Monetary Policy Under Okun's Hypothesis[*]

Felipe Alves Giovanni L. Violante

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Abstract

The current monetary policy framework of the Fed intends to be more 'inclusive' by running the economy hot for longer during expansions. The logic of this new strategy rests on Okun's (1973) hypothesis that sustaining a 'high-pressure economy' persistently improves labor market outcomes of low-wage workers. To evaluate this conjecture, we develop a Heterogeneous Agent New Keynesian framework with a three-state frictional model of the labor market where low-skilled workers are more exposed to the business cycle and recessions have a long-lasting effect on their labor force participation and earnings, in line with the evidence. Under a canonical Inflation Targeting rule, the ZLB generates a deflationary bias and severely amplifies the persistent scars of recessions at the bottom of the wage distribution. The new Lower-for-Longer strategy is an effective antidote to the ZLB-driven hysteresis and leads to notable earnings gains for low-wage workers and a reduction to overall earnings inequality. If pursued aggressively, however, the policy reverts the inflation bias from negative to positive. Since policymakers might prioritize differently inflation relative to inclusion, we conclude by quantifying the inflation-inclusion trade-off implied by various monetary policy rules.

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[*]Alves: Bank of Canada, felipe.a.alves0@gmail.com. Violante: Princeton University, CEPR, IFS, IZA and NBER, violante@princeton.edu.

1 Introduction

Monetary policy regimes are neither permanent nor timeless. As economies evolve, monetary rules must adapt to the changing macroeconomic landscape. All central banks are fully aware of this reality and regularly reassess their conduct. The most recent strategic review conducted by the U.S. Federal Reserve (Fed), and concluded in 2020, culminated in a substantially revised monetary policy framework. The objective of this paper is to assess the aggregate and distributional implications of this regime shift through the lenses of a state-of-the-art macroeconomic model.

The Fed's review contained two major novelties. The first one was motivated by the Zero Lower Bound (ZLB) on nominal rates. In a low 'natural rate' environment, the ZLB can dramatically constrain monetary policy's ability to support the economy during downturns. *The result is worse economic outcomes in terms of both employment and price stability, with the costs of such outcomes likely falling hardest on those least able to bear them* (Powell, 2020). To address this concern, the Fed adopted a more flexible approach to its price stability mandate, shifting from a 2 percent inflation target to an average inflation framework. Specifically, after periods of persistently low inflation—such as those resulting from extended episodes at the ZLB—the Fed *will likely aim to achieve inflation moderately above 2 percent for some time* (Powell, 2020). Notably, this approach was designed to be asymmetric: while the Fed would pursue inflation above 2 percent following periods where inflation remained below target, it would not actively seek inflation below 2 percent after inflationary episodes (Clarida, 2022).

The second novelty is a reinterpretation of the maximum employment mandate—the other pillar of the Fed's mission—as a *broad-based and inclusive goal*. This policy shift stemmed from FedListens, a series of nationwide events where the Fed engaged with a diverse array of organizations to better understand how monetary policy impacts people's livelihoods. In the foreword of the project's final report (Federal Reserve System, 2020), Chair Powell notes that: *One clear takeaway from these events was the importance of sustaining a strong job market, particularly for people from low- and moderate-income communities. Everyone deserves the opportunity to participate fully in our society and in our economy.*[1] In alignment with this objective, the new framework stipulates that monetary policy is no longer informed by deviations, but only by shortfalls of employment from its max-

[1] Interestingly, the European Central Bank's (ECB) most recent monetary policy strategy review reveals that, while price stability remains its sole official objective, the ECB now acknowledges more explicitly the indirect impact of its policy decisions on aspects of social progress, such as wealth and income inequality (Ioannidis et al., 2021).

imum level, adding another element of asymmetry in the policy response to aggregate disturbances.

Jointly, these two shifts in the conduct of monetary policy indicate that interest rates would be kept *lower for longer* following contractions in order to let the economy *run hot for longer* during recoveries. The new strategy marked a sharp departure from the Fed's traditional "preemptive restraint" approach, whereby the Fed would raise rates early on during recoveries out of fear of fueling inflation. The shift reflected the broad consensus formed in the aftermath of the Great Recession that the Phillips curve had flattened, indicating that a robust labor market could be sustained without causing an outbreak in inflation. Low-wage workers, who are severely hurt by downturns and stand to gain the most from extended and vigorous recoveries, are meant to especially benefit from this new strategy.

