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Monetary Policy

The Forward Guidance Puzzle and Anchored Inflation Expectations

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Abstract

In recent years, central banks have turned to forward guidance as a key tool of monetary policy. However, standard DSGE models overestimate the impact of forward guidance on the economy, a phenomenon known as the "forward guidance puzzle." In the model employed, the reaction of firms to a central bank's announcements depends on the degree of anchoring of inflation expectations. When firms do not revise their forecasts much in response to inflation surprises, the effects of forward guidance shocks are attenuated. Furthermore, an increase in the Taylor rule coefficients implies a faster reversion of inflation and output to their steady state levels, thus resulting in more anchored inflation expectations and dampened effects of forward guidance announcements. However, the central bank's exclusive focus on price stability eliminates forward guidance effects. This paper also studies the dependence of forward guidance on fiscal policy, which arises in a non-Ricardian economy. We show that the initial effects of the central bank's announcements become considerably stronger when steady state debt is positive, whereas a stronger reaction of fiscal policy to debt fluctuations attenuates the power of forward guidance.

Keywords: forward guidance, inflation expectations, bounded rationality, trend inflation.

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Introduction

After the global financial crisis, forward guidance became an increasingly important tool of monetary policy. By providing information about future policy rates, central banks might expect to affect current allocations even at the zero lower bound. Acknowledging the significant role that expectations for the future path of interest rates play in the economy, central banks promised to keep policy rates at exceptionally low levels for some time in order to prompt more consumption and investment. Moreover, many central banks implemented forward guidance even when their usual policies of lowering interest rates had not been exhausted by nearing the zero lower bound. In these circumstances, communication provides a better understanding of the central bank's future actions and increases credibility and transparency regarding future monetary policy.

While the importance of forward guidance has been defended in the recent literature [Woodford, 2003], there is no convincing evidence about the quantitative effects on key macroeconomic variables due to a central bank's announcements. For instance, standard DSGE models predict unreasonably large responses of the economy to signals about future interest rates — a phenomenon known as the forward guidance puzzle and attributable to the interaction between many features of DSGE models. For example, the output gap expected in a dynamic IS curve is not discounted; and the New Keynesian Phillips curve is related to front-loading properties. However, recent literature focuses predominantly on the excess sensitivity of consumption to interest rate changes implied by the standard Euler equation [Del Negro et al., 2023; McKay et al., 2016]. Thus, the modification of the dynamic IS curve is the principal way to attenuate the responses of inflation and output to forward guidance shocks.

The contribution of this paper is twofold. The authors first provide one possible resolution to the forward guidance puzzle by highlighting the role of expectations in the success of central banks' communication. To investigate the magnitude of forward guidance effects, a New Keynesian model is considered in which the effectiveness of forward guidance is linked with the degree to which inflation expectations are anchored. To this end, this study departs from the standard general equilibrium model by incorporating one more realistic feature; specifically, the authors suppose that firms are boundedly rational and have imperfect knowledge about the dynamics of inflation. Firms construct their subjective inflation forecasts by solving the problem of signal extraction through separation of temporary shocks to an unobserved inflationary trend from permanent shocks to it. The frequency of price resetting may vary significantly depending upon what kind of shock is perceived, and this results in different degrees of anchoring in inflation expectations. The degree of anchoring in turn alters the effects of forward guidance.

Moreover, this paper builds upon the literature on the interaction between monetary and fiscal policy, which is extended by identifying fiscal assumptions that affect the power of forward guidance. In order to understand how forward guidance depends on the stance of fiscal policy, the model employed here incorporates non-Ricardian consumers, a modification which tends to strengthen the dependence of monetary policy on the fiscal stance by generating wealth effects for households [Bhatnagar, 2023; Caramp, Silva, 2023]. In standard DSGE models steady state debt is equal to zero. However, most governments around the world in fact allow for non-zero government debt holdings. The authors explore how different values of the debt and fiscal policy parameters have the potential to impact the forward guidance announcements concerning the economy.

After a brief literature review in section 1, an explanation of the model including a framework for analyzing the effects of forward guidance in a boundedly rational equilibrium with Ricardian and non-Ricardian consumers is presented in section 2. Section 3 provides the authors' solution to the forward guidance puzzle. Section 4 examines the dependence of forward guidance on fiscal policy in a non-Ricardian economy and is followed by the conclusion.

1. Literature Review

The current paper augments previous studies on the effectiveness of forward guidance. For instance, [Woodford, 2003] shows that the central bank may reduce the impact on the economy of a negative shock to the natural rate by holding interest rates at the zero lower bound for a long time. The importance of transparent communication and the central bank's capacity to influence inflation expectations via precise signals is underlined in [Coenen et al., 2017]. In turn, [Campbell et al., 2012] investigate the impact of forward guidance shocks on the economy using DSGE models and find that forward guidance contributes significantly to business cycle fluctuations. However, those theoretical dynamics do not align with the actual data, and this discrepancy is known as the forward guidance puzzle.

Much of the literature on this topic has proposed several solutions to the forward guidance puzzle, and most of them resort to discounting key equations of the DSGE model and center around including agent heterogeneity. For instance, [Del Negro et al., 2023] show that the overestimation of an economy's reaction to announcements about future interest rates is likely due to lack of discounting future economic outcomes.

Incorporating a perpetual youth framework into a DSGE model attenuates the changes in the main variables and suggests that announcements of policy changes far in the future generate effects on current aggregate variables that are much closer to the empirical estimates. [McKay et al., 2016] modify the standard framework by introducing incomplete markets and show that precautionary savings, which are caused by insurable risk and liquidity constraints, may attenuate the effects of forward guidance. Adding heterogeneity in risk aversion may also provide a solution to the forward guidance puzzle [Caballero, Farhi, 2018].

