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Brent Bundick and Nicolas Petrosky-Nadeau

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Federal Reserve Bank of Kansas City

# From Deviations to Shortfalls: The Effects of the FOMC's New Employment Objective*

Brent Bundick† Nicolas Petrosky-Nadeau‡

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**Abstract**

We analyze the effects of a monetary policy that stabilizes "shortfalls" rather than "deviations" of employment from its maximum level. A shortfalls-stabilization rule leads to expectations of more accommodative policy in expansions, raising average inflation and nominal rates. These effects are significantly amplified by incorporating history dependence in labor markets, a feature in labor-search frameworks. In a calibrated model of labor-search frictions and nominal rigidities, the adoption of a shortfalls rule raises average inflation and nominal policy rates by 90 basis points, reduces the likelihood of a binding zero lower bound, and implies a steeper and nonlinear Phillips curve.

**JEL Classification:** E32, E52, J64

**Keywords:** Monetary Policy, Equilibrium Unemployment, Nominal Rigidities, Zero Lower Bound

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†Federal Reserve Bank of Kansas City. Email: brent.bundick@kc.frb.org

‡Federal Reserve Bank of San Francisco. Email: nicolas.petrosky-nadeau@sf.frb.org

# 1 Introduction

At the conclusion of the Federal Reserve's recent policy review, the Federal Open Market Committee (FOMC) made several changes to its Statement on Longer-Run Goals and Strategy in August 2020.[1] One important change was the Committee's reinterpretation of its maximum employment mandate. Specifically, the Statement now communicates that, "the Committee seeks over time to mitigate shortfalls of employment from the Committee's assessment of its maximum level ..." In contrast, the previous consensus statement cited a desire to stabilize "deviations" of employment from its maximum level. In explaining this policy change, Powell (2021) stated that this change "means that we will not tighten monetary policy solely in response to a strong labor market."

Seminal work by Blanchard and Galí (2010) and Ravenna and Walsh (2011) highlights that different monetary policy strategies can substantially affect inflation and unemployment dynamics. Given this importance established by the previous literature, our goal is to examine how the Committee's reinterpretation of its employment mandate may affect macroeconomic outcomes, exposing at the same time important implications for the conduct of monetary policy.

This policy change from offsetting both positive and negative employment deviations to instead stabilizing one-sided shortfalls introduces an asymmetry in the monetary policy reaction function. In this paper, we use two theoretical frameworks to analyze the possible effects of this new policy. We first examine the policy change in a simple three-equation model of the macroeconomy, which we use to illustrate the key intuition and qualitative results. Then, we build and calibrate a second model featuring frictional labor markets, nominal rigidities, and a zero lower bound (ZLB) constraint on nominal interest rates to examine the potential quantitative implications of adopting a shortfalls-stabilization strategy. We solve both models using global solution methods to properly account for the asymmetric policy reaction function.

The adoption of a shortfalls approach to stabilizing the labor market leads to a significant increase in average inflation and policy rates. Under a shortfalls-stabilization rule, policymakers remain more accommodative in a tight labor market relative to a symmetric deviations rule, which leads to lower unemployment in expansions. Expectations of more accommodative policy in expansions induce forward-looking firms to adopt higher price in-

[1] The Statement on Longer-Run Goals and Monetary Policy Strategy is available at `www.federalreserve.gov/monetarypolicy/files/FOMC_LongerRunGoals.pdf`.

creases at all times to insure against having a suboptimally low price when demand is elevated. This increase in average inflation also leads to an increase in average policy rates as policymakers aim to achieve their inflation objective.

Moreover, we show that incorporating empirically relevant history dependence in labor markets significantly amplifies the effects of adopting a shortfalls rule because firms expect that a tight labor market will likely persist for longer versus what would occur under a spot labor market. These results show that the exact quantitative implications of adopting a shortfalls-stabilization rule depend on the features of the labor market, and in particular persistence in unemployment dynamics that arises in search and matching frameworks.

To ensure we appropriately model important features of the labor market, we then build a second theoretical framework which features a microfounded model of frictional labor markets, nominal rigidities, and a zero lower bound constraint. We discipline our model's calibration using observed fluctuations in unemployment, inflation, and nominal interest rates over the 25 years immediately preceding the new consensus statement. Similar to the intuition from our simpler model, a monetary policy which stabilizes shortfalls rather than deviations leads to expectations of more accommodative policy in expansions, which leads to higher inflation in all states of the world.

In this quantitative macroeconomic model, we find that switching to a shortfalls-stabilization rule raises average inflation and nominal policy rates by about 90 basis points. This upward shift in average inflation more than offsets the downward bias in inflation stemming from the presence of the zero lower bound and asymmetric fluctuations in the labor market. In addition, the higher average nominal policy rate under a shortfalls rule significantly reduces the probability that policymakers will become constrained by the zero lower bound. If policymakers do encounter the zero lower bound, a shortfalls rule helps stabilize the economy since households and firms understand that the central bank will provide more accommodative policy in the future.

Changing to a one-sided shortfalls rule also implies a steeper and potentially nonlinear reduced-form Phillips curve in the economy. Even in a tight labor market, inflation often runs below the central bank's 2% objective under a symmetric deviations rule. In contrast, under a shortfalls rule, our model predicts a pronounced decline in the probability of inflation outcomes below 1% while the realizations of inflation above 3% become more likely. By removing these low inflation outcomes, we observe a stronger negative correlation between unemployment and inflation if policymakers adopt a shortfalls rule. Moreover, low levels of unemployment tend to correlate with much higher rates of inflation, which induces a nonlinearity in the reduced-form Phillips curve as the labor market tightens. Taken together, our results show that adopting an asymmetric shortfalls rule may have implications for longer-run average outcomes, business-cycle correlations, and the potential for the zero lower bound to constrain policy actions.

If all other features of the economy and policymaker behavior remain unchanged, the increase in average inflation after adopting of a shortfalls rule could cause policymakers to persistently miss on their longer-run 2% inflation objective. However, we show that if policymakers also increase their weight on inflation fluctuations when adopting a shortfalls rule, then they can achieve their inflation objective on average while still significantly reducing the probability of encountering the zero lower bound. We also provide additional analysis comparing the outcomes under a shortfalls rule to other changes in the policy rule as well as examine the sensitivity of our results to our calibration of key labor market parameters.

Finally, we examine the effects of adopting a shortfalls-stabilization rule within a flexible average inflation targeting (FAIT) framework, another key change in the FOMC's most recent Statement on Longer-Run Goals and Strategies.[2] In addition to changing its interpretation of its employment mandate, the FOMC stated its intention for inflation to *average* two percent over time. Using our simple three-equation framework, our model suggests that the effects of adopting the shortfalls rule either remained unchanged or become amplified relative to our previous results depending on the horizon over which policymakers aim to stabilize average inflation. All else equal, increasing the look-back period over which policymakers target average inflation acts like a reduction in the central bank's response to *current* inflation, further increasing average inflation under a shortfalls rule. However, we argue additional research is needed to fully explore the interactions of all elements of the FOMC's new framework.

Our model shares features with a large literature which studies the interactions between search and matching frictions in the labor market and nominal pricing rigidities such as Walsh (2005), Krause and Lubik (2007), Gertler, Sala and Trigari (2008), Christiano, Eichenbaum and Trabandt (2016), and many others. However, our quantitative model incorporates the zero lower bound and demand shocks, two features which are often absent from models in

[2]See Altig et al. (2020) for an overview of the research undertaken as part of the Federal Reserve's 2019 review of its monetary policy framework. Mertens and Williams (2019), Amano et al. (2020), and Nessen and Vestin (2005) show that average inflation targeting can help alleviate the downward pressure on longer-term inflation expectations caused by the zero lower bound.

the literature. We examine outcomes at the zero lower bound since the FOMC cited it as an important rationale behind the recent changes to its framework. In addition, the inclusion of demand shocks in our model help reproduce the downward-sloping Phillips curve between inflation and unemployment we observe in the data and generate zero lower bound episodes. Thus, our model is closest to Albertini and Poirier (2015) which examines an extension of unemployment benefits at the zero lower bound in a model with frictional labor markets, nominal rigidities, and demand shocks.

Our work also contributes to the large literature on the conduct of monetary policy in the presence of search frictional labor markets beginning with Cooley and Quadrini (1999), Walsh (2005), and many others. In this context, our work relates to Sala, Soderstrom and Trigari (2008) and Faia (2008) which compares the performance of central bank policy rules targeting different measures of output or unemployment. Another strand of this work, such as Blanchard and Galí (2010), focuses on the role of real-wage rigidity for the conduct of optimal monetary policy. To keep our model as simple as possible, our baseline model features bilateral Nash bargaining between workers and firms over hours worked and wages, instead of staggered wage bargaining as in Gertler and Trigari (2009) or alternative offers bargaining as in Hall and Milgrom (2008) or Christiano, Eichenbaum and Trabandt (2016).

While our primary goal is examining the *descriptive* outcomes of the FOMC's change in its employment objective, our work relates to the literature on optimal monetary policy in the face of nonlinearities in the economy. Orphanides and Wieland (2000) and Dolado, Maria-Dolores and Naveira (2005) derive the implications of a nonlinear Phillips curve for optimal monetary policy rules within a conventional symmetric quadratic loss function framework. They argue that the policy reaction function should include an asymmetry with a stronger reaction to inflation or employment when they are above their respective targets. In contrast, Surico (2007) and Gust, López-Salido and Meyer (2017) show that asymmetric loss functions naturally lead to asymmetries in the central bank's reaction function, which result in a positive inflation bias when policymakers have greater aversion to contractions than expansions. McLeay and Tenreyro (2020) highlights that changes in the conduct of monetary policy can have significant implications for the observed reduced-form Phillips curve. Relative to their work, we show that changes in the economy's reduced-form Phillips curve arise endogenously if policymakers adopt a shortfalls-stabilization rule. Finally, our shortfalls rule shares features with the endogenous regime switching policy rules examined by Davig and Leeper (2006) and Maih et al. (2021).

The rest of the paper is organized as follows: Section 2 uses a simple three-equation framework to illustrate the key intuition for the impact of a shortfalls rule on the economy. Section 3 derives a richer model calibrated to the U.S. economy to fully examine the quantitative implications of a shortfalls-stabilization policy in Section 4. Section 5 examines the robustness of the main results to alternative policy rules and parameterizations, including an increased weight on inflation in the central bank's reaction function under the shortfalls rule to bring average inflation back down to target. Finally, in Section 6, we return to our simple model and illustrate how the simultaneous adoption of a flexible average inflation targeting framework could alter the effects of adopting a shortfalls rule.

# 2 Stabilizing Shortfalls Raises Average Inflation and Nominal Rates

We first analyze the effects of adopting a shortfalls-stabilization rule in a textbook model of nominal price rigidity augmented with an ad-hoc representation of a frictional labor market. We show that a shortfalls rule leads to a significant increase in average inflation and nominal rates. Then, we relax some of the assumptions of our ad-hoc labor market and show that incorporating more realistic features further amplifies these effects. Later in Section 3, we solve a microfounded model with frictional labor markets, price rigidities and a zero lower bound constraint on the nominal policy rate to fully examine the quantitative impacts of adopting a shortfalls-stabilization rule.

## 2.1 A Textbook Model of Nominal Rigidities

Starting from optimizing behavior of households and firms, Woodford (2003), Galí (2015), and many others show that we can derive the following first-order approximation of the macroeconomy:

$$x_t = E_t\, x_{t+1} - \Big(i_t - E_t\, \pi_{t+1} - r_t^n\Big), \tag{1}$$

$$\pi_t = \beta\, E_t\, \pi_{t+1} + \varphi\, x_t, \tag{2}$$

where $x_t$ denotes the gap between actual and potential output, $\pi_t$ represents inflation in deviations from the central bank's objective, and $i_t$ denotes the nominal policy rate in deviations from its steady-state value. Equations (1) and (2) denote the New Keynesian intertemporal substitution and Phillips curves, respectfully. $\beta$ represents the household's discount factor and $\varphi$ denotes the slope of the Phillips curve. $r_t^n$ is the economy's natural rate of interest (in deviations from its steady-state value) which can capture fundamental changes in firm productivity or household preferences.

While quite standard, this simple model assumes a frictionless spot labor market and thus lacks a concept of unemployment. To address this shortcoming, we first assume a simple Okun's law relating deviations of the unemployment rate from its longer-run level, $u_t$, to the output gap:

$$u_t = -\frac{1}{c}\,x_t \tag{3}$$

where $c$ is a parameter (typically around 2 in empirical work).[3] Substituting Equation (3) into Equations (1) and (2), we derive a simple model linking unemployment and inflation:

$$u_t = E_t\,u_{t+1} + \frac{1}{c}\Big(i_t - E_t\,\pi_{t+1} - r_t^n\Big), \tag{4}$$

$$\pi_t = \beta\,E_t\,\pi_{t+1} - \varphi\,c\,u_t. \tag{5}$$

Shocks that raise the natural rate of interest result in lower unemployment and higher inflation (unless they are fully offset with changes in the policy rate).

Finally, we assume monetary policy sets its nominal policy rate to systematically offset adverse fluctuations in inflation and unemployment.[4] To examine the possible effects from the change in the FOMC's employment objective, we posit two different rules for the central bank's reaction function. The first rule intends to capture the setting of the nominal policy rate prior to the announcement of the new consensus statement in August 2020. We refer to the first specification as the *Deviations* rule as it treats deviations of inflation and unemployment from their respective targets symmetrically:

$$i_t = \phi_\pi \pi_t + \phi_u u_t \tag{6}$$

where $\phi_\pi > 1$ and $\phi_u < 0$ are parameters. In the second rule, monetary policy no longer reacts to the labor market when unemployment falls below its longer-run level. We denote this second specification as the *Shortfalls* rule as it aims to capture the reinterpretation of

[3]Tables 1 and 2 of Ball, Leigh and Loungani (2017) report empirical values of $c$ ranging from 2.0 to 2.7.

[4]Although public communications by members of the FOMC often reference the unemployment rate as a benchmark indicator for the labor market, policymakers do not look at a single indicator for assessing full employment as outlined in the consensus statement (see Brainard, 2021). An often discussed alternative, the employment to population ratio, provides a similar signal of slack once adjusted for the changing age-composition of the population, a point members of the FOMC have commented on regularly when discussing the set of indicators entering their assessment of the labor market and the current distance from an assessment of full employment. We provide a more detailed discussion in Appendix section A.

the employment mandate in the recent Goals and Strategies statement.

$$i_t = \begin{cases} \phi_\pi \pi_t + \phi_u u_t & \text{if } u_t \geq 0 \\ \phi_\pi \pi_t & \text{if } u_t < 0 \end{cases} \tag{7}$$

This policy is consistent with Powell (2021)'s discussion of the new employment objective as policymakers in the model will not adjust the stance of policy solely to a tight labor market.

## 2.2 Outcomes Under Deviations & Shortfalls Rules

To properly account for the nonlinearity introduced by the shortfalls rule, we solve the model in Equations (4) and (5) globally using a policy function iteration algorithm under both the deviations or shortfalls rule. Figure 1 plots the model-implied policy functions using standard quarterly parameter values from the literature and setting $c = 2$ in our Okun's law assumption. Specifically, we set $\beta = 0.99$, $\varphi = 0.1$, $\phi_\pi = 1.5$, and assume $r_t^n \sim N(0, \sigma^r)$ with $\sigma^r = 0.005$.[5] In models without a concept of unemployment, previous work often assumes that monetary policy instead reacts to the output gap with a reaction coefficient of 0.125. Using our Okun's law relation with $c = 2$, this common parameterization implies a response to unemployment $\phi_u = -0.25$, which we use for our baseline parameterization in Figure 1.

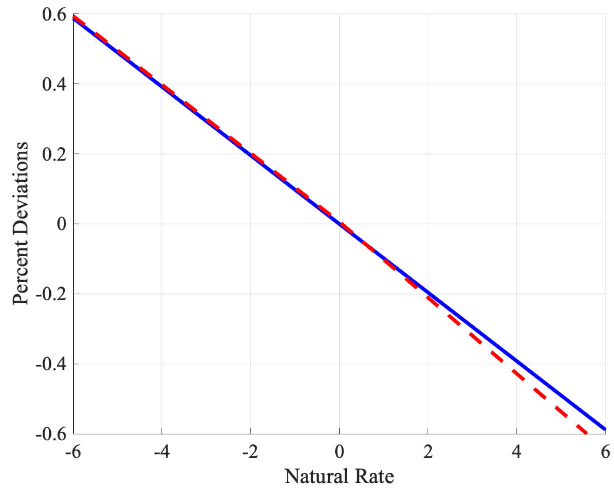
Under the deviations rule, policymakers symmetrically offset positive and negative fluctuations in the natural rate. This results in symmetric and linear solutions for both unemployment and inflation as a function of the natural rate. Both solutions take a value of zero when the natural rate takes its steady-state value of zero. In contrast, under the shortfalls rule, policymakers no longer react to the labor market when unemployment falls below its longer-run level. Thus, the shortfalls rule implies more accommodative policy in a tight labor market versus the deviations rule. As a result, the red dashed line in the top panel of Figure 1 shows that the economy experiences modestly lower unemployment during expansions (when the natural rate is high) under the shortfalls rule.

