ_w, are calibrated to their estimated value from Smets and Wouters (2007). Finally, the Taylor Rule parameters, ϕ_π and ϕ_Y, are calibrated at their standard value, and the Fed's smoothing parameters, ρ_{TR}, ρ_B and ρ_F, are calibrated so the Fed has consistent smoothing preferences between the fed funds rate and QE.

4 Results: Full Information

This paper examines the effectiveness of monetary policy changes along two dimensions: average inflation targeting and information availability. To isolate the effects of average inflation targeting vs standard inflation targeting, I first look at AIT only in the case of full information. Examining the policy through this lens shows the potential for average inflation targeting, provided the central bank transparently commits to a specific averaging window and households are attentive. Section 4.1 examines how the dynamics of the model

Table 1: Key Parameter Calibration

Parameter	Value	Description
κ	0.975	Bond duration
ψ	0.81	Fraction of investment from debt
σ	0.95	Intermediary survival probability
θ	3	Steady state spread
X	4	Steady state leverage
Δ	0.33	Government bond recoverability
ρ_b, ρ_f	0.8	AR Fed bond holdings
β	0.995	Discount factor
ϕ_p, ϕ_w	0.75	Price/wage rigidity
γ_p, γ_w	0.5	Price/wage indexation
ρ_{TR}	0.8	Taylor Rule: smoothing
ϕ_π	1.5	Taylor Rule: Inflation
ϕ_Y	0.5	Taylor Rule: Output growth
ρ_{π^J}	0.99	AR: Average misperception
ρ_e	0.01	AR: monetary shock

vary with different averaging windows, while section 4.2 reports the results of a simulation where the model is hit by a variety of shocks.

4.1 IRFs

In addition to the standard inflation targeting baseline ($J = 1$), I consider 2 different averaging windows: $J = 8$, $J = 20$. Broadly, these averaging windows can be considered short and long averaging windows. Impulse response functions from the model can be seen in Figures 3 - 6. Importantly, each model begins from its steady state, which has a real interest rate of 2%. Thus, each IRF begins with interest rate policy and only switches to QE if the zero-lower bound is reached. A consistent theme emerges across all IRFs: longer averaging windows lead to greater responses in each variable from the shock, and greater overshooting of each variable later in the IRF.

Figure 3 shows the response from a credit shock, or a sudden increase in θ. In response to the credit shock, output, employment, and inflation decline. This leads to a decline in household utility and causes the central bank to decrease its target interest rate to the lower bound. Interestingly, while output and employment decline more significantly with longer averaging windows, they recover more quickly. Moreover, the longer averaging windows lead to less time spent against the lower bound utilizing unconventional policies, returning interest rates to close to its steady state more quickly.

A productivity shock, shown in Figure 4, presents an interesting challenge for the central bank. Because output and inflation are moving in opposite directions, the weights in the Taylor Rule and the averaging window play an important role in the movement of the interest rate. Under standard inflation targeting, the central bank cuts rates modestly to counteract the decline in inflation. However, as longer averaging windows dull the sensitivity of the central bank to current inflation, the central bank actually raises rates modestly under AIT. The dynamics of other variables are largely similar in each scenario.

Figure 5 shows the response of the model to 100bp interest rate shock. Interestingly, output and employment decline *more* after a 100bp interest rate shock under AIT than they do under standard IT, while the inflation response is similar. These greater declines are likely due to slower expected policy responses in the future, as the central bank is responding to average inflation rather than the large decline in current inflation.

Finally, while output and employment respond similarly to a government spending shock, inflation increases significantly more with longer averaging windows. This, in turn, requires the central bank to undershoot inflation more in later periods to stabilize average inflation, leading to lower interest rates and a similar level of output.

4.2 Simulation Results

Next, I simulate the model across 1,000 periods to see how average inflation targeting compares to standard inflation targeting when the economy is hit by a combination of shocks, rather than each in shock isolation. Each variable begins in steady state, and is hit with a sequence of credit, technology, interest rate, and productivity shocks.