Departing from the assumption of rational expectations may provide another way to reach a resolution of the forward guidance puzzle. [Angeletos, Lian, 2018] depart from the assumption of common knowledge, whereas [Gabaix, 2020] solves the forward guidance puzzle by adding agent myopia to the behavioral DSGE model. [Afrouzi, Yang, 2021] provide a method for solving dynamic rational inattention problems, which allows for a design in which the nature of inattention is endogenous. Finally, a few contributions discuss imperfect credibility of the central bank as a possible solution to the puzzle [Bernanke, 2020; Bodenstein et al., 2012; Campbell et al., 2019]. [Andrade et al., 2019] present a model in which agents doubt the central bank's ability to commit and therefore interpret forward guidance announcements as Delphic rather than Odyssean.

The article also fits into the literature concerning the dependence of forward guidance on fiscal policy. Several papers investigate the interaction of unconventional monetary policy and fiscal policy [Corhay et al., 2017; Leeper, Leith, 2016]. [Ascari et al., 2020] study the effects of forward guidance on the efficiency of monetary and fiscal policy at the zero lower bound. Several papers study forward guidance effects by incorporating the fiscal theory of price level. [Caramp, Silva, 2023] explain how the forward guidance puzzle hinges on the wealth effects generated by the direct response of fiscal transfers to monetary policy. In addition, [McClung, 2021] shows that the fiscal theory of price level considerably dampens the effects of a central bank's announcements under an active fiscal policy regime. [Cochrane, 2017] also studies forward guidance and fiscal theory, although his focus is not on the forward guidance puzzle.

2. Model

In this section, we introduce a standard New Keynesian model expanded to take into account boundedly rational agents. In this study's baseline model, a representative household supplies labor to firms and consumes a bundle of goods to maximize expected lifetime utility. To analyze the effects of forward guidance in a non-Ricardian economy, we introduce the model of [Rigon, Zanetti, 2018] and incorporate the overlapping generations model into our baseline framework. The overlapping generations concept assumes that during each period the economy coexists simultaneously with several generations of households at different ages, each of which faces a constant probability of surviving. Also, both the non-Ricardian and Ricardian consumers exist parallel to a continuum of imperfectly competitive firms, such that each firm has an imperfect understanding of the course of inflation and behaves in a boundedly rational manner. Fiscal policy responds to debt deviations from its steady state by implementing a simple rule for government taxes. To close the model, we assume that the central bank conducts policy in accordance with a simple policy rule and provides signals about future interest rates.

Ricardian Households

The economy contains a continuum of identical consumers. During each period, each household consumes a bundle of goods, C_t, and supplies labor, N_t, to maximize the following expected utility function:

$$U_t(C_t, N_t) = \mathbb{E}_t \sum_{t=0}^{\infty} \beta^t (\ln C_t + \varphi \ln[1 - N_t]), \tag{1}$$

where β is a discount rate and φ measures the degree to which leisure contributes to utility.

The household's expenditures include consumption, C_t, and purchase of new bonds, B_t, whose expected value is $Q_{t,t+1}B_{t+1}$, where $Q_{t,t+1}$ denotes the stochastic discount factor for a single-period riskless asset. To cover expenses, each consumer supplies units of labor, N_t, at the nominal wage rate, W_t. T_t includes lump-sum taxes and an employment subsidy to firms that offsets distortions generated by monopolistic competition.

Hence, the following budget constraint holds:

$$P_t C_t + \mathbb{E}_t\left[Q_{t,t+1} B_{t+1}\right] \leq W_t N_t + B_t - T_t. \tag{2}$$

Finally, real debt holdings of consumers must satisfy a transversality condition:

$$\lim_{k \to \infty} \mathbb{E}_t\left[Q_{t,t+k} B_{t+k}\right] = 0. \tag{3}$$

The agent solves the following optimization problem:

$$\max_{C_t, C_{t+1}, N_t, B_{t+1} \geq 0} \mathbb{E}_t \sum_{t=0}^{\infty} \beta^t (\ln C_t + \varphi \ln[1 - N_t]) +$$

$$+ \sum_{t=0}^{\infty} \lambda_t \left(W_t N_t + B_t - T_t - P_t C_t - \mathbb{E}_t\left[Q_{t,t+1} B_{t+1}\right]\right).$$

The first-order conditions for this problem reflect the optimality conditions for labor supply and intertemporal consumption choice, respectively:

$$\frac{W_t}{P_t} = \varphi \frac{C_t}{1-N_t}, \tag{4}$$

$$\frac{1}{C_t} = \beta \mathbb{E}_t \left[\frac{1}{C_{t+1}} \frac{P_{t+1}}{P_t} R_t\right], \tag{5}$$

where $R_t = \frac{1}{\mathbb{E}_t Q_{t,t+1}}$ is the gross return on a riskless single-period asset [Woodford, 2003].

Log-linearized first-order conditions are:

$$c_t + \eta n_t = w_t - p_t, \tag{6}$$

$$c_t = \mathbb{E}_t c_{t+1} - (r_t - \mathbb{E}_t \pi_{t+1}), \tag{7}$$

where lowercase letters denote the natural logs of the corresponding variable and $\eta = \frac{N}{1-N}$ is the inverse of the Frisch elasticity of labor supply.