This modestly lower unemployment during expansions significantly increases average inflation under the shortfalls rule. Solving Equation (5) forward, we can write inflation today

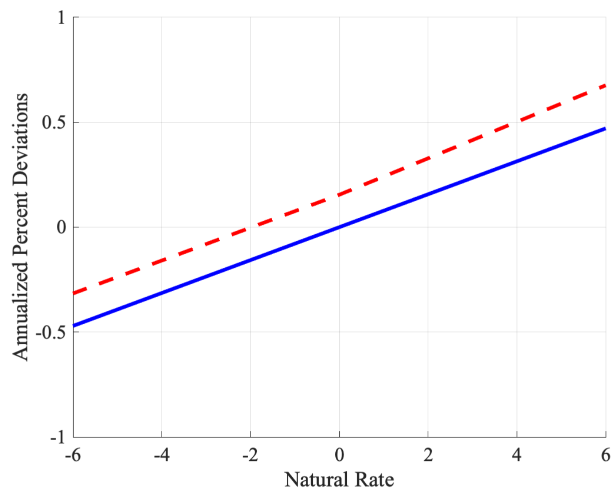
[5] This parameterization is generally similar to the calibrated model of Billi (2011). However, we assume iid shocks and a unitary intertemporal elasticity of substitution for simplicity.

Figure 1: Model Policy Functions Under Deviations & Shortfalls Rules

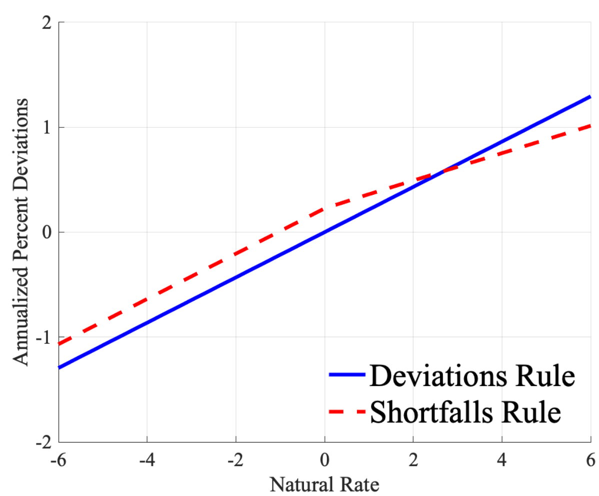
(a) Unemployment




(b) Inflation




(c) Nominal Policy Rate




Note: The natural rate, the x-axis in panels (a)-(c), is plotted in annualized percent deviations from its steady-state value.

as a function of future expected unemployment (gaps):

$$\pi_t = -\varphi\, c \sum_{i=0}^{\infty} \beta^i\, E_{t+i}\, u_{t+i}. \tag{8}$$

Expectations of lower unemployment in economic expansions (when $u_t < 0$), which only occur when the natural rate is high, raise inflation in *all* states through the forward-looking Phillips curve. Thus, expectations of more accommodative policy in expansions induce forward-looking firms to adopt greater price increases at all times to insure against having a suboptimally low price when demand is high. The center panel of Figure 1 illustrates this effect graphically. The policy function for inflation shifts upward under the shortfalls rule and the economy experiences above-target inflation on average.[6]

The bottom panel of Figure 1 shows the equilibrium effects of both the higher average inflation and more accommodative policy towards unemployment induced by the shortfalls rule. When the natural rate is low and the economy experiences elevated unemployment, the higher average inflation under the shortfalls rule causes policymakers to set higher nominal rates when compared to outcomes under the deviations rule. In contrast, when unemployment is low towards the right side of the panel, policymakers following the shortfalls rule do not try and actively lean against the tight labor market resulting in lower policy rates. In equilibrium, we find that the quantitative effect of higher average inflation dominates: the nominal policy rates under the shortfalls rule commonly run above the deviations-rule outcomes. Thus, adopting a shortfalls rule leads to higher average policy rates despite being more accommodative in tight labor markets.[7]

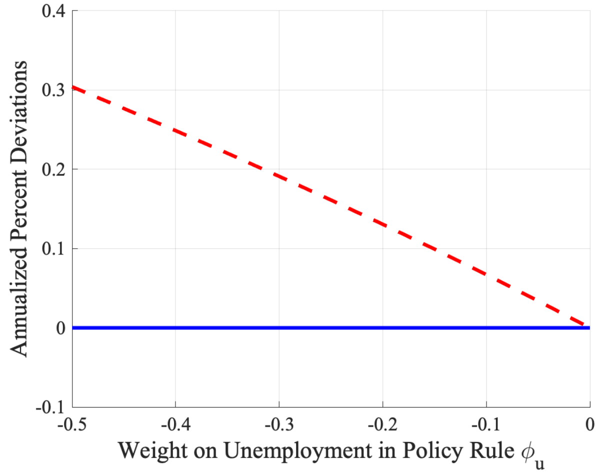
The quantitative effect on average inflation and policy rates of adopting a shortfalls rule depends on the weight placed on unemployment $\phi_u$ in the central bank's policy rule. Specifically, the magnitude of the increase in average inflation directly relates to the amount of asymmetry introduced into policymaker behavior by the shortfalls rule. To illustrate this result, we resolve the simple model using different values for $\phi_u$, leaving all other parameters unchanged at their previous values. The first panel of Figure 2 shows the model-implied average inflation rate as a function of $\phi_u$. This exercise suggests that, depending on the

[6] In Appendix B, we illustrate this effect analytically in a three-period model. A recent criticism of the standard New Keynesian model in Equations (1) and (2) is that it assumes too much forward-looking behavior by households and firms. In Appendix B, we show that the effects of adopting the shortfalls rule remain important for macroeconomic outcomes even in the bounded rationality model of Gabaix (2020) which reduces the sensitivity of current outcomes to expectations about the future.

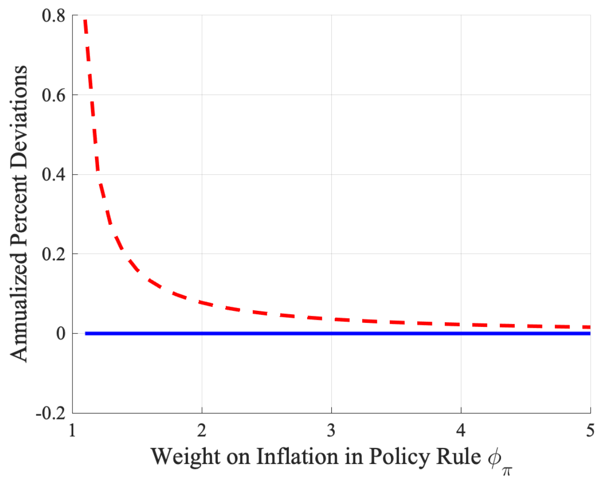
[7] Recent work by Dupraz, Nakamura and Steinsson (2023) highlights a "plucking" model of the labor market in which asymmetries in the labor market also can affect average outcomes.

Figure 2: Average Inflation Under Deviations and Shortfalls Rules

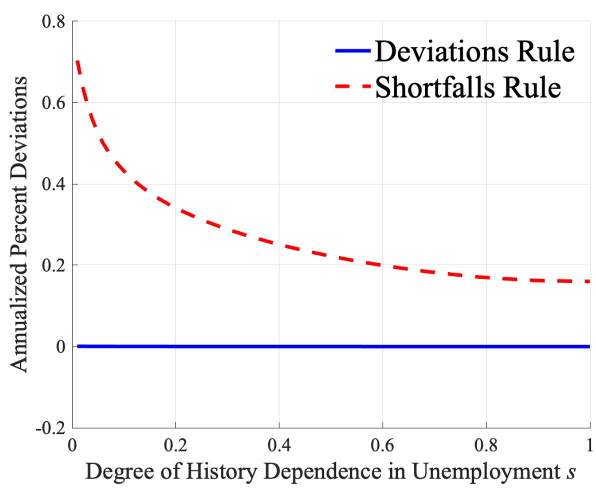
(a) Varying Weight on Unemployment Gap $\phi_u$




(b) Varying Weight on Inflation Gap $\phi_\pi$




(c) Varying Degree of History Dependence in Unemployment $s$




Note: Panel (a) sets $\phi_\pi = 1.5$ and varies the value of the weight on unemployment $\phi_u$. Panel (b) sets $\phi_u = -0.25$ and varies the value of the weight on inflation $\phi_\pi$. Panel (c) sets $\phi_\pi = 1.5$ and $\phi_u = -0.25$ and varies the job separation rate $s$ from high persistence ($s = 0$) to low ($s = 1$).

weight policy makers place on stabilizing the labor market, an asymmetric response to unemployment in the shortfalls rule can generate significant implications for average inflation, and hence policy rates, in the economy.

The equilibrium outcomes of adopting a shortfalls rule also depends on the central bank's desire to stabilize inflation. The second panel of Figure 2 illustrates average inflation if we resolve the model using our baseline weight on unemployment of $\phi_u = -0.25$ but under alternative values of $\phi_\pi$, which controls the central bank's response to inflation fluctuations. If the central bank responds more significantly to inflation fluctuations (for example, if $\phi_\pi \geq 2$), then we observe a much smaller quantitative effect on average inflation induced by the adoption of the shortfalls rule. In contrast, if the central bank responds less to inflation fluctuations, then adopting a shortfalls rule may cause inflation to run significantly above the central bank's objective on average.

## 2.3 History Dependence in the Labor Market Amplifies Effects

Our simple model highlights that adopting a shortfalls rule can significantly increase average inflation and policy rates in the economy. We now show that incorporating a more realistic assumption on the structure of the labor market further amplifies the quantitative effects of adopting a shortfalls rule. Specifically, we show that the law of motion for unemployment that search and matching frameworks commonly use introduces *history dependence*. Incorporating this feature into our simple model significantly magnifies the quantitative effects of adopting a shortfalls rule.

Search and matching approaches to labor market frictions usually result in the following law of motion for aggregate unemployment:

$$U_{t+1} = U_t + s\,(1 - U_t) - G_t. \tag{9}$$

where $U_t$ denotes the aggregate unemployment rate, $(1 - U_t)$ is aggregate employment assuming a constant labor force normalized to 1, and $s$ is an exogenous separation rate for existing employment matches. $G_t$ denotes the quantity of new matches formed between unemployed workers and vacant jobs per period. This outflow from unemployment is offset by the inflow of job losses $s\,(1 - U_t)$ to determine the next period unemployment rate.

Under the assumption that equilibrium matches are proportional to economic activity (which will be the case in the structural model of Section 3), the law of motion (9) expressed as deviations around a steady state becomes:[8]

$$u_t = (1 - s)u_{t-1} - \frac{1}{c}\, x_t. \tag{10}$$

Given a typical value of separation rates ($s$ around 0.1 at a quarterly frequency), this highlights that search and matching models imply significant persistence in the dynamics of unemployment, a feature that was missing from our previous ad hoc Okun's law assumption in Equation (3). We also note that this specification nests our previous Okun's law assumption when $s = 1$.

Incorporating history dependence in unemployment, as in Equation (10), significantly amplifies the quantitative effects of adopting a shortfalls-stabilization rule. When labor market dynamics feature history dependence, households and firms understand that the additional accommodation provided by the shortfalls rule in expansions will persist for a longer period of time. To avoid a sub-optimally low price during these persistent periods of accommodative policy, firms choose to set larger price increases when compared to a spot labor market (which corresponds to the limiting case of $s = 1$). Panel (c) of Figure 2 plots the average level of inflation for alternative values of $s$ using the baseline calibration of $\phi_\pi = 1.5$ and $\phi_u = -0.25$. Depending on the exact calibration of the separation rate, incorporating history-dependence in unemployment can more than double the effect of adopting the shortfalls rule

This exercise shows that the exact quantitative implications of adopting a shortfalls-stabilization depend on the features of the labor market. Therefore, the following section rigorously solves a fully microfounded model with frictional labor markets and price rigidities to examine the potential quantitative implications of adopting a shortfalls-stabilization rule.

# 3 A Model of Labor Markets & Nominal Rigidities

In order to fully examine the quantitative effects of the FOMC's new interpretation of its employment mandate, we posit, calibrate, and solve a richer model of the U.S. economy. The key features of our economic environment are search frictional labor markets, nominal rigidities in price setting, and a zero lower bound constraint on short-term nominal interest rates. Fluctuations in the economy are driven by changes in household demand and productivity.

[8] Equation (10) presents a slight abuse in notation: taking deviations of Equation (9) around a steady state we have $u_t = (1 - s)u_{t-1} - \frac{\bar{G}}{\bar{U}}\, g_t$, where $\bar{G}$ and $\bar{U}$ are steady state matches and unemployment. We assume $g_t = 1/\tilde{c} \times x_t$ such that $c$ in (10) is equal to $\tilde{c} \times \bar{U}/\bar{G}$.

To account for the asymmetric policy reaction function under shortfalls stabilization and the zero lower bound constraint on the policy rate, we solve our model using a global solution method and discipline our model's calibration using observed fluctuations in economy over the 25 years immediately preceding the new interpretation of its employment mandate. Since our primary focus is determining the possible effects from the change in the policy reaction function, we first describe our specifications for monetary policy before providing details on the other features of the model.

## 3.1 Monetary Policy

As in the previous section, monetary policy sets the short-term nominal interest rate to systematically offset adverse fluctuations in inflation and unemployment in our model. However, we now write the two different policy rules in levels rather than deviations from a steady state and allow for the monetary policy to face a zero lower bound constraint. Accordingly, the *Deviations* rule, intended to capture the setting of the nominal policy rate prior to the announcement of the new consensus statement in August 2020, is now written as:

$$r_t^d = r + \phi_\pi \left(\pi_t - \pi^*\right) + \phi_u \left(U_t - U^*\right), \tag{11}$$

where $r_t^d$ is the central bank's desired policy rate, $\pi_t = \log(P_t \,/\, P_{t-1})$ denotes inflation, $P_t$ denotes the price level, $U_t$ denotes the unemployment rate, and $r$ denotes the steady-state nominal rate. The parameters $\phi_\pi > 0$ and $\phi_u < 0$ determine the policy reactions to deviations of inflation from the central bank's inflation target $\pi^*$ and fluctuations of unemployment from its longer-run natural rate $U^*$.[9]

In contrast, the *Shortfalls* rule, meant to capture the reinterpretation of the employment mandate in the recent Goals and Strategies statement, is now written as:

$$r_t^d = \begin{cases} r + \phi_\pi \left(\pi_t - \pi^*\right) + \phi_u \left(U_t - U^*\right) & \text{if } U_t \geq U^* \\ r + \phi_\pi \left(\pi_t - \pi^*\right) & \text{if } U_t < U^* \end{cases} \tag{12}$$

Finally, under both the deviations and shortfalls rules, monetary policy faces a zero lower bound constraint such that actual nominal policy rates $r_t$ cannot fall below zero:

$$r_t = \max\left(0\,,r_t^d\right) \tag{13}$$

[9]Equivalently, the policy rule may be expressed in terms of setting the gross nominal rate and the reaction function in proportional departures from target. See Section C.1 of the Appendix for a more detailed discussion and mapping between the two representations.

## 3.2 Households

Our model features a representative household in which a fraction $N_t$ of the unit mass of members are employed, work $H_t$ hours on the job at an hourly wage $W_t$, and a fraction $U_t$ are unemployed and searching for work. The representative household chooses consumption $C_t$ and holdings of the one-period nominal bond $B_t$ to maximize its lifetime utility $J_t$:

$$J_t = \max_{C_t, B_t} \left\{ \exp(\gamma_t) \frac{C_t^{1-\sigma}}{1-\sigma} + \nu_0 \frac{(1-H_t)^{1-\nu_1}}{1-\nu_1} N_t + \nu_u U_t + \beta E_t \Big[ J_{t+1} \Big] \right\} \tag{14}$$

$$\text{subject to} \quad C_t + T_t + \frac{B_t}{P_t R_t} = \frac{B_{t-1}}{P_t} + W_t H_t N_t + b U_t + D_t,$$

where $\beta$ represents household discount factor over time. The parameters $\sigma > 0$, $\nu_0 > 0$ and $\nu_1 > 0$ affect the utility of consumption and the disutility of hours worked out of a total amount of time available (which is normalized to 1 each period). $\nu_u$ affects the utility of non-employment and $b$ denotes unemployment benefits. Finally, $R_t = \exp(r_t)$ denotes the gross nominal interest rate, $T_t$ denotes lump sum taxes to fund unemployment benefits, and $D_t$ denotes dividends from owning all shares in wholesale and retail firms. This specification of preferences over consumption, hours worked on the job, and employment is close the foundational work of the Andolfatto (1996) incorporating labor market search frictions into real business cycles.[10]

The variable $\gamma_t$ is an exogenous random process that shifts the level of utility over consumption. Changes in $\gamma_t$ generate fluctuations in household demand over time through the household's stochastic discount factor. The law of motion for this preference shock process is as follows:

$$\gamma_t = \rho_\gamma \gamma_{t-1} + \sigma_\gamma \varepsilon_t^\gamma, \tag{15}$$

where $\rho_\gamma \in (0,1)$ and $\sigma_\gamma > 0$ control the persistence and volatility of the demand shocks, and $\varepsilon_t^\gamma$ is an independently and identically-distributed standard normal shock.