The hypothesis that a hot economy especially benefits workers at the bottom of the distribution is not new. In his classic article, *Upward Mobility in a High Pressure Economy* (Okun, 1973), Arthur Okun conjectured that a 'high-pressure' economy could persistently improve the economic circumstances of more disadvantaged workers by giving them opportunities to find steady employment, strengthen their skills, and gradually climb the job ladder. While Okun recognized explicitly that running a 'high-pressure' economy carries the risk of propelling inflationary pressures, he also thought that renouncing these gains to most disadvantaged groups *should be carefully reckoned as a high cost of accepting slack as an insurance policy against inflation* (page 244). Policymakers, according to Okun, thus face a stark *inflation-inclusion trade-off*.

The post-pandemic experience in the U.S. is indicative of such trade-off. Unlike the recovery from the Great Recession, when it raised rates preemptively at the first signs of a tightening labor market, the Fed waited much longer to raise rates in the post-pandemic recovery. On the one hand, employment rates and earnings for low-educated and minority workers reached historic highs and, for the first time in decades, the economy also experienced a notable compression in the wage distribution (Autor et al., 2023; Blanchet et al., 2022). On the other hand, the US recorded a severe spike of surprise inflation — arguably for a variety of other reasons as well— and five years later inflation is still above target.

In this paper, we develop a quantitative framework to assess the labor market implications of this monetary policy regime shift for the entire distribution of workers. To this end, our first challenge is how to formalize and give content to Okun's hypothesis. At the time of his writing, Okun presented only tentative empirical evidence to bolster his conjecture that a high-pressure economy would primarily benefit low-wage workers. Nearly fifty years later, our understanding of the employment and earnings dynamics of workers has significantly deepened, with numerous findings from micro data corroborating this insight. First, the employment outcomes of low-income groups are more cyclically sensitive than those of the broader population. During economic downturns, these groups experience disproportionately higher unemployment while, in recoveries, their unemployment rates decline more significantly due to increased job-finding rates and reduced job-separation rates. Second, unemployed (U) workers are far more likely to exit the labor force (N) compared to their employed (E) counterparts ($UN >> EN$), regardless of the phase of the cycle. This disparity in labor force attachment between employed and unemployed workers ("attachment wedge") makes the size of the unemployment pool a crucial driver of procyclical fluctuations in participation—a force often referred to as the 'participation cycle.' Since low-wage workers are particularly vulnerable to unemployment during recessions, this force is especially pronounced among them. Third, earnings losses resulting from job displacement are substantial and enduring, especially at the lower end of the income distribution, where they more frequently lead to a persistent exit from the labor force. These three mechanisms—uneven exposure to aggregate fluctuations, the labor force attachment wedge, and long-lasting displacement effects—form the foundation of how we concretely think about Okun's hypothesis.

To study the aggregate and distributional effects of alternative monetary policy regimes under Okun's hypothesis, we integrate these three channels into a heterogeneous-agent incomplete-markets New-Keynesian (HANK) framework featuring a three-state frictional labor market model. Workers can be either employed, unemployed, or out of the labor force. Low-skilled workers face higher separation and lower job-finding rates, leading to higher unemployment and stronger exposure to business cycle fluctuations at the bottom of the distribution. Labor market frictions and participation decisions give rise to a large attachment wedge and thus a strong "participation cycle", just as in the data. Finally, we make the evolution of workers' skills contingent on their individual labor market status. Specifically, workers' productivity typically increases while employed but gradually diminishes during periods of nonemployment. When combined with the attachment wedge, this skill depreciation during nonemployment contributes to generate significant and persistent earnings losses following displacement. Together, these three factors make running a hot economy particularly beneficial to low-income groups.

While we substantially enrich the labor market block of the model to attain a credible quantification of the employment and earnings gains under the new framework, inflation costs are modeled as in the canonical sticky-wage New Keynesian literature by making nominal wage adjustments costly. This choice is meant to isolate the impact of the new framework on the average systematic rate of inflation, thus reducing the cost to a single number, the positive inflation bias caused by the policy shift.[2] The rest of the model is standard. A wage Phillips curve links inflation to fluctuations in hours per worker, a fiscal authority taxes labor and provides unemployment insurance, a monetary authority sets the nominal rate subject to a Zero Lower Bound (ZLB), and demand and supply shocks drive the business cycle. The model is parameterized to match a wide set of macro and micro facts, which discipline the strength of the three Okun's channels.