Non-Ricardian Households

In a non-Ricardian economy, a new generation, *s*, is born during each period while existing consumers face a constant probability of surviving, γ, independent of age. Newborns dispose of the present discounted value of their labor income and do not hold assets at their birth (no bequest motive). As in [Blanchard, 1985], financial wealth is redistributed by insurance companies to survivors that additionally are paid with a premium proportional to their financial wealth.

For any period, each household of age *s* consumes a bundle of goods, $C_{s,t}$, and supplies labor, $N_{s,t}$, to maximize the following anticipated utility function:

$$U_{s,t}\left(C_{s,t}, N_{s,t}\right) = \mathbb{E}_t \sum_{t=0}^{\infty} \beta^t \gamma^t (\ln C_{s,t} + \varphi \ln[1 - N_t]), \tag{8}$$

where γ is a constant probability of survival.

A non-Ricardian household's budget constraints are the same as for Ricardian consumers, but with one exception: T_t now includes lump-sum taxes, employment subsidies to firms, and generation-specific transfers, which equalize the distribution of steady-state debt holdings across generations. Hence, the budget constraints for non-Ricardian consumers are as follows:

$$P_t C_{s,t} + \gamma \mathbb{E}_t\left[Q_{t,t+1}^s B_{s,t+1}\right] \leq W_t N_{s,t} + B_{s,t} - T_{s,t}. \tag{9}$$

Finally, the model stipulates that real debt holdings of non-Ricardian consumers must satisfy a transversality condition given the survival rate, thus:

$$\lim_{k\to\infty} \mathbb{E}_t\left[Q^s_{t,t+k}\gamma^k B_{s,t+k}\right] = 0. \tag{10}$$

The first-order conditions for the maximization problem of each household are the same as for Ricardian consumers.

By solving the Euler equation (5) forward, using the budget constraint (9) and imposing the no-Ponzi condition (10), individual consumption can be expressed as a linear function of financial wealth, $B_{s,t}$, and human wealth, $H_{s,t}$, defined as an expected stream of future income from wages net of taxes and transfers:

$$P_t C_{s,t} = \frac{1}{(1+\varphi)\Phi_{s,t}}\left[B_{s,t} - Tr_{s,t} + H_{s,t}\right], \tag{11}$$

where $\Phi_{s,t}$ is the inverse of the propensity to consume out of financial and human wealth; $Tr_{s,t} = Tr_s$ denotes a generation-specific transfer and has no effect on the aggregate dynamics of the economy; and $H_{s,t} = H_t$ is human wealth which is the same across cohorts.

Since during each period the economy coexists simultaneously with several generations of households, aggregate consumption in period $t + 1$ can be rewritten as a weighted sum of the consumption of two groups of households — those already alive in period $t + 1$ and newborns in period $t + 1$ — as follows:

$$C_{t+1} = \gamma\tilde{C}_{t+1} + (1-\gamma)C^{NB}_{t+1}. \tag{12}$$

Hence, we obtain the Euler equation in a non-Ricardian economy, which determines both the optimal path of consumption over time and the difference in consumption across newborns, as well as the aggregate consumption in the same period:

$$C_t = \frac{1}{\beta R_t}\mathbb{E}_t\frac{P_{t+1}}{P_t}\left[C_{t+1} + \frac{1-\gamma}{\gamma}\frac{1}{(1+\varphi)\Phi_{s,t}}(b_{t+1} - b)\right], \tag{13}$$

where b_{t+1} and b are the real bond holdings at time $t + 1$ and at the steady state, respectively. By setting consumers' probability of survival equal to 1, the model nests the standard Ricardian framework with infinitely lived consumers.

We can rewrite the Euler equation for non-Ricardian consumers in log-linearized form:

$$c_t = \mathbb{E}_t c_{t+1} - (r_t - \mathbb{E}_t\pi_{t+1}) + \frac{1-\gamma}{(1+\varphi)\gamma\Phi}b_{t+1}. \tag{14}$$

Firms

Firms interact under monopolistic competition. For any period, each firm demands $N_t(j)$ units of labor and produces $Y_t(j)$ according to the production technology described by:

$$Y_t(j) = A_t N_t(j), \tag{15}$$

where A_t is the aggregate productivity shock, which evolves according to an AR(1) process. For $\ln A_t = \rho_A \ln A_{t-1} + \varepsilon_{A,t}$, the stochastic shock, $\varepsilon_{A,t}$, has a zero mean and the standard deviation is equal to σ_A.

A firm's problem in minimizing cost is defined in the following way:

$$\min_{N_t \geq 0} N_t(1-\tau)\frac{W_t}{P_t} + MC_t(Y_t(j) - A_t N_t(j)), \tag{16}$$

where τ denotes the rate at which the cost of employment is subsidized and MC_t is the firm's marginal costs.

The first-order condition for this problem is:

$$MC_t = (1-\tau)\frac{W_t}{P_t A_t}. \tag{17}$$

In accordance with [Calvo, 1983], each firm has an opportunity during each period to reoptimize its prices with constant probability $1 - \theta$ or not to reoptimize it with probability θ. Thus, the parameter θ measures the degree of nominal rigidity. To reoptimize the price, firms maximize the expected discounted value of their profits:

$$\mathbb{E}_t \sum_{i=0}^{\infty} \theta^i \beta^i \left(\frac{P_t(j)}{P_{t+i}} Y_{t+i}(j) - MC_{t+i} Y_{t+i}(j)\right) \tag{18}$$

subject to the demand function for goods $Y_t(j) = \left(\frac{P_t(j)}{P_t}\right)^{\epsilon} Y_t$.