Denote $\lambda_t^C$ as the Lagrange multiplier on the household's budget constraint and denote $\Pi_t = P_t/P_{t-1}$ as the gross inflation rate. The household's first-order condition for bond

[10] Since Andolfatto (1996), a majority of the work studying the business cycle in models of equilibrium unemployment do not consider the intensive margin of hours adjustments and assumes risk neutral workers. These two elements have been found not to be central for the dynamics of the main outcomes of interest in that stream of research, namely the rate of unemployment and job vacancies, unless they enter and affect the dynamics of equilibrium wages (see Rudanko, 2009, for an example of wage rigidity arising from employers offering wage contracts to risk averse workers). We allow for hours on the intensive and extensive margins such that the inflation response to, say, a technology shocks aligns with the evidence in Altig et al. (2011) and achieved with nominal wage rigidities in Gertler, Sala and Trigari (2008).

holdings yields the Euler equation

$$1 = E_t \left\{ M_{t,t+1} \frac{R_t}{\Pi_{t+1}} \right\}, \tag{16}$$

in which the stochastic discount factor, $M_{t,t+1}$, is given by:

$$M_{t,t+1} \equiv \beta \left( \frac{\lambda_{t+1}^C}{\lambda_t^C} \right) = \beta \left( \frac{\exp(\gamma_{t+1})}{\exp(\gamma_t)} \right) \left( \frac{C_{t+1}}{C_t} \right)^{-\sigma}. \tag{17}$$

## 3.3 The Labor Market

Firms post a number of job vacancies, $V_t$, to attract jobs seekers and employed workers are subject to a job separation shock at rate $s$ at the end of a period. Each vacant position costs $\kappa_t = \kappa_0 + \kappa_1 q_t > 0$ units of final output per unit of time. $\kappa_0 > 0$ is a variable cost and $\kappa_1$ a fixed cost paid by a representative firm after hiring. $q_t$ is the vacancy filling rate discussed below. Vacancies are filled via a constant returns to scale matching function, $G(U_t, V_t)$. We define labor market tightness as $\theta_t \equiv V_t/U_t$. The probability for a worker searching in the labor market to find a job per unit of time (the job finding rate), denoted $f(\theta_t)$, is:

$$\frac{G(U_t, V_t)}{U_t} = f(\theta_t) \text{ with } f'(\theta_t) > 0. \tag{18}$$

The probability for a vacancy to be filled per unit of time (the vacancy filling rate) is:

$$\frac{G(U_t, V_t)}{V_t} = q(\theta_t) \text{ with } q'(\theta_t) < 0, \tag{19}$$

and such that $q(\theta_t)V_t$ is the number of new hires. Employment, $N_t$, evolves as

$$N_{t+1} = (1 - s)N_t + q(\theta_t)V_t. \tag{20}$$

The matching function is specified as $G(U_t, V_t) = \frac{U_t V_t}{(U_t^\iota + V_t^\iota)^{1/\iota}}$, in which $\iota > 0$ is a constant parameter. This matching function, specified as in Haan, Ramey and Watson (2000), has the desirable property that matching probabilities fall between zero and one. The job finding and filling rates are given by $f(\theta_t) = \left(1 + \theta_t^{-\iota}\right)^{-1/\iota}$ and $q(\theta_t) = (1 + \theta_t^{\iota})^{-1/\iota}$, respectively.

## 3.4 Aggregating Sector

The aggregating sector produces the aggregate final consumption good $Y_t$ using a basket of differentiated retail goods as inputs. Denote by $y_t(j)$ a type $j$ retail good for $j \in [0, 1]$. We assume that

$$Y_t = \left( \int_0^1 y_t(j)^{\frac{\omega-1}{\omega}} \mathrm{d}j \right)^{\frac{\omega}{\omega-1}}, \tag{21}$$

where $\omega > 1$ denotes the elasticity of substitution between differentiated products. Expenditure minimization implies a demand for type $j$ retail good that is inversely related to the relative price, with the demand schedule given by

$$y_t^d(j) = \left( \frac{y_t(j)}{P_t} \right)^{-\omega} Y_t, \tag{22}$$

where $y_t^d(j)$ and $y_t(j)$ denote the demand for and the price of retail good of type $j$, respectively. The price index $P_t$ is related to individual prices $p_t(j)$ through

$$P_t = \left( \int_0^1 p_t(j)^{\frac{1}{1-\omega}} \mathrm{d}j \right)^{1-\omega}. \tag{23}$$

### 3.5 Retail Sector

There is a continuum of retail goods producers each producing a differentiated product using a homogenous intermediate good produced by a wholesale sector as input. The production function of a retail good of type $j \in [0, 1]$ is given by

$$y_t(j) = i_t(j), \tag{24}$$

where $i_t(j)$ is the input of intermediate goods used by retailer $j$, purchased at the unit price $\psi_t$ on a competitive intermediate goods market.

Retail goods producers are price takers in the input market and monopolistic competitors in the product markets, where they set the price for their goods taking as given the demand schedule in Equation (22) and in the price index in Equation (23). We assume quadratic costs to adjusting prices:

$$\frac{\Omega}{2} \left( \frac{p_t(j)}{\Pi^* P_{t-1}} - 1 \right)^2 Y_t \tag{25}$$

where the parameter $\Omega > 0$ measures the cost of price adjustments and $\Pi^* = \exp(\pi^*)$ denotes the deterministic steady state inflation rate which equals the central bank's inflation objective. Price adjustment costs are assumed to be in units of aggregate output.

A retail firm that produces good $j$ maximizes the value of its equity $S_t^r$ by choosing the price $p_t(j)$ for its differentiated good, solving the problem:

$$S_t^r \equiv \max_{p_t(j)} E_t \left[ \sum_{i=0}^{\infty} M_{t,t+i} \left[ \left( \frac{p_{t+i}(j)}{P_{t+i}} - \psi_{t+i} \right) y_{t+1}^d(j) - \frac{\Omega}{2} \left( \frac{p_{t+i}(j)}{\Pi^* P_{t+i-1}} - 1 \right)^2 Y_{t+i} \right] \right] \tag{26}$$

The optimal price setting decision implies that, in a symmetric equilibrium with $p_t(j) = P_t$ for all $j$, the input price $\psi_t$ and price inflation $\Pi_t$ are related through the equilibrium condition:

$$\frac{\Pi_t}{\Pi^*} \left( \frac{\Pi_t}{\Pi^*} - 1 \right) \ = \ \frac{\omega}{\Omega} \left( \psi_t - \frac{\omega - 1}{\omega} \right) \ + \ E_t M_{t,t+1} \frac{Y_{t+1}}{Y_t} \frac{\Pi_{t+1}}{\Pi^*} \left( \frac{\Pi_{t+1}}{\Pi^*} - 1 \right) \tag{27}$$

in which currently inflation is increasing in the input price $\psi_t$, and in expected future demand $(Y_{t+1})$ and inflation $(\Pi_{t+1})$.

### 3.6 Wholesale Sector

Firms in the wholesale sector produce with labor hired on a labor market subject to search frictions. Output, sold at unit price $\psi_t$, is produced with a production technology $X_t N_t H_t^{\alpha}$, where $H_t$ are hours of work on the job per worker, $\alpha \in (0, 1)$, and $X_t$ is aggregate productivity in the wholesale sector. The latter follows the law of motion for $x_t \equiv \log(X_t)$:

$$x_t = \rho_x x_{t-1} + \sigma_x \varepsilon_t^x, \tag{28}$$

in which $\rho_x \in (0, 1)$ is the persistence, $\sigma_x > 0$ is the conditional volatility, and $\varepsilon_t^x$ is an independently and identically-distributed standard normal shock.

The wage rate $W_t$ and hours of work $H_t$ are determined through bargaining with workers, as discussed below. The firm posts an optimal number of job vacancies to maximize the cum-dividend market value of equity, denoted $S_t^w$, taking the vacancy filling rate, employment, wage and hours of work as given:

$$S_t^w \equiv \max_{\{V_{t+i}, N_{t+i+1}\}_{i=0}^{\infty}} \ E_t \left[ \sum_{i=0}^{\infty} M_{t,t+i} \left[ \psi_{t+i} X_{t+i} N_{t+1} H_{t+i}^{\alpha} - W_{t+i} H_{t+i} N_{t+i} - \kappa_{t+i} V_{t+i} \right] \right], \tag{29}$$

subject to the employment accumulation Equation (20) and a nonnegativity constraint on vacancies as the only source of job destruction in the model is the exogenous separation of employed workers from the firm:

$$V_t \geq 0. \tag{30}$$

Let $\lambda_t^V$ denote the multiplier on the non-negativity constraint rewritten as $q(\theta_t)V_t \geq 0$. From the first-order conditions with respect to $V_t$ and $N_{t+1}$, we obtain the intertemporal job creation condition:

$$\frac{\kappa_t}{q(\theta_t)} - \lambda_t^V = E_t \left[ M_{t,t+1} \left[ \psi_{t+1} X_{t+1} H_{t+1}^\alpha - W_{t+1} H_{t+1} + (1-s) \left[ \frac{\kappa_{t+1}}{q(\theta_{t+1})} - \lambda_{t+1}^V \right] \right] \right]. \quad (31)$$

Intuitively, the marginal cost of hiring at time $t$ equals the marginal value of employment to the firm, which in turn equals the marginal benefit of hiring at period $t+1$, discounted to $t$. The marginal benefit at $t+1$ includes the marginal revenue from an employed worker, $\psi_{t+1} X_{t+1} H_{t+1}^\alpha$, net of the wage bill, $W_{t+1} H_{t+1}$, plus the marginal value of a retained worker into the next period, which is equal the marginal cost of hiring at $t+1$. Finally, the optimal vacancy policy also satisfies the Kuhn-Tucker conditions:

$$q_t V_t \geq 0, \quad \lambda_t^V \geq 0, \quad \text{and} \quad \lambda_t^V q_t V_t = 0. \quad (32)$$

### 3.7 Wages and Hours of Work

A common approach, which we follow here, is to assume workers and firms engage in bilateral Nash bargaining over hours and wages. Assuming this takes place at the beginning of each period, after observing the state of the economy, hours and wages are the solution to

$$\Lambda_t = \max_{W_t, H_t} \left( \frac{J_{Nt} - J_{Ut}}{\lambda_t^C} \right)^\eta \left( S_{N,t}^w - S_{V,t}^w \right)^{1-\eta}$$

where $\eta \in (0,1)$ is the worker's relative bargaining weight, and $(J_{Nt} - J_{Ut})$ and $(S_{N,t}^w - S_{V,t}^w)$ are the worker's and the firm's respective labor match surpluses (defined in Appendix C.2, along with detailed derivations). This leads to an equilibrium condition for hours:

$$\frac{\nu_0}{\lambda_t^C} (1 - H_t)^{-\nu_1} = \alpha \psi_t X_t H_t^{\alpha - 1} \quad (33)$$

equating the marginal utility of hours of leisure to the marginal revenue product of an additional hour of work.

The Nash bargained wage is most easily expressed as compensation per worker $W_t H_t$:

$$W_t H_t = \eta \left[ \psi_t X_t H_t^\alpha + \kappa_t \theta_t \right] + (1-\eta) Z_t, \quad (34)$$

It increases with the marginal revenue product of labor, conditions in the labor market through changes in $\theta_t$, and with the variable $Z_t = b + \nu_u / \lambda_t^C - \nu_0 \frac{(1-H_t)^{1-\nu_1}}{1-\nu_1} / \lambda_t^C$. The latter captures the worker's reservation wage, a function of unemployment compensation $b$ and the change in flow utility from employment compared to remaining unemployed.

## 3.8 Equilibrium

Financial markets clear in equilibrium. The risk-free asset is in zero net supply, and the household holds all the shares of the firms in retail and wholesale sectors. The goods market clearing condition is then given by:

$$C_t + \kappa_t V_t + \frac{\Omega}{2}\left(\frac{\Pi_t}{\Pi^*} - 1\right)^2 Y_t = Y_t. \tag{35}$$

Intermediate goods market clearing implies

$$Y_t = X_t N_t H_t^{\alpha}. \tag{36}$$

Appendix C.3 summarizes the key model equations and provides the definition of the competitive equilibrium.

## 3.9 Calibration

Our primary goal is examining the possible effects if monetary policymakers change from a symmetric deviations rule to a one-sided shortfalls rule. To ensure that our model provides a reasonable description of the U.S. economy prior to the policy change, we first assume that monetary policy follows the deviations rule and choose the parameters of our model to match key first- and second-moments in the labor market as well as inflation and nominal interest rates over the 1995–2019 sample period. Table 1 lists the resulting parameter values for calibration of our model solved at a monthly frequency . After calibrating the model, we then study the implications of moving from a deviations to shortfalls policy rule. We solve the model under both policy rules using a global solution method which accounts for the potential asymmetries in the policy reaction function as well as the zero lower bound and nonlinear dynamics in the labor market.[11]

Turning first to the parameters in the central bank's policy rule, we set the inflation target $\Pi^*$ to be consistent with the Federal Reserve's stated goal for price stability of 2

[11] We use a projection algorithm, detailed in Appendix Section C.4, developed and studied for its accuracy in models with search frictional labor markets and kinked policy functions in Petrosky-Nadeau and Zhang (2017). The latter also discuss the non-linearity in the dynamics stemming from the matching frictions in the labor market. For a discussion of the nonlinear dynamics present at the zero lower bound in standard New Keynesian frameworks, see Fernández-Villaverde et al. (2015).

percent inflation. Following the work of Taylor (1993) and many others, we set the central bank's inflation response to a standard value $\phi_\pi = 1.5$. In calibrating the unemployment response parameter $\phi_u$, we follow a conservative approach. As we discussed in Section 2, the quantitative impact of switching from a deviations rule to a shortfalls rule crucially depends on the calibration of the central bank's response to unemployment $\phi_u$. Specifically, the magnitude of the inflationary impact of switching to a shortfalls rule is increasing in the weight placed on the unemployment gap. Recent work from Kahn and Palmer (2016) and Feroli et al. (2017) estimates the FOMC's implied policy reaction function in Equation (11) using the FOMC's quarterly Summary of Economic Projections (SEP). Using data prior to the new consensus statement, they find estimates for $\phi_u$ that range from -0.05 to -0.18 (at the monthly frequency of our model). Thus, in calibrating $\phi_u$, we take a conservative approach and set $\phi_u$ = -0.05 under both the deviations and shortfalls rule.

Finally, with regards to the central bank's policy rule, our baseline assumes monetary policymakers assess the long-run value of the unemployment rate $U^*$ to be 5 percent, which is close to the average rate of unemployment observed in our sample period for the U.S. However, the FOMC's view of longer-run unemployment was steadily declining over the decade leading up to the adoption of the new consensus statement. The median longer-run rate of unemployment reported in the quarterly SEP fell from 5 percent in 2010 to 4.3 percent in 2019, mirroring the secular decline in the Congressional Budget Office's (CBO) estimate of the longer run non-cyclical rate of unemployment. We discuss the robustness to instead assuming the central bank targets a $U^*$ of 4 percent in Section 5.