Variances of output, inflation, the interest rate, and utility from the full information

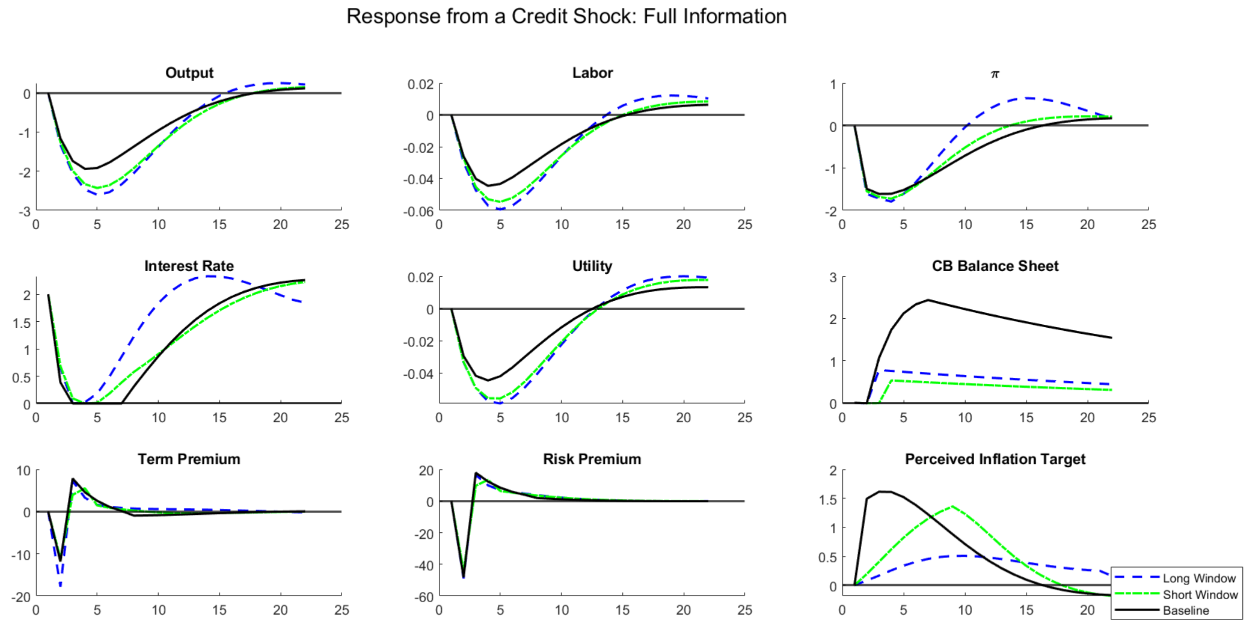

Figure 3: Response of the model to a credit shock

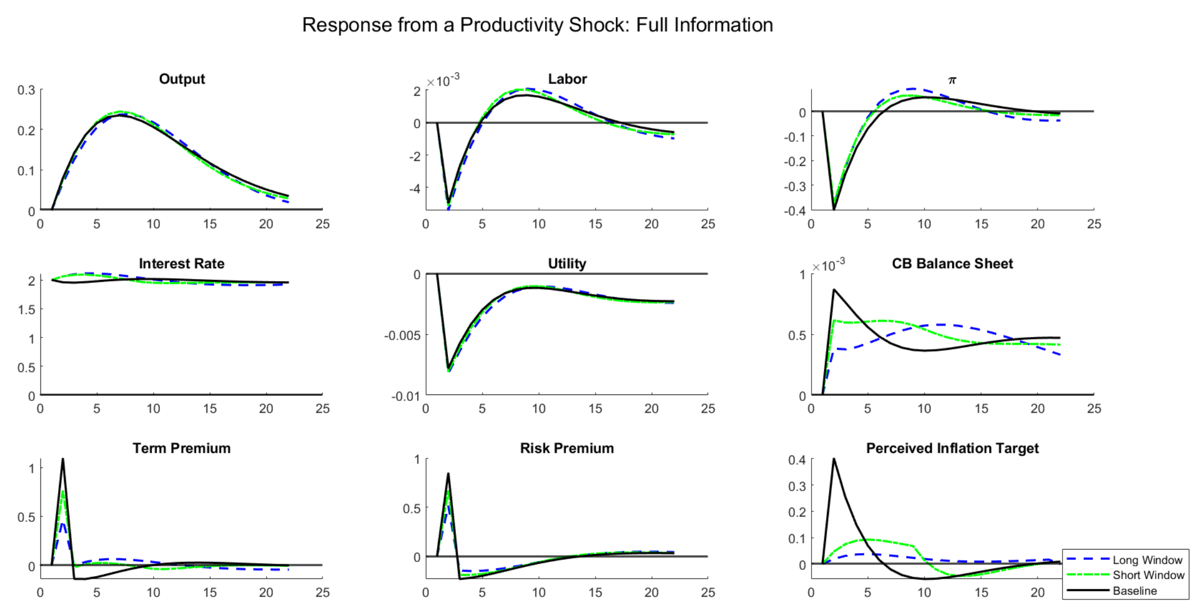

Figure 4: Response of the model to a productivity shock

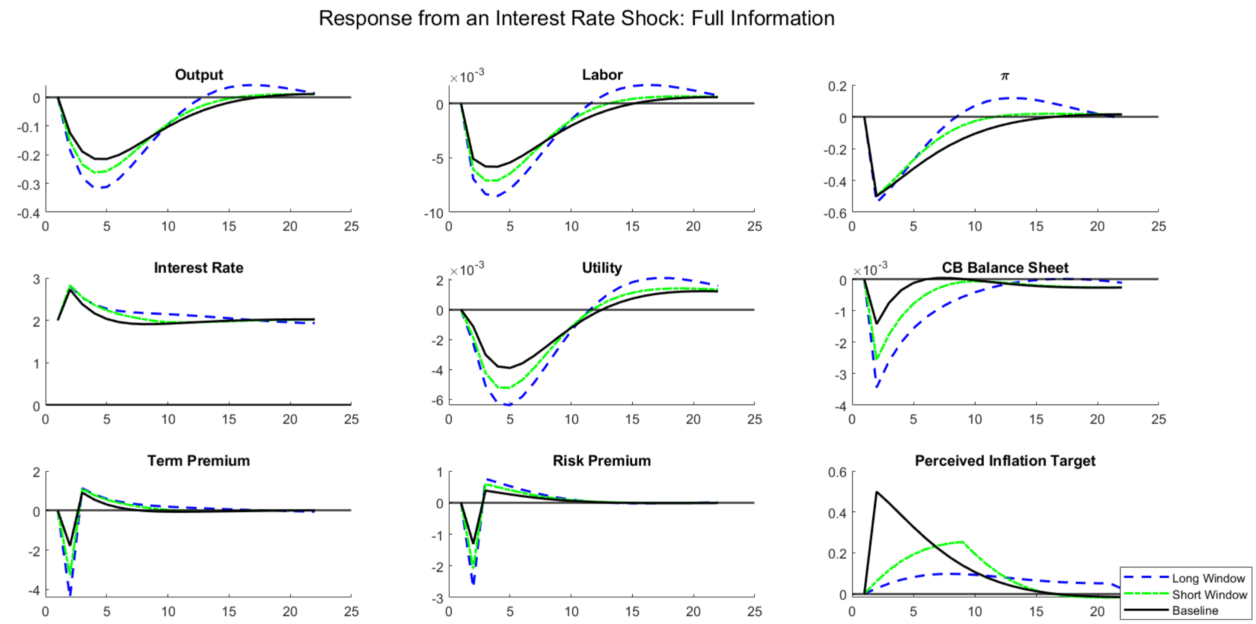

Figure 5: Response of the model to an interest rate shock

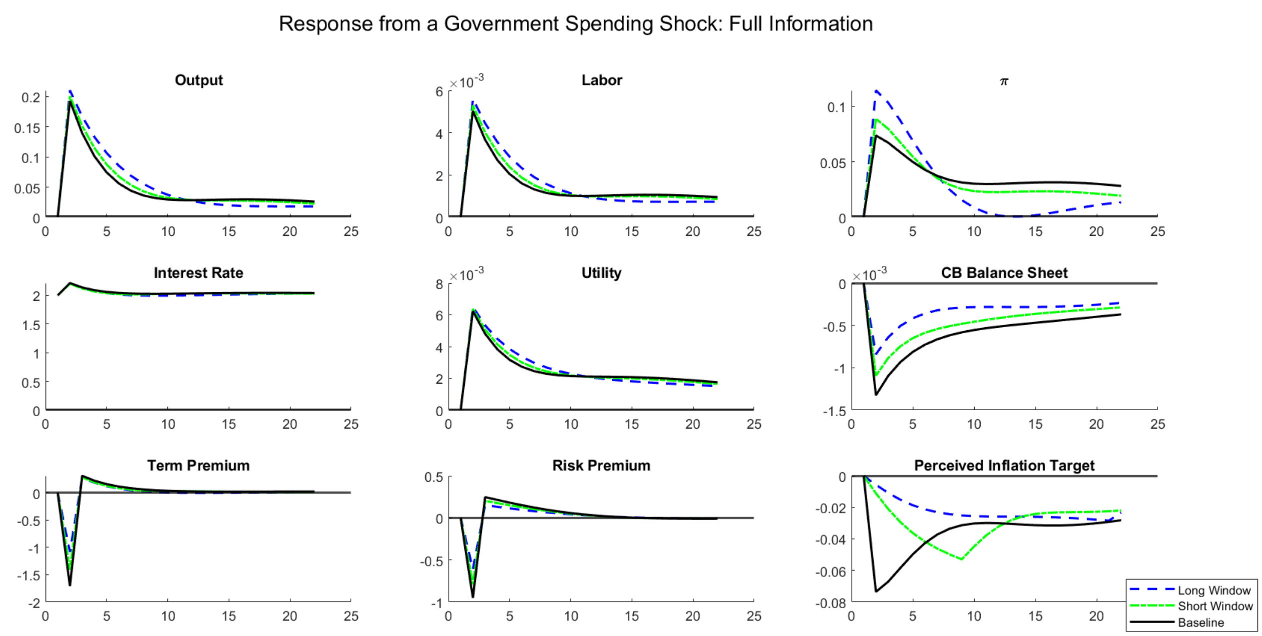

Figure 6: Response of the model to a government spending shock

simulation can be seen as the black lines in Figure 7. A notable takeaway from the table is that variables are stabilized best with different averaging windows. Output is best stabilized using standard inflation targeting, and becomes less stable as the averaging window increases. Alternatively, inflation is most stable with a moderate averaging window ($J = 8$ quarters) and least stable under the baseline, $J = 1$. Interest rates are most stable with a