The first-order condition for this problem is:

$$\frac{p_t^*}{P_t} = \frac{\epsilon}{\epsilon-1} \frac{\mathbb{E}_t \sum_{i=0}^{\infty} \theta^i \beta^i Y_{t+i} MC_{t+i} \left(\frac{P_t(j)}{P_{t+i}}\right)^{\epsilon}}{\mathbb{E}_t \sum_{i=0}^{\infty} \theta^i \beta^i Y_{t+i} \left(\frac{P_t(j)}{P_{t+i}}\right)^{\epsilon-1}}. \tag{19}$$

Assuming that all firms can reoptimize their prices, the first order condition may be rewritten in the following way:

$$\frac{p_t^*}{P_t} = \frac{\epsilon}{\epsilon-1} MC_t. \tag{20}$$

Firms that fail to reoptimize prices keep them unchanged. As a result, the aggregate price index, P_t, can be rewritten as a weighted average of newly set prices, P_t^*, and those set in the previous period, P_{t-1}. Therefore, the aggregate price index can be written as:

$$P_t^{\frac{\epsilon}{\epsilon-1}} = \theta(P_{t-1})^{\frac{\epsilon}{\epsilon-1}} + (1-\theta)(p_t^*)^{\frac{\epsilon}{\epsilon-1}}. \tag{21}$$

Assuming relative price $\bar{P}_t = \frac{p_t^*}{P_t}$, we obtain:

$$1 = (1-\theta)(\bar{P}_t)^{\frac{\epsilon}{\epsilon-1}} + \theta\left(\frac{P_{t-1}}{P_t}\right)^{\frac{\epsilon}{\epsilon-1}}. \tag{22}$$

The log-linearized aggregate price index is then:

$$0 = (1-\theta)(\bar{p}_t)^{\frac{\epsilon}{\epsilon-1}} - \theta\pi_t. \tag{23}$$

We can rewrite equation (19) in the following way:

$$\left[\mathbb{E}_t \sum_{i=0}^{\infty} \theta^i \beta^i\, Y_{t+i} \left(\frac{P_t(j)}{P_{t+i}}\right)^{\epsilon-1}\right] \bar{p}_t =$$
$$= \frac{\epsilon}{\epsilon-1}\left[\mathbb{E}_t \sum_{i=0}^{\infty} \theta^i \beta^i Y_{t+i} MC_{t+i} \left(\frac{P_t(j)}{P_{t+i}}\right)^{\epsilon}\right]. \tag{24}$$

The log-linearized version of equation (24) is equal to:

$$\bar{p}_t + p_t = (1-\theta\beta)(mc_t + p_t) + \theta\beta(\mathbb{E}_t\bar{p}_{t+1} + \mathbb{E}_t p_{t+1}). \tag{25}$$

Using equation (23), we can rewrite equation (25) in the following way:

$$\frac{\theta}{1-\theta}\pi_t = (1-\theta\beta)mc_t + \theta\beta\frac{1}{1-\theta}\mathbb{E}_t\pi_{t+1}. \tag{26}$$

Hence, aggregate inflation is described by the following equation:

$$\pi_t = \beta\mathbb{E}_t\pi_{t+1} + \kappa mc_t, \tag{27}$$

where $\kappa = \frac{(1-\theta\beta)(1-\theta)}{\theta}$.

Monetary and Fiscal Policy

To finance public expenditures, G_t, and to serve outstanding debt, B_t, the government issues single-period bonds, B_{t+1}, that pay a gross nominal interest rate, R_t, and change lump-sum taxes, Tx_t.

Hence, the government budget constraint is:

$$\frac{B_{t+1}}{R_t} + Tx_t = B_t + G_t, \tag{28}$$

where government expenditures, G_t, vary in accordance with the AR(1) process. For $\ln G_t = \rho_G \ln G_{t-1} + \varepsilon_{G,t}$, the stochastic shock, $\varepsilon_{G,t}$, has a zero mean and the standard deviation is equal to σ_G.

As in [Leith, Von Thadden, 2008], fiscal policy is described by a simple rule, which takes the following form:

$$Tx_t = Tx + \phi_G(B_t - B), \tag{29}$$

where Tx is the steady state level of taxes and $\phi_G > 0$ is the reaction of taxation to outstanding debt.

The central bank conducts monetary policy in accordance with the standard Taylor rule:

$$r_t = \phi_\pi \pi_t + \phi_y y_t, \tag{30}$$

where ϕ_π and ϕ_y reflect the reaction of the central bank to inflation and output deviations.

In order to consider the effects of forward guidance, it is assumed that at time $t = 0$ the central bank announces that it will decrease nominal interest rate by 100 basis points in period $t = 4$. During the subsequent periods, the nominal interest rate will follow the standard Taylor rule.

Equilibrium Dynamics

The system may be rewritten in terms of the output gap x_t, defined as the deviation of output y_t from its natural level y_t^n, where y_t^n is the equilibrium level of output under sticky prices.

Then, the output gap can be defined as:

$$x_t = y_t - y_t^n. \tag{31}$$

Assuming that under flexible prices $mc_t = 1$, the natural level of output equals:

$$y_t^n = a_t + \frac{1}{1+\eta} g_t. \tag{32}$$

The relation between marginal costs and the output gap takes the following form:

$$mc_t = (1+\eta)x_t. \tag{33}$$

Hence, the New Keynesian Phillips curve may be derived:

$$\pi_t = \beta \mathbb{E}_t \pi_{t+1} + \tilde{\kappa} x_t, \tag{34}$$

where $\tilde{\kappa} = (1+\eta)\kappa$.