We begin our analysis by revisiting the deleterious effects of the ZLB under Inflation Targeting (IT) through the lenses of our heterogeneous-agent model. In agreement with much of the existing literature, we find that the ZLB gives rise to only modest inflation (-20bp) and unemployment (+0.55 ppt) biases in the model's ergodic distribution. However, these small aggregate effects masks a much greater impact on individuals at the lower end of the distribution. Specifically, looking at the ZLB's negative impact on total labor earnings across the skill distribution, we find a bias that ranges from just 2% in the top tercile to 12% in the bottom tercile. When we analyze the sources of the earnings bias at the bottom, we find that weaker labor force attachment and lower labor productivity explain 90% of the earnings losses. Similar results emerge when we shift from the cross-section to individual life-cycle dynamics. In both dimensions, the stronger response among low-wage workers is driven by labor market hysteresis. A temporary negative shock that pushes the economy into the ZLB and increases unemployment, particularly at the bottom, creates a vicious cycle that weakens labor force attachment and erodes skills, leaving low-skilled workers scarred well beyond the ZLB period.

These shortcomings of IT open the door to alternative, potentially more effective policy regimes, like the *Lower-for-Longer* (LfL) strategy embedded in the new framework. We ask whether this alternative rule that promises to run the economy hot for longer during expansions can, possibly at the cost of higher inflation, foster an economy with more robust labor force attachment, enduring earnings growth, and stronger upward mobility among low-skilled workers. To answer this question, we run two counterfactuals. First, we ask how the recovery from the U.S. economy from the Great Recession would have differed had the Fed followed an LfL strategy.[3] Second, we contrast the model's aggre-

[2] In particular, we abstract from assessing how different monetary regimes deal with bouts of *surprise* inflation which transmit to households through many different channels such as heterogeneous consumption baskets, nominal net positions, and nominal wage rigidity.

[3] This historical episode offers an ideal laboratory for this counterfactual because of its depth, the ex-

gate and distributional outcomes in the ergodic distribution under IT and LfL strategies, separating the roles played by the asymmetric *Average Inflation Targeting* (AIT) and *Shortfall* (SR) components of LfL. Taken together, our two counterfactuals yield three main findings.

First, we find that the LfL strategy successfully reverses the contractionary labor market biases that emerge under IT. Relative to the economy under IT, the average levels of participation, labor productivity, and earnings at the skill distribution's bottom tercile under LfL are 3.5 ppts, 6.5%, and 17% higher, respectively. Moreover, adopting a LfL strategy delivers an economy with more life-cycle upward mobility at the bottom of the distribution, as hypothesized by Okun. Inflation, the other side of the trade-off, averages 33 bp above the target. Compared to an alternative policy that increases the central bank's inflation target but keeps the same reaction to inflation and unemployment deviations as our baseline IT (Higher IT), we show that the LfL displays much stronger labor market gains among low-skilled workers at the same cost in terms of inflation.

Our second message pertains to the contribution of each of the two components of the LfL strategy. We find that AIT and SR generate similar benefits to average labor market outcomes of low-skilled workers. The gains under each rule are, however, realized at different points of the business cycle. The AIT component primarily reduces the likelihood and severity of the episodes triggering the ZLB, lessening the long-lasting harmful effects of recessions on low-wage workers. In contrast, the SR component operates mainly by letting the economy run hot during recoveries, which enables low-wage workers to partially make up for previous losses.

Finally, since policymakers may have different attitudes towards inclusion vs inflation, we leverage our model to trace out the menu of choices available under the LfL approach, which, because of its shape, we denote by "Okun's cone." These cones map the cost, in terms of inflation, required to achieve specific average improvements in labor market outcomes across the distribution. For example, we establish that a "hawkish" central bank interested only in closing the deflationary bias induced by the ZLB, but with zero tolerance for any additional inflation, would already boost participation rates by 1.5 ppts and labor earnings by 8% at the bottom tercile of the skill distribution.

tended duration of the ZLB, and the preemptive tightening by the Fed upon the very first signs of a tight labor market.