Turning to the labor market, we target a steady state unemployment rate of 5% in the model, in line with policy makers' views on longer run unemployment $U^*$, first setting the separation rate $s$ to 3% based on the underlying labor market flows to take into account the two state (employed/unemployed) nature of the model (Petrosky-Nadeau and Valletta, 2020). This places a restriction on the average job finding rate $f$ and will pin down the value of worker's bargaining weight in wage setting $\eta$ given our calibration strategy for the remaining parameters. This results in a value of $\eta = 0.25$, placing the implied bargaining weight near the center of the range obtained in other work, from values as low as 0.05 in Hagedorn and Manovskii (2008) to a value of 0.72 in Shimer (2005). We set the curvature parameter of the labor market matching function $\iota$ to 1.25, the value in the original work of Haan, Ramey and Watson (2000) and applied in Petrosky-Nadeau, Zhang and Kuehn (2018). Silva and Toledo (2009) report that recruiting costs are 14 percent of quarterly pay per hire, or 0.4 months of pay per hire, based on data collected by PriceWaterhouseCoopers. We set $\kappa = \kappa_0 + \kappa_1$ such that, on average, the cost of job creation $\kappa/q(\theta) = 0.4 \times WH$. We then use

Table 1: Calibrated Model Parameters

| Parameter | Notation | Value | Target/Source |
|---|---|---|---|
| Preferences: | | | |
| Discount factor | $\beta$ | $e^{(-0.5/1200)}$ | 0.5% annualized real risk free rate |
| Elast. of subst. btw. goods | $\omega$ | 10 | Average markup over marginal cost |
| Utility: consumption | $\sigma$ | 2 | External |
| Utility: leisure, level | $\nu_0$ | 6.4 | Average hours worked |
| Utility: leisure, curvature | $\nu_1$ | 2 | Elasticity of labor supply |
| Non-employment utility | $\nu_u$ | -6.7 | Reservation to wage ratio |
| Firm technology and price setting: | | | |
| Production function: curvature | $\alpha$ | 0.67 | External |
| Price adjustment cost | $\Omega$ | 500 | Volatility of inflation |
| Labor market: | | | |
| Matching function: curvature | $\nu$ | 1.25 | Den Haan et al (2000) |
| Worker bargaining weight | $\eta$ | 0.25 | Unemployment rate |
| Vacancy cost | $\kappa_0$ | 0.04 | Recruiting costs to monthly wage |
| Fixed hiring cost | $\kappa_1$ | 0.06 | Volatility of unemployment |
| Job destruction rate | $s$ | 0.03 | Unemployment flow accounting[1] |
| Unemployment benefits | $b$ | 0.15 | Replacement rate |
| Monetary policy: | | | |
| Weight on inflation | $\phi_\pi$ | 1.50 | Estimated on U.S. data[2] |
| Weight on unemp. gap | $\phi_u$ | -0.05 | Estimated on U.S. data[2] |
| Inflation target | $\pi^*$ | $1.02^{(1/12)}$ | FOMC target inflation |
| Unemployment: natural rate | $U^*$ | 0.05 | Long run rate of unemployment |
| Shock processes: | | | |
| Technology: persistence | $\rho_x$ | 0.98 | U.S. labor productivity[3] |
| Technology: standard deviation | $\sigma_x$ | 0.004 | U.S. labor productivity[3] |
| Demand: persistence | $\rho_\gamma$ | 0.98 | Ireland (2011) |
| Demand: standard deviation | $\sigma_\gamma$ | 0.03 | Corr. between unemp. and inflation |

Notes: We calibrate the model to monthly frequency. (1) based on the underlying labor market flows to take into account the two state (employed/unemployed) nature of the model (Petrosky-Nadeau and Valletta, 2020); (2) See the discussion in the text; (3) Non-farm business labor productivity, see discussion in text.

the volatility of unemployment in the data to determine the relative importance of variable and fixed costs $\kappa_0$ and $\kappa_1$. A greater fixed relative to variable cost increases the volatility of unemployment (Pissarides, 2009). This results in $\kappa_0 = 0.04$ and $\kappa_1 = 0.06$. Finally, with respect to the labor market, we set the value of unemployment benefit $b$ such that on average $b/WH = 0.4$. This correspond to the typical earnings replacement rate across U.S. states reported by the Department of Labor (Department of Labor, 2019).

For the household preference parameters $\beta$ and $\omega$, we set the time discount factor, $\beta$, equal to $\exp(-0.5/1200)$ such that the annualized long-run neutral rate equals 0.5%. This target is informed by estimates of the longer-run equilibrium real rate of interest from a variety approaches (Laubach and Williams, 2003; Lubik and Matthes, 2015; Christensen and Rudebusch, 2019). We set the elasticity of substitution between differentiated goods to $\omega = 10$, such that the average markup $1/\psi$ is about 11%. This is broadly inline with microeconomic evidence presented in Basu and Fernald (1997). We set the coefficient of relative risk aversion to a standard value of $\sigma = 2$. The level parameter in the utility for leisure $\nu_0$ is set such that employed individuals spend on average 20 percent of their time endowment working. The curvature parameters $\nu_1$ is set to an individual labor supply elasticity of $\nu_1^{-1}\left(\frac{1}{H} - 1\right) = 2$ in line with estimates reviewed and discussed in Hall (2009). This results in $\nu_1 = 2$. Lastly, the utility associated with non-employment $\nu_u$ is set such that there is small gap between earnings and the reservation utility $Z/WH = 0.90$. This is close to the value calibrated in Rudanko (2009) and estimated by Christiano, Eichenbaum and Trabandt (2016), resulting in a value of $\nu_u = -6.7$.

On the production side, the parameter $\alpha$ in the production function is set to a common value of two thirds. We choose the nominal price adjustment cost $\Omega$ such that the model generates the volatility in inflation observed over the last two decades. To a first-order approximation (in which our quadratic-cost specification is observationally equivalent to a Calvo setting), our monthly calibrated value of $\Omega = 500$ implies that firms adjust prices about every eight months, which is broadly consistent with the micro evidence in Nakamura and Steinsson (2008).

For the productivity process $X_t$, we set the persistence, $\rho_x$ to 0.98 and its conditional volatility, $\sigma_x = 0.004$, to match the standard deviation of labor productivity in the data.[12]

[12] We measure the labor productivity as seasonally adjusted real average output per job in the nonfarm business sector (Series id: PRS85006163) from the Bureau of Labor Statistics. The sample is quarterly from 1951 to 2012. We detrend the series as the Hodrick-Prescott (1997, HP) filtered cyclical component of proportional deviations from the mean with a smoothing parameter of 1,600.

For the demand shock process, we also set the persistence $\rho_\gamma = 0.98$, which, at the monthly frequency of our model, is consistent with the quarterly estimated value of Ireland (2011). We calibrate the standard deviation of the demand shock process to match the empirically observed correlation between inflation and unemployment, which results in $\sigma_\gamma = 0.03$.

Table 2 compares the implied quarterly moments in our model under the deviations policy rule to their empirical counterparts. Overall, the results in Table 2 suggests that our model likely provides a reasonable, but highly stylized, description of the economy that we can use to conduct policy experiments. The model is able to generally reproduce the first and second moments of unemployment, inflation, and the nominal policy rate we observe in the data. The model closely matches the average and volatility of unemployment over the 1995–2019 period. The model also matches the volatility of inflation as well as the model-implied correlation between unemployment and inflation (the reduced-form Phillips curve). The presence of the zero lower bound and asymmetric fluctuations in the unemployment rate pushes average inflation under the deviations rule to to 1.8 percent which is below the targeted and deterministic steady state of 2 percent. Note that this rate is similar to actual inflation over the last couple decades. The model is generally close, though somewhat above, the average and volatility of the nominal policy rate observed in the data, and likewise for the correlation between the nominal policy rate and inflation. Finally, the fourth row reports the frequency with which policy is at the zero lower bound. The baseline calibration of the model under the deviations rule results in an unconditional probability of being at the zero lower bound of 26 percent, implying that the economy frequently encounters the lower bound.

# 4 From Deviations to Shortfalls

We now analyze the qualitative and quantitative implications of changing from a symmetric deviations rule in Equation (11) to the one-sided shortfalls rule in Equation (12), leaving all other parameters unchanged. First, we use the policy functions of the model to examine the qualitative effects of adopting a shortfalls-stabilization rule. Then, we discuss the quantitative impacts of the new policy rule on inflation, unemployment and the nominal policy rate. Shifting to a shortfalls rule not only affects longer-term average outcomes in the economy but also changes the entire distribution of inflation and nominal policy rate outcomes. Finally, we examine the model-implied implications for the economy's reduced-form Phillips curve and its performance in the presence of the zero lower bound on nominal interest rates.

Table 2: Empirical and Model-Implied Moments

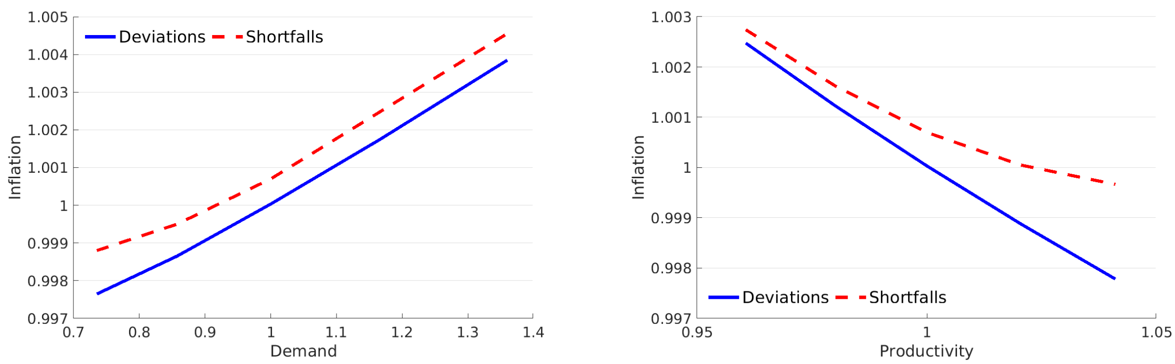
| | Data | Deviations Rule | Shortfalls Rule |
|---|---|---|---|
| Mean: | | | |
| $U$ | 5.7 | 5.2 | 5.2 |
| $\pi$ | 1.7 | 1.8 | 2.7 |
| $R$ | 2.5 | 2.8 | 3.7 |
| Pr(ZLB) | – | 26.0 | 0.9 |
| Standard deviation: | | | |
| $\sigma(U)$ | 0.08 | 0.08 | 0.08 |
| $\sigma(\pi)$ | 0.42 | 0.40 | 0.21 |
| $\sigma(R)$ | 0.39 | 0.46 | 0.31 |
| $\sigma(H)$ | 0.01 | 0.03 | 0.03 |
| Cross. correlation: | | | |
| $corr(U,\pi)$ | -0.23 | -0.24 | -0.30 |
| $corr(U,H)$ | -0.70 | -0.71 | -0.70 |
| $corr(R,\pi)$ | 0.49 | 0.66 | 0.70 |
| $corr(R,U)$ | -0.74 | -0.34 | -0.40 |

Notes: Details on the sources and transformation applied to the U.S data are available in Appendix Section D. The empirical sample period is 1995Q1–2019Q4. Model moments are computed on 10,000 simulations of 300 periods, equal to the number of months in the data sample and then averaged over three periods for a quarterly frequency. Empirical and model data are converted to proportional deviations and Hodrick-Prescott filtered before computing second moments. Pr(ZLB) corresponds to the unconditional probability the nominal policy rate is at the zero lower bound in model simulations.

Figure 3: Policy Functions to Demand and Productivity Shocks

(a) Inflation & Demand

(b) Inflation & Productivity




## 4.1 Policy Functions Under Deviations & Shortfalls Rules

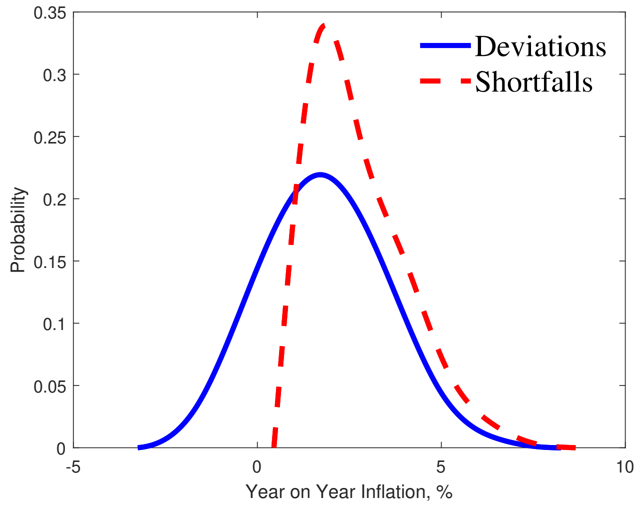
Figure 3 plots the model's policy functions for the monthly gross inflation rate ($\Pi_t$) as a function of the demand shock ($\exp(\gamma_t)$, in panel a) and productivity ($X_t$, in panel b) under both the deviations and shortfalls rules.[13] The policy functions show that inflation and labor market tightness move in opposite directions in response to a change in productivity. Since unemployment is inversely related to labor market tightness, demand shocks need to be more important in driving aggregate fluctuations for the model to reproduce the negative relationship between unemployment and inflation that we observe in the data.

While the difference in policymakers' behavior under the deviations or shortfalls rules in Equations (11) and (12) technically only becomes actualized when the unemployment rate falls below the targeted rate $U^*$, changing to a shortfalls rule implies higher inflation in *all* states of the world. Under a shortfalls-stabilization rule, forward-looking firms internalize that policymakers will not lean against a tight labor market. This expectation of more accommodative policy and higher demand in the future, in states of the world where unemployment falls below $U^*$, leads them to adopt greater price increases at all level of current productivity and demand.

These policy functions also highlight a second implication when monetary policy is no longer working to offset states of the world where unemployment falls below $U^*$. First, there is a flattening of the negative slope of inflation to changes in productivity, particularly in

[13] To produce these figures, we set employment $N_t$ (the endogenous state variable in our model) equal to its longer-run value. Appendix Figure C.3 plots the policy functions for labor market tightness, inflation and hours worked on the job over employment and, separately, productivity and demand.

Figure 4: Model-Implied Stationary Distributions Under Deviations & Shortfalls Rules




Note: Model distributions obtain from 10,000 simulations of 300 periods, equal to the number of months in the data sample.

high productivity states of the world. Thus, we see that increases in productivity result in a smaller downward pressure on price inflation under the shortfalls rule and this effect become more pronounce as the rate of unemployment falls. Second, further declines in demand when demand is already at a low level are less deflationary. As we discuss later, this outcome follows from the fact that the zero lower bound constraint rarely binds under the shortfalls rule, which alleviates a source of downward pressure on inflation when demand is low. Overall, these results suggest that the FOMC's new employment objective may affect the economy's response to many types of shocks hitting the economy.

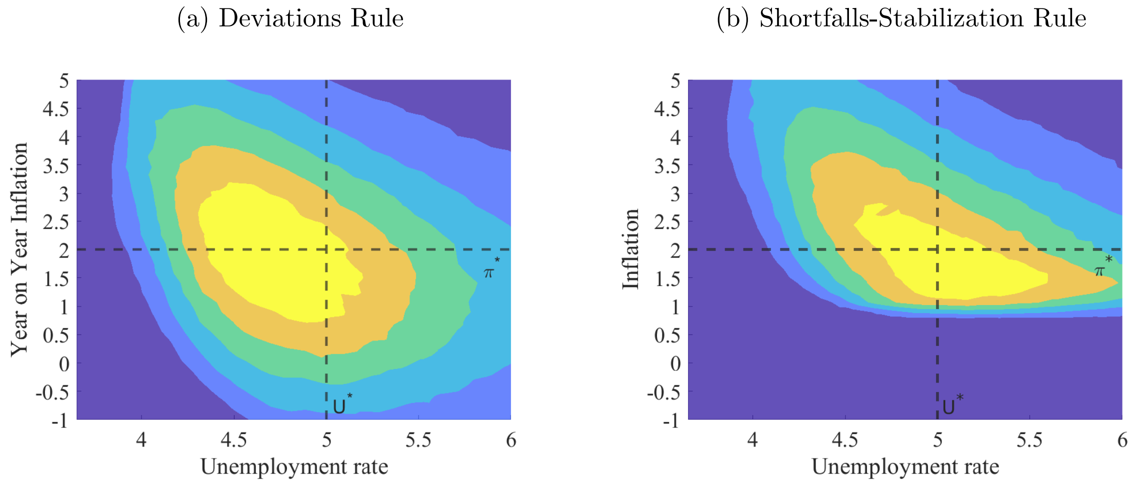
## 4.2 Quantitative Impacts

Moving to a shortfalls stabilization rule can have quantitatively significant effects on both the business-cycle properties and the longer-run outcomes for the economy. The last column of Table 2 reports the effect on first and second moments of interest of adopting the shortfalls-stabilization rule, keeping all other parameters fixed to their calibrated values.

### 4.2.1 Higher and Less Volatile Inflation

The more accommodative response to low unemployment under the shortfalls rule raises average inflation by roughly 90 basis points, while the impact on the average unemployment rate is quantitatively negligible. Alongside the increase in average inflation, we see a roughly equivalent increase in the average nominal policy rate from 2.8 to 3.8 percent under the

Figure 5: Model-Implied Joint Distributions of Inflation & Unemployment




Note: Model distributions obtained from 10,000 simulations of 300 periods. Lighter shaded region correspond to a greater frequency of realizations.

