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Trend Inflation Under Bounded Rationality

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Why This Study Is Important

This paper provides valuable insights into macroeconomic stability in New Keynesian models. By incorporating more realistic assumptions about human decision making, researchers can better understand how the economy works in practice and develop more effective policy interventions.

The implications of this research are important for policymakers interested in stabilizing macroeconomic outcomes through monetary policy. Gaining an understanding of how bounded rationality affects the relationship between trend inflation and stability can help policymakers make more-informed decisions about interest rates, forward guidance, and balance sheet policies. The authors note that their findings have important implications for inflation-targeting frameworks and for models that depart from rational expectations.

Key Findings

1. **Economic models may not capture true decision making.**
Traditional economic models use rational expectations to pin down beliefs. These models may not fully capture how people make decisions in the real world.

2. **Inflation is less likely to cause instability when cognitive discounting is factored in.**
When people place more weight on current events than on future events, they are less likely to be influenced by changes in inflation expectations. This cognitive discounting increases the region of model determinacy, making it less susceptible to instability.

Methodology

In the canonical model, trend inflation generates macroeconomic instability by making the economy more susceptible to equilibrium indeterminacy. This paper evaluates the implications of introducing bounded rationality into a New Keynesian model with trend inflation.

The authors derive the behavioral counterpart of the Generalized New Keynesian model in Ascari and Sbordone (2014) by introducing cognitive discounting modeled following Gabaix (2020).

To test the model, the authors estimate it using Bayesian methods and compare model fit against standard models. They find that the best-performing model features bounded rationality and a unique equilibrium.

TREND INFLATION UNDER BOUNDED RATIONALITY

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Abstract. This paper evaluates the implications of introducing bounded rationality into a New Keynesian model with trend inflation. With rational expectations, trend inflation generates macroeconomic instability by making the economy more susceptible to equilibrium indeterminacy. We find that cognitive discounting increases the region of determinacy, and therefore, trend inflation becomes less destabilizing. We estimate the model using Bayesian methods allowing for both determinacy and indeterminacy. We find that the best-fitting model features bounded rationality and a determinate equilibrium.

Keywords: Determinacy and Indeterminacy, Bayesian Estimation, Inflation Targeting, Departures from Rational Expectations.

JEL Codes: E70, E52, E3, C22, E31

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1. Introduction

Price stability in monetary economics and central banking today features low rates of inflation. In post-war industrialized economies, inflation has been positive for the past several decades,[1] a fact that is well documented empirically. From 1990 through 2020, average annual CPI inflation was around 3.26 percent in OECD countries and 2.4 percent in the United States. Furthermore, inflation has been stable during the Great Moderation period after the Volcker disinflation of the early 1980s, with fewer episodes of high volatility as compared to the preceding sample. Several central banks in advanced economies adopted inflation targets, with values ranging from 1% to 3%. Central banks were generally successful in managing to maintain inflation within these bands, up until the recent bout of high inflation in the post-COVID-19 pandemic era.

Hoping to reverse the recent historic rise in inflation, central banks have rapidly raised interest rates. The Federal Reserve increased the Federal Funds Rate by over 500 basis points over 18 months after leaving it at near zero during the pandemic. In these type of scenarios, some have predicted that central banks' efforts to lower inflation could come with substantially higher levels of unemployment and generate risks to financial stability (see Blot, Creel, and Geerolf, 2023; IMF, 2023). At the moment, inflation has dropped from 9% to 3.2% in the United States with no discernible jump in unemployment. Therefore, this prediction appears unlikely to be right at a first glance. Bernanke and Blanchard (2023), however, show that going the last mile to get inflation back to 2% could come with substantially higher unemployment rates. In particular, Blanchard said "*Maybe we don't need to run the last mile. We can walk the last mile or we cannot walk at all and we can decide that maybe 3% target inflation would be a really good number.*" In addition, before the post-pandemic surge in inflation, the prolonged period at the effective lower bound led several economists to propose an increase of the inflation target (see Blanchard, Dell'Ariccia, and Mauro, 2010; Ball, 2014; Cecchetti and Schoenholtz, 2017; Summers, 2018); which would essentially lead to an increase in trend inflation over time. These proposals are based on the hope that by allowing for higher trend inflation, the pernicious effects of rapid interest rate hikes can be alleviated. On the other hand, several papers have shown that higher trend inflation can lead to a more volatile economy. In this paper, we contribute to this debate by studying the effects of trend inflation on macroeconomic stability in a model where agents form boundedly rational expectations.

While workhorse monetary models often assume zero inflation in the steady state, a number of papers investigate the implications of modeling trend inflation in a New Keynesian model. Indeed the theoretical push back against a higher inflation target comes from results

[1]Schmitt-Grohé and Uribe (2007).

in Ascari and Ropele (2007); Ascari and Ropele (2009); Ascari and Sbordone (2014); Arias, Bodenstein, Chung, Drautzburg, and Raffo (2020); and Kara and Yates (2021). The idea is that trend inflation can be costly, in terms of both output losses and increased macroeconomic instability. Allowing for positive trend inflation in a baseline model can lead to macroeconomic instability by destabilizing inflation expectations and thus requiring a more aggressive policy response to inflation deviations from trend. The aforementioned papers show that higher trend inflation can lead to inflation that is more volatile and persistent, a more unstable economy, and inflation expectations that could de-anchor from central bank targets. The mechanism at work in these settings is the finding that trend inflation makes the economy more susceptible to equilibrium indeterminacy and sunspot shocks.

We revisit this evidence in a modelling environment that more accurately specifies agents' expectations, departing from the standard rational expectation assumption. We derive a New Keynesian model with trend inflation (see Ascari and Sbordone, 2014) and cognitive discounting (see Gabaix, 2020), which we name the Behavioral Generalized New Keynesian model. Once we relax the assumption that all agents in these models have unlimited cognitive capabilities, we find that trend inflation becomes less destabilizing. Specifically, we find that even with slight degrees of bounded rationality, a determinate equilibrium in a model with trend inflation becomes more attainable.

If trend inflation isn't as costly as previously thought, then the trade-offs of monetary tightening should take this into account. In addition, repercussions from central bank balance sheet normalization are not well understood and could potentially lead to financial stability risks (Sablik, 2022; Smith and Valcarcel, 2021). While we take no stance on what the optimal trend inflation should be, we are able to contribute to this discussion by highlighting the role of expectations when it comes to assessing the macroeconomic effects of a higher target.

Moreover, we show that a puzzling result emerges in an environment with rational expectations. When estimating a standard model with trend inflation using macroeconomic U.S. data from the last 30 years, the data strongly prefer equilibrium indeterminacy, consistent with volatile inflation dynamics subject to sunspot fluctuations and additional persistence. Yet, pre-pandemic inflation after the 1980s has been both positive and incredibly stable, particularly after central banks began adopting inflation targets in the 1990s. If the data prefer equilibrium indeterminacy when allowing for trend inflation, then we ought to expect higher volatility and persistence in inflation. Estimating the Generalized New Keynesian model on U.S. data from 1992 to 2019 yields results that favor indeterminacy. This indicates that the canonical trend inflation model implies that the data prefer a model with trend inflation, but with a dovish central bank and an economy subject to self-fulfilling expectations and sunspot shocks.

We are able to resolve this by departing from rational expectations and assuming cognitive discounting. We take our competing models to the data, and we find that our Behavioral Generalized New Keynesian model solves the puzzling result that emerges from the trend inflation literature and also fits the data better. Our estimation results indicate that the data prefer a model featuring trend inflation and bounded rationality, with a unique equilibrium and a central bank that is adhering to the Taylor Principle.

The rest of this paper proceeds as follows. Section 1.1 reviews the related literature. Section 2 sets up our model, first by revisiting key equations from Ascari and Sbordone (2014), then by introducing cognitive discounting as in Gabaix (2020), and finally by deriving the key equations for our Behavioral Generalized New Keynesian model. Section 3 outlines the conditions for determinacy in our model as well as in the building blocks, and it builds an intuition for how both trend inflation and cognitive discounting affect these conditions. Section 4 conducts a counterfactual exercise. Section 5 details our data and estimation procedure. Section 6 reports our results. Section 7 concludes.

1.1. **Related Literature.** Our paper is related to the extensive literature investigating the implications of estimating and modeling trend inflation. Cogley and Sargent (2002) estimate the trend component of inflation and find that it bears most of the responsibility for post-war U.S. inflation dynamics. Stock and Watson (2007) provide further evidence that the dynamics of inflation have been largely dominated by this trend component. They focus on the forecastability of inflation using a split-sample analysis around the second Volcker chairmanship at the Federal Reserve. Their results indicate that inflation has become more predictable due to smaller variance in its shock yet less predictable due to future inflation becoming less correlated with its predictors, such as current inflation. Taking these empirical estimates as given, Ascari and Ropele (2007) and Ascari and Ropele (2009) show that trend inflation makes price-setting firms more forward-looking, which flattens the Phillips curve and widens the indeterminacy region. This is a result also found in Hornstein and Wolman (2005) and Kiley (2007), who show that the Taylor principle is not enough to guarantee equilibrium determinacy when trend inflation is positive. Ascari and Sbordone (2014) further study this result by developing a New Keynesian model allowing for the approximation around a non-zero inflation steady state, which they call a Generalized New Keynesian model. They show that an increase in trend inflation is associated with a more volatile and unstable economy and tends to destabilize inflation expectations. Kara and Yates (2021) extend this Generalized New Keynesian model to include heterogeneity in price stickiness. In their model, higher trend inflation leads to a relatively greater long-run output loss and, consequently, an even larger indeterminacy region than that in Ascari and Sbordone (2014). When trend inflation is 4%, the indeterminacy region of the Kara and Yates (2021) model emerges across nearly all parameter combinations, offering even more caution against increasing the inflation target to 4% as a means to avoid the zero lower bound in the future. Their results suggest that higher inflation targets are very costly– they lead to higher output losses and equilibrium indeterminacy in authors' model.

Our work is also related to papers that conduct empirical examinations using modified versions of the Generalized New Keynesian model to study the Great Inflation period while assuming that agents hold rational expectations. Hirose, Kurozumi, and Van Zandweghe (2020) estimate a New Keynesian model positive with trend inflation for the Great Inflation period. They find uncertainty as to whether the policy response to inflation was active or passive during the pre-1979 period, though they find support for indeterminacy in the pre-1979 period and determinacy in the post-1982 period. Arias, Ascari, Branzoli, and Castelnuovo (2020) corroborate these findings by revisiting the relation between the systematic component of monetary policy, trend inflation, and determinacy within a medium-scale DSGE model. They study the period from 1984 to 2008, focusing on determinacy alone. Haque (2019) documents that a time-varying target empirically fits the data better, compared to a constant target as modeled in Hirose, Kurozumi, and Van Zandweghe (2020), and that determinacy prevails during the Great Inflation. Haque, Groshenny, and Weder (2021) employ a sticky-price model with trend inflation, commodity price shocks, and sluggish real wages to revisit the role of monetary policy during the Great Inflation. Their estimation concludes that U.S. data prefers determinacy, but with a central bank that was under-responsive to the output gap.

We also provide empirical evidence in favor of modelling cognitive discounting in New Keynesian models. A number of recent papers have focused on introducing cognitive discounting using different microfounded approaches, but yielding similar models. Woodford (2018) introduces finite horizon planning into a New Keynesian DSGE model. Angeletos and Lian (2018) develop a similar model with imperfect common knowledge, and Farhi and Werning (2019) introduce level-k thinking. While these papers focus on introducing cognitive discounting into standard New Keynesian models, our paper is the first to do so while allowing for positive steady-state inflation. Furthermore, the results of our estimation serve as empirical validation in favor of cognitive discounting. A number of papers including Hirose (2018), Ilabaca, Meggiorini, and Milani (2020), Andrade, Cordeiro, and Lambais (2019), and Afsar and Gallegos (2018) have conducted estimations of New Keynesian models with cognitive discounting as in Gabaix (2020). Hirose and coauthors estimate a model incorporating bounded rationality and the zero lower bound on the nominal interest rate. They find better model fit, substantial degrees of bounded rationality, and weaker forward guidance. The New Keynesian model with cognitive discounting estimated in Ilabaca, Meggiorini, and

Milani (2020) finds that the substantial estimated degrees of bounded rationality prevent the economy from falling into indeterminacy and that determinacy is preferred both before and after 1979. Our results are aligned with these studies.