The market clearing condition takes the following log-linearized form:

$$y_t = c_t + g_t. \tag{35}$$

Substituting equation (35) into the Euler equation for a Ricardian economy results in:

$$y_t - g_t = \mathbb{E}_t(y_{t+1} - g_{t+1}) - (r_t - \mathbb{E}_t\pi_{t+1}). \tag{36}$$

Rearranging the equation above, yields:

$$y_t = \mathbb{E}_t y_{t+1} - (r_t - \mathbb{E}_t\pi_{t+1}) - \mathbb{E}_t\Delta g_{t+1}. \tag{37}$$

The dynamic IS curve for a Ricardian economy may be rewritten combining $y_t^n = a_t + \frac{1}{1+\eta} g_t$ and equation (37) as follows:

$$x_t = \mathbb{E}_t x_{t+1} - (r_t - \mathbb{E}_t\pi_{t+1} - r_t^n), \tag{38}$$

where $r_t^n = \frac{\eta}{1+\eta}(1-\rho_G)g_t - (1-\rho_A)a_t$ is the natural interest rate.

The derivation of the dynamic IS curve for non-Ricardian consumers follows the same algorithm but includes the dynamics of debt holdings:

$$x_t = \mathbb{E}_t x_{t+1} - (r_t - \mathbb{E}_t\pi_{t+1} - r_t^n) + \frac{(1-\gamma)\upsilon_B}{(1+\varphi)\gamma\Phi} b_{t+1}, \tag{39}$$

where $\upsilon_B = \frac{B}{Y}$ and the natural interest rate is the same as for the Ricardian economy.

Debt holdings in log-linearized form equal:

$$b_{t+1} = (r_t - \mathbb{E}_t\pi_{t+1}) + \frac{1}{\beta}(1-\phi_G)b_t + \frac{1}{\beta\upsilon_B} g_t. \tag{40}$$

Boundedly Rational Expectations

In contrast to the standard New Keynesian model in which expectations are rational, it is postulated that firms are boundedly rational and have an imperfect knowledge of the inflation dynamics. Thus, a representative firm's subjective inflation forecast, $\widetilde{\mathbb{E}}_t\pi_{t+1}$, is determined in the following way:

$$\widetilde{\mathbb{E}}_t\pi_{t+1} = \widetilde{\mathbb{E}}_{t-1}\pi_t + \lambda_\pi\left(\pi_t - \widetilde{\mathbb{E}}_{t-1}\pi_t\right), \tag{41}$$

where $\lambda_\pi \in (0, 1]$ is the sensitivity of inflation expectations to short-run inflation surprises.

As in the studies of [Stock, Watson, 2007; 2010], it is assumed that firms arrive at their inflation forecasts using a univariate time-series model for inflation which allows for both temporary and permanent shocks:

$$\begin{bmatrix} \pi_t \\ \bar{\pi}_t \end{bmatrix} = \begin{bmatrix} 0 & 1 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} \pi_{t-1} \\ \bar{\pi}_{t-1} \end{bmatrix} + \begin{bmatrix} 1 & 1 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} \xi_t \\ u_t \end{bmatrix}, \tag{42}$$

where $\bar{\pi}_t$ is the unobservable inflation trend, ξ_t is a transitory shock that pushes π_t away from the trend, and u_t is a permanent shock that shifts the trend over time.

Thus, the optimal subjective forecast, $\widetilde{\mathbb{E}}_t \pi_{t+1}$, is determined in the following way:

$$\widetilde{\mathbb{E}}_t \pi_{t+1} = \widetilde{\mathbb{E}}_t \bar{\pi}_t = \lambda_\pi \pi_t + (1 - \lambda_\pi) \widetilde{\mathbb{E}}_{t-1} \pi_t. \tag{43}$$

The value of λ_π may be viewed as measuring the degree to which inflation expectations remain anchored. A low value of λ_π means that agents do not revise their inflation forecasts much in response to inflation surprises and implies that expectations are well anchored. In contrast, when inflation is driven mostly by a permanent shock, agents are quick to revise their estimate of trend inflation in response to incoming data, and this means that expectations are poorly anchored.

Substituting the agent's subjective inflation forecast (43) into the standard New Keynesian Phillips curve yields:

$$\pi_t = \frac{\beta(1-\lambda_\pi)}{(1-\beta\lambda_\pi)} \widetilde{\mathbb{E}}_{t-1} \pi_t + \frac{\widetilde{\kappa}}{(1-\beta\lambda_\pi)} x_t. \tag{44}$$

The degree to which inflation expectations are anchored affects the dynamics of inflation through its influence on the steepness of the Phillips curve. [Carvalho et al., 2023; Coibion, Gorodnichenko, 2015] find empirical evidence of more firmly anchored inflation expectations over time. Moreover, [Jorgensen, Lansing, 2019] estimate the degree of anchoring of inflation expectations and the slope of the Phillips curve simultaneously and show that well-anchored expectations during the Great Recession served to flatten the Phillips curve. Thus, an increase in anchoring of inflation expectations dampens the magnitude of the inflation response to any variation in the output gap.

The authors also postulate that agents employ an analogous perceived law of motion for the output gap, as given by:

$$\begin{bmatrix} x_t \\ \bar{x}_t \end{bmatrix} = \begin{bmatrix} 0 & 1 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} x_{t-1} \\ \bar{x}_{t-1} \end{bmatrix} + \begin{bmatrix} 1 & 1 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} \vartheta_t \\ \chi_t \end{bmatrix}, \tag{45}$$

where $\bar{x}_t$ is the perceived long-run output gap, ϑ_t is a transitory shock that pushes x_t away from the trend, and χ_t is a permanent shock.