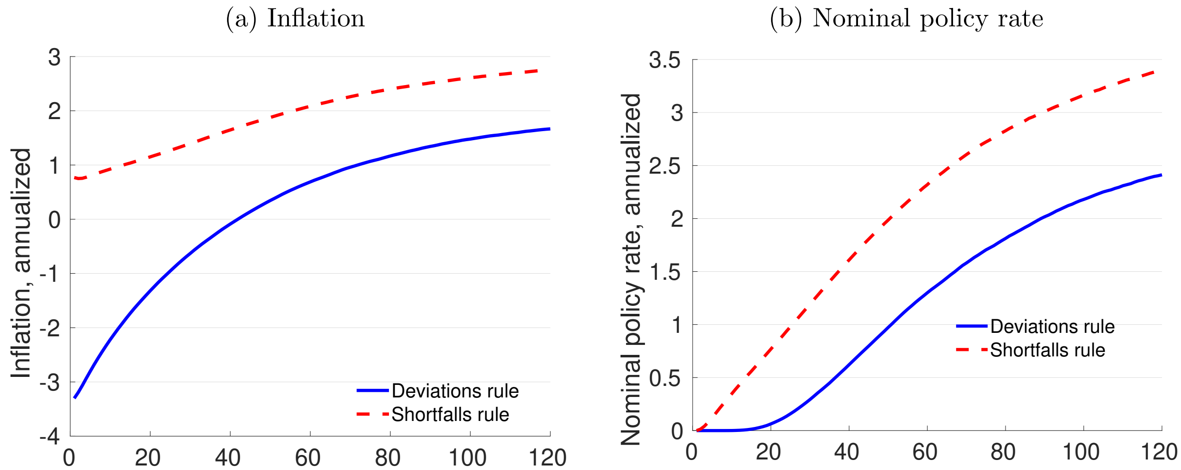
shortfalls stabilization rule. In addition, adopting a shortfalls rule significantly lowers the volatility of inflation, from 0.40 to 0.21. This reduction, however, does not occur due to a symmetric narrowing of realized of inflation around its mean. Changing to a shortfalls rule results in an increased likelihood of expansions with high inflation and a pronounced decline in the probability of inflation significantly below the central bank's target. Figure 4 highlights this result by reporting the model's simulated distribution of inflation under both the deviations (blue) and shortfalls (red) rules. Realizations of inflation below 1%, frequent under the deviations rule, become very rare under a shortfalls rule while realizations of inflation above 3% become more likely. Specifically, the frequency of inflation below 1% declines from 33% to 4% when adopting the shortfalls stabilization rule and the frequency of inflation above 3% increases from 25% to 37%.

### 4.2.2 Implications for the Phillips Curve

A change in the monetary policy rule toward only stabilizing employment shortfalls increases the intercept and results in a steeper slope of the reduced-form Phillips curve. This can be observed in the increase in the average inflation, just discussed, and in the contemporaneous cross-correlation between inflation and unemployment. The latter steepens from -0.24 to -0.30 following the adoption of a shortfalls stabilization rule (see Table 2).

Over and above the steepening of the reduced for Phillips curve from adopting a shortfalls-stabilization rule is the appearance of a non-linearity in the relation between inflation and unemployment that results from the change in monetary policy strategy. Figure 5 plots

Figure 6: Recovery From a Zero Lower Bound Episode Under Deviations & Shortfalls Rules




Note: Average paths for inflation and nominal policy rates from an initial state of 9% unemployment, demand at the 5th percentile of its ergodic distribution, productivity at the 95th percentile of its distribution, and no additional innovations.

the joint density of inflation and unemployment under the deviations rule in panel (a), and shortfalls rule in panel (b) with yellow shaded areas corresponding to joint realizations with greatest frequency. The pronounced drop in the frequency of low realizations of inflation (1 percent or lower) occurs for all levels of the unemployment rate under the shortfalls rule. As a result, especially when unemployment exceeds the 5 percent target, increases in unemployment are no longer associated with below target inflation. The reduced-form Phillips curve appears very flat in the quadrant with inflation below two percent and unemployment above $U^*$. This is in sharp contrast to the strong negative correlation when unemployment is below the central bank's target and inflation is running above target (the upper left quadrant).

### 4.2.3 A Shortfalls Rule Helps Alleviate the Zero Lower Bound Constraint

These combined effects on inflation and unemployment under the shortfalls rule also help alleviate the contractionary effects of the zero lower bound in two ways. First, the zero lower bound constrains policymakers much less often under a shortfalls rule. Specifically, the unconditional probability of being at the ZLB declines from 26 to 0.9 percent when moving from the deviations to the shortfalls rule.

Second, conditional on hitting the zero lower bound, the expectations of higher inflation imply a quicker recovery from a zero lower bound episode. Figure 6 plots the average path of inflation and nominal policy rates as the economy converges to its stationary mean (assuming no additional innovations) starting from a state in which the economy is at the lower bound. That is, demand is at the 5th percentile of its ergodic distribution and expected to rise, productivity is at the 95th percentile of its distribution and expected to decline, and unemployment is elevated at 9%. Inflation, shown in panel (b), returns to and exceeds target over the period shown here under the shortfalls rule. In contrast, inflation just manages to exceed 1.5% over the same time horizon under the deviations rule. With these more favorable outcomes, the nominal policy rate exits the zero lower bound earlier, and more rapidly, than under the deviations rule.

# 5 Robustness

This section investigates the robustness of the main results from adopting a shortfalls stabilization rule along a number of key dimensions. We begin by considering elements in the central bank's policy rule, beginning with the assumed level of the longer-run unemployment rate $U^*$, followed by the importance of the ZLB constraint on the nominal policy rate. Next, we evaluate the possibility for a greater weight on inflation in the policy rule to lower average inflation toward target after adopting the shortfalls stabilization rule. Finally, we compare the baseline results against a pair of alternative policy rules: one that responds, strongly, to inflation alone and a second symmetric rule with a greater weight on the unemployment gap. This set of results is reported in Table 3. We then turn to the impact of key labor market parameters: workers' wage bargaining power, the value of non-employment and the curvature of the matching function, and present the results in Table 4.

## 5.1 Role of Policy Parameters & Alternative Policy Rules

The baseline calibration assumed policymakers target a longer-run rate of unemployment of 5%, close to the historical average in the period prior to the adoption of the new consensus statement. However, during the late stage of the long expansion that followed the Great Recession, FOMC participants progressively revised their views of longer-run unemployment in the face of persistent low inflation and unemployment. As reported in the quarterly SEP, the FOMC's views of unemployment in the longer run as having declined from 5 percent in 2010 to 4.3 percent in 2019.

We now consider an alternative calibration in which policy makers view longer run unemployment at 4%, instead of 5%, and perform the same calibration of the model under the deviations rule with this revised assumption. The results, reported in the second set of columns in Table 3, show this has a negligible impact on the main results. Inflation increases from 1.9 to 2.5 percent following the adoption of the shortfalls rule, an increase of similar magnitude as under the baseline calibration. Likewise, adopting a shortfalls stabilization rule generates a similar decline in the volatility of inflation and an increase the slope of the reduced-form Phillips curve.

The ZLB constraint on the nominal policy rate contributes a downward pull on inflation below the central bank's desired 2 percent target. Table 3 shows that removing this constraint somewhat increases the average rate of inflation under the deviations rule: average inflation in the calibrated model increases from 1.81 to just under 1.85 percent. Removing the ZLB constraint on the nominal policy also moderates the impacts of adopting a shortfalls rule. That is, average inflation increases just over 50 basis points, instead of around 90 basis points with the ZLB constraint present. In addition, adopting a shortfalls rule results in a smaller effect on the volatility of inflation in the absence of a ZLB constraint but a more pronounced steepening of the slope of the reduced-form Phillips curve.

The adoption of a shortfalls stabilization rule led to a significant increase in the average rate of inflation, well above the desired target rate of 2%. However, as we showed in the simple model of Section 2, the inflationary impact is moderated by the weight on inflation deviations in the policy rule, $\phi_\pi$. Building on this intuition, the fourth set of results in Table 3 increases the weight on deviations from target inflation in the policy rule after adopting a shortfalls rule. By sufficiently leaning against the upward pressures on inflation (setting $\phi_\pi = 3$), policymakers can push average inflation back down to their 2% target while operating under a shortfalls stabilization rule. Moreover, this outcome still provides additional policy space: the frequency of ZLB periods remains very low, at 3 percent, relative to the baseline under the deviations rule.

The last two columns of Table 3 present the results from adopting two rules as alternatives to the shortfalls-stabilization rule for comparison. The first assumes the central bank switches to a strict inflation targeting rule with a significantly greater weight on inflation deviations. That is, it sets $\phi_\pi = 3$, up from 1.5, and $\phi_u = 0$. This rule, as expected, reduces the volatility of realized inflation but has no material impact on average inflation, which remains well below the desired 2 percent target. However, it results in a substantial increase in the slope of the reduced form Phillips curve, from $-0.24$ to $-0.54$. The second case is a version of the deviations rule with a significantly greater weight on the unemployment gap. In this calibration, we maintain a deviations rule with $\phi_\pi = 1.5$ but set $\phi_u = -0.1$ instead of $-.05$. In contrast to the previous case, this results in an increased average rate of inflation, to about 2 percent, and a change in the sign of the correlation between unemployment and inflation from $-0.23$ to 0.14. However, there is no significant change in the frequency of ZLB events.

Table 3: Model-Implied Moments: Alternative Policy Rules

| | Baseline | | Lower $U^{*a}$ | | No ZLB constraint[b] | | Greater weight on $\pi^c$ | Inflation target only[d] | Greater weight on U gap[e] |
|---|---|---|---|---|---|---|---|---|---|
| | Deviations | Shortfalls | Deviations | Shortfalls | Deviations | Shortfalls | | | |
| Mean: | | | | | | | | | |
| $U$ | 5.2 | 5.2 | 4.2 | 4.2 | 5.2 | 5.2 | 5.1 | 5.2 | 5.2 |
| $\pi$ | 1.8 | 2.7 | 1.9 | 2.5 | 1.8 | 2.3 | 2.1 | 1.8 | 2.0 |
| $R$ | 2.8 | 3.8 | 2.9 | 3.5 | 2.4 | 3.0 | 2.6 | 2.4 | 2.9 |
| Pr(ZLB) | 26.0 | 0.9 | 26.5 | 5.1 | – | – | 3.4 | 16.4 | 21.4 |
| Standard deviation: | | | | | | | | | |
| $\sigma(U)$ | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 |
| $\sigma(\pi)$ | 0.40 | 0.21 | 0.48 | 0.25 | 0.40 | 0.36 | 0.20 | 0.14 | 0.35 |
| $\sigma(R)$ | 0.46 | 0.31 | 0.50 | 0.38 | 0.62 | 0.55 | 0.34 | 0.37 | 0.41 |
| $\sigma(H)$ | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 |
| Cross. correlation: | | | | | | | | | |
| $corr(U,\pi)$ | -0.24 | -0.30 | -0.22 | -0.26 | -0.24 | -0.34 | -0.32 | -0.54 | 0.13 |
| $corr(U,H)$ | -0.71 | -0.70 | -0.68 | -0.67 | -0.71 | -0.71 | -0.72 | -0.68 | -0.71 |
| $corr(R,\pi)$ | 0.66 | 0.70 | 0.65 | 0.69 | 0.71 | 0.71 | 0.67 | 0.66 | 0.64 |
| $corr(R,U)$ | -0.34 | -0.40 | -0.32 | -0.39 | -0.37 | -0.43 | -0.47 | -0.45 | -0.14 |

Notes: Model moments are computed on 10,000 simulations of 300 periods, equal to the number of months in the data sample and then averaged over three periods for a quarterly frequency. Model data are converted to proportional deviations and Hodrick-Prescott filtered before computing second moments. (a) Longer run unemployment in policy rule set to $U^* = 4\%$ and deviations model re-calibrated to a steady state unemployment of 4%; (b) Models solved and calibrated without the zero-lower=bound constraint on the nominal policy rate; (c) Increased weight in on inflation in the shortfalls rule keeping other parameters constant; (d) Weights in the deviations policy rule set to $\phi_\pi = 2$ and $\phi_u = 0$; (e) Deviations rule policy with the weight on the unemployment gap set to $\phi_u = -0.1$.

Table 4: Model-Implied Moments: sensitivity to labor market parameters

| | Baseline | | Labor market power[a] | | Reservation wage[b] | | Matching curvature[c] | |
|---|---|---|---|---|---|---|---|---|
| | Deviations | Shortfalls | Deviations | Shortfalls | Deviations | Shortfalls | Deviations | Shorfalls |
| Mean: | | | | | | | | |
| $U$ | 5.2 | 5.2 | 5.0 | 5.0 | 5.0 | 5.0 | 5.3 | 5.3 |
| $\pi$ | 1.8 | 2.7 | 1.6 | 2.6 | 1.6 | 2.6 | 2.0 | 2.8 |
| $R$ | 2.8 | 3.8 | 2.7 | 3.6 | 2.7 | 3.7 | 3.0 | 3.9 |
| P(ZLB) | 26.0 | 0.9 | 28.5 | 0.7 | 28.6 | 0.3 | 24.2 | 1.2 |
| Standard deviation: | | | | | | | | |
| $\sigma(U)$ | 0.08 | 0.08 | 0.08 | 0.08 | 0.07 | 0.07 | 0.08 | 0.08 |
| $\sigma(\pi)$ | 0.40 | 0.21 | 0.46 | 0.22 | 0.46 | 0.22 | 0.37 | 0.21 |
| $\sigma(R)$ | 0.46 | 0.31 | 0.49 | 0.32 | 0.49 | 0.32 | 0.45 | 0.31 |
| $\sigma(H)$ | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 |
| Cross. correlation: | | | | | | | | |
| $corr(U,\pi)$ | -0.24 | -0.30 | -0.25 | -0.30 | -0.27 | -0.31 | -0.26 | -0.31 |
| $corr(U,H)$ | -0.71 | -0.70 | -0.70 | -0.70 | -0.71 | -0.71 | -0.71 | -0.71 |
| $corr(R,\pi)$ | 0.66 | 0.70 | 0.66 | 0.70 | 0.66 | 0.70 | 0.67 | 0.70 |
| $corr(R,U)$ | -0.34 | -0.40 | -0.34 | -0.39 | -0.36 | -0.41 | -0.35 | -0.42 |

Notes: Model moments are computed on 10,000 simulations of 300 periods, equal to the number of months in the data sample and then averaged over three periods for a quarterly frequency. Model data are converted to proportional deviations and Hodrick-Prescott filtered before computing second moments. (a) Worker's wage bargaining power lowered by 15 percent; (b) Unemployment benefits reduced by 2.5 percent; (c) Labor market matching function curvature lowered from 1.25 to 1.1.

## 5.2 Sensitivity to Key Labor Market Parameter Values

The dynamics of the labor market are heavily influenced by the response of wages over the business cycle. We investigate the sensitivity of the main results to a different value of workers' bargaining power in wage setting, $\eta$, lowering it from 0.25 in the baseline calibration to 0.2. The results are reported in the second set of columns in Table 4. This change increases the volatility of inflation and the frequency of ZLB episodes under the deviations rule but has little effect on the impacts from adopting a shortfalls-stabilization rule.

Next, we examine the impact of changing our assumption on the value of unemployment benefits, lowering them by 2.5 percent. Lowering the value of a worker's outside option in wage bargaining, resulting in a larger surplus to the labor match between a worker and a firm, reduces the average rate of unemployment and its volatility. Nonetheless, the impact of adopting a shortfalls-stabilization rule is about the same as under the baseline calibration.

Lastly, we change the value of the labor market matching function's curvature parameter, $\iota$, from 1.25 to 1.1. This results in somewhat higher unemployment on average but less frequent realizations of very elevated unemployment rates that bring about periods of commensurately low inflation. As a result, average inflation under the deviations rule is now close to 2 percent. Nonetheless, the impact on average inflation, its volatility and the frequency of ZLB episodes of adopting a shortfalls stabilization rule are similar to the baseline results.

# 6 Adoption of Flexible Average Inflation Targeting

As we discuss in the Introduction, the 2020 update to the FOMC's Statement on Longer-Run Goals and Strategy motivates the analysis in our paper. Our results thus far suggest that a monetary policy which stabilizes "shortfalls" rather than "deviations" of employment from its maximum level can lead to a significant increase in average inflation and policy rates.

However, the FOMC also made changes to its interpretation of its inflation objective in its 2020 Statement. In addition to stating its desire to stabilize shortfalls of employment, the Committee adopted a flexible average inflation targeting (FAIT) framework in which they seek, "to achieve inflation that averages 2 percent over time." Using our simple model from Section 2, we now illustrate how the simultaneous adoption of a flexible average inflation targeting framework could alter the quantitative effects of adopting a shortfalls rule. Our model suggests that the effects of adopting the shortfalls rule either remained unchanged or become amplified relative to our previous results depending on the horizon over which policymakers aim to stabilize average inflation.