Finally, we contribute to the emerging literature that employs the methodological contributions of Lubik and Schorfheide (2004); Farmer, Khramov, and Nicolò (2015); and Bianchi and Nicolò (2021) to estimate models with potential indeterminacy. Recent examples of this work include Nicolò (2018); Ilabaca, Meggiorini, and Milani (2020); Ilabaca and Milani (2021); Cuba-Borda and Singh (2019); Haque, Groshenny, and Weder (2021), among others. We add to this growing body of work by considering a model in which indeterminacy can emerge from two channels: trend inflation, and how expectations are modelled.

2. Model

The following sections describe the set up of the Generalized New Keynesian model from Ascari and Sbordone (2014), followed by a model derivation in which agents are boundedly rational à la Gabaix (2016), and culminating in the equations for the Behavioral Generalized New Keynesian model that we analyze and estimate later.

2.1. Generalized New Keynesian Model.

Ascari and Sbordone (2014) develop a Generalized New Keynesian model that allows for the approximation of the canonical New Keynesian model around a non-zero steady state inflation. This Generalized New Keynesian model can be fully described by five equations: (1) a usual consumption Euler equation, (2) a Phillips curve, (3) a Taylor rule, and the two novel equations (4) an equation for the evolution of price dispersion that arises in the case of non-zero steady state inflation, and (5) an auxiliary process with no economic interpretation.[2]

2.1.1. *Households.*

The utility function of the representative agent is assumed to be separable in consumption (C) and labor (N):

$$U(C_t, N_t) = \frac{C_t^{(1-\sigma)}}{1-\sigma} - d_n \frac{N_t^{(1+\varphi)}}{1+\varphi}$$

, where σ is the intertemporal elasticity of substitution in consumption, d_n is a constant, and φ is the Frisch elasticity of labor supply. The period-by-period budget constraint is given by:

$$P_t C_t + (1+i_t)^{-1} B_t = W_t N_t + D_t + B_{t-1}, \tag{1}$$

where i_t is the nominal interest rate, B_t is the one-period bond holdings, W_t is the nominal wage rage, N_t is the labor input, and D_t is distributed dividends. The representative

[2] We refer the reader to the Online Appendix of Ascari and Sbordone (2014) for the full model derivation. Here we show the minimum details to derive these five equations.

consumer maximizes the expected discounted intertemporal utility, subject to the budget constraints.

Aggregate demand in this model features a utility-maximizing representative agent:

$$U(C_t, N_t) = \widehat{\mathbb{E}}_t \sum_{j=0}^{\infty} \beta^j \left[\frac{C_{t+j}^{(1-\sigma)}}{1-\sigma} - d_n \frac{N_{t+j}^{(1+\varphi)}}{1+\varphi} \right]$$

subject to the budget constraint (1). The first-order constraint with respect to consumption yields the following Euler equation:

$$\frac{1}{C_t^{\sigma}} = \beta \widehat{\mathbb{E}}_t \left[\left(\frac{P_t}{P_{t+1}} \right) (1+i_t) \left(\frac{1}{C_{t+1}^{\sigma}} \right) \right]$$

where $\widehat{\mathbb{E}}_t$ is either the rational expectation operator $\mathbb{E}_t^{RE}$ or the boundedly rational expectation operator $\mathbb{E}_t^{BR}$. The labor supply equation is given by:

$$\frac{W_t}{P_t} = d_n N_t^{\varphi} C_t^{\sigma}$$

. Log-linearizing the Euler equation around steady-state yields:

$$-\sigma c_t = -\widehat{\mathbb{E}}_t \pi_{t+1} + i_t - \sigma \widehat{\mathbb{E}}_t c_{t+1}$$

$$c_t = \widehat{\mathbb{E}}_t c_{t+1} - \sigma^{-1}(i_t - \widehat{\mathbb{E}}_t \pi_{t+1})$$

In this simple model, there is no capital and no fiscal spending; hence the aggregate resource constraint is simply given by $Y_t = C_t$, which leads to

$$y_t = \widehat{\mathbb{E}}_t y_{t+1} - \sigma^{-1}(i_t - \widehat{\mathbb{E}}_t \pi_{t+1}). \tag{2}$$

When expectations are rational, the Euler equation is given by:

$$y_t = \mathbb{E}_t \, y_{t+1} - \sigma(i_t - \mathbb{E}_t \, \pi_{t+1}) + g_t, \tag{3}$$

where y_t is the output gap, i_t is the nominal interest rate, π_t is inflation and g_t is an AR(1) demand-side disturbance.

2.1.2. *Firm's Pricing.* The pricing model is based on the Calvo assumption such that in each period, there is a fixed probability $1-\alpha$ that a firm i can re-optimize its nominal price, which we denote by $P_{i,t}^*$. The price-setting problem is:

$$\max_{P^*i,t} \widehat{\mathbb{E}}_t \sum_{j=0}^{\infty} \mathcal{D}_{t,t+j} \alpha_j \left[\frac{P_{i,t}^*}{P_{t+j}} Y_{i,t+j} - \frac{MC_{t+j}^n}{P_{t+j}} Y_{t+j} \right],$$

subject to the demand constraint:

$$Y_{i,t_j} = \left(\frac{P_{i,t}^*}{P_{t+j}} \right)^{-\epsilon} Y_{t+j}$$

where $\mathcal{D}_{t,t+j} = \beta^j \frac{\lambda_{t+j}}{\lambda_0}$ is the stochastic discount factor, with λ_{t+j} denoting the $t+j$ marginal utility of consumption, Y_t denoting output, and MC^n denoting the nominal marginal cost.

The firm's first-order condition is:

$$\widehat{\mathbb{E}}_t \sum_{j=0}^{\infty} \alpha^j \mathcal{D}_{t,t+j} \left[\frac{(1-\epsilon)(P^*_{i,t})^{-\epsilon} Y_{t+j}}{P_{t+j}^{(1-\epsilon)}} + \epsilon (P^*_{i,t})^{(-\epsilon-1)} \frac{MC^n_{t+j} Y_{t+j}}{P_{t+j}^{(1-\epsilon)}} \right] = 0$$

Multiplying by $(P^*_{i,t})^{(1+\epsilon)}$ and isolating $P^*_{i,t}$, we get:

$$P^*_{i,t} = \frac{\epsilon}{\epsilon - 1} \frac{\widehat{\mathbb{E}}_t \sum_{j=0}^{\infty} \alpha^j \mathcal{D}_{t,t+j} \left[\frac{MC_{t+j} Y_{t+j}}{P^{-\epsilon}_{t+j}} \right]}{\widehat{\mathbb{E}}_t \sum_{j=0}^{\infty} \alpha^j \mathcal{D}_{t,t+j} \left[\frac{Y_{t+j}}{P^{(1-\epsilon)}_{t+j}} \right]}$$

Dividing by P_t and denoting $p^*_{i,t} = \frac{P^*_{i,t}}{P_t}$ yields:

$$p^*_{i,t} = \frac{\epsilon}{\epsilon - 1} \frac{\widehat{\mathbb{E}}_t \sum_{j=0}^{\infty} \alpha^j \mathcal{D}_{t,t+j} \left[\frac{MC_{t+j} Y_{t+j}}{\Pi^{-\epsilon}_{t,t+j}} \right]}{\widehat{\mathbb{E}}_t \sum_{j=0}^{\infty} \alpha^j \mathcal{D}_{t,t+j} \left[\frac{Y_{t+j}}{\Pi^{(1-\epsilon)}_{t,t+j}} \right]} \tag{4}$$

where $\Pi_{t,t+j}$ indicates cumulative inflation between periods t and $t+j$:

$$\Pi_{t,t+j} = \begin{cases} 1 & \text{for} \quad j = 0 \\ \frac{P_{t+1}}{P_t} \frac{P_{t+2}}{P_{t+1}} \times \cdots \times \frac{P_{t+j}}{P_{t+j-1}} & \text{for} \quad j \geq 1 \end{cases}$$

In a steady state with constant inflation, Equation (4) becomes:

$$p^*_i = \frac{\epsilon}{\epsilon - 1} \frac{\widehat{\mathbb{E}}_t \sum_{j=0}^{\infty} (\alpha \beta \overline{\pi}^{\epsilon})^j MC}{\widehat{\mathbb{E}}_t \sum_{j=0}^{\infty} (\alpha \beta \overline{\pi}^{(\epsilon-1)})^j}, \tag{5}$$

Taking a log-linear approximation of the firms' equilibrium conditions and the aggregate price relation around a steady state characterized by zero inflation (i.e. $\overline{\pi} = 1$), and assuming rational expectations $\widehat{\mathbb{E}}_t = \mathbb{E}^{RE}_t$, we get the usual expression of the Phillips curve:

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

where $\kappa = \frac{(1-\alpha)(1-\alpha\beta)}{\alpha}$. Instead, we follow Ascari and Sbordone (2014) to log-linearize the equilibrium conditions around a steady state characterized by a positive trend inflation. We use the recursive formulation of the optimal price-setting equation, such that

$$p^*_{i,t} = \frac{\epsilon}{\epsilon - 1} \frac{\widehat{\mathbb{E}}_t \sum_{j=0}^{\infty} \alpha^j \mathcal{D}_{t,t+j} \left[\frac{MC_{t+j} Y_{t+j}}{\Pi^{-\epsilon}_{t,t+j}} \right]}{\widehat{\mathbb{E}}_t \sum_{j=0}^{\infty} \alpha^j \mathcal{D}_{t,t+j} \left[\frac{Y_{t+j}}{\Pi^{(1-\epsilon)}_{t,t+j}} \right]} = \frac{\epsilon}{\epsilon - 1} \frac{\Psi_t}{\Phi_t}$$

The auxiliary variables Ψ_t and Φ_t are defined as:

$$\Psi_t \equiv \widehat{\mathbb{E}}_t \sum_{j=0}^{\infty} (\beta\alpha)^j Y_{t+j}^{-\sigma} \left[MC_{t+j} Y_{t+j} \Pi_{t,t+j}^{\epsilon} \right] \tag{6}$$

$$\Phi_t \equiv \widehat{\mathbb{E}}_t \sum_{j=0}^{\infty} (\beta\alpha)^j \left(\frac{Y_{t+j}^{(1-\sigma)}}{\Pi_{t,t+j}^{(1-\epsilon)}} \right), \tag{7}$$

using the definition of the discount factor $\mathcal{D}_{t,t+j} = \beta^j \frac{\lambda_{t+j}}{\lambda_0}$ and the fact that $\lambda_{t+j} = Y_{t+j}^{-\sigma}$.

Log-linearizing Equation (6) around a steady state characterized by a positive trend inflation yields:

$$\psi_t = \widehat{\mathbb{E}}_t \sum_{j=0}^{\infty} (\beta\alpha)^j \left\{ \left[\frac{MC \cdot Y^{(1-\sigma)} \overline{\Pi}_j^{\epsilon}}{\psi} \right] \left(mc_{t+j} + (1-\sigma) y_{t+j} + \epsilon \widehat{\Pi}_{t,t+j} \right) \right\} \tag{8}$$

Substituting the steady state value of $\psi = \frac{MC \cdot Y^{(1-\sigma)}}{1-\beta\alpha\overline{\pi}^{\epsilon}}$ into Equation (8), we can rewrite it as:

$$\begin{aligned} \psi_t &= \widehat{\mathbb{E}}_t \sum_{j=0}^{\infty} (\beta\alpha)^j \left\{ (1-\beta\alpha\overline{\pi}^{\epsilon}) \overline{\Pi}_j^{\epsilon} \left(mc_{t+j} + (1-\sigma) y_{t+j} + \epsilon \widehat{\Pi}_{t,t+j} \right) \right\} \\ &= (1-\beta\alpha\overline{\pi}^{\epsilon})(mc_t + (1-\sigma) y_t) + \widehat{\mathbb{E}}_t \sum_{j=1}^{\infty} (\beta\alpha)^j \overline{\Pi}_j^{\epsilon} (1-\beta\alpha\overline{\pi}^{\epsilon}) \left(mc_{t+j} + (1-\sigma) y_{t+j} + \epsilon \widehat{\Pi}_{t,t+j} \right) \end{aligned} \tag{9}$$

given that $\overline{\Pi}_j = 1$ and $\widehat{\Pi}_{t,t+j} = 0$ when $j = 0$.