In accordance with the perceived law of motion for the output gap given by equation (45), the optimal forecast rule is:

$$\widetilde{\mathbb{E}}_t x_{t+1} = \widetilde{\mathbb{E}}_t \bar{x}_t = \lambda_x x_t + (1 - \lambda_x) \widetilde{\mathbb{E}}_{t-1} x_t. \tag{46}$$

Given the agent's perceived optimal forecast rules (43) and (46), the actual law of motion for the economy is governed by dynamic IS curves and the New Keynesian Phillips curve, and it provides a complete description of the Ricardian and non-Ricardian economies with boundedly rational expectations.

3. Forward Guidance Puzzle

This section offers one possible solution to the forward guidance puzzle by examining the model with anchored inflation expectations. Forward guidance operates via the expectations of the agents in the economy. However, standard DSGE models pay little attention to the behavior of expectations, which are formed endogenously via the dynamics of the model. This study shows that the introduction of firms with an imperfect understanding of the inflation dynamics significantly impacts the expectations in DSGE models.

Figure 1 shows the reaction of the economy to a forward guidance shock for boundedly rational agents. When the central bank announces that the interest rate will decrease by one percent for T periods in the future, fully rational agents tend to overreact to this information. Thus, the responsiveness of inflation and output to the forward guidance announcements becomes amplified. When agents are boundedly rational, the effects of the central bank's announcements concerning monetary policy decisions are attenuated. The fact that expectations are anchored makes inflation and output responses more modest, both because the slope of the New Keynesian Phillips curve becomes less steep and also because the announcements about the nominal interest rate reduction result in a smaller decrease in the real interest rate in accordance with the Fisher equation. Therefore, when expectations are well anchored and agents do not much revise their forecasts in response to recent forecast errors, the effects of forward guidance are considerably attenuated. However, when inflation expectations are less anchored, the dynamics of the economy are only partially muted.

It is worth separately noting the dynamics of output below its steady state level. The reason is that central banks follow the standard Taylor rule and seek to return the economy to its potential level after the forward guidance announcement passes. While there is a consensus in the literature about the long duration of forward guidance policies at the zero lower bound, a central bank's commitment to reduce the nominal interest rate far in the future may result in larger cumulative inflation and output and, therefore, a more aggressive response of the monetary policy without a zero lower bound constraint. This problem could be solved by switching to less prolonged forward guidance policies or reduction in the frequency of the announcements; however, evaluating those strategies is beyond the scope of this work.

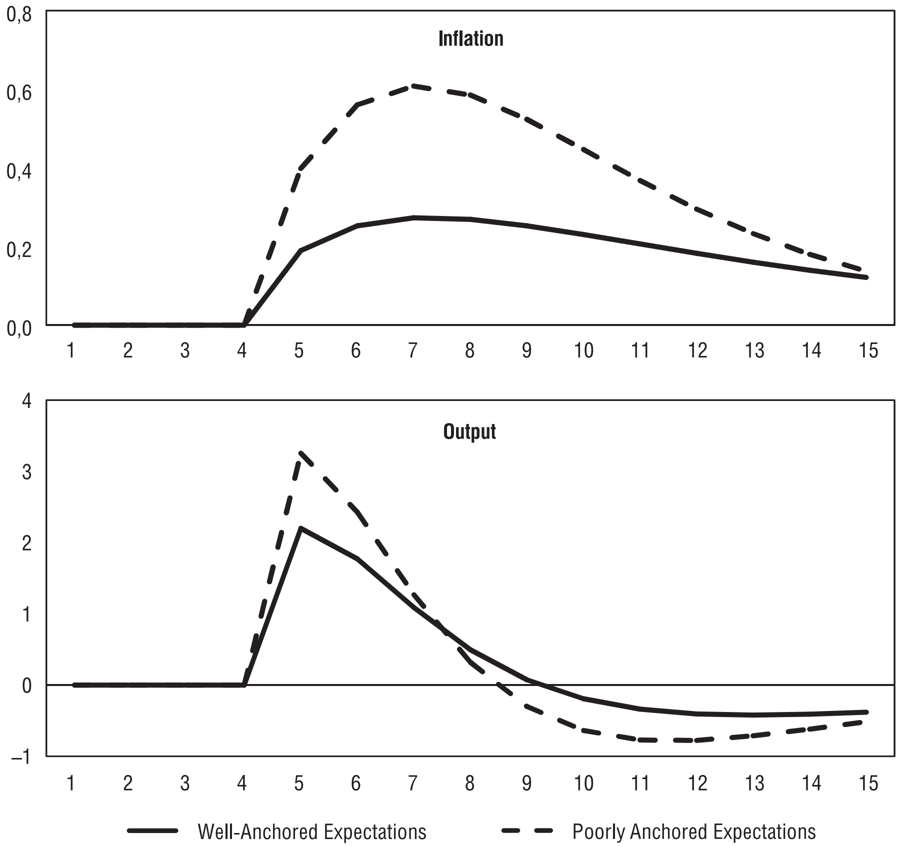

Fig. 1. **Inflation and Output Responses to a Forward Guidance Shock With Anchored Inflation Expectations**

The effectiveness of forward guidance may also vary depending on the policy type. The implications of a shift employed in this article toward a Taylor rule with higher coefficients within the New Keynesian model accompanied by boundedly rational agents are also worth elaborating. Figure 2 shows how the heightened desire of a central bank to maintain price stability and to reduce the output gap will influence the economy's response to a forward guidance shock under poorly and well-anchored expectations, respectively. The responses in inflation and output are reduced under both conditions. Higher values for the Taylor rule coefficients of a policy entail a faster reversion of inflation and output to a steady state in response to a shock and, hence, serve to anchor firms' inflation expectations. Therefore, a plausible increase in the coefficients results in a less inflationary response and may be desirable when inflation expectations are poorly anchored. However, well-anchored expectations may mitigate the adverse effects of higher coefficients on forward guidance. On the one hand, positive trend inflation necessitates more aggressive monetary policy for the Blanchard and Kahn conditions to be met [Ascari et al., 2014]. On the other hand, a higher degree of anchoring expands the scope of determinacy and allows the central bank more flexibility. Anchored inflation expectations thus negate some of the adverse effects of trend inflation and allow central banks to apply forward guidance policies that remain effective.