1.1 Related Literature and Contribution

Our paper stands at the intersection of several key areas in macroeconomics. From a modelling perspective, it presents two novelties relative to the growing literature that employs Heterogeneous Agent New Keynesian (HANK) models to study aggregate fluctuations and stabilization policies (see Auclert et al., 2024a, for a recent survey of this literature). First, we augment the canonical sticky-wage HANK framework to include the participation margin of labor supply. In doing so, our paper joins an emerging trend calling for a more prominent role of labor supply in this class of models (Huo and Ríos-Rull, 2020; Bardóczy, 2022). Recall that the short-run response of labor in the baseline sticky-wage New-Keynesian is "demand-determined," leaving little or no role to labor supply forces in shaping the transmission of aggregate shocks. Graves et al. (2023), however, find that "supply-driven" flows (e.g., EN and UN) play a quantitatively important role in the response of employment to a monetary policy shock. In Alves and Violante (2024), we have shown that our framework generates impulse responses to monetary policy surprises which are qualitatively in line with their evidence for all labor flows.

Second, within this framework we give formal content to Okun (1973) conjecture. Our interpretation of Okun's hypothesis through the exposure, attachment, and persistence channels rests on solid empirical evidence from micro data. Cajner et al. (2017) and Aaronson et al. (2019) document that low-income groups are (unconditionally) more exposed than the average to business cyclical fluctuations.[4] Hobijn and Şahin (2021) measure the 'participation cycle' from workers' flows and document that this channel is more pronounced for low-skill ones, who are more marginally attached. With respect to the persistence channel, Davis and Von Wachter (2011) show that earnings losses upon job displacement are sizable and long-lasting, especially in recessions. Guvenen et al. (2017), Yagan (2019), and Athey et al. (2023) illustrate that this phenomenon is particularly severe at the bottom of the distribution where it is associated with more frequent exit from the labor force. We leverage this large body of empirical work to parameterize the strength of the three channels in our model.

Our modelling of Okun (1973) conjecture relies on ingredients that are common in the macro-labor literature. The treatment of labor market frictions in the presence of an extensive participation decision builds on Krusell et al. (2017). The assumption that frictions depend on individual skills, crucial to obtain higher exposure for low-wage workers, fol-

[4] A growing literature using survey and administrative individual-level data has uncovered similar patterns also conditional on a monetary policy shock (Amberg et al., 2022; Lenza and Slacalek, 2024; Broer et al., 2023; Chang et al., 2024), with changes along the extensive margin being particularly important to explain the higher exposure of low-income groups.

lows Heathcote et al. (2020). Finally, making skills drift down during nonemployment is a natural way to capture earnings losses upon displacement and duration dependence (Ljungqvist and Sargent, 1998; Kehoe et al., 2019; Braxton and Herkenhoff, 2021; Jarosch, 2023).

Our paper also relates to a long-standing body of work on labor market hysteresis which goes back at least to Blanchard and Summers (1986) who applied this idea to make sense of the differential experience of European labor markets during the 1970s and 1980s relative to the U.S. (see Cerra et al., 2023, for a recent survey). Fueled by the Great Recession's long shadow over the macroeconomy, a more recent literature has argued that monetary policy shocks (or demand shocks more generally) can have long-run repercussions on the economy (Comin and Gertler, 2006; Jordà et al., 2024; Fornaro and Wolf, 2023; Ma and Zimmermann, 2023). We contribute to this literature by offering a novel mechanism, operating via human capital accumulation and labor force attachment, through which micro hysteresis in the labor market translates into macro hysteresis for the whole economy. Furlanetto et al. (2025) find evidence of precisely this transmission mechanism on U.S. time series.

Our paper also relates to recent work, within representative-agent models, arguing that the ZLB can lead to macroeconomic hysteresis when the central bank follows a strict IT rule (Garga and Singh, 2021; Galí, 2022). We extend the analysis of this interaction between hysteresis, ZLB, and monetary policy rules to a heterogeneous-agent incomplete-market economy. Fernàndez-Villaverde et al. (2024) also studies the negative impacts of the ZLB in a HANK environment. They emphasize how, in these models, ZLB episodes can drive up aggregate precautionary saving and, in turn, lower the natural real rate and reduce the effectiveness of monetary policy. Our main insight is, instead, that the deleterious effects of the ZLB are unequally distributed, and disproportionately concentrated on low-wage workers.