Under rational expectations, with $\widehat{\mathbb{E}}_t = \mathbb{E}_t^{RE}$, we can rewrite the infinite sum in Equation (9) recursively using the law of iterated expectations, as

$$\psi_t = (1-\beta\alpha\overline{\pi}^{\epsilon})\, mc_t + (1-\sigma)(1-\beta\alpha\overline{\pi}^{\epsilon}) y_t + (\alpha\beta\overline{\pi}^{\epsilon})\, \epsilon\, \mathbb{E}_t^{RE}\, \pi_{t+1} + (\alpha\beta\overline{\pi}^{\epsilon})\, \mathbb{E}_t^{RE}\, \hat{\psi}_{t\,+1}. \tag{10}$$

Similarly, recalling the fact that $\overline{\Pi}_j = 1$ and $\widehat{\Pi}_{t,t+j} = 0$ when $j = 0$, we can follow similar steps to log-linearize ϕ_t in Equation (7) around its steady-state value $\phi = \frac{Y^{(1-\sigma)}}{1-\alpha\beta\overline{\pi}^{(\epsilon-1)}}$, which leads to

$$\begin{aligned} \phi_t &= \widehat{\mathbb{E}}_t \sum_{j=0}^{\infty} (\beta\alpha)^j \left\{ \frac{Y^{(1-\sigma)} \overline{\Pi}_j^{(\epsilon-1)}}{\phi} \left[(1-\sigma) y_{t+j} + (\epsilon-1) \widehat{\Pi}_{t,t+j} \right] \right\} \\ &= \widehat{\mathbb{E}}_t \sum_{j=0}^{\infty} (\beta\alpha)^j \left\{ \left(1-\beta\alpha\overline{\pi}^{(\epsilon-1)}\right) \overline{\Pi}_j^{(\epsilon-1)} \left[(1-\sigma) y_{t+j} + (\epsilon-1) \widehat{\Pi}_{t,t+j} \right] \right\}. \end{aligned} \tag{11}$$

Under rational expectations, when $\widehat{\mathbb{E}}_t = \mathbb{E}_t^{RE}$, we can rewrite the infinite sum in Equation (11) recursively using the law of iterated expectations, as

$$\begin{aligned}
\phi_t &= \mathbb{E}_t^{RE} \sum^{\infty} (\beta\alpha)^j \left\{ \left(1 - \beta\alpha\overline{\pi}^{(\epsilon-1)}\right) \overline{\Pi}_j^{(\epsilon-1)} \left[(1-\sigma) y_{t+j} + (\epsilon - 1)\widehat{\Pi}_{t,t+j} \right] \right\} \\
&= (1 - \beta\alpha\overline{\pi}^{(\epsilon-1)})(1-\sigma)y_t + \mathbb{E}_t^{RE} \sum_{j=1}^{\infty} (\beta\alpha)^j \overline{\Pi}_j^{(\epsilon-1)} (1 - \beta\alpha\overline{\pi}^{(\epsilon-1)}) \Big((1-\sigma) y_{t+j} + (\epsilon-1)\widehat{\Pi}_{t,t+j} \Big) \\
&= (1-\sigma)(1 - \alpha\beta\overline{\pi}^{(\epsilon-1)}) y_t + (\epsilon - 1)\alpha\beta\overline{\pi}^{(\epsilon-1)} \, \mathbb{E}_t^{RE} \, \widehat{\pi}_{t+1} + \alpha\beta\overline{\pi}^{(\epsilon-1)} \, \mathbb{E}_t^{RE} \, \phi_{t+1}.
\end{aligned} \tag{12}$$

To express the auxiliary process in Equation (10) as an inflation-output relationship, we can substitute the expression for labor input, $n_t = s_t + y_t$, into that for real wage, $w_t = \varphi n_t + \sigma y_t$, to obtain:

$$w_t = \varphi s_t + (\varphi + \sigma) y_t$$

and

$$mc_t = w_t = \varphi s_t + (\varphi + \sigma) y_t \tag{13}$$

We can substitute Equation (13) into Equation (10) to get:

$$\psi_t = (1 - \beta\alpha\overline{\pi}^{\epsilon}) \, \varphi s_t + (1 - \beta\alpha\overline{\pi}^{\epsilon})(\varphi + 1) y_t + (\alpha\beta\overline{\pi}^{\epsilon}) \, \epsilon \, \mathbb{E}_t^{RE} \, \pi_{t+1} + (\alpha\beta\overline{\pi}^{\epsilon}) \, \mathbb{E}_t^{RE} \, \hat{\psi}_{t+1}. \tag{14}$$

Finally, combining

$$\hat{p}_{i,t}^* = \frac{\alpha\overline{\pi}^{(\epsilon-1)}}{1 - \alpha\overline{\pi}^{(\epsilon-1)}} \hat{\pi}_t$$

with Equations (4), (12), and (14), we achieve a Phillips curve linearized around a positive steady state that can be written as:

$$\pi_t = \lambda(\overline{\pi}) y_t + b_1(\overline{\pi}) \, \mathbb{E}_t \, \pi_{t+1} + \kappa(\overline{\pi})(\omega s_t + u_t) + b_2(\overline{\pi})(y_t(1 - \sigma^{-1}) - \mathbb{E}_t \, \psi_{t+1}) \tag{15}$$

where u_t is an AR(1) supply-side disturbance, s_t is price dispersion introduced in Equation (16), and ψ_t is an auxiliary process described in Equation (14). The composite coefficients $b_1(\overline{\pi})$, $b_2(\overline{\pi})$, $\kappa(\overline{\pi})$, and $\lambda(\overline{\pi})$ respectively equal $b_1(\overline{\pi}) = \beta[1 + \epsilon(1 - \alpha\overline{\pi}^{\epsilon-1})(\overline{\pi} - 1)]$, $b_2(\overline{\pi}) = \beta(1 - \alpha\overline{\pi}^{\epsilon-1})(1 - \overline{\pi})$, $\kappa(\overline{\pi}) = \frac{(1-\alpha\overline{\pi}^{\epsilon-1})(1-\alpha\beta\overline{\pi}^{\epsilon})}{\alpha\overline{\pi}^{\epsilon-1}}$, and $\lambda(\overline{\pi}) = \kappa(\overline{\pi})(\sigma^{-1} + \omega)$, where β is the discount factor, $\overline{\pi} = \left(1 + \frac{\pi_{ss}}{100}\right)^{1/4}$, π_{ss} is trend inflation, α is the Calvo parameter, ϵ the elasticity of substitution among intermediate goods, and ω is the inverse of the Frisch elasticity of labor supply. The canonical Phillips curve obtained linearizing around a steady state of zero inflation is nested into this specification when $\overline{\pi} = 1$.

The novel variable s_t describes price dispersion and arises in the case of positive trend inflation. The following equation describes the dynamics of price dispersion:

$$s_t = \left[\frac{\epsilon\alpha\overline{\pi}^{\epsilon-1}}{1-\alpha\overline{\pi}^{\epsilon-1}}(\overline{\pi}-1)\right]\pi_t + \alpha\overline{\pi}^{\epsilon}s_{t-1}. \tag{16}$$

2.1.3. *Monetary Policy.* The model is closed with a Taylor Rule for the monetary authority:

$$i_t = \rho i_{t-1} + (1-\rho)(\phi_\pi \pi_t + \phi_y y_t) + \nu_t, \tag{17}$$

where ρ, ϕ_π, and ϕ_y are monetary policy coefficients and ν_t is a monetary policy shock.

To conclude, the Generalized New Keynesian Model is fully described by Equations (3), (14), (15), (16), and (17). Note that when $\overline{\pi} = 1$, the canonical New Keynesian model is easily recovered, as $b_1(\overline{\pi}) = 0$, $b_2(\overline{\pi}) = 0$, $\kappa(\overline{\pi}) = \kappa = \frac{(1-\alpha)(1-\alpha\beta)}{\alpha}$, $s_t = 0\ \forall t$, and the equation for the auxiliary process ψ_t becomes redundant.

2.2. **Bounded Rationality.** Under rational expectations, agents in these models have unlimited cognitive capabilities and are assumed to form expectations conditioned on a correctly specified model of the economy. We depart from these assumptions and introduce behavioral elements into the Generalized New Keynesian model. In particular, we introduce "cognitive discounting" as proposed in Gabaix (2020). The model is based on micro-foundations previously developed in Gabaix (2014) and Gabaix (2016). Similarly to the canonical New Keynesian model, infinitely lived agents formulate state-contingent plans over an infinite horizon to maximize their utility, but here, they form expectations with perceived laws of motion that are subject to an attenuated cognitive discount factor, or cognitive discounting parameter. Agents are still fully rational for steady-state variables, but they are partially myopic to deviations from the deterministic steady state. Cognitive discounting captures the idea that agents cannot fully understand events that will take place in the distant future, so they progressively shrink those events toward steady-state values. Agents rely on defaults (typically, expected values or steady states) to supply the missing elements due to limited attention. If, under rational expectations, the economy evolves according to the de-meaned and linearized law of motion

$$X_{t+1} = \Gamma X_t + \epsilon_{t+1},$$

then behavioral agents use the misperceived law of motion

$$X_{t+1} = \overline{m}(\Gamma X_t + \epsilon_{t+1}),$$

where $\overline{m} \in [0,1]$ is the cognitive discount factor. Agents are more myopic to events that are more distant in the future, since

$$\mathbb{E}_t^{BR}[X_{t+1}] = \overline{m}\Gamma X_t = \overline{m}\,\mathbb{E}_t^{RE}[X_{t+1}], \tag{18}$$

where $\mathbb{E}_t^{BR}$ is the subjective behavioral expectation operator that uses the misperceived law of motion and $\mathbb{E}_t^{RE}$ is the rational one that uses the rational law of motion. Iterating forward,

$$\mathbb{E}_t^{BR}[X_{t+k}] = (\overline{m}\Gamma)^k X_t = \overline{m}^k \, \mathbb{E}_t^{RE}[X_{t+k}], \ \ \forall k. \tag{19}$$

The more distant the events in the future, the more the behavioral agent sees them with a dampened cognitive discount factor $\overline{m}^k$ for any horizon k. Behavioral firms also have a less accurate view of reality and perceive the future with a similar cognitive discounting mechanism. Furthermore, when forming expectations about their future profits, the firms observe only a fraction $\overline{m}$ of future inflation and $\overline{m}$ of future marginal costs.

2.3. **Behavioral Generalized New Keynesian model.** Turning to our model, we apply this behavioral framework to the Generalized New Keynesian model.

When agents are boundedly rational, we can apply Equation (18) to Equation (2), which yields:

$$y_t = \overline{m}\, \mathbb{E}_t^{BR}\, y_{t+1} - \sigma^{-1}(i_t - \overline{m}\, \mathbb{E}_t^{BR}\, \pi_{t+1}) + g_t. \tag{20}$$

When $\overline{m} = 1$, the rational agent's consumption Euler equation is recovered.