longer averaging window. This is largely expected, as longer averaging windows will slow the policy response to inflation. Finally, utility is best stabilized under standard inflation targeting, largely because output is more stable. Thus, while AIT can clearly stabilize inflation more effectively, it is not a free lunch.

A rationale behind the average inflation targeting was to push interest rates away from the zero lower bound, decreasing the use of unconventional policies. Interestingly, this rationale looks to hold true, at least for moderate averaging windows. Policy hits the zero-lower bound in 9.3% of the simulation when inflation is targeted over $J = 8$ quarters, and only 8% when targeted of $J = 12$ quarters. In contrast, the baseline hits the zero-lower bound in over 9% of periods the simulation, so standard policy is more likely to have to resort to unconventional policies, like QE, than moderate average inflation targeting. However, there is a risk in over-averaging inflationary signals through this lens too, as a long averaging window of $J = 20$ quarters hits the zero-lower bound in 10% of the simulation.

5 Results: Imperfect Information

While targeting average inflation over moderate periods can lower the variability of inflation and increase total household utility, these results assume households and firms have perfect information about the averaging window, and that the central bank will commit to the averaging. However, the Fed has not publicly stated how they plan to implement the new policy framework. What's more, surveys done by Coibion and Gorodnichenko (2020) and Candia et al. (2021) show that most households did not know about the policy shift, and

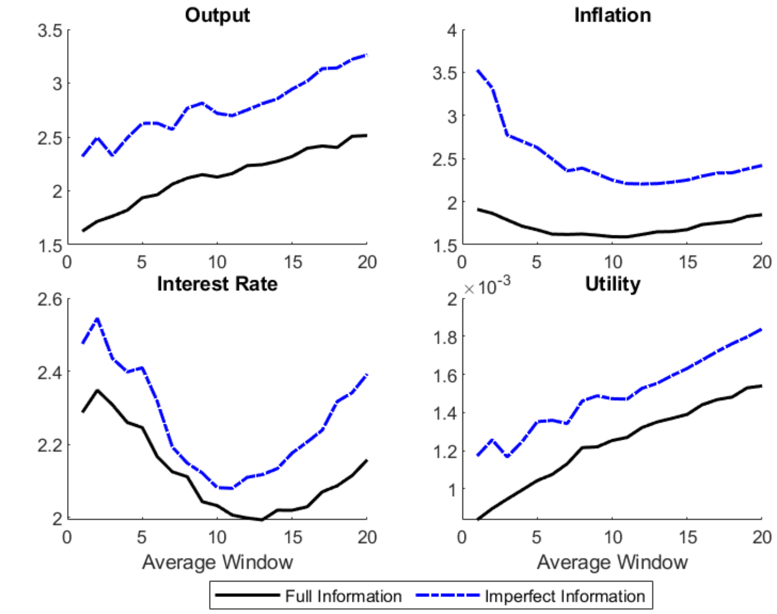

Figure 7: Variance of each variable from model simulation over 1,000 periods with random shocks to credit, productivity, spending, and the interest rate.