Motivated by the shift in the Fed's framework, several recent papers explore the macroeconomic implications of asymmetric monetary policy rules. Bianchi et al. (2021) study how an asymmetric rule with respect to inflation gaps can correct the deflationary bias caused by the ZLB. Bundick and Petrosky-Nadeau (2021) analyze the impact of employment shortfall-based rules on business cycle dynamics, while Cairó and Lipton (2023) investigate its impact on the unemployment rate gap between white and black workers. All these contributions, however, analyze the effects of asymmetric rules within representative agent models with no or very limited heterogeneity. In contrast, our interest lies in assessing how inclusive these rules might be towards the low-wage segment of the labor force, which requires us to move beyond the representative agent framework.

A number of contemporaneous papers have also started to investigate the impact of monetary policy on racial income and wealth gaps (Bartscher et al., 2022; Bergman et al., 2020; Lee et al., 2021; Nakajima, 2022; Cairó and Lipton, 2023). Our approach differs from this literature along several dimensions. First, we chose to focus on a more comprehensive notion of skills and inequality whose sources can be both unobservable (e.g., innate abilities, specialized knowledge) and observable (e.g., race, gender, education). Second, these papers contain at most one of the three Okun's channels we model (the uneven exposure), but abstract from human capital losses from non-employment and from the labor force attachment margin which are crucial to the hysteresis. Third, most of these papers concentrate on the impact of monetary policy *shocks* to standard Taylor rules on racial inequality, while we think that it is more consequential to study how alternative monetary policy *rules* in reaction to aggregate shocks can generate durable gains for low-income groups.[5] Focusing on systematic rules also allows us to quantify the inflation-inclusion trade-off faced by policymakers.

The rest of the paper is organized as follows. Section 2 outlines the model. Section 3 discusses its parameterization. Section 4 analyzes the economy's dynamics under an Inflation Targeting rule and highlights the negative hysteresis effects of the ZLB. Section 5 evaluates aggregate and distributional outcomes under the Lower-for-Longer strategy. Section 6 concludes.

2 Model

It is useful to begin with an overview of the model, starting from its real side. Individuals consume, save and can be either employed, unemployed, or out of the labor force. Some transitions are exogenous and some are endogenous. Workers endogenously choose whether to participate to the labor market. Job finding opportunities for unemployed, and at a lower rate for non-participants, arise exogenously, but workers choose whether to accept them or not. Layoffs are exogenous. Individuals' efficiency units of labor (skills) are subject to uninsurable idiosyncratic shocks whose distribution depends on labor market status. Both job finding and job separation rates are indexed by skill level.

Monopolistically competitive intermediate good producers with flexible prices take wages as given and demand the profit-maximizing amount of labor. A competitive final

[5] Cairó and Lipton (2023) is an exception in this list, as the authors also explore the impact of the Shortfall rule on the unemployment gap between different racial groups.

good sector packages the intermediate goods into a final good, the numeraire of the economy, and sells it to households. Households trade shares of a mutual fund which owns claims to the firms' profits and holds government bonds. The fiscal authority finances expenditures and transfers by levying taxes on households and issuing debt.

The nominal side of the model follows closely the New Keynesian tradition. Every employed worker adheres to labor unions which set nominal wages subject to adjustment frictions which give rise to a wage Phillips curve. The central bank (monetary authority) sets the nominal interest rate to stabilize the economy in response to aggregate demand and supply shocks.

2.1 Households

Demographics. Time is continuous and indexed by t. The economy is populated by a continuum of households (or individuals) with measure 1 who discount the future at rate $\tilde{\rho} > 0$, and face mortality rate ϱ. Let $\rho = \tilde{\rho} + \varrho$ be the effective discount rate.