Similarly, on the firms' side, when departing from rational expectations, we can employ Equation (19) to transition from rational to behavioral agents. Equation (9) can be rewritten as:

$$\begin{aligned}\psi_t &= \mathbb{E}_t^{BR} \sum_{j=0}^{\infty} (\beta\alpha)^j \left\{ (1-\beta\alpha\overline{\pi}^{\epsilon})\overline{\Pi}_j^{\epsilon} \left(mc_{t+j} + (1-\sigma)y_{t+j} + \epsilon\widehat{\Pi}_{t,t+j} \right) \right\} \\ &= \mathbb{E}_t^{RE} \sum_{j=0}^{\infty} (\overline{m}\beta\alpha)^j \left\{ (1-\beta\alpha\overline{\pi}^{\epsilon})\overline{\Pi}_j^{\epsilon} \left(mc_{t+j} + (1-\sigma)y_{t+j} + \epsilon\widehat{\Pi}_{t,t+j} \right) \right\}\end{aligned} \tag{21}$$

Finally, we can rewrite the infinite sum in Equation (21) recursively, using the law of iterated expectations, as

$$\psi_t = (1-\beta\alpha\overline{\pi}^{\epsilon})\, mc_t + (1-\sigma)(1-\beta\alpha\overline{\pi}^{\epsilon})y_t + (\alpha\beta\overline{\pi}^{\epsilon})\, \epsilon\, \overline{m}\, \mathbb{E}_t^{RE}\, \pi_{t+1} + (\alpha\beta\overline{\pi}^{\epsilon})\, \overline{m}\, \mathbb{E}_t^{RE}\, \hat{\psi}_{t+1}. \tag{22}$$

Similarly, for ϕ_t, Equation (11) can be rewritten as:

$$\begin{aligned}\phi_t &= \mathbb{E}_t^{BR} \sum_{j=0}^{\infty} (\beta\alpha)^j \left\{ \left(1-\beta\alpha\overline{\pi}^{(\epsilon-1)}\right) \overline{\Pi}_j^{(\epsilon-1)} \left[(1-\sigma)y_{t+j} + (\epsilon-1)\widehat{\Pi}_{t,t+j} \right] \right\} \\ &= \mathbb{E}_t^{RE} \sum_{j=0}^{\infty} (\overline{m}\beta\alpha)^j \left\{ \left(1-\beta\alpha\overline{\pi}^{(\epsilon-1)}\right) \overline{\Pi}_j^{(\epsilon-1)} \left[(1-\sigma)y_{t+j} + (\epsilon-1)\widehat{\Pi}_{t,t+j} \right] \right\} \\ &= (1-\beta\alpha\overline{\pi}^{(\epsilon-1)})(1-\sigma)y_t + \mathbb{E}_t^{RE} \sum_{j=1}^{\infty} (\overline{m}\beta\alpha)^j \overline{\Pi}_j^{(\epsilon-1)} (1-\beta\alpha\overline{\pi}^{(\epsilon-1)}) \left((1-\sigma)y_{t+j} + (\epsilon-1)\widehat{\Pi}_{t,t+j} \right).\end{aligned} \tag{23}$$

Finally, we can rewrite the infinite sum in Equation (23) recursively, using the law of iterated expectations, as

$$\phi_t = (1-\sigma)(1-\alpha\beta\overline{\pi}^{(\epsilon-1)})y_t + (\epsilon-1)\alpha\beta\overline{\pi}^{(\epsilon-1)}\overline{m}\,\mathbb{E}_t^{RE}\,\pi_{t+1} + \alpha\beta\overline{\pi}^{(\epsilon-1)}\overline{m}\,\mathbb{E}_t^{RE}\,\phi_{t+1}. \tag{24}$$

To express the auxiliary process in Equation (22) as an inflation-output relationship, we can substitute Equation (13) into Equation (22) to get:

$$\psi_t = (1-\beta\alpha\overline{\pi}^{\epsilon})\,\varphi s_t + (1-\beta\alpha\overline{\pi}^{\epsilon})(\varphi+1)y_t + (\alpha\beta\overline{\pi}^{\epsilon})\,\epsilon\,\overline{m}\,\mathbb{E}_t^{RE}\,\pi_{t+1} + (\alpha\beta\overline{\pi}^{\epsilon})\,\overline{m}\,\mathbb{E}_t^{RE}\,\psi_{t+1}. \tag{25}$$

The auxiliary process in the rational setup is nested into the one in the behavioral setup when the degree of cognitive discounting $\overline{m}$ equals 1.

Finally, combining

$$\hat{p}_{i,t}^{*} = \frac{\alpha\overline{\pi}^{(\epsilon-1)}}{1-\alpha\overline{\pi}^{(\epsilon-1)}}\hat{\pi}_t$$

with Equations (4), (24), and (25), we achieve the behavioral Phillips curve linearized around a positive steady state that can be written as:

$$\pi_t = \lambda(\overline{\pi})y_t + b_1(\overline{\pi})\overline{m}\,\mathbb{E}_t\,\pi_{t+1} + \kappa(\overline{\pi})(\varphi s_t + u_t) + b_2(\overline{\pi})(y_t(1-\sigma^{-1}) - \overline{m}\,\mathbb{E}_t\,\psi_{t+1}), \tag{26}$$

where the composite coefficients $b_1(\overline{\pi})$, $b_2(\overline{\pi})$, $\kappa(\overline{\pi})$, and $\lambda(\overline{\pi})$ respectively equal $b_1(\overline{\pi}) = \beta[1+\epsilon(1-\alpha\overline{\pi}^{\epsilon-1})(\overline{\pi}-1)]$, $b_2(\overline{\pi}) = \beta(1-\alpha\overline{\pi}^{\epsilon-1})(1-\overline{\pi})$, $\kappa(\overline{\pi}) = \frac{(1-\alpha\overline{\pi}^{\epsilon-1})(1-\alpha\beta\overline{\pi}^{\epsilon})}{\alpha\overline{\pi}^{\epsilon-1}}$, and $\lambda(\overline{\pi}) = \kappa(\overline{\pi})(\sigma^{-1}+\varphi)$. The rational Phillips curve is nested into the behavioral one when the degree of cognitive discounting $\overline{m}$ equals 1. In addition, the canonical Phillips curve obtained by linearizing around a steady state of zero inflation is nested into this specification when $\overline{\pi} = 1$.

To conclude, when transitioning from rational expectations to bounded rationality, we transform Equation (3) into (20), (14) into (25), and (15) into (26), while Equations (16) and (17) remain unchanged. The model can be summarized by the following equations:

$$\begin{cases} y_t = \overline{m}\,\mathbb{E}_t\,y_{t+1} - \sigma^{-1}(i_t - \overline{m}\,\mathbb{E}_t\,\pi_{t+1}) + g_t \\ \pi_t = \lambda(\overline{\pi})y_t + b_1(\overline{\pi})\overline{m}\,\mathbb{E}_t\,\pi_{t+1} + \kappa(\overline{\pi})(\varphi s_t + u_t) + b_2(\overline{\pi})(y_t(1-\sigma^{-1}) - \overline{m}\,\mathbb{E}_t\,\psi_{t+1}) \\ \psi_t = (1-\beta\alpha\overline{\pi}^{\epsilon})\,\varphi s_t + (1-\beta\alpha\overline{\pi}^{\epsilon})(\varphi+1)y_t + (\alpha\beta\overline{\pi}^{\epsilon})\,\epsilon\,\overline{m}\,\mathbb{E}_t^{RE}\,\pi_{t+1} + (\alpha\beta\overline{\pi}^{\epsilon})\,\overline{m}\,\mathbb{E}_t^{RE}\,\psi_{t+1} \\ s_t = \left[\frac{\epsilon\alpha\overline{\pi}^{\epsilon-1}}{1-\alpha\overline{\pi}^{\epsilon-1}}(\overline{\pi}-1)\right]\pi_t + \alpha\overline{\pi}^{\epsilon}s_{t-1} \\ i_t = \rho i_{t-1} + (1-\rho)(\phi_\pi\pi_t + \phi_y y_t) + \nu_t \\ g_t = \rho_g g_{t-1} + \varepsilon_t^{g} \\ u_t = \rho_u u_{t-1} + \varepsilon_t^{u} \end{cases} \tag{27}$$

3. Determinacy Conditions

In the standard New Keynesian model with zero trend inflation and rational expectations (in our model, the case where $\overline{m} = 1$ and $\overline{\pi} = 1$), failure by the central bank to fulfill the Taylor principle leads to equilibrium indeterminacy and sunspot-driven fluctuations. In this setting, it can be shown that a necessary and sufficient condition for the rational expectations equilibrium to be unique[3] is:

$$\phi_\pi + \frac{(1-\beta)}{\kappa}\phi_y > 1 \tag{28}$$

, which is the familiar "Taylor Principle." Bounded rationality, however, alters the conditions for ensuring a determinate equilibrium; partially-myopic agents ($\overline{m} < 1$) become less reactive to future expected fluctuations, and, as a result, the economy becomes potentially less sensitive to instability stemming from a passive central bank. In Gabaix (2020), bounded rationality is embedded in the standard New Keynesian model (with no trend inflation). The introduction of the cognitive discounting coefficient $\overline{m}$ expands the region of determinacy and the analytical solution for conditions ensuring a unique equilibrium becomes:

$$\phi_\pi + \left(\frac{1-\beta\overline{m}}{\kappa}\right)\phi_y + \frac{(1-\beta\overline{m})(1-\overline{m})}{\kappa\sigma} > 1. \tag{29}$$

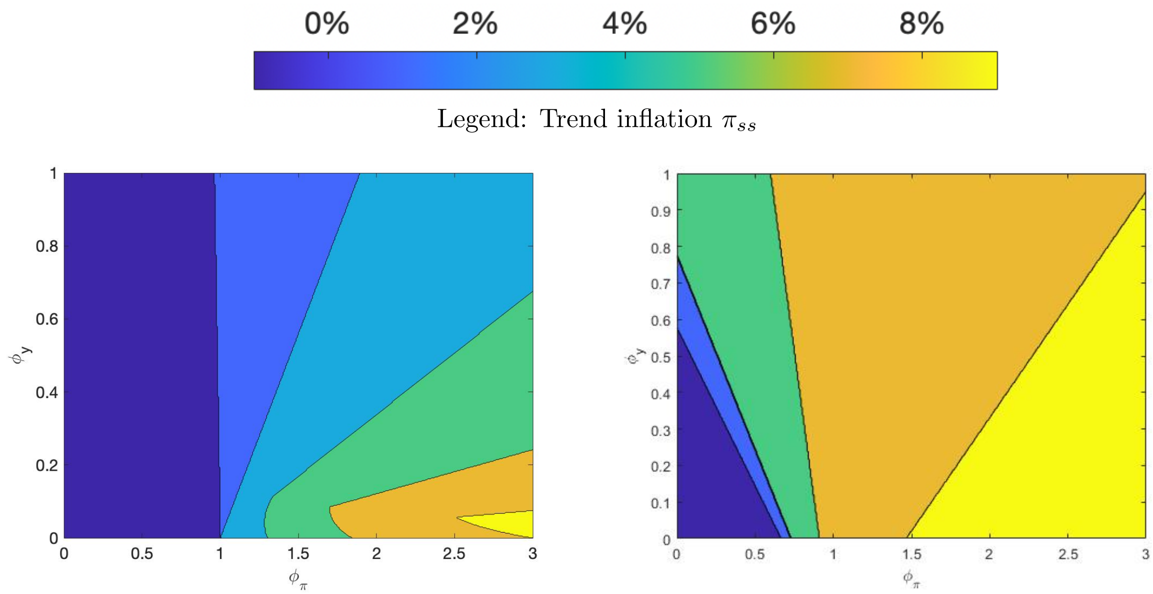
Monetary policies that respond far less than one-to-one with respect to inflation may still be conducive to determinacy, as long as the degree of bounded rationality is sufficiently large.

By contrast, increasing trend inflation is destabilizing when it comes to equilibrium determinacy. In the Ascari and Sbordone (2014) model, the region of determinacy is not only determined by the response of the central bank, but also by the level of trend inflation. This is due to the additional equations (e.g., price dispersion) that contain parameters that are generally functions of trend inflation. As shown in Panel A of Figure 1, as the level of trend inflation increases from 0% (dark, blue) to 8% (light, yellow), the region of determinacy shrinks.[4] As trend inflation increases, so does the range of parameter combinations that lead to indeterminacy. Each line corresponds to the threshold between indeterminacy and determinacy for increasing levels of trend inflation from left to right. The combination of parameters to the right of each line leads to determinacy for the corresponding level of trend inflation shown in the legend.

The rational expectation hypothesis, however, plays a big role. We repeat the exercise using our Behavioral Generalized New Keynesian model, but now we set bounded rationality

[3] Woodford (2003), Ch. 4.2.2

[4] With trend inflation, the closed form solution for the determinacy condition becomes numerically intractable and thus the region can only be obtained numerically. A closed form solution such as the one in (29) is not available.



(A) Rational Model: $\overline{m} = 1$

(B) Behavioral Model: $\overline{m} = 0.7$

FIGURE 1. Regions of Determinacy and Indeterminacy. Note: Each line represents the threshold between indeterminacy and determinacy for increasing levels of trend inflation from left to right. Any combination of parameters to the right of each line leads to determinacy for the corresponding level of trend inflation shown in the legend. The remaining parameters are fixed as follows to replicate Figure 11 in Ascari and Sbordone (2014): $\beta = 0.99$, $\alpha = 0.75$, $\epsilon = 11$, $\sigma = 1$, $\varphi = 2$, and $\rho = 0$. Source: Authors' analysis.

to $\overline{m} = 0.7$, following the parameter for bounded rationality in the IS curve[5] from Ilabaca, Meggiorini, and Milani (2020). Panel B of Figure 1 shows that with this degree of bounded rationality, the region of determinacy is significantly larger for all levels of trend inflation. That is, when agents are boundedly rational, the economy becomes much less sensitive to instability stemming not only from a passive monetary authority, but also from high trend inflation. These results hold when allowing the central bank to respond with different Taylor rules (e.g., backwards looking, forward looking, myopic forward-looking, see Appendix A).