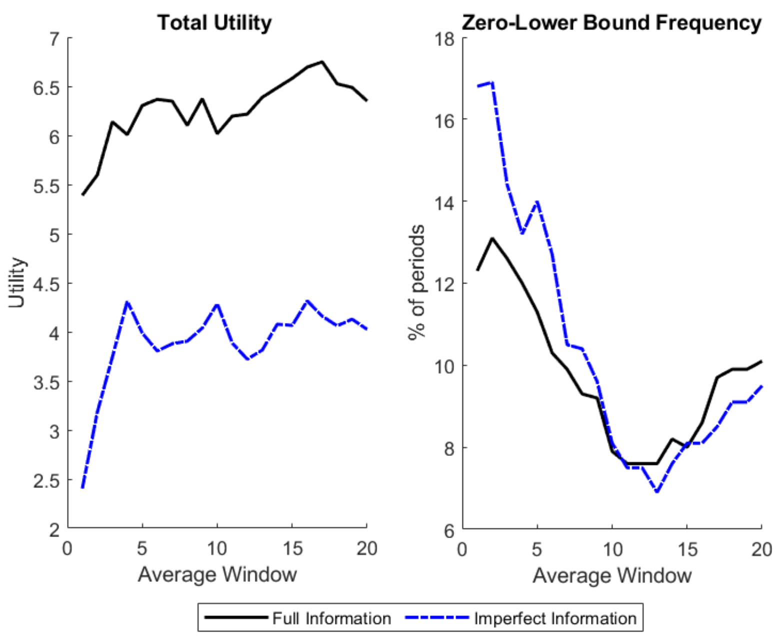

Figure 8: Total utility and zero-lower bound frequency from simulations.

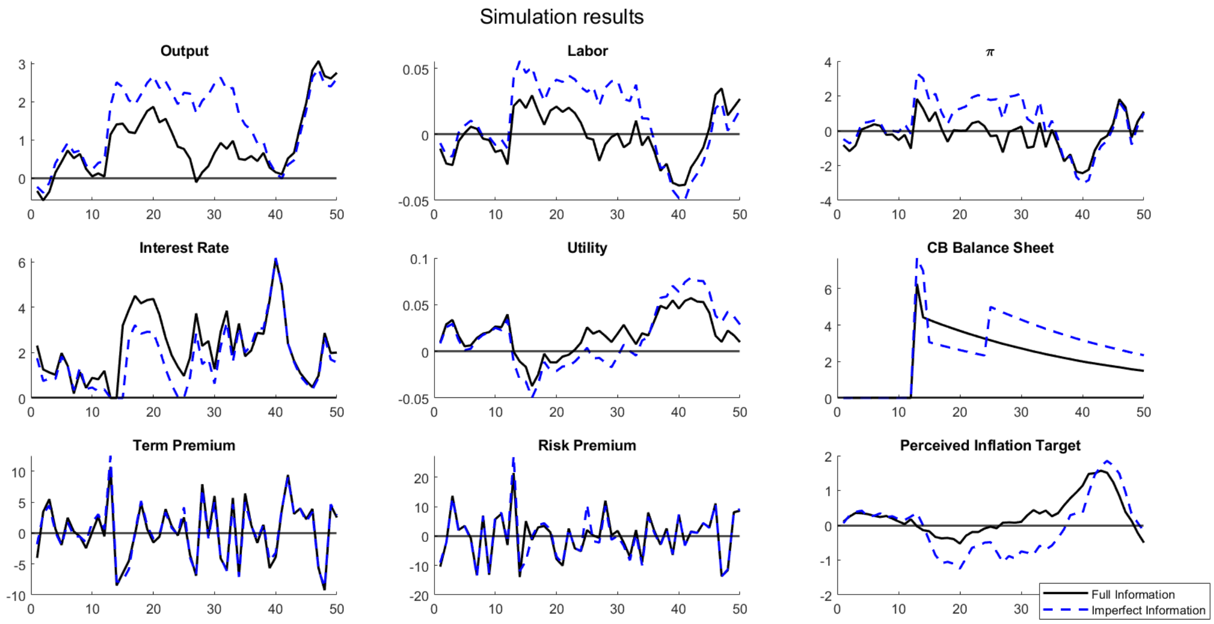

Figure 9: Plots of each variable over the 50 periods of the simulation under full and imperfect information with a $J = 8$ period averaging window

inflation expectations had become "unanchored" and began to drift upwards. In turn, there has been a substantial amount of uncertainty about how high inflation will get, and how soon and forcefully the Fed will respond. Clearly, there is imperfect information surrounding average inflation targeting, due to both ambiguity by the Fed on the policy roll-out and by household and firm inattention.