We incorporate average inflation targeting in our simple model by changing the measure of inflation in the central bank's reaction function. First, we follow Swanson and Rudebusch (2012) and define an exponential moving average of recent inflation:

$$\pi_t^a = \left(\frac{K}{K+1}\right)\pi_{t-1}^a + \left(\frac{1}{K+1}\right)\pi_t, \tag{37}$$

where $\pi_t^a$ tracks the recent average history of inflation deviations from target.[14] The parameter $K$ controls the "look-back" period in average inflation which we roughly interpret as the number of lags in the calculation of average inflation. Setting $K = 5$, for instance, roughly corresponds to stabilizing average inflation over the previous 1.5 years in a quarterly model.

Incorporating this concept of average inflation targeting in our deviations and shortfalls rules in Equations (6) and (7) implies:

$$i_t = \phi_\pi \pi_t^a + \phi_u u_t \tag{38}$$

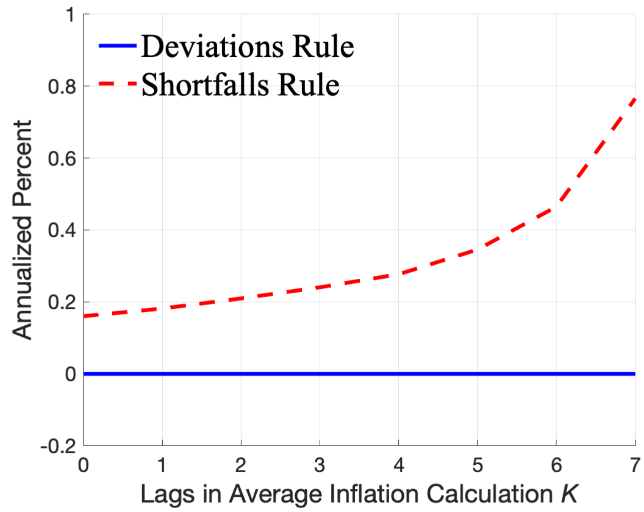
$$i_t = \begin{cases} \phi_\pi \pi_t^a + \phi_u u_t & \text{if } u_t \geq 0 \\ \phi_\pi \pi_t^a & \text{if } u_t < 0, \end{cases} \tag{39}$$

Equations (38) and (39) model the adoption of an average inflation targeting framework under both a deviations and and shortfalls approach to stabilizing the labor market. These specifications also nest our previous policy rules when $K = 0$ which implies policymakers only respond to current inflation. Figure 7 illustrates the results for average inflation if we resolve our model from Section 2 using Equations (38) and (39) under different values of $K$. When $K = 0$, we recover our previous results from Section 2.

The quantitative effects of adopting a shortfalls rule increase under longer look-back periods in the average inflation targeting. Setting the look-back period to roughly 1.5 years ($K = 5$), the inflationary impact of adopting a shortfalls stabilizing rule is roughly twice as large. Moreover, the quantitative impact increases nonlinearly as the look-back period increases in the calculation of average inflation.

[14] This parsimonious formulation of average inflation targeting using an exponential moving average adds only a single variable to the model. Alternatively, using a simple arithmetic average adds one state variable for each lag of inflation, which would be infeasible using our global solution method. Budianto, Nakata and Schmidt (2023) follows a similar approach in their recent study of average inflation targeting.

Figure 7: Average Inflation Under Flexible Average Inflation Targeting




Notes: $K = 0$ corresponds to our previous results in which only current inflation appears in the central bank's policy rule. For this exercise, we set $\phi_\pi = 1.5$ and $\phi_u = -0.25$.

Increasing the look-back period by acts like a reduction in the central bank's response to current inflation, amplifying the inflationary impact of adopting a shortfalls rule. Substituting Equation (37) into Equation (39) illustrates this result:

$$i_t = \begin{cases} \phi_\pi \left(\frac{K}{K+1}\right) \pi^a_{t-1} + \phi_\pi \left(\frac{1}{K+1}\right) \pi_t + \phi_u u_t & \text{if } u_t \geq 0 \\ \phi_\pi \left(\frac{K}{K+1}\right) \pi^a_{t-1} + \phi_\pi \left(\frac{1}{K+1}\right) \pi_t & \text{if } u_t < 0. \end{cases} \tag{40}$$

Since the coefficient on current inflation is now $\phi_\pi \left(\frac{1}{K+1}\right)$ and decreasing in $K$, an increase in the look-back period effectively lowers the central bank's response to current inflation. Our results for average inflation targeting in Figure 7 look similar to the middle row of Figure 2, which highlighted that a smaller reaction to inflation fluctuations $\phi_\pi$ also results in higher average inflation and policy rates under the shortfalls rule. Thus, our model suggests that the key quantitative results regarding the shortfalls rule are either unchanged or amplified if we incorporate average inflation targeting into our analysis. However, given its policy importance, we acknowledge that further research is needed to further explore the interactions between all the elements of the FOMC's 2020 adoption of its new framework.

# 7 Conclusion & Possible Areas for Future Research

The Federal Open Market Committee recently revised its consensus statement indicating it seeks "over time to mitigate shortfalls of employment from the Committee's assessment of its maximum level ..." In contrast, the previous statement cited a desire to stabilize "deviations" of employment from its maximum level. In this paper, we analyze the possible inflation and employment outcomes of this policy change using two theoretical frameworks. We show that adopting a shortfalls-stabilization policy may have quantitatively important implications for longer-run average outcomes for inflation and nominal rates, observed business-cycle correlations, and the potential for the zero lower bound to constrain policy actions.

We believe our results suggests to additional implications for future research. First, given that different monetary policy strategies can substantially affect inflation and unemployment dynamics, more research may be needed to further explore the interactions of all elements of the FOMC's new framework. Second, the asymmetric reaction function embedded in the FOMC's new employment objective suggests that global solution methods may be necessary tools to fully examine the effects of the FOMC's new framework.

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# Appendix

## A Measuring Full Employment

The FOMC's newly adopted consensus statement explicitly states that full employment cannot be summarized by a single statistic. However, public communications by members of the FOMC often reference the unemployment rate as a benchmark indicator for the labor market.

The employment-to-population ratio is an often discussed alternative indicator for the health of the labor market from the perspective of assessing the distance from a full employment objective. However, policymakers and economists equally discuss challenges associated with using the employment-to-population ratio as a measure of maximum employment. One concern is the clear downward trend in overall labor force participation caused by an aging workforce (see Aaronson et al., 2014, Krueger, 2017). That said, the Committee has discussed in the past and we show next, once an adjustment is made for the aging of the population, the employment-to-population ratio and unemployment rate convey a very similar degree of tightness in the labor market across time.[15]

The share of the working age population 55 years of age and older increased from 27% in 2000 to 37% in 2019. And while the employment-to-population ratio for this age group increased from about 32 to 40 percent between 2000 and 2008, stabilizing thereafter, it remains significantly below that of 25 to 54 year olds with rates around 83%. A standard approach to address the effect on the overall employment-to-population ratio of an aging population is to keep the population shares of different age groups fixed at a reference date. In this instance, we use the age groupings of 16 to 24, 25 to 34, 35 to 44, 45 to 54, 55 and older, and build a counterfactual, age-adjusted employment-to-population ratio as:

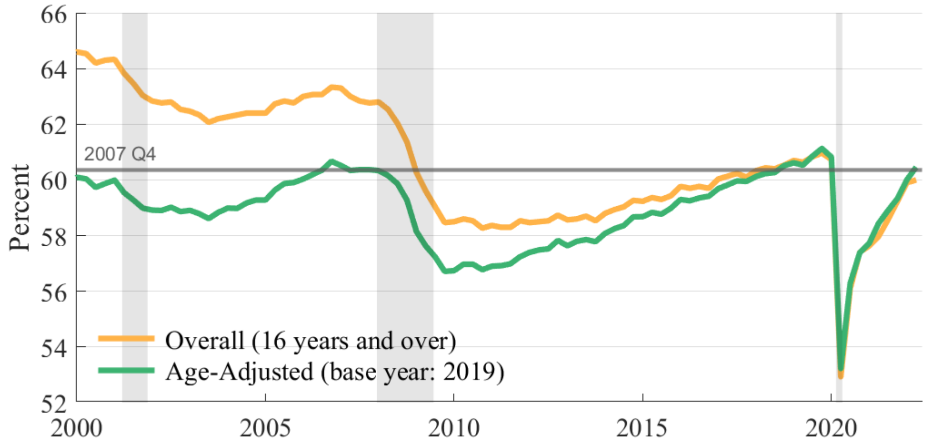
$$\widetilde{epop}(t) = \sum_i \omega(i, t_0) \times epop(i, t)$$

where $\omega(i, t_0)$ is the population share of age group $i$ at a base date $t_0$ and $epop(i, t)$ is the employment-to-population ratio of group $i$ at date $t$. By construction $\widetilde{epop}(t_0) = epop(t_0)$. Figure (A.1a) plots the actual and age-composition adjusted employment-to-population ra-

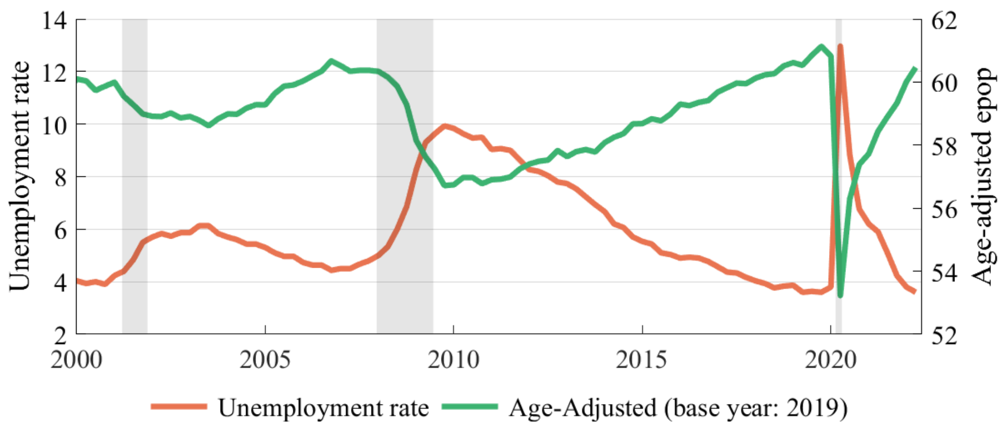
[15] For instance, the minutes from the Sept. 2019 meeting of the FOMC indicate participants focused on trends in labor force participation of prime age workers for the purpose of separating out the issue of an aging population. The minutes from the April 2019 meeting of the FOMC stated, "Participants agreed that labor market conditions remained strong [...] and, while the labor force participation rate moved down a touch, it remained high relative to estimates of its underlying demographically driven, downward trend."

Figure A.1: Measuring Labor Market Tightness:
Age-Adjusted Employment-to-Population Ratios and the Unemployment Rate

(a) Actual and Age-Adjusted Employment-to-Population Ratio




(b) Unemployment Rate and Age-Adjusted Employment-to-Population Ratio




tios over the last 25 years. We select 2019Q4 as the reference date which implies that the age-adjusted employment-to-population ratio in green is lower than the actual overall employment to population ratio in yellow prior to 2019. Moreover, the level in 2019 is now similar to that at the end of 2017, just prior to the Great Recession (this is indicated by the horizontal solid gray line).

Once we adjust for the age-composition of the population, there no longer appears to be a longer run downward trend of the employment-to-population ratio. Moreover, as Figure A.1b makes clear, the the employment-to-population ratio and unemployment rate convey a very similar degree of tightness in the labor market. The movements in each series closely mirror each other (the series are highly correlated at $-0.85$), signaling a similar degree of tightness in the labor market at a particular point in time.

# B Additional Results Using a Textbook Model

## B.1 Analytical Implications of Adopting a Shortfalls Rule

Using a simplified process for the natural rate $r_t^n$, we can use a three-period version of the model in Equations (4) and (5) to analytically highlight the macroeconomic effects if the central bank chooses to adopt the one-sided shortfalls rule versus the symmetric deviations rule. Suppose that the natural rate $r_t^n$ takes either a positive value $\Delta$ or a negative value $-\Delta$ in period 2. Both outcomes occur with a probability of 1/2. Furthermore, assume that the natural rate takes a value of 0 in periods 1 and 3.

Beginning first with the outcomes under the deviations rule in Equation (6), we solve the model backwards in time to determine the paths for unemployment and inflation. Since the natural rate equals zero in period 3 (and the model economy ceases to exist after that period), this implies $u_3 = \pi_3 = 0$. Since households and firms fully understand this outcome for certain, we know $E_2\,\pi_3 = 0$ and $E_2\,u_3 = 0$. Then, we solve for unemployment and inflation in period 2 depending on if the economy experiences the positive ($\Delta$) or negative ($-\Delta$) outcome:

$$u_2^{\Delta} = -\frac{1}{c}\left(\frac{1}{1+\phi_\pi\varphi - \phi_u/c}\right)\Delta \qquad u_2^{-\Delta} = \frac{1}{c}\left(\frac{1}{1+\phi_\pi\varphi - \phi_u/c}\right)\Delta$$

$$\pi_2^{\Delta} = \left(\frac{\varphi}{1+\phi_\pi\varphi - \phi_u/c}\right)\Delta \qquad \pi_2^{-\Delta} = -\left(\frac{\varphi}{1+\phi_\pi\varphi - \phi_u/c}\right)\Delta$$

In an expansion ($\Delta$), the economy experiences low unemployment and above target inflation. The magnitude of these fluctuations depend on the size of the shock $\Delta$, the slope of the Phillips curve $\varphi$, the assumed Okun's Law relation $c$, as well as the central bank's response of inflation $\phi_\pi$ and unemployment $\phi_u$. In blue, we highlight parts of the solution that will play a key role in the coming analysis. Note that the solutions to unemployment and inflation in an expansion ($\Delta$) are simply the symmetric inverse of the outcomes in a contraction ($-\Delta$). Using these possible solutions in period 2, we can compute expectations of unemployment and inflation in the period prior to the shock occurring:

$$E_1 u_2 = \frac{1}{2}\left(u_2^{\Delta}\right) + \frac{1}{2}\left(u_2^{-\Delta}\right) = 0,$$

$$E_1 \pi_2 = \frac{1}{2}\left(\pi_2^{\Delta}\right) + \frac{1}{2}\left(\pi_2^{-\Delta}\right) = 0,$$

Continuing to solve backward, since $r_1^n = 0$, $E_1 u_2 = 0$, & $E_1 \pi_2 = 0$, then it follows that $u_1 = 0$ & $\pi_1 = 0$ under the symmetric deviations rule.

However, if policy instead follows the shortfalls rule in Equation (7), we find the same outcomes after the shock occurs in period 3 ($\pi_3 = u_3 = 0$ and $E_2\,\pi_3 = E_2\,u_3 = 0$), but now the solutions in period 2 are no longer symmetric inverses (differences in red):

$$u_2^{\Delta} = -\frac{1}{c}\left(\frac{1}{1+\phi_\pi\varphi}\right)\Delta \qquad u_2^{-\Delta} = \frac{1}{c}\left(\frac{1}{1+\phi_\pi\varphi-\phi_u/c}\right)\Delta$$
$$\pi_2^{\Delta} = \left(\frac{\varphi}{1+\phi_\pi\varphi}\right)\Delta \qquad \pi_2^{-\Delta} = -\left(\frac{\varphi}{1+\phi_\pi\varphi-\phi_u/c}\right)\Delta$$

By not leaning directly against the labor market in good times, the economy experiences larger fluctuations in unemployment and inflation in the expansionary state. If the economy instead experiences a contraction, the outcomes for unemployment and inflation are the same under both the deviations and shortfalls rules. Given these outcomes (and recall $\phi_u < 0$), we can solve for expectations in period 1 under the shortfalls rule.

$$\begin{aligned}
E_1 u_2 &= \frac{1}{2}\left(u_2^{\Delta}\right) + \frac{1}{2}\left(u_2^{-\Delta}\right) \\
&= \frac{1}{2\,c^2}\,\frac{1}{(1+\phi_\pi\varphi)\,(1+1\phi_\pi\varphi-\phi_u/c)}\,\phi_u\,\Delta < 0 \\
E_1 \pi_2 &= \frac{1}{2}\left(\pi_2^{\Delta}\right) + \frac{1}{2}\left(\pi_2^{-\Delta}\right) \\
&= -\frac{1}{2\,c}\,\frac{\varphi}{(1+\phi_\pi\varphi)\,(1+1\phi_\pi\varphi-\phi_u/c)}\,\phi_u\,\Delta > 0
\end{aligned}$$

Under the shortfalls rule, expectations of more accommodative policy in expansions leads to higher inflation and lower unemployment. Since $r_1^n = 0$ and $E_1 u_2 < 0$, we know that $u_1 < 0$ in the shortfalls rule. So, we can solve for outcomes in period 1:

$$\begin{aligned}
u_1 &= \frac{1}{2\,c^2}\,\frac{1-\varphi\,(\phi_\pi\beta-1)}{(1+\phi_\pi\varphi)^2\,(1+\phi_\pi\varphi-\phi_u/c)}\,\phi_u\,\Delta < 0 \\
\pi_1 &= -\frac{1}{2\,c^2}\,\frac{\varphi\,(1+\beta+\varphi)}{(1+\phi_\pi\varphi)^2\,(1+\phi_\pi\varphi-\phi_u/c)}\,\phi_u\,\Delta > 0
\end{aligned}$$

Even without shocks in period 1, the economy experiences higher inflation and lower unemployment under the shortfalls rule despite the symmetric shocks hitting the economy.