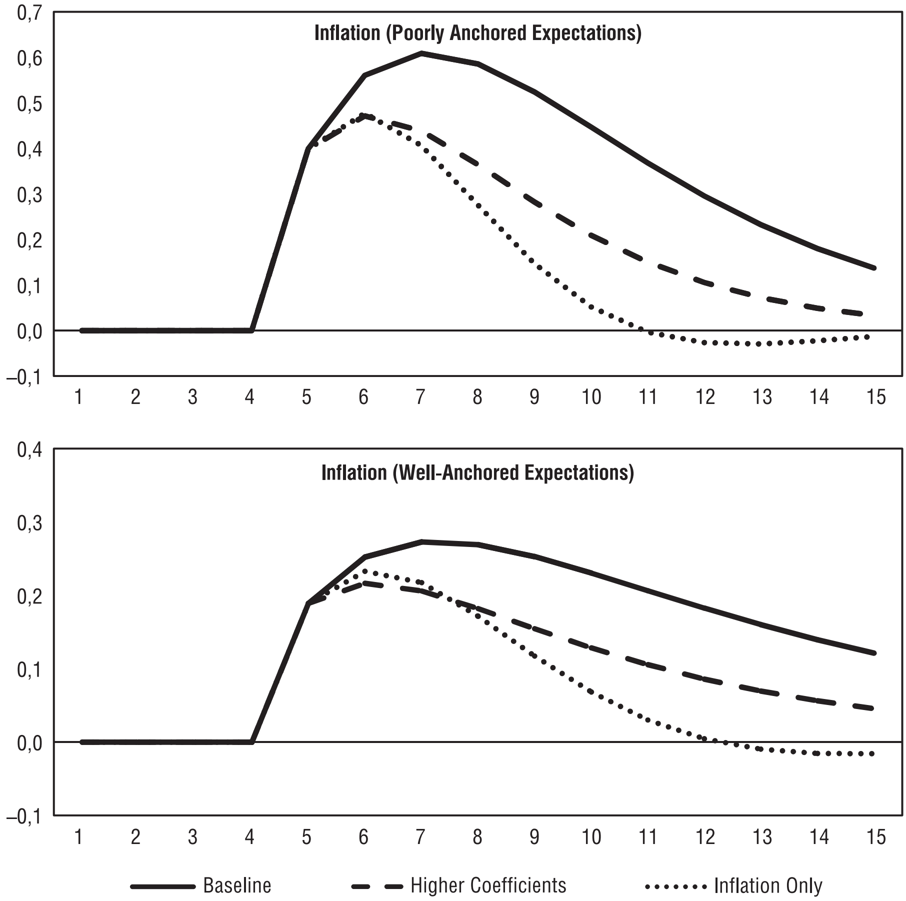

Fig. 2. **Inflation Response to a Forward Guidance Shock Under Different Policy Coefficients**

Figure 2 also shows the reaction of inflation to a forward guidance shock when the central bank seeks to stabilize only deviations in inflation. While such a policy considerably reduces the persistence of the effects of shocks on macroeconomic variables, zero weight on output in the policy rule makes the effectiveness of forward guidance extremely low. This result is applicable whether inflation expectations are more anchored or less so. It follows that central banks which provide signals about future interest rates should be flexible in their policies. When expectations are well anchored, a central bank should maintain both price and output stability in a non-aggressive manner. However, poorly anchored expectations require the central bank to achieve the right balance between higher policy coefficients in the Taylor rule and the effectiveness of forward guidance.

4. Forward Guidance and Fiscal Policy

This section analyzes the dependence of forward guidance on fiscal policy. In the baseline model, steady state government debt is equal to zero. However, most governments around the world in fact allow non-zero government debt. How different values of the debt-to-output ratio could impact forward guidance effects on the economy is explored first.

While empirical papers find evidence for the dependence of forward guidance on fiscal policy, recent theoretical literature supports this idea only under fixed active fiscal regimes. This study argues that introducing non-Ricardian consumers enables analysis of the influence of a fiscal policy stance on a central bank's announcements. That relationship arises because the dependence of monetary policy on the fiscal stance is strengthened by magnifying wealth effects for households in a non-Ricardian economy.

[Del Negro et al., 2023] show that the effects of forward guidance are considerably attenuated in the model with non-Ricardian consumers. This is because as yet unborn households cannot immediately increase their consumption to benefit from the future interest rate drop. Therefore, aggregate consumption trends lower, and the responsiveness of inflation and output is dampened. Figure 3 shows that the forward guidance puzzle may hold even in a non-Ricardian framework. Although the effects of a central bank's announcements on the dynamics of inflation and output are attenuated in comparison with a fully rational framework, an increase in debt magnifies the wealth channel so that fluctuations in real debt holdings have a larger impact on the economy. Moreover, a high value for bond holdings moves debt farther from the initial value in response to a forward guidance shock and therefore constrains the convergence of debt to a steady state. As a result, a positive debt level amplifies the effects of forward guidance.