Figure 9 shows plots of each variable over the first 100 periods of the simulation, holding the averaging window constant at $J = 8$ periods. Holding the averaging window constant isolates the effect of imperfect information surrounding average inflation targeting. Importantly, each variable appears to be less stable under imperfect information, as output and employment quickly increase more above their steady state, leading to higher inflation. Inflation stays at a higher level for longer under imperfect information, as there is uncertainty surrounding the perceived averaging window. Interest rates hit the zero-lower bound early in the simulation for both full and imperfect information, but they remain against the zero-lower bound for longer under imperfect information. What's more, interest rates are driven to the lower bound a second time under imperfect information. Taken as a whole, the full information policy leads to a smaller central bank balance sheet over the simulation, as unconventional policies are both more effective and used less frequently.

The blue lines in Figures 7 and 8 show how the variance of inflation, output, and the interest rate change under imperfect information. Interestingly, output is most stable under a standard inflation targeting regime, similar to the full information policy. Moreover, inflation is most stable over a shorter averaging window (roughly 8 quarters), and has roughly equivalent variance under standard inflation targeting and long averaging windows. Interest rates are most stable under longer averaging windows, though the variance is roughly stable between a moderate AIT and a long AIT.

Utility is most stable under standard inflation targeting or short AIT, largely due to greater stability in output with shorter averaging windows. However, while under full information utility is similarly high under short and long averaging windows, utility is highest under a short averaging window with imperfect information. This reveals the tradeoff that AIT faces under imperfect information. Targeting inflation over longer averaging windows dulls the effect of imperfect information in a single period. However, longer averaging windows lead to slower contemporaneous responses and the higher variance of output seen in Figure 7. This trade-off is most effectively balanced when inflation is targeted over 4 quarters, and there are similar effects between moderate and long windows.

Finally, interest rates hit the zero-lower bound less frequently under long averaging, and the frequency increases as the averaging window shortens. Thus, under imperfect information, the central bank balance sheet stays smaller when policy targets inflation over longer windows.

Importantly, the performance of the model under imperfect information is strictly dominated by full information: the variance of each variable is lower, total utility is higher, and the zero-lower bound tends to bind less frequently. This illustrates the importance of information for a policy's effectiveness: when agents don't know the specifics around AIT, they frequently must update not only their expectations about the future, but also their expectations about the true policy rule. This additional uncertainty makes it more difficult for households to plan consumption and firms to plan investment decisions, leading to greater variances and lower total welfare. In short, AIT has benefits over standard inflation targeting if the central bank credibly commits to a specific rule and the households are attentive. However, if the central bank cannot commit, or households simply are inattentive to a policy change, the model shows outcomes are better if the Fed returns to a commitment to standard inflation targeting.

6 Conclusion & Policy Implications

In this paper, I evaluate the effectiveness of average inflation targeting in the context of a DSGE model with an occasionally binding zero-lower bound, unconventional monetary policy, and imperfect information about the policy. This is an important step in the literature around average inflation targeting, as previous papers have only considered AIT in the context of interest rate policy and had not fully incorporated policy information availability. I emphasize that targeting average inflation plays an important role in the formation of expectations, and the effectiveness of the policy depends on its ability to influence expectations. Overall, average inflation targeting more effectively stabilizes inflation compared to the standard inflation targeting baseline. Moreover, it decreases the incidence of the zero lower bound, and improves the effectiveness of unconventional policies.

Taken as a whole, the combination of inflation and output are most effectively stabilized when the central bank targets inflation over a period of 1-2 years under both perfect and imperfect information. This modest averaging window also decreases the frequency with which interest rates hit the zero-lower bound and the central bank shifts to unconventional policy.