In the Ascari and Sbordone (2014) model, the determinacy region shrinks very rapidly with increasing trend inflation, which requires the central bank to adopt a stronger response to inflation and a weaker response to output. In this case, typical values of the Taylor Rule would result in an indeterminate rational expectations equilibrium for levels of trend inflation close to 3%. By contrast, in the Behavioral Generalized New Keynesian model, the classical values of the Taylor rule would ensure a unique equilibrium for trend inflation closer to 6%.

Two general policy implications emerge. First, higher trend inflation can still be destabilizing, but much less so than in the rational expectations case. The level of trend inflation

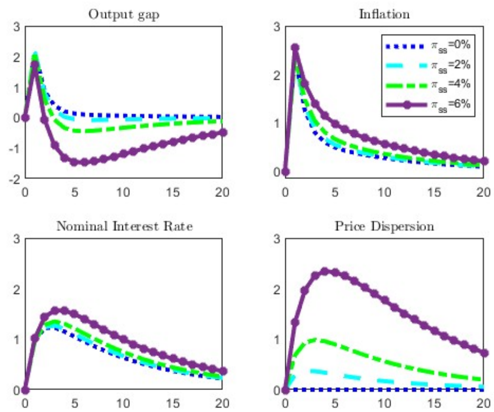
[5]This serves as an upper bound in our case, given that the parameter for bounded rationality in the Phillips curve in this paper is around 0.4.

needed to induce instability in the classical Taylor Rule parameterization needs to be about double the level needed in the case with rational expectations. Second, monetary policy can respond to both inflation and output gaps in regimes with trend inflation around 6% or below, but it ought to respond more to inflation in regimes with trend inflation that is higher than around 6%. This is in contrast to the result found in Ascari and Sbordone (2014), in which, for all levels of positive trend inflation, monetary policy should respond more to deviations of inflation from target and less to output gaps.

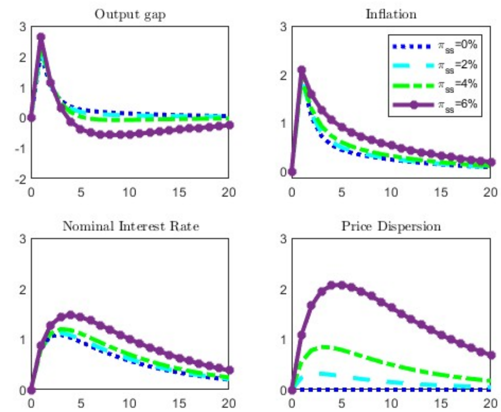
4. Counterfactual Exercise

Figure 2 shows the theoretical impulse response functions of output, inflation, nominal interest rates, and price dispersion to a positive 1 percent demand-side shock for four values of trend inflation equal to 0, 2, 4, and 6 percent. Each panel corresponds to a different parameterization of the bounded rationality parameter $\overline{m}$. Panel A in Figure 2 assumes rational expectations, thus $\overline{m} = 1$. As shown in Ascari and Sbordone (2014), under rational expectations, trend inflation dampens the effect on output and amplifies the effect on inflation, price dispersion, and interest rates. Price dispersion does not move in the case of zero steady-state inflation because, in that case, it does not matter to a first order. When steady-state inflation is positive, price dispersion increases the persistence of output and inflation because there is mutual feedback between inflation and price dispersion, whose strength is governed by the parameter φ.

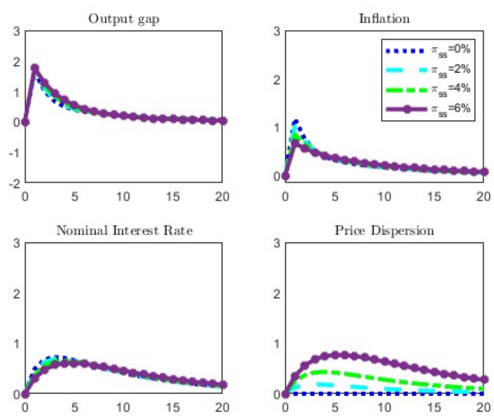
In Panels B, C, and D, we assume a departure from rational expectations with increasing levels of bounded rationality $\overline{m}$ equal to 0.80, 0.40, and 0.2, respectively. As the level of bounded rationality increases, the effects of trend inflation are counteracted. In this scenario, an increase in trend inflation does not affect the response of output, inflation, and nominal interest rate. Similarly, the response of price dispersion is significantly dampened when agents are not rational. This is in line with the empirical findings in Nakamura, Steinsson, Sun, and Villar (2018) who extend the Bureau of Labor Statistics' micro-data set back to 1977. This expanded data-set allows them to study the period of double-digit inflation as well as the Great Moderation period. They find no evidence that price dispersion was greater in the high-inflation period. In fact, the magnitude of price adjustments was stable over decades, and an increased frequency of price changes in periods of higher inflation limited inefficient price dispersion.



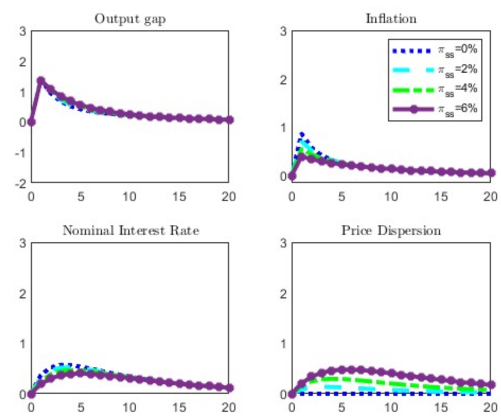
(A) Rational Model: $\overline{m} = 1$



(B) Behavioral Model: $\overline{m} = 0.8$



(C) Behavioral Model: $\overline{m} = 0.4$



(D) Behavioral Model: $\overline{m} = 0.2$

FIGURE 2. Impulse response functions to a 1% positive demand shock. Note: The remaining parameters are fixed as follows: $\beta = 0.99$, $\alpha = 0.75$, $\epsilon = 11$, $\sigma = 1$, $\varphi = 2$, and $\rho = 0$. Source: Authors' analysis.

5. ESTIMATION

We focus on this empirical relationship among bounded rationality, trend inflation, and monetary policy during the Great Moderation period. At least since 1996,[6] the U.S. Federal Reserve has used monetary policy with the aim of keeping inflation at 2%, a number that Ben Bernanke, the former Fed chair, made an explicit policy target in 2012. We estimate the Generalized New Keynesian model with rational expectations and with cognitive discounting over the period spanning the years between 1990:Q1 and 2019:Q4 (ending before the Covid-19 Pandemic) by allowing the parameters to fall into either the determinacy or the indeterminacy regions.

[6]See Bernanke and Mishkin (1997).

5.1. **Data.** We use quarterly data on the output gap, inflation, and interest rates for the United States from 1990 to 2019. The output gap is obtained as the log difference between real GDP and real Potential GDP, using the CBO's series, Inflation is the quarterly log-difference of the Consumer Price Index. The interest rate is given by the Federal Funds rate transformed into a quarterly rate, and we employ the shadow rates introduced by Wu and Xia (2016) to account for the zero lower bound period.[7]

5.2. **State Space Representation.** We can write the Behavioral Generalized New Keynesian model as a linear model of the form:

$$\Gamma_0(\theta)X_t = \Gamma_1(\theta)X_{t-1} + C + \Psi(\theta)\varepsilon_t + \Pi(\theta)\eta_t \tag{30}$$

, where $X_t = [y_t, \pi_t, \psi_t, s_t, i_t, g_t, u_t]'$ is a vector of endogenous variables, $\varepsilon_t = [\varepsilon_t^g, \varepsilon_t^u, \nu_t]'$ is a vector of exogenous shocks, C is a vector of constants, η_t collects the one-step ahead forecast errors for the expectational variables of the system and $\theta \equiv vec(\Gamma_0, \Gamma_1, \Psi, \Omega_{\varepsilon\varepsilon})' \in \Theta$ is a vector of structural parameters of the model as well as the covariance matrix of the exogenous shocks. We assume $E_{t-1}(\varepsilon_t) = 0 = E_{t-1}(\eta_t)$. The matrix $\Omega_{\varepsilon\varepsilon} \equiv E_{t-1}(\varepsilon\varepsilon')$ represents the covariance matrix of exogenous shocks.

We then add the following observation equation:

$$\begin{bmatrix} y_{obs} \\ \pi_{obs} \\ i_{obs} \end{bmatrix} = \underbrace{\begin{bmatrix} y_{ss} \\ \pi_{ss} \\ i_{ss} \end{bmatrix}}_{H_0} + \underbrace{\begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 \end{bmatrix}}_{H} \underbrace{\begin{bmatrix} y_t \\ \pi_t \\ \psi_t \\ s_t \\ i_t \\ g_t \\ u_t \end{bmatrix}}_{X_t}$$

where H_0 collects average, or steady-state, values, and H is a matrix of ones and zeroes, which selects observables from the state vector X_t. As discussed in the text, the vector of observable variables includes the inflation rate, the output gap, and the Federal Funds rate, for π_t, y_t, and i_t.

5.3. **Estimation under Indeterminacy.** The challenges related to the solution and estimation of the model in the region of indeterminacy are solved by using the techniques proposed by Bianchi and Nicolò (2021). The approach consists of adding to the system of

[7]All data series have been obtained from FRED, the Federal Reserve Economic Database, and the Federal Reserve Bank of Atlanta Research & Data website.

equations 27 an auxiliary variable λ_t, which follows an autoregressive process:

$$\lambda_t = \delta\lambda_{t-1} + \zeta_t - \eta_t^j, \tag{31}$$

, where δ is the autoregressive coefficient, ζ_t is a sunspot shock, and η_t^j, is the expectational error related to inflation or output gap, with $j = \{x, \pi\}$.[8]

We denote a new vector of endogenous variables $\hat{X}_t \equiv (X_t, \lambda_t)'$ and a newly defined vector of exogenous shocks $\hat{\varepsilon}_t \equiv (\varepsilon_t, \nu_t)'$, and now, we can write the system in 30 and 31 as

$$\hat{\Gamma}_0\hat{X}_t = \hat{\Gamma}_1\hat{X}_{t-1} + \hat{C} + \hat{\Psi}\hat{\varepsilon}_t + \hat{\Pi}\eta_t \tag{32}$$

where

$$\hat{\Gamma}_0 \equiv \begin{bmatrix} \Gamma_0(\theta) & \mathbf{0} \\ \mathbf{0} & \mathbf{I} \end{bmatrix}, \qquad \hat{\Gamma}_1 \equiv \begin{bmatrix} \Gamma_1(\theta) & \mathbf{0} \\ \mathbf{0} & \delta \end{bmatrix}$$

$$\hat{\Psi} \equiv \begin{bmatrix} \Psi(\theta) & \mathbf{0} \\ \mathbf{0} & \mathbf{I} \end{bmatrix}, \qquad \hat{\Pi} \equiv \begin{bmatrix} \Pi_n(\theta) & \Pi_f(\theta) \\ \mathbf{0} & -\mathbf{I} \end{bmatrix},$$

where the matrix Π in (30) can be partitioned as $\Pi = [\Pi_n\Pi_f]$ without loss of generality. The augmented representation of our model delivers solutions in the determinate region of the parameter space, Θ^D, which are equivalent to those obtained using standard solution algorithms. In the indeterminate region, Θ^I, the solution is identical to Lubik and Schorfheide (2004) and Farmer (2019).

Recall the conditions for determinacy as stated by Blanchard and Kahn (1980). Equilibrium indeterminacy arises when the parameter values are such that the number of explosive roots is less than the number of forward-looking variables in a linear model. The key idea of the methodology is to provide the missing explosive root by augmenting the model with the autoregressive process. When the model is indeterminate, the autoregressive coefficient is set above one ($\delta > 1$) to restore the necessary number of explosive roots. The auxiliary process λ_t doesn't influence the remaining parts of the system, but it permits the inclusion of a sunspot shock by inducing a mapping between the expectational errors η_t^j and the sunspot ζ_t. When the equilibrium is determinate, all the roots of the auxiliary process are assumed to be within the unit circle, and the auxiliary process is again irrelevant for the dynamics of the model.[9] In this case, the law of motion for the endogenous variables is equivalent to

[8] As shown by Bianchi and Nicolò (2021), the choice of expectational errors to include does not affect the solution. In this paper, we will make the modeling assumption that the expectational error included corresponds to inflation. Furthermore, we will be focusing on the case where the degree of indeterminacy is 1.