## B.2 Shortfalls Rule in a Model of Bounded Rationality

A recent criticism of the standard New Keynesian model in Equations (1) and (2) that we use in Section 2 is that it assumes too much forward-looking behavior by households and firms. In this section, we shows that the effects of adopting the shortfalls rule remain important for macroeconomic outcomes even in a model of bounded rationality, which tempers the response of current outcomes to expectations far in the future. Specifically, Gabaix (2020) derives a behavioral New-Keynesian model that introduces two additional parameters:

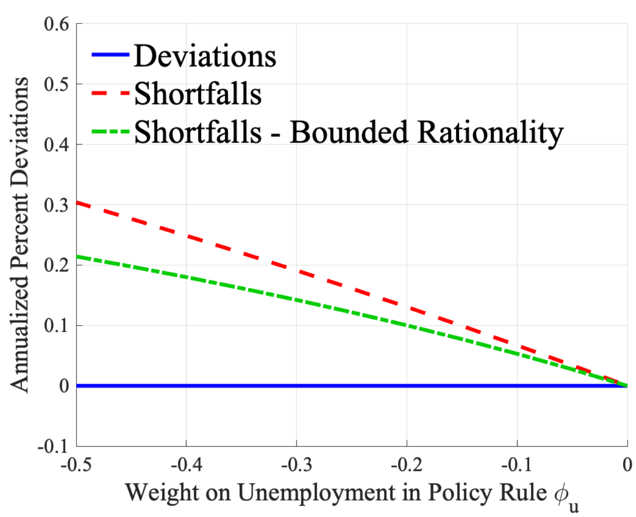
$$x_t = E_t\, m^h\, x_{t+1} - \Big( i_t - E_t\, \pi_{t+1} - r_t^n \Big),$$

$$\pi_t = \beta\, E_t\, m^f\, \pi_{t+1} + \varphi\, x_t,$$

where $m^h$ and $m^f$ control the sensitivity of current outcomes to future expectations for households ($h$) and firms ($f$). When $m^h = m^f = 1$, the model collapses back to the standard case we use in Section 2. To examine the effect of adopting a shortfalls rule in this model of bounded rationality, we redo the exercise in the top panel of Figure 2 in the main text using a calibration of $m^h = m^f = 0.9$. Figure B.1 shows that the assumption of bounded rationality only modestly reduces the quantitative impact of adoption a shortfalls rule. Thus, our key conclusions about the possible effects of adopting a shortfalls rule are robust to alternative assumptions on the forward-looking behavior of households and firms.

Figure B.1: Average Inflation Under Shortfalls Rule in Model of Bounded Rationality

(a) Varying Weight on Unemployment Gap $\phi_u$




Note: Panel (a) sets $\phi_\pi = 1.5$ and varies the value of the weight on unemployment $\phi_u$. In the bounded rationality model of Gabaix (2020), we set $m^h = m^f = 0.9$.

# C Derivation & Results of the Quantitative Model

## C.1 Notes on the Form of the Monetary Policy Rule

In this section, we provide some additional discussion on the mapping between the policy rules in log deviations from Section 2 versus the levels specification we use in solving the model of Section 3. Consider the *deviations* monetary policy rule for the gross nominal rate in the absence of a zero lower bound:

$$R_t = \; R^r \Pi \left(\frac{\Pi_t}{\Pi^*}\right)^{\widehat{\phi}_\pi} \left(\frac{U_t}{U^*}\right)^{\widehat{\phi}_u} \tag{C.1}$$

where $R^r$ is the real gross rate. The coefficient $\widehat{\phi}_\pi$ and $\widehat{\phi}_u$ correspond to the elasticities of $R_t$ to inflation $\Pi_t$ and $U_t$, respectively $((\partial R_t/\partial \Pi_t)\,(\Pi_t/R_t) = \widehat{\phi}_\pi)$.

Take the log of (C.1):

$$\log(R_t) = \log(R^r) + \log(\Pi) + \widehat{\phi}_\pi \log\left(\frac{\Pi_t}{\Pi^*}\right) + \widehat{\phi}_u \log\left(\frac{U_t}{U^*}\right) \tag{C.2}$$

Using the approximation for $|x| < 1$, $\log(1+x) \approx x$, we have $\log\left(\frac{\Pi_t}{\Pi^*}\right) \approx \frac{\Pi_t - \Pi^*}{\Pi^*}$ and $\log\left(\frac{U_t}{U^*}\right) \approx \frac{U_t - U^*}{U^*}$, such that the previous expression may be approximately rewritten as :

$$R_t = r^r + \pi + \frac{\widehat{\phi}_\pi}{\Pi^*}\left(\pi_t - \pi^*\right) + \frac{\widehat{\phi}_u}{U^*}\left(U_t - U^*\right) \tag{C.3}$$

The empirical literature estimates Taylor-type rules for the central bank policy setting often use a specification of the type described by (C.3) to obtain values of $\phi_\pi = \frac{\widehat{\phi}_\pi}{\pi^*}$ and $\phi_u = \frac{\widehat{\phi}_u}{U^*}$ .

## C.2 Derivation of Match Surplus & Bargained Hours & Wage

This section provides additional detail on key derivations involving the labor market.

### C.2.1 Wholesale Sector Firm and Worker Marginal Values & Match Surplus

Write the firm's value function as

$$S_t^w = \psi_t X_t N_t H_t^\alpha - W_t N_t H_t - \kappa_t V_t + E_t\left[M_{t,t+1} S_{t+1}^w\right] + \lambda_t^V q(\theta_t) V_t.$$

The optimality condition of this problem guarantees that

$$S_{Vt}^{w} \equiv \frac{\partial S_t^w}{\partial V_t} = 0. \tag{C.4}$$

The marginal value of a hired worker is obtained from differentiating the firm's value function with respect to $N_t$, using the law of motion for employment and the definition of the household's stochastic discount factor:

$$\begin{aligned} S_{Nt}^{w} &= \psi_t X_t H_t^{\alpha} - W_t H_t + E_t\left[M_{t,t+1}\left[S_{Nt+1}^{w}\frac{\partial N_{t+1}}{\partial N_t}\right]\right] \\ S_{Nt}^{w} &= \psi_t X_t H_t^{\alpha} - W_t H_t + (1-s)\beta E_t\left[\frac{\lambda_{t+1}^C}{\lambda_t^C} S_{Nt+1}^{w}\right] \end{aligned} \tag{C.5}$$

The household's problem (14) is described by:

$$\begin{aligned} J_t &= \mathcal{U}\left(C_t, H_t, N_t\right) + \nu_u U_t + \beta E_t\left[J_{t+1}\right] \\ &\quad + \lambda_t^C\left[\frac{B_{t-1}}{P_t} + W_t\, H_t\, N_t + b\, U_t + D_t - C_t - T_t - \frac{B_t}{P_t R_t}\right] \end{aligned}$$

and the laws of motion for employment, unemployment. We consider the case for household preferences over consumption and hours worked:

$$\mathcal{U}\left(C_t, H_t, N_t\right) = \exp(\gamma_t)\frac{C_t^{1-\sigma}}{1-\sigma} + \nu_0\frac{\left(1-H_t\right)^{1-\nu_1}}{1-\nu_1} N_t \tag{C.6}$$

Differentiating the household's value function, we obtain the marginal values of an employed and unemployed worker to the representative household:

$$\begin{aligned} J_{N,t} &= \frac{\partial \mathcal{U}(\cdot)}{\partial N_t} + \lambda_t^C W_t H_t + \beta E_t\left[(1-s) J_{N,t+1} + s J_{U,t+1}\right] \\ J_{U,t} &= \frac{\partial \mathcal{U}(\cdot)}{\partial U_t} + \lambda_t^C b + \beta E_t\left[f_t J_{N,t+1} + (1-f_t) J_{U,t+1}\right] \end{aligned}$$

The marginal benefit being employed over unemployment is:

$$J_{N,t} - J_{U,t} = \lambda_t^C W_t H_t - \left(\lambda_t^C b + \frac{\partial \mathcal{U}(\cdot)}{\partial U_t} - \frac{\partial \mathcal{U}(\cdot)}{\partial N_t}\right) + \left(1 - f_t - s\right)\beta E_t\left[J_{N,t+1} - J_{U,t+1}\right]$$

for a match surplus to the household:

$$\frac{J_{N,t} - J_{U,t}}{\lambda_t^C} = W_t H_t - Z_t + \left(1 - f_t - s\right)\beta\frac{\lambda_{t+1}^C}{\lambda_t^C} E_t\left[\frac{J_{N,t+1} - J_{U,t+1}}{\lambda_{t+1}^C}\right]$$

where

$$Z_t \;=\; b + \frac{1}{\lambda_t^C}\left(\frac{\partial \mathcal{U}(\cdot)}{\partial U_t} - \frac{\partial \mathcal{U}(\cdot)}{\partial N_t}\right) = b + \frac{1}{\lambda_t^C}\left(\nu_u - \nu_0 \frac{(1-H_t)^{1-\nu_1}}{1-\nu_1}\right)$$

### C.2.2 Wages and hours

Firms and workers engage in pairwise Nash bargaining over wages and hours each period. Equilibrium wages and hours solve the problem

$$\Lambda_t = \max_{W_t, H_t} \left(\frac{J_{Nt} - J_{Ut}}{\lambda_t^C}\right)^{\eta} \left(S_{N,t}^w - S_{V,t}^w\right)^{1-\eta}$$

After first taking the log of the problem the first order condition for the wage is:

$$\begin{aligned}
\frac{\partial \Lambda_t}{\partial W_t} &= \eta \frac{\lambda_t^C}{J_{N,t} - J_{U,t}} \frac{\partial (J_{N,t} - J_{U,t})}{\partial W_t} + (1-\eta)\frac{1}{S_{N,t}^w}\frac{\partial S_{N,t}^w}{\partial W_t} = 0 \\
\frac{\partial \Lambda_t}{\partial W_t} &= \eta \frac{\lambda_t^C}{J_{N,t} - J_{U,t}} H_t - (1-\eta)\frac{1}{S_{N,t}^w} H_t = 0 \\
\Rightarrow \; (1-\eta)\frac{J_{N,t} - J_{U,t}}{\lambda_t^C} &= \eta S_{N,t}^w
\end{aligned} \tag{C.7}$$

while the first order condition for hours is :

$$\begin{aligned}
\frac{\partial \Lambda_t}{\partial H_t} &= \eta \frac{\lambda_t^C}{J_{N,t} - J_{U,t}} \frac{\partial (J_{N,t} - J_{U,t})}{\partial H_t} + (1-\eta)\frac{1}{S_{N,t}^w}\frac{\partial S_{N,t}^w}{\partial H_t} = 0 \\
&= \eta \frac{\lambda_t^C}{J_{N,t} - J_{U,t}} \left(W_t - \frac{\partial Z_t}{\partial H_t}\right) + (1-\eta)\frac{1}{S_{N,t}^w}\left(\alpha \psi_t X_t H_t^{\alpha-1} - W_t\right) = 0 \\
&= \eta \frac{\lambda_t^C}{J_{N,t} - J_{U,t}} \left(-\frac{\partial Z_t}{\partial H_t}\right) + (1-\eta)\frac{1}{S_{N,t}^w}\left(\alpha \psi_t X_t H_t^{\alpha-1}\right) = 0 \\
&= \left(-\frac{\partial Z_t}{\partial H_t}\right) + \left(\alpha \psi_t X_t H_t^{\alpha-1}\right) = 0
\end{aligned}$$

which results in, depending on the assumption made for $\mathcal{U}()$ on either:

$$\frac{\nu_0}{\lambda_t^C}(1-H_t)^{-\nu_1} \;=\; \alpha \psi_t X_t H_t^{\alpha-1} \tag{C.8}$$

$$\nu_0 (1-H_t)^{-\nu_1} \;=\; \alpha \psi_t X_t H_t^{\alpha-1} \tag{C.9}$$

To derive the wage:

$$
\begin{aligned}
(1-\eta)\frac{J_{N,t}-J_{U,t}}{\lambda_t^C} &= \eta S_{N,t}^w \\
(1-\eta)\left[W_tH_t - Z_t + (1-f_t-s)\,\beta\frac{\lambda_{t+1}^C}{\lambda_t^C}E_t\left[\frac{J_{N,t+1}-J_{U,t+1}}{\lambda_{t+1}^C}\right]\right] &= \eta\left[\psi_t X_t H_t^\alpha - W_tH_t\right. \\
&\quad \left.+(1-s)\beta E_t\frac{\lambda_{t+1}^C}{\lambda_t^C}S_{Nt+1}^w\right] \\
(1-\eta)\left[W_tH_t - Z_t + (1-f_t-s)\,\beta\frac{\lambda_{t+1}^C}{\lambda_t^C}E_t\left[\frac{J_{N,t+1}-J_{U,t+1}}{\lambda_{t+1}^C}\right]\right] &= \eta\left[\psi_t X_t H_t^\alpha - W_tH_t\right. \\
&\quad \left.+(1-s)\beta E_t\frac{\lambda_{t+1}^C}{\lambda_t^C}S_{Nt+1}^w\right] \\
(1-\eta)\left[W_tH_t - Z_t - f_t\beta\frac{\lambda_{t+1}^C}{\lambda_t^C}E_t\left[\frac{J_{N,t+1}-J_{U,t+1}}{\lambda_{t+1}^C}\right]\right] &= \eta\left[\psi_t X_t H_t^\alpha - W_tH_t\right]
\end{aligned}
$$

$$
\begin{aligned}
W_tH_t &= \eta\alpha\psi_t X_t N_t^{\alpha-1}H_t^\alpha + (1-\eta)Z_t + (1-\eta)f_t\beta\frac{\lambda_{t+1}^C}{\lambda_t^C}E_t\left[\frac{J_{N,t+1}-J_{U,t+1}}{\lambda_{t+1}^C}\right] \\
W_tH_t &= \eta\psi_t X_t H_t^\alpha + (1-\eta)Z_t + \eta f_t\beta\frac{\lambda_{t+1}^C}{\lambda_t^C}E_t\left[S_{N,t+1}^w\right] \\
W_tH_t &= \eta\psi_t X_t H_t^\alpha + (1-\eta)Z_t + \eta f_t\left(\frac{\kappa_t}{q(\theta_t)-\lambda_t}\right) \\
W_tH_t &= \eta\left[\psi_t X_t H_t^\alpha + \kappa_t\theta_t\right] + (1-\eta)Z_t \qquad \text{(C.10)}
\end{aligned}
$$