However, average inflation targeting is not without its own drawbacks. Inflation increases much more substantially in response to positive demand shocks under AIT, requiring the central bank to undershoot inflation in the future. Additionally, targeting inflation over long periods can mitigate the benefits of AIT, slowing monetary policy's response to current shocks and leading to greater instability. This, in turn, means interest rates actually hit the zero-lower bound *more frequently* when targeting average inflation for periods longer than 3 years. Moreover, switching policy frameworks introduces uncertainty, as shown by Coibion and Gorodnichenko (2020) and Candia et al (2021). Under imperfect information, households and firms have a harder time forming expectations, leading to lower overall welfare. Thus, credibility and transparency of the averaging window is key to the effectiveness of the policy. In short, AIT has benefits if the central bank credibly and transparently commits to the policy, and households pay attention to the policy shift. However, AIT can create new uncertainty that outweighs the potential benefits.

There is a promising research frontier based on these results, as future research can focus on how the effectiveness of AIT changes when households have a more direct involvement in the financial sector, through either holding mortgages or long-term bonds. Additionally, research can focus on incorporating default risk into the structure of interest rates, allowing for a more formal modeling of both the term and risk structure. Finally, future research can take a more empirical approach, examining how sustainably interest rates and inflation stabilize at a higher level as the effects of the COVID-19 pandemic wane and the economy begins to return to a more normal state.

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Appendix

6.1 Alternative Specifications

Under standard average inflation targeting, the central bank responds equally as strongly to current and past inflation. Instead, AIT could be implemented by incorporating a decay parameter on past inflation. In this scenario, I replace the inflation averaging ($\frac{1}{J}\sum_{j=1}^{J-1}\pi_{t-j}$) in equations (3.6.4), (3.6.5), and (3.6.6) with:

$$\hat{\pi}_t = \omega\pi_t + (1-\omega)\hat{\pi}_{t-1} \tag{6.1.1}$$

In this specification, agents can have imperfect information about the central bank's decay parameter, ω, rather than the averaging window.

Similar to the specification discussed in section 5, imperfect information still leads to consistently higher variances in output and inflation, as well as lower utility. Under this specification, inflation is most effectively stabilized when $\omega \approx .2$, so changes in inflation have a half-life of 4 quarters. The zero-lower bound incidence is minimized at a similar value of ω. However, utility consistently declines as ω increases, so utility is maximized under a price-level target in this specification.

Under imperfect information, a similar theme holds: output is stabilized by targeting current inflation ($\omega = 1$), inflation and interest rates are stabilized with a moderate averaging, and utility is highest under a price level target. Importantly, similar to the earlier specification of AIT, the least effective full information policy still leads to higher utility than the most effective imperfect information policy, reiterating the importance of commitment and transparency to a policy by the central bank, and attentiveness to the policy by households and firms.

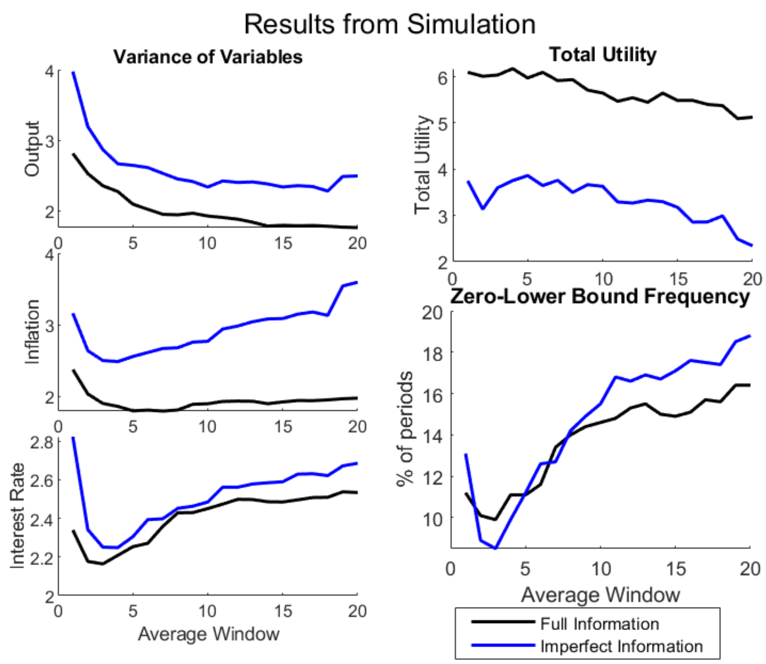

Figure 10: Total utility and zero-lower bound frequency from simulations.