Taking both poorly and well-anchored inflation expectations into account has valuable policy implications for central banks as they im-

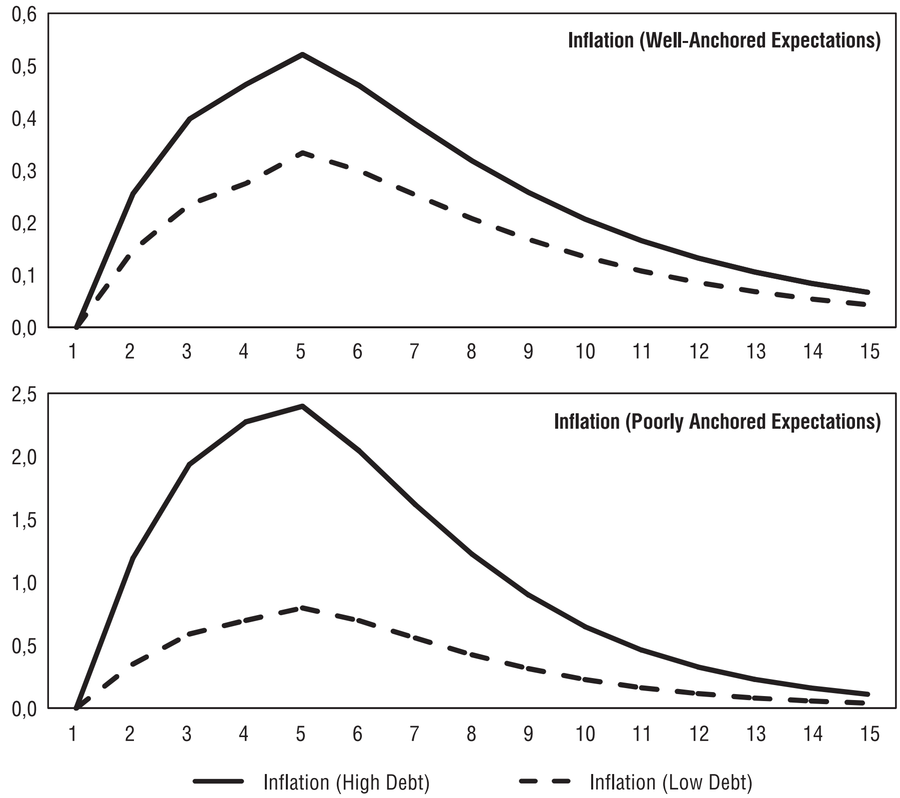

Fig. 3. **Inflation Response to a Forward Guidance Shock With Positive Debt**

plement forward guidance under conditions of low and high government debt. When expectations are well anchored, a sustainable level of debt results in a more effective forward guidance policy. However, central banks need to be restrained in their announcements when expectations are de-anchored and the governments accumulate a large amount of debt. In that circumstance, an overactive information policy may destabilize the economy.

This study also points out ways in which the power of forward guidance depends on the fiscal policy responses to debt fluctuations. In the baseline framework, the fiscal policy parameter is positive and equal to 0.5. As [Cochrane, 2017] has demonstrated, only an active fiscal policy may attenuate the inflation and output responses that are elicited by forward guidance announcements. However, in this study's non-Ricardian framework, an increase in the fiscal policy parameter does dampen the power of forward guidance, which may additionally stabilize an economy with high levels of debt and an active forward guidance policy.

Conclusion

With nominal interest rates approaching the zero lower bound, forward guidance has become an increasingly important tool of monetary policy. However, general equilibrium models predict implausibly large reactions to forward guidance and devote little scrutiny to analyzing the course of inflation expectations. This study argues that the effectiveness of forward guidance depends crucially on the degree to which inflation expectations are anchored and on the central bank's ability to maintain price stability. The introduction of boundedly rational equilibrium constrains the dynamics of expectations in the model developed and provides a possible solution to the forward guidance puzzle. When agents have an imperfect understanding of the inflation process and arrive at their subjective inflation forecasts, the degree of anchoring of inflation expectations may vary. When expectations are well anchored, the dynamics of key macroeconomic variables in response to forward guidance shocks are relatively attenuated. Moreover, higher coefficients in a policy rule entail a faster convergence of inflation and output to their steady state and also anchor inflation expectations. Stronger responses of monetary policy to inflation and output fluctuations significantly dampen the effects of forward guidance and result in higher accuracy for the model. However, an excessive urge to stabilize inflation deviations without paying attention to output fluctuations nullifies the effectiveness of forward guidance when expectations are well anchored.

The analysis in this article supplements the literature pertaining to the dependence of forward guidance on fiscal policy. In contrast to existing papers, however, it indicates that the effects of central bank announcements depend on the fiscal policy stance when non-Ricardian households are incorporated into the model. The initial effects of forward guidance thus depend significantly on the steady state debt. Higher levels of debt holdings amplify the effects of forward guidance on inflation and output, but this condition leads to destabilization of the economy when expectations are poorly anchored. A stronger reaction of fiscal policy to debt fluctuations attenuates the effects of central bank announcements when debt is high.

Finally, it is worth clarifying the following point. This paper focuses on an equilibrium in which the degree of anchoring is determined exogenously. However, a significant surge in inflation in recent years has caused an increase in uncertainty and therefore higher noise in perceived signals. Modifying the model to account for the ability of agents to endogenously extract information from the central bank announcements may ultimately provide a better understanding of forward guidance policies.

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