[9] The methodology in Bianchi and Nicolò (2021) is a simplification of previous approaches proposed by Lubik and Schorfheide (2004) and Farmer, Khramov, and Nicolò (2015); in all cases, however, the solutions under indeterminacy remain equivalent.

the one obtained using standard algorithms (see Sims, 2002), which we employ to obtain the solution to the model.

5.4. **Priors.** The prior distributions are shown in the second column of Table 1. We assume a Gamma prior with mean 1.5 and standard deviation 0.5 for σ, consistent with log-preferences commonly used in the literature; a Beta prior with mean 0.66 and standard deviation 0.1 for the Calvo parameter α; and a Gamma prior with mean 2 and standard deviation 0.5 for yearly trend inflation π_{ss}. The priors on the parameters governing the monetary policy rule are standard, assuming a greater response to inflation and a moderate response to output. The priors for the AR(1) coefficients are Beta with mean 0.5 and standard deviation 0.2, and an Inverse Gamma prior with mean 0.3 and standard deviation 1 for the shocks' standard deviations. For the inattention parameter $\overline{m}$, we choose a Beta prior with mean 0.7 and standard deviation 0.15. This accommodates the parameter estimates found in Ilabaca, Meggiorini, and Milani (2020), while slightly favoring rational expectations. For the sunspot shock, we assume an Inverse-Gamma prior for its standard deviation, and Uniform[-1,1] distributions for the corresponding correlation parameters.[10]

5.5. **Estimation.** We use Bayesian methods to estimate the parameters of our model. Using a Metropolis-Hastings random walk algorithm with a Markov Chain Monte Carlo procedure, we generate 1,250,000 draws from the posterior distribution and discard the first 40% as burn-in. Our estimation procedure is done using Dynare. The steps are as follows:

(1) We begin with a numerical optimization routine to maximize the log posterior. We denote the vector of parameters at the posterior mode as $\hat{\theta}$.
(2) We compute $\hat{\Sigma}$, the inverse negative Hessian at the posterior mode $\hat{\theta}$ from a preliminary run of a posterior sampler.
(3) We draw θ^0 from $N(\hat{\theta}, c_0^2\hat{\Sigma})$, where c_0 is a tuning parameter adjusted to get a reasonable acceptance rate
(4) For $i = 1, ..., N$:
   - Draw ϑ from the proposal distribution $N(\theta^{i-1}, c^2\hat{\Sigma})$.
   - Let $r(\theta^{i-1}, \vartheta|Y) = \frac{p(Y|\vartheta)p(\vartheta)}{p(Y|\theta^{i-1})p(\theta^{i-1})}$.
   - Let

$$\theta^i = \begin{cases} \vartheta & \text{with probability } min\{1, r(\theta^i, \vartheta|Y)\} \\ \theta^{i-1} & \text{otherwise.} \end{cases}$$

[10]The rest of the parameters that are fixed in the estimation are the discount factor $\beta = 0.99$, the inverse of the Frisch elasticity $\varphi = 2$, and the elasticity of substitution across differentiated goods $\epsilon = 11$, which implies a steady-state markup of prices over marginal costs equal to 10%.

A Kalman filter is employed to evaluate the likelihood function $p(Y|\vartheta)p(\vartheta)$. We run multiple chains to ensure that the algorithm converges and that parameters are well identified. We estimate the model across both regions of the parameter space, determinate and indeterminate, and compare marginal likelihoods to assess model fit. To ensure this, we choose a parameterization for initializing the preliminary posterior sampler that ensures the equilibrium is indeterminate. Additionally, we estimate the rational expectations version of our model by setting $m = 1$. This turns our Behavioral Generalized New Keynesian Model into the model in Ascari and Sbordone (2014) by shutting down cognitive discounting and ensuring agents are fully rational. Results from our procedure are reported in the next section.

5.6. **Identification.** Prior to estimating the model, we check whether all parameters can be identified from the data. There could be several sources of lack of identification: problems in the structure of the model, some parameters not affecting the equilibrium conditions of the model, different parameters having identical impact, or that the effect of some parameters on the likelihood function being observationally equivalent to the effect of other parameters. We know that the rational expectations version of the model is identified (see Iskrev, 2010b). Our model introduces two new parameters (i.e. trend inflation and cognitive discounting) and that could cause problems with identification.

A necessary and sufficient condition for identifiability is that the Jacobian matrix with derivatives of first- and second-order moments, which enters the likelihood function, has a full rank. Following Iskrev (2010a), we check the rank condition at 100,000 random draws from the prior distribution of the parameter described in Table 1. We find that the Jacobian matrix has a full rank at all points, and we therefore conclude that the model can be identified.

Figure 3 shows the identification and sensitivity analysis at the prior mean following Ratto (2008). This identification strength is based on the Fisher information matrix normalized by either the parameter at the prior mean (blue bars) or the standard deviation at the prior mean (red bars). The bars represent the normalized curvature of the log likelihood function at the prior mean in the direction of the parameter. Again, we find that all parameters are well identified[11]. No identification implies that the likelihood function is flat in that direction and would be represented by no bar. We also verify that the rank condition for identification is satisfied at the posterior mean, confirming that the estimated parameters are identified at that point as well.

[11]The graph is in log-scale for the parameters that are identified, which are ordered in the direction of increasing identification strength relative to the parameter value.

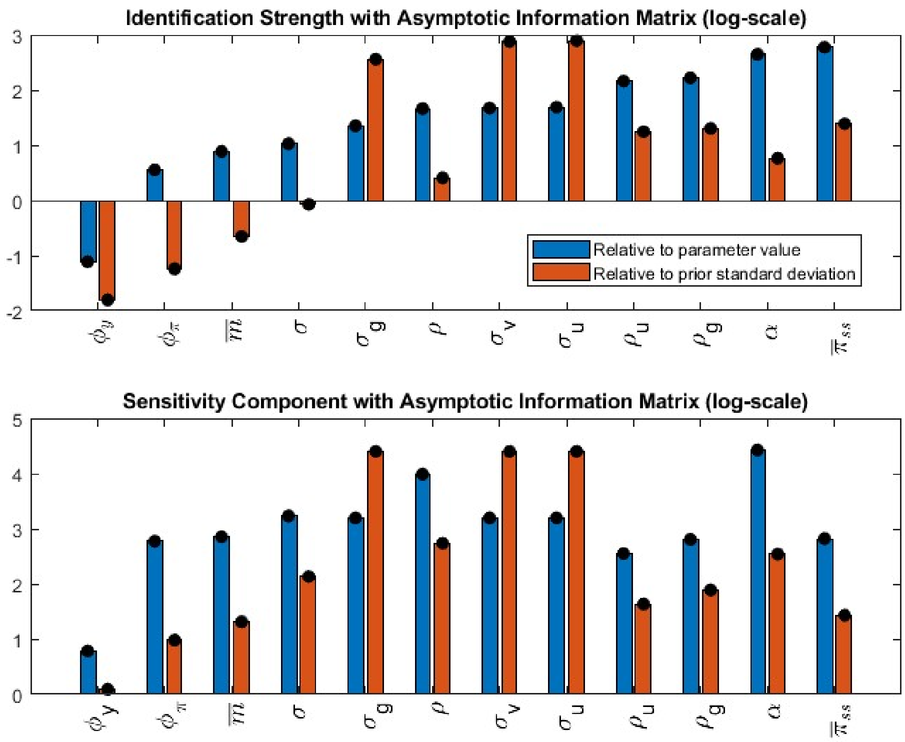


FIGURE 3. Source: Generated following Ratto (2008), Authors' analysis.

6. Results

Table 1 shows the posterior estimates for the model with bounded rationality and rational expectations, each with both determinacy and indeterminacy. The bottom row reports the marginal likelihood for each case. With rational expectations, model comparison shows that the best-fitting model is one characterized by indeterminacy. The log marginal likelihoods are -127.34 for indeterminacy and -155.52 for determinacy, and these values imply posterior model probabilities equal to essentially 1 for indeterminacy and 0 for determinacy. This is in line with findings in Doko Tchatoka, Groshenny, Haque, and Weder (2017), who find positive evidence regarding the probability of indeterminacy for the 2002 to 2007 period.

The emergence of indeterminacy with rational expectations seems empirically puzzling given the relatively stable conditions in the sample considered. Indeed, this is commonly referred to as the Great Moderation period. It is not surprising, however, given the theoretical evidence shown in Panel A of Figure 1. Even when trend inflation is as low as 2%, consistent with the estimated values of steady-state inflation $\overline{\pi}_{ss}$ shown in Table 1, there is a large scope for indeterminacy for empirically realistic values of the policy coefficients in this model.

This puzzle is solved when departing from the rational expectations hypothesis and allowing for bounded rationality. The-best fitting model is one characterized by determinacy; the log marginal likelihoods are -123.33 for determinacy and -144.11 for indeterminacy. These values imply posterior model probabilities equal to 1 for determinacy and 0 for indeterminacy. The results show that even though the estimated monetary policy response to inflation falls closer to 1, a failure of the central bank to move nominal interest rates more than one-to-one with respect to inflation is still conducive to determinacy, as a consequence of bounded rationality. The extent of inattention is substantial: $\overline{m}$ has a posterior mean equal to 0.42.

6.1. **Second Moments.** In addition to using Bayesian model comparison via marginal likelihoods, we compare the two models' implied characteristics with those of the data. Table 2 presents our model-implied moments, evaluated at the posterior modes from our estimation, and provides a comparison with those in the actual data. We look at the standard deviation of output, inflation and interest rates, the cross-correlation of these variables with output, and their auto-correlations of order 1. We find that our Behavioral Generalized New Keynesian model generally performs better than its counterpart model with rational expectations across most measures.

6.2. **Impulse Responses.** Figure 4 shows the median Bayesian impulse response functions from our model alongside the standard model, with rational expectations alongside the impulse response functions from a Bayesian VAR (BVAR) using our data. We follow the approach in Smets and Wouters (2007) for the BVAR and use a Minnesota-type prior with prior parameters as in Sims and Zha (1998).[12]

As we can see in this figure, the mean impulse responses generated from our model with bounded rationality tend to perform better than the standard model featuring rational expectations. For example, the response of output to a demand-side shock in our model is able to capture the magnitude and persistence generated with the BVAR, while the standard model generates a response that decays too quickly.

[12]We use the standard values suggested. The decay parameter is set at 1.0, the overall tightness is set at 10, the parameter determining the weight on the sum of coefficients is set at 2.0, and the parameter determining the weight on the co-persistence is set at 5. We estimate the Bayesian VAR using the toolbox by Canova and Ferroni (2021).