Labor market status. At any date t, individuals can be in one of three mutually exclusive labor market states s_t: employed ($s_t = e$), unemployed and searching for a job ($s_t = u$), and non-participant, or outside the labor force, ($s_t = n$). Among the unemployed, we distinguish between eligible ($u = u_1$) and not eligible ($u = u_0$) for unemployment insurance (UI) benefits. Workers gain eligibility when they enter the unemployment pool due to an exogenous separation, and they lose it at some constant rate which reflects benefit duration. Among those out of the labor force, we distinguish between "active" non-participants ($n = n_1$) and "passive" non-participants ($n = n_0$). The former still receive job offers and thus can transition back into employment, though at a lower rate than the unemployed. The latter, instead, do not engage in any search and hence do not transition into employment. This differentiation is meant to capture the fact that the pool of non-participants is heterogeneous (Hall and Kudlyak, 2019) with some individuals able and willing to work while others are unable and not searching at all for a job (e.g., because they are sick, heavily involved in household care, or discouraged by the failure of previous job search).

Labor productivity. Each individual is endowed with efficiency units of labor (or skills) z evolving according to a Ornstein-Uhlenbeck diffusion process which depends on labor market status s_t

$$d \log z_t = \Big\{ - \gamma_z \log z_t + \mathbb{I}_{\{s_t = e\}} \, \delta_z^+ - \mathbb{I}_{\{s_t \neq e\}} \, \delta_z^- \Big\} dt + \sigma_z d\mathcal{W}_t. \tag{1}$$

	e	u_1	u_0	n_1	n_0
e	$\ddots$	λ_{zt}^{eu}	$\times$	$\blacktriangleright$	η^{en_0}
u_1	$\lambda_{zt}^{ue} \cdot \triangleright$	$\ddots$	$\lambda_z^{u_1u_0}$	$\blacktriangleright$	η^{un_0}
u_0	$\lambda_{zt}^{ue} \cdot \triangleright$	$\times$	$\ddots$	$\blacktriangleright$	η^{un_0}
n_1	$\lambda_{zt}^{ne} \cdot \triangleright$	$\times$	$\blacktriangleright$	$\ddots$	$\eta^{n_1n_0}$
n_0	$\times$	$\times$	$\times$	$\eta^{n_0n_1}$	$\ddots$

Table 1: Transition matrix across the 5 employment states. The $\times$ symbol means that transition cannot happen. The $\blacktriangleright$ symbol means that an endogenous participation decision moves the individual in that state. The $\triangleright$ symbol means that an endogenous job acceptance decision moves the individual into employment. $\lambda_{zt}^{ss'}$ and $\eta^{ss'}$ are exogenous Poisson rates capturing labor market frictions and nonparticipation shocks, respectively. The diagonal dots stand for the negative of the sum of all the other entries on that line.

When workers are employed ($s_t = e$), skills drift up at rate $\delta_z^+ > 0$, and when they are not employed ($s_t = u, n$) they drift down at rate $\delta_z^- < 0$. The parameter $\gamma_z > 0$ measures the degree of mean reversion in skill dynamics, σ_z determines uncertainty about future realizations, and $\mathcal{W}_t$ is a Wiener process. Upon death, workers are replaced by an offspring with log skill drawn from a Normal distribution with mean $\bar{z}_0$ and variance $\sigma_{z_0}^2$.

Labor market transitions. Every period individuals can transition between employment states through a combination of exogenous Poisson rates and optimal mobility decisions. Table 1 describes all the possible transitions and their endogenous/exogenous nature. Employed and unemployed workers can choose to quit the labor force and enter active non-participation (rows 1, 2, 3 of Table 1). Similarly, an active non-participant can choose to re-enter the labor force as unemployed ineligible for UI (row 4). Employed workers who decide to remain attached can still be laid off, and thus move from e to u at an exogenous rate λ_{zt}^{eu} which depends on the worker's skill level z (row 1). Unemployed workers draw a job opportunity at an exogenous rate λ_{zt}^{ue} and choose whether to accept it or not (rows 2 and 3).[6] Upon expiration of UI benefits, at rate $\lambda_z^{u_1u_0}$, eligible unemployed become ineligible (row 2). Active participants receive job opportunities at rate λ_{zt}^{ne} and decide whether to accept them or not (row 4). All workers can exogenously transition into passive nonparticipation at rate η^{sn_0} (rows 1, 2, 3, 4). At rate $\eta^{n_0n_1}$, passive nonparticipants

[6]The unemployed ineliglible for UI always accept job offers because in equilibrium there is a unique wage per effective hours, and if they did not want to work, they would choose non-participation. Eligible unemployed instead may turn down job opportunities if UI benefits are generous enough.

become active again (row 5).