## C.3 Summary of the Quantitative Model

The model's 17 endogenous variables, $N_t$, $U_t$, $H_t$, $V_t$, $\theta_t$, $q$, $f$, $W_t$, $M_t$, $\lambda_t^C$, $Z_t$, $Y_t$, $C_t$, $\psi_t$, $\Pi_t$, $\kappa_t$, $R_t$, are determined by the 17 equations that follow (ignoring the conditions for the Lagrange multiplier on the non-negativity constraint $\lambda_t^V$):

$$\psi_t = \frac{\omega-1}{\omega} + \frac{\Omega}{\omega}\left[\frac{\Pi_t}{\Pi}\left(\frac{\Pi_t}{\Pi}-1\right) - E_t M_{t,t+1}\frac{Y_{t+1}}{Y_t}\frac{\Pi_{t+1}}{\Pi}\left(\frac{\Pi_{t+1}}{\Pi}-1\right)\right] \tag{C.11}$$

$$\frac{\kappa_t}{q(\theta_t)} - \lambda_t^V = E_t\left[M_{t,t+1}\left[\psi_{t+1}X_{t+1}H_{t+1}^{\alpha} - W_{t+1}H_{t+1} + (1-s)\left[\frac{\kappa_{t+1}}{q(\theta_{t+1})} - \lambda_{t+1}\right]\right]\right] \tag{C.12}$$

$$W_t H_t = \eta\left[\psi_t X_t H_t^{\alpha} + \kappa_t\theta_t\right] + (1-\eta)Z_t \tag{C.13}$$

$$Z_t = b + \frac{1}{\lambda_t^C}\left(\nu_u - \nu_0\frac{(1-H_t)^{1-\nu_1}}{1-\nu_1}\right) \tag{C.14}$$

$$\frac{\nu_0}{\lambda_t^C}(1-H_t)^{-\nu_1} = \alpha\psi_t X_t H_t^{\alpha-1} \tag{C.15}$$

$$\lambda_t^C = exp(\gamma_t)C_t^{-\sigma} \tag{C.16}$$

$$1 = E_t\left[M_{t,t+1}\frac{R_t}{\Pi_{t+1}}\right] \tag{C.17}$$

$$M_{t,t+1} = \beta\left(\frac{\lambda_{t+1}^C}{\lambda_t^C}\right) \tag{C.18}$$

$$Y_t = C_t + \kappa_t V_t + \frac{\Omega}{2}\left(\frac{\Pi_t}{\Pi}-1\right)^2 Y_t \tag{C.19}$$

$$Y_t = X_t N_t H_t^{\alpha} \tag{C.20}$$

$$\kappa_t = \kappa_0 + \kappa_1 q_t \tag{C.21}$$

$$\theta_t = \frac{V_t}{U_t} \tag{C.22}$$

$$N_{t+1} = (1-s)N_t + q(\theta_t)V_t \tag{C.23}$$

$$U_t = 1 - N_t \tag{C.24}$$

$$q_t = \frac{1}{(1+\theta_t^{\iota})^{1/\iota}} \tag{C.25}$$

$$f_t = \frac{1}{\left(1+\theta_t^{-\iota}\right)^{1/\iota}} \tag{C.26}$$

$$\text{Deviations rule:} \qquad R_t = \max\left[1, \quad R\left(\frac{\Pi_t}{\Pi^*}\right)^{\widehat{\phi}_\pi}\left(\frac{U_t}{U^*}\right)^{\widehat{\phi}_u}\right] \tag{C.27}$$

$$\text{Shortfalls rule:} \qquad R_t = \max\left[1, \quad R\left(\frac{\Pi_t}{\Pi^*}\right)^{\widehat{\phi}_\pi}\left(\max\left[1, \frac{U_t}{U^*}\right]\right)^{\widehat{\phi}_u}\right] \tag{C.28}$$

The competitive equilibrium in the economy consists of vacancy posting, $V_t \geq 0$; hours per worker $H_t$; multiplier, $\lambda_t^{V,\star} \geq 0$; consumption, $C_t^{\star}$; prices $\Pi_t$ and $\psi_t$; and nominal interest rate $R_t^{N\star}$; such that (i) $V_t$, $H_t^{\star}$ and $\lambda_t^{V,\star}$ satisfy the intertemporal job creation condition and the Kuhn-Tucker conditions, while taking the stochastic discount factor and the hours and wage equations as given; (ii) $C_t$, satisfies the intertemporal consumption-portfolio choice conditions; (iii) the retail price setting satisfies optimality condition; (iv) the desired nominal rate follows either the deviations or the shortfalls rule; (v) the nominal policy rate satisfies the zero lower bound constraint, and (vi) the goods markets clears.

## C.4 Computation

We adopt the globally nonlinear projection algorithm in Petrosky-Nadeau and Zhang (2017). In particular, given the state variables summarized in $\Gamma_t = \{x_t, \gamma_t, N_t\}$, we need to solve for the labor market tightness, $\theta_t = \theta(\Gamma_t)$, the multiplier function, $\lambda^V_t = \lambda^V(\Gamma_t)$, hours worked on the job, $H_t = H(\Gamma_t)$, intermediate input cost, $\psi_t = \psi(\Gamma_t)$, and inflation, $\Pi_t = \Pi(\Gamma_t)$ from the following five functional equations:

$$
\begin{aligned}
\frac{\kappa_t}{q(\theta(\Gamma_t))} - \lambda^V(\Gamma_t) &= E_t\left[M_{t,t+1}\left[\psi(\Gamma_{t+1})X_{t+1}H(\Gamma_{t+1})^\alpha - W_{t+1}H(\Gamma_{t+1})\right.\right. \\
&\quad \left.\left. +(1-s)\left[\frac{\kappa_{t+1}}{q(\theta(\Gamma_{t+1}))} - \lambda_{t+1}\right]\right]\right] \qquad \text{(C.29)} \\
\psi(\Gamma_t) &= \frac{\omega-1}{\omega} + \frac{\Omega}{\omega}\left[\frac{\Pi(\Gamma_t)}{\Pi}\left(\frac{\Pi(\Gamma_t)}{\Pi} - 1\right)\right. \\
&\quad \left. -E_t M_{t,t+1}\frac{Y_{t+1}}{Y_t}\frac{\Pi(\Gamma_{t+1})}{\Pi}\left(\frac{\Pi(\Gamma_{t+1})}{\Pi} - 1\right)\right] \qquad \text{(C.30)} \\
\frac{\nu_0}{\lambda^C_t}\left(1 - H(\Gamma_t)\right)^{-\nu_1} &= \alpha\psi(\Gamma_t)X_t H(\Gamma_t)^{\alpha-1} \\
1 &= E_t\left[M_{t,t+1}\frac{R_t}{\Pi(\Gamma_{t+1})}\right] \qquad \text{(C.31)}
\end{aligned}
$$

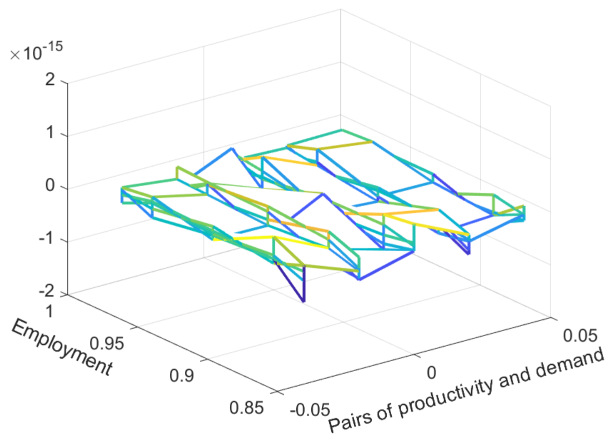
In addition, $\theta(\Gamma_t)$ and $\lambda^V(\Gamma_t)$ must also satisfy the Kuhn-Tucker conditions.

Rather than separately parameterizing $\theta(\Gamma_t)$ and $\lambda^V(\Gamma_t)$, we follow the approach in Christiano and Fisher and parameterize the conditional expectation in the right hand side of equation (C.29) a $\mathcal{E} \equiv \mathcal{E}(\Gamma_t)$. Specifically, after obtaining the parameterized $\mathcal{E}_t$, we first calculate $\tilde{q}(\theta_t) \equiv \kappa_t/\mathcal{E}_t$. If $\tilde{q}(\theta_t) < 1$, the nonnegativity constraint is not binding, we set $\lambda^V_t = 0$ and $q(\theta_t) = \tilde{q}(\theta_t)$. We then solve $\theta_t = q^{-1}(\tilde{q}(\theta_t))$, in which $q^{-1}(\cdot)$ is the inverse function of $q(\cdot)$ from equation (19), and $V_t = \theta_t(1-N_t)$. If $\tilde{q}(\theta_t) \geq 1$, the nonnegativity constraint is binding, we set $V_t = 0$, $\theta_t = 0$, $q(\theta_t) = 1$, and $\lambda^V_t = \kappa_t - \mathcal{E}_t$. We approximate the log productivity and the preference shock process, $x_t$ and $\gamma_t$, with the discrete state space method of Rouwenhorst (1995). We use 25 grid points to cover pairs of values of $x_t$ and $\gamma_t$. We use extensively the approximation toolkit in the Miranda and Fackler (2002) CompEcon Toolbox in Matlab and the model's steady state as an initial guess.

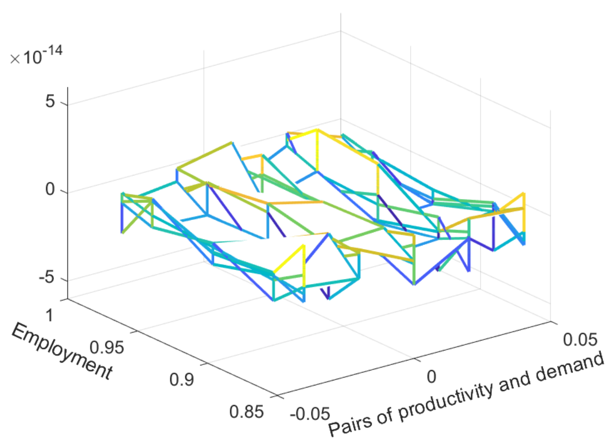
Figure C.1 reports the errors in the functional equation (A.29) through (A.31). The errors are extremely small, suggesting an accurate solution. See Petrosky-Nadeau and Zhang (2017) for more technical details on the global algorithm.

Figure C.1: Policy Function Approximation Errors

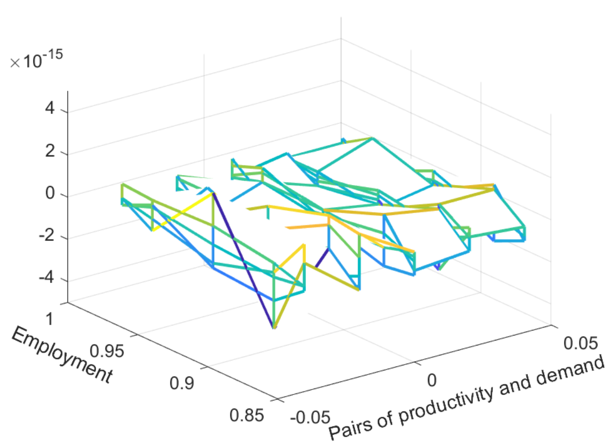
(a) Job creation condition




(b) Optimal price equation

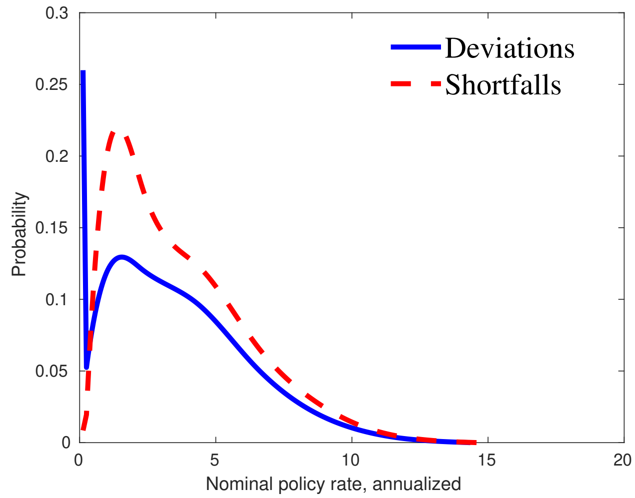



(c) Equilbrium hours condition



## C.5 Additional Policy Functions and Simulation Results

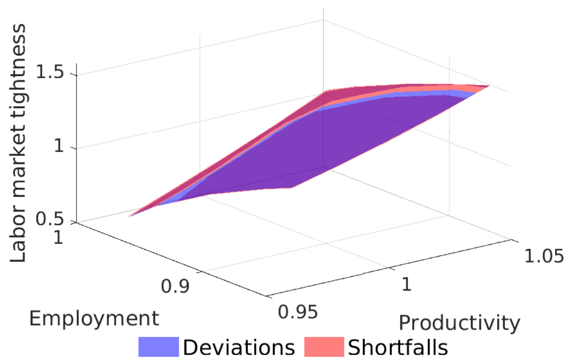
Figure C.2: Model-Implied Stationary Distributions Under Deviations & Shortfalls Rules



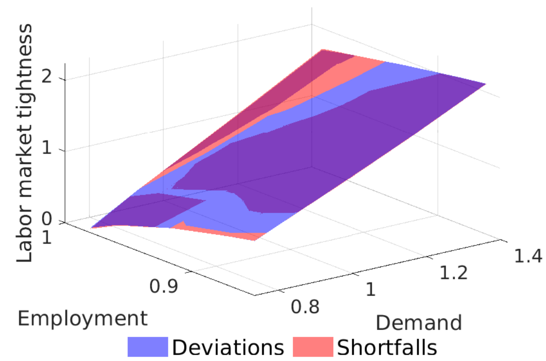

Note: Model distributions obtain from 10,000 simulations of 300 periods, equal to the number of months in the data sample. Vertical lines correspond to sample means of the respective variables.

Figure C.3: Model economy policy function for labor market tightness, hours per worker and inflations under deviation and shortfall policy rules

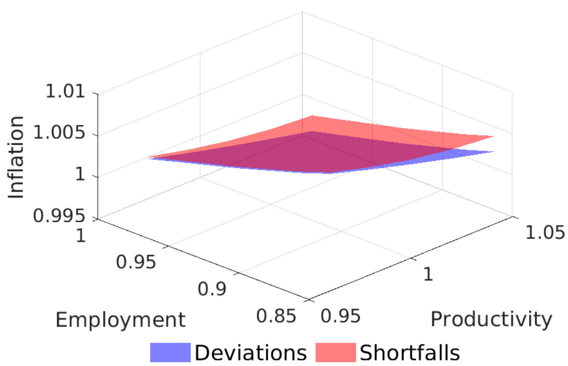
(a) Labor market tightness and productivity



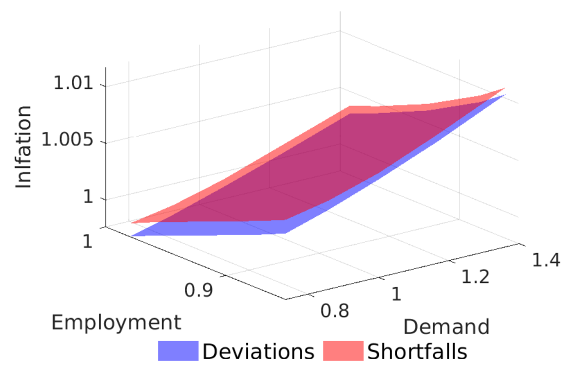

(b) Labor market tightness and demand



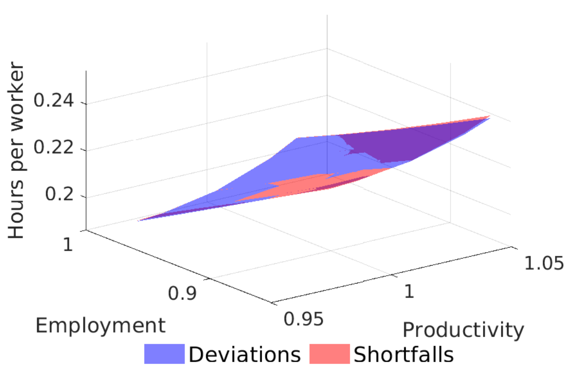

(c) Inflation and productivity



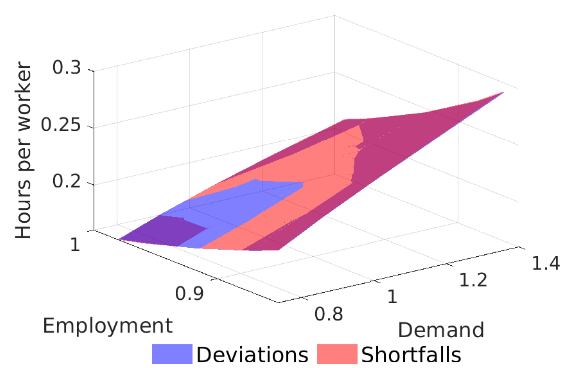

(d) Inflation and demand




(e) Hours per worker and productivity




(f) Hours per worker and demand



# D Data

The sources for the empirical data, and their transformations, are as follows.

**Unemployment rate:** Unemployment rate for the civilian population, 16 years old and over, monthly, seasonally adjusted. Obtained from FRED II, series ID UNRATE. The monthly series spans from Jan. 1948 to March 2021. Converted to quarterly by three-month averaging.

**Fed Funds rate:** Effective Federal Funds rate, percent, monthly, NSA. Obtained from FRED II, series ID FEDFUNDS. The monthly series spans from July 1954 to Jan. 2021. Converted to quarterly by three-month averaging.

**Inflation:** The underlying price level series is the overall PCE Chain-type Price Index (2012=100), monthly and seasonally adjusted, obtained from FRED II, series ID PCEPI. The series spans from Jan. 1959 to Feb. 2021. The series is used to construct the following measure of price inflation:

- Year on year inflation: The monthly price index is converted to a quarterly frequency using 3 month averages. Then the year on year inflation is calculated using the quarterly series.

**Hours worked:** We use actual hours worked on the job constructed from the CPS micro data. The monthly series spans Jan. 1983 to March 2021 is seasonal adjusted with the Census Bureau's X-12 procedure, and converted to quarterly by three-month averaging.