Parameters	Prior Distribution	Posterior Distribution			
		BR+det	**BR+indet**	**RE+det**	**RE+indet**
EE & PC					
σ	$\Gamma(1.5,0.5)$	0.38 [0.18,0.58]	1.01 [0.63,1.36]	0.16 [0.11,0.21]	1.43 [0.74,2.09]
α	$B(0.66,0.1)$	0.85 [0.82,0.89]	0.89 [0.87,0.92]	0.90 [0.88,0.91]	0.34 [0.26,0.42]
$\overline{\pi}_{ss}$	$\Gamma(2,0.5)$	2.79 [2.28,3.31]	1.81 [1.26,2.35]	1.76 [1.40,2.12]	1.65 [1.19,2.10]
Taylor Rule					
ρ	$B(0.7,0.2)$	0.96 [0.93,0.99]	0.95 [0.92,0.98]	0.95 [0.94,0.96]	0.82 [0.76,0.89]
ϕ_π	$N(1.5,0.25)$	1.33 [0.92,1.75]	0.74 [0.38,1.07]	1.96 [1.68,2.24]	0.94 [0.87,1.01]
ϕ_y	$N(0.1,0.05)$	0.16 [0.08,0.23]	0.14 [0.07,0.21]	0.18 [0.10,0.25]	0.18 [0.14,0.23]
Behavioral					
$\overline{m}$	$B(0.7,0.15)$	0.42 [0.23,0.63]	0.91 [0.86,0.95]	–	–
Shocks					
ρ_g	$B(0.5,0.2)$	0.96 [0.93,0.99]	0.96 [0.92,1.00]	0.89 [0.87,0.91]	0.87 [0.80,0.95]
ρ_u	$B(0.5,0.2)$	0.28 [0.14,0.42]	0.25 [0.04,0.46]	0.38 [0.23,0.54]	0.96 [0.93,0.98]
σ_g	$\Gamma^{-1}(0.3,1)$	0.34 [0.22,0.45]	0.26 [0.12,0.43]	0.10 [0.08,0.12]	0.34 [0.16,0.51]
σ_u	$\Gamma^{-1}(0.3,1)$	0.39 [0.34,0.45]	0.33 [0.25,0.40]	0.27 [0.20,0.34]	1.86 [1.03,2.64]
σ_v	$\Gamma^{-1}(0.3,1)$	0.12 [0.10,0.13]	0.11 [0.10,0.13]	0.12 [0.11,0.13]	0.13 [0.11,0.16]
Sunspot					
σ_ζ	$\Gamma^{-1}(0.3,1)$	–	0.50 [0.44 ,0.56]	–	0.48 [0.37,0.58]
ρ_{ζ_t,g_t}	U[-1,1]	–	-0.31 [-0.50,-0.12]	–	-0.05 [-0.65,0.49]
ρ_{ζ_t,u_t}	U[-1,1]	–	0.89 [0.82,0.97]	–	-0.07 [-0.25,0.09]
ρ_{ζ_t,v_t}	U[-1,1]	–	0.24 [0.19,0.30]	–	-0.75 [-0.95,-0.56]
Log - Marginal Likelihood		-123.33	-144.11	-155.52	-127.34

Table 1. Posterior Estimates. *Note*: B denotes Beta distribution, N denotes Normal distribution, U denotes Uniform distribution, Γ denotes Gamma distribution, and Γ^{-1} denotes Inverse Gamma distribution. The prior distributions are expressed in terms of mean and standard deviation, except for the Uniform distribution expressed in terms of bounds. The Table reports mean posterior estimates, along with 5% and 95% percentiles. We ran 1,250,000 MH draws, discarding the first 40% as initial burn-in. Marginal likelihoods are computed using Geweke's modified harmonic mean approximation. Source: Federal Reserve Economic Database, Federal Reserve Bank of Atlanta Research & Data, Authors' analysis .

	Output	Inflation	Interest Rates
	Standard Deviation		
Data	1.7891	0.4869	0.6884
Behavioral Generalized NK	1.8911	0.5081	0.5372
Generalized NK	1.3933	0.6716	0.4904
	Cross-correlation with Output		
Data	–	0.2561	0.6710
Behavioral Generalized NK	–	0.3180	0.3349
Generalized NK	–	0.2544	-0.1440
	Autocorrelation (Order = 1)		
Data	0.9486	0.2741	0.9689
Behavioral Generalized NK	0.9525	0.3778	0.9744
Generalized NK	0.8613	0.6401	0.9653

Table 2. Selected Moments.
Source: Federal Reserve Economic Database, Federal Reserve Bank of Atlanta Research & Data, Authors' analysis.

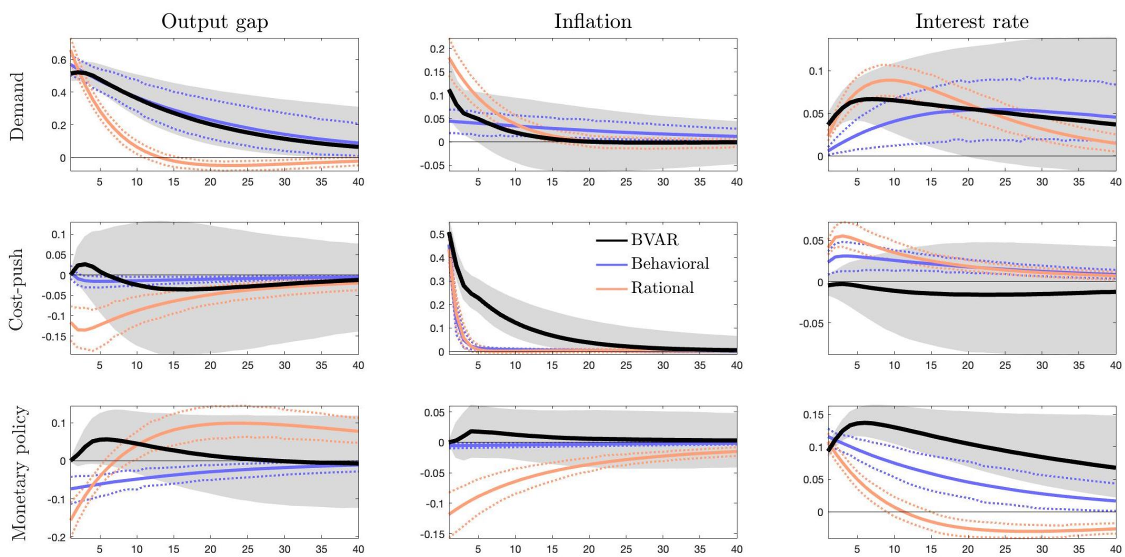


Figure 4. Impulse Response Functions to a Standard Deviation Shock. Note: We show the median IRF from the Bayesian VAR (black) with 10% and 90% credible intervals (gray-shaded region), with the Bayesian IRF from the Behavioral Generalized New Keynesian model (median in solid blue and credible intervals in dotted blue) and from the Generalized New Keynesian model (median in solid orange and credible intervals in dotted orange.) Source: Federal Reserve Economic Database, Federal Reserve Bank of Atlanta Research & Data, Authors' analysis. .

7. Conclusion

In this paper, we develop a New Keynesian model with trend inflation that departs from rational expectations and introduces cognitive discounting. In a model with rational expectations, higher trend inflation generates macroeconomic instability by making the economy more susceptible to equilibrium indeterminacy. The rational expectations hypothesis, however, implies a very large weight given to expectations far into the future, with only minimal discounting. Since determinacy or indeterminacy of the equilibrium is a property of the whole model, a failure to recognize and explicitly model deviations from benchmark models of expectations formation may skew the results. Indeed, we find that this instability hinges on the conventional assumption of rational expectations, and we also find that introducing cognitive discounting into the model increases the region of determinacy and counteracts the instability introduced by trend inflation. Therefore, trend inflation is not as destabilizing as previously thought. We also show that the data favor this specification including bounded rationality and a determinate equilibrium during the Great Moderation sample.

References

Afsar, Atahan, and Jose Elias Gallegos. 2018. "Reconciling Empirics and Theory: The Behavioural Hybrid New Keynesian Model." (December): 1–19.

Andrade, Joaquim, Pedro Cordeiro, and Guilherme Lambais. 2019. "Estimating a Behavioral New Keynesian Model." 1–23, http://arxiv.org/abs/1912.07601, arXiv: 1912.07601.

Angeletos, George-Marios, and Chen Lian. 2018. "Forward guidance without common knowledge." *American Economic Review* 108 (9): 2477–2512. 10.1257/aer.20161996.

Arias, Jonas, Martin Bodenstein, Hess Chung, Thorsten Drautzburg, and Andrea Raffo. 2020. "Alternative Strategies: How Do They Work? How Might They Help?" *Finance and Economics Discussion Series* 2020 (068): 1–31, https://www.federalreserve.gov/econres/feds/alternative-strategies-how-do-they-work-how-might-they-help.htm.

Arias, Jonas E, Guido Ascari, Nicola Branzoli, and Efrem Castelnuovo. 2020. "Positive Trend Inflation and Determinacy in a Medium-Sized New Keynesian Model." *International Journal of Central Banking* 16 (3): 44, https://www.ijcb.org/journal/ijcb20q2a2.pdf.

Ascari, Guido, and Tiziano Ropele. 2007. "Optimal monetary policy under low trend inflation." *Journal of Monetary Economics* 54 (8): 2568–2583, https://www.sciencedirect.com/science/article/pii/S0304393207000773.

Ascari, Guido, and Tiziano Ropele. 2009. "Trend Inflation, Taylor Principle, and Indeterminacy." *Journal of Money, Credit and Banking* 41 (8): 1557–1584, https://doi.org/10.1111/j.1538-4616.2009.00272.x.

Ascari, Guido, and Argia M. Sbordone. 2014. "The Macroeconomics of Trend Inflation." *Journal of Economic Literature* 52 (January): 679–739, https://www.aeaweb.org/articles?id=10.1257/jel.52.3.679.

Ball, Laurence. 2014. "The Case for a Long-Run Inflation Target of Four Percent." *IMF Working Papers*.

Bernanke, Ben, and Olivier Blanchard. 2023. "What Caused the U.S. Pandemic-Era Inflation?" *Conference Draft*.

Bernanke, Ben S, and Frederic S Mishkin. 1997. "Inflation Targeting: A New Framework for Monetary Policy?" *The Journal of Economic Perspectives* 11 (2): 97–116, https://www.jstor.org/stable/pdf/2138238.pdf.

Bianchi, Francesco, and Giovanni Nicolò. 2021. "A Generalized Approach to Indeterminacy in Linear Rational Expectations Models." *Quantitative Economics* 12 (3): 843–868, https://doi.org/10.3982/QE949.

Blanchard, Olivier, Giovanni Dell'Ariccia, and Paolo Mauro. 2010. "Rethinking macroeconomic policy." *Journal of Money, Credit and Banking* 42 (SUPPL. 1): 199–215. 10.1111/j.1538-4616.2010.00334.x.

Blanchard, Olivier Jean, and Charles M. Kahn. 1980. "The Solution of Linear Difference Models under Rational Expectations." *Econometrica*, `https://www.jstor.org/stable/1912186`.

Blot, Christophe, Jérôme Creel, and François Geerolf. 2023. "Is monetary tightening a threat to financial stability?" *Monetary Dialogue Papers*.

Canova, Fabio, and Filippo Ferroni. 2021. "A hitchhiker's guide to empirical macro models." 10.21033/wp-2021-15.

Cecchetti, Stephen G, and Kermit L Schoenholtz. 2017. "The case for a higher inflation target gets stronger." *Money and Banking*, `https://www.moneyandbanking.com/commentary/2017/4/2/the-case-for-a-higher-inflation-target-gets-stronger`.

Cogley, Timothy, and Thomas Sargent. 2002. "Evolving Post-World War II U.S. Inflation Dynamics." *NBER Macroeconomics Annual*, `https://www.nber.org/system/files/chapters/c11068/c11068.pdf`.

Cuba-Borda, Pablo, and Sanjay R. Singh. 2019. "Understanding Persistent Stagnation." `https://papers.ssrn.com/abstract=3247350`.

Doko Tchatoka, Firmin, Nicolas Groshenny, Qazi Haque, and Mark Weder. 2017. "Monetary policy and indeterminacy after the 2001 slump." *Journal of Economic Dynamics and Control* 82 83–95, `https://www.sciencedirect.com/science/article/pii/S0165188917301008?via%3Dihub`.

Farhi, Emmanuel, and Iván Werning. 2019. "Monetary policy, bounded rationality, and incomplete markets." *American Economic Review* 109 (11): 3887–3928. 10.1257/aer.20171400.

Farmer, Roger E. A. 2019. "The Indeterminacy Agenda in Macroeconomics." *NBER Working Paper Series* 46, `http://www.nber.org/papers/w25879`.

Farmer, Roger E. A., Vadim Khramov, and Giovanni Nicolò. 2015. "Solving and estimating indeterminate DSGE models." *Journal of Economic Dynamics and Control* 54 (C): 17–36. 10.1016/j.jedc.2015.02.01.

Gabaix, Xavier. 2014. "A sparsity-based model of bounded rationality." *Quarterly Journal of Economics* 129 (4): 1661–1710, `https://doi.org/10.1093/qje/qju024`.

Gabaix, Xavier. 2016. "Behavioral Macroeconomics via Sparse Dynamic Programming." *SSRN Electronic Journal* National Bureau of Economic Research. 10.3386/w21848.

Gabaix, Xavier. 2020. "A Behavioral New Keynesian Model." *American Economic Review* 110 (8): 2271–2327. 10.1257/aer.20162005.

Haque, Qazi. 2019. "Monetary Policy, Inflation Target and the Great Moderation: An Empirical Investigation." *SSRN Electronic Journal*, https://dx.doi.org/10.2139/ssrn.3409539.

Haque, Qazi, Nicolas Groshenny, and Mark Weder. 2021. "Do we really know that U.S. monetary policy was destabilizing in the 1970s?" *European Economic Review* 131 103615, https://doi.org/10.1016/j.euroecorev.2020.103615.

Hirose, Yasuo. 2018. "An estimated DSGE model." *Macroeconomic Dynamics* 2–15. 10.1017/S1365100518000743.

Hirose, Yasuo, Takushi Kurozumi, and Willem Van Zandweghe. 2020. "Monetary policy and macroeconomic stability revisited." *Review of Economic Dynamics* 37 255–274, https://www.sciencedirect.com/science/article/pii/S1094202520300132.

Hornstein, Andreas, and Alexander L Wolman. 2005. "Trend Inflation, Firm-Specific Capital, and Sticky Prices." *Federal Reserve Bank of Richmond Economic Quarterly* 91/4.

Ilabaca, Francisco, Greta Meggiorini, and Fabio Milani. 2020. "Bounded rationality, monetary policy, and macroeconomic stability." *Economics Letters* 186 108522, https://doi.org/10.1016/j.econlet.2019.07.007.

Ilabaca, Francisco, and Fabio Milani. 2021. "Heterogeneous expectations, indeterminacy, and postwar US business cycles." *Journal of Macroeconomics* 68 103307, https://doi.org/10.1016/j.jmacro.2021.103307.

IMF. 2023. "Global Financial Stability Report: Safeguarding Financial Stability amid High Inflation and Geopolitical Risks."Technical report, International Monetary Fund, Washington, DC, https://www.imf.org/-/media/Files/Publications/GFSR/2023/April/English/text.ashx.

Iskrev, Nikolay. 2010a. "Local identification in DSGE models." *Journal of Monetary Economics* 57 (2): 189–202. 10.1016/j.jmoneco.2009.12.007, Publisher: Elsevier.

Iskrev, Nikolay. 2010b. "Parameter Identification in Dynamic Economic Models." *Banco de Portugal Economics Bulletin* 169–185.

Kara, Engin, and Tony Yates. 2021. "A Case against a 4% Inflation Target." *Journal of Money, Credit and Banking* 53 (5): 1097–1119, https://doi.org/10.1111/jmcb.12765.

Kiley, Michael T. 2007. "Is Moderate-to-High Inflation Inherently Unstable?" *International Journal of Central Banking*.

Lubik, Thomas A., and Frank Schorfheide. 2004. "Testing for Indeterminacy: An Application to U.S. Monetary Policy: Comment." *American Economic Review* 97 (1): 524–529. 10.1257/aer.97.1.524.

Nakamura, Emi, Jón Steinsson, Patrick Sun, and Daniel Villar. 2018. "The Elusive Costs of Inflation: Price Dispersion during the U.S. Great Inflation." *The Quarterly*

Journal of Economics 133 (4): 1933–1980, https://doi.org/10.1093/qje/qjy017.

Nicolò, Giovanni. 2018. *Essay on Macroeconomics and Expectations*. Ph.D. dissertation, https://www.proquest.com/docview/2054553210/abstract/4BCA671EDD0B49EBPQ/1.

Ratto, Marco. 2008. "Analysing DSGE Models with Global Sensitivity Analysis." *Computational Economics* 31 (2): 115–139. 10.1007/s10614-007-9110-6.

Sablik, Tim. 2022. "The Fed Is Shrinking Its Balance Sheet. What Does That Mean?" *Federal Reserve Bank of Richmond* Econ Focus (Third Quarter): , https://www.richmondfed.org/-/media/RichmondFedOrg/publications/research/econ_focus/2022/q3/federal_reserve.pdf.

Schmitt-Grohé, Stephanie, and Martín Uribe. 2007. "Optimal simple and implementable monetary and fiscal rules." *Journal of Monetary Economics* 54 (6): 1702–1725, https://linkinghub.elsevier.com/retrieve/pii/S030439320600167X.

Sims, Christopher A. 2002. "Solving Linear Rational Expectations Models." *Computational Economics* 20 (1-2): 1–20. 10.1023/A:1020517101123.

Sims, Christopher A., and Tao Zha. 1998. "Bayesian Methods for Dynamic Multivariate Models." *International Economic Review* 39 (4): 949–968. 10.2307/2527347, Publisher: [Economics Department of the University of Pennsylvania, Wiley, Institute of Social and Economic Research, Osaka University].

Smets, Frank, and Rafael Wouters. 2007. "Shocks and Frictions in US Business Cycles: A Bayesian DSGE Approach." *ECB Working Paper Series* February (No 722): 1–54, https://www.aeaweb.org/articles?id=10.1257/aer.97.3.586.

Smith, Andrew Lee, and Victor Valcarcel. 2021. "The Financial Market Effects of Unwinding the Federal Reserve's Balance Sheet." *The Federal Reserve Bank of Kansas City Research Working Papers*, https://www.kansascityfed.org/research/research-working-papers/financial-market-effects-unwinding-fed-reserve/.

Stock, James H., and Mark W. Watson. 2007. "Why Has U.S. Inflation Become Harder to Forecast?" *Journal of Money, Credit and Banking* 39 (s1): 3–33, https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1538-4616.2007.00014.x.

Summers, Larry. 2018. "Why the Fed needs a new monetary policy framework." https://www.brookings.edu/research/why-the-fed-needs-a-new-monetary-policy-framework.

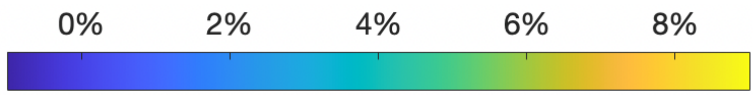
Woodford, Michael. 2003. *Imperfect Common Knowledge and the Effects of Monetary Policy*. Volume Knowledge, information, and expectations in modern macroeconomics: in honor of Edmund S. Phelps. Princeton University Press.

Woodford, Michael. 2018. "Monetary Policy Analysis when Planning Horizons are Finite." *NBER Macroeconomics Annual* 33, https://doi.org/10.1086/700892.

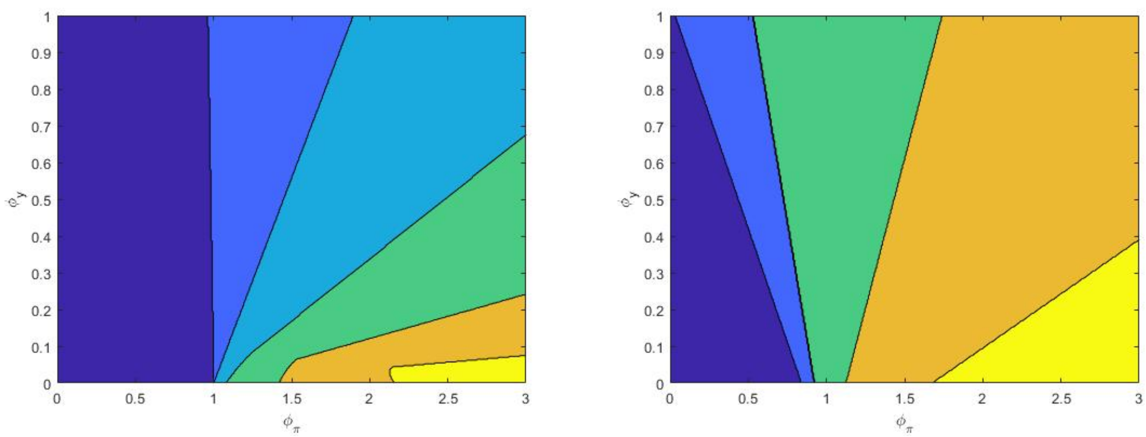
Wu, Jing Cynthia, and Fan Dora Xia. 2016. "Measuring the macroeconomic impact of monetary policy at the zero lower bound." *Journal of Money, Credit and Banking* 48 (2-3): 253–291, https://doi.org/10.1111/jmcb.12300.

Appendix A. Robustness

A.1. **Taylor Rules.** We generate the regions of indeterminacy, both for the Generalized New Keynesian Model as in Ascari and Sbordone (2014) and for the behavioral counterpart for three different types of central bank Taylor rules: a backward-looking Taylor rule to account for lags in data releases, a forward-looking Taylor rule with model-implied one-period-ahead expectations, and a myopic forward-looking Taylor rule.



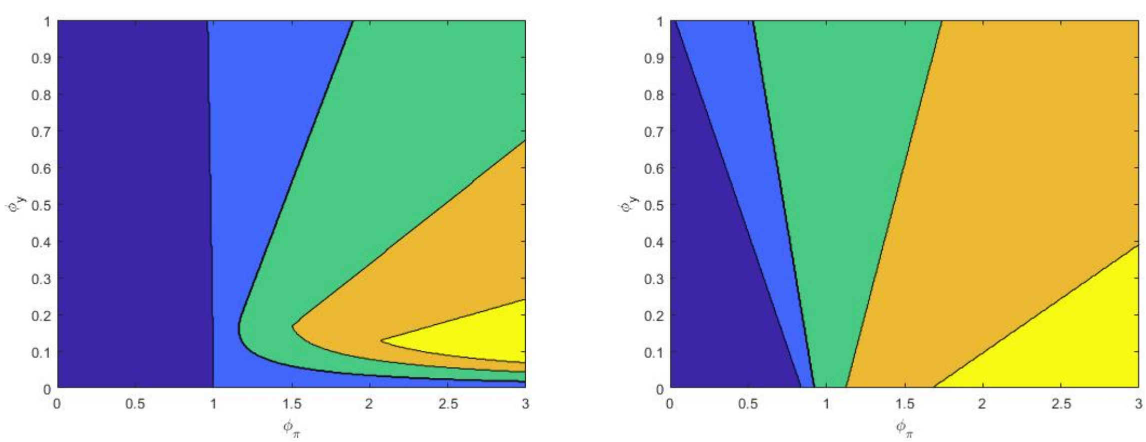
Legend: Trend inflation π_{ss}



Rational Model: $\overline{m} = 1$

Behavioral Model: $\overline{m} = 0.8$

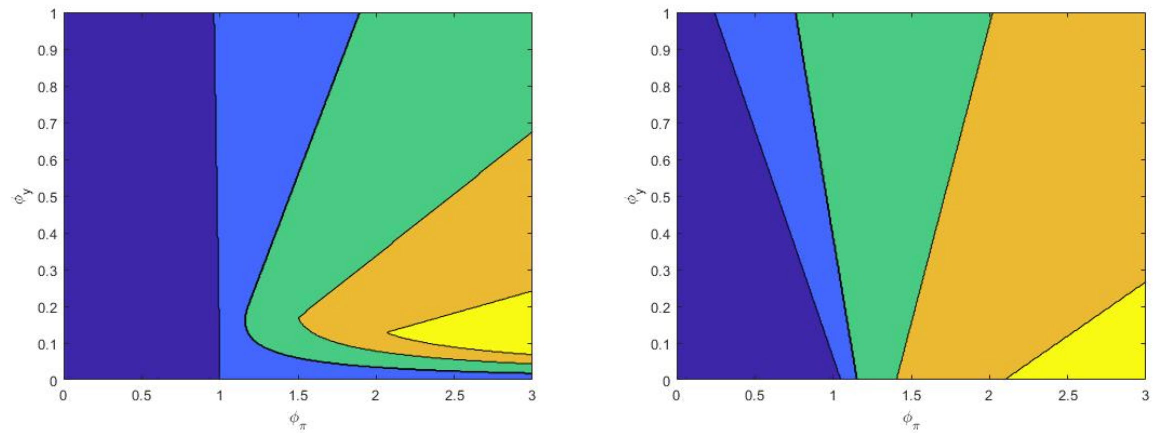
Figure 5. Taylor Rule: $i_t = \phi_\pi \pi_{t-1} + \phi_y y_{t-1}$. Source: Authors' analysis.



Rational Model: $\overline{m} = 1$

Behavioral Model: $\overline{m} = 0.8$

Figure 6. Taylor Rule: $i_t = \phi_\pi \, \mathbb{E}_t \, \pi_{t+1} + \phi_y \, \mathbb{E}_t \, y_{t+1}$. Source: Authors' analysis.



Rational Model: $\overline{m} = 1$ Behavioral Model: $\overline{m} = 0.8$

FIGURE 7. Taylor Rule: $i_t = \phi_\pi \overline{m}\, \mathbb{E}_t\, \pi_{t+1} + \phi_y \overline{m}\, \mathbb{E}_t\, y_{t+1}$. Source: Authors' analysis.