Employed individuals earn labor income $w_t h_t z_t$, where w_t is the real wage per effective hour, and eligible unemployed receive benefits $b(z_t)$. We let UI benefits be a function of current worker productivity z_t, as a proxy for actual replacement rates. Both types of income are taxed at a proportional rate τ. Every household is entitled to a lump-sum transfer ϕ.

Preferences. Households derive utility from consumption c_t, suffer disutility from the effort cost κ^s associated to being in labor market status s (the extensive margin) and, if employed, from the effort cost of working h_t hours (the intensive margin). We specify the following functional form for period utility

$$u^s(c_t, h_t; z_t) = \log\left(c_t - \psi z_t \frac{h_t^{1+\frac{1}{\sigma}}}{1+\frac{1}{\sigma}}\right) - \kappa^s \tag{2}$$

where $\sigma > 0$ is the Frisch elasticity of labor supply, and $\kappa^e > \kappa^u > \kappa^n \geq 0$. Note that these preferences induce wealth effects on the extensive margin (labor force participation), but not on the intensive margin (hours worked) of labor supply of employed workers. In addition, because the disutility of hours is scaled by individual productivity z_t, optimal hours worked are the same for every employed individual. This property is useful to isolate the sources of inefficiency arising from nominal wage rigidity, as we explain in Section 2.7.[7]

Saving instruments. Households can save through a financial asset a_t with rate of return r_t, and face a zero unsecured credit limit. Newborn workers enter the economy with zero wealth holdings. Perfect annuity markets insure workers against survival risk, so that the net wealth of the deceased is redistributed to surviving households in proportion to their own net wealth.[8]

Household problem

The dynamic problem solved by the household at time t is a mix of an optimal control problem, the choice of $c_t > 0$, and two optimal stopping problems: a continuous one,

[7] We have also solved the model with a specification of period utility that is separable between consumption and hours worked, and results of all our numerical experiments are qualitatively robust and quantitatively similar. This set of results is available upon request.

[8] We fold this adjustment directly into the rate of return r_t, which should therefore be interpreted as inclusive of the rate of return ϱ from annuity contracts.

the participation decision $\mathfrak{p}_t^s \in \{0,1\}$, and one arising at random Poisson jump times, the job acceptance decision $\mathfrak{j}_t^s \in \{0,1\}$. The stochastic nature of the problem is due to both the Poisson arrival rates that determine transitions across labor market states, and the diffusion that determines the evolution of skills z_t. Conditional on these realizations, wealth evolves deterministically. Let $v_t^s(a,z)$ be the value at date t of an individual with employment state s, wealth a, and productivity z.

Consider first the problem of the passive non-participant (n_0):

$$\begin{aligned} v_0^{n_0}(a_0,z_0) = \max_{\{c_t\}_{t\geq 0}} & \quad \mathbb{E}_0 \int_0^{\mathfrak{t}^{n_1}} e^{-\rho t} \mathfrak{u}^n(c_t,0)\, dt + e^{-\rho \mathfrak{t}^{n_1}} v_{\mathfrak{t}^{n_1}}^{n_1}\left(a_{\mathfrak{t}^{n_1}}, z_{\mathfrak{t}^{n_1}}\right) \\ s.t. & \\ c_t + \dot{a}_t &= r_t a_t + \phi \\ a_t &\geq 0 \end{aligned} \tag{3}$$

Passive non-participants do not receive any job opportunity. At rate $\eta^{n_0 n_1}$, with $\mathfrak{t}^{n_1}$ being the first arrival rate of this event, they become active non-participants and enter employment status n_1.[9] The conditional expectation reflects the uncertainty in transition rates and in the evolution of skill dynamics. In addition to the participation decision $\mathfrak{p}_t^{n_0}$, at every instant the worker chooses its consumption flow c_t. The last two lines of this problem state the budget constraint (in real terms) and the borrowing limit.

The problem of the active non-participant (n_1) is:

$$\begin{aligned} v_0^{n_1}(a_0,z_0) = \max_{\{c_t\}_{t\geq 0}, \mathfrak{t}^*} & \quad \mathbb{E}_0 \Bigg[\int_0^{\mathfrak{t}^{\min}} e^{-\rho t} \mathfrak{u}^n(c_t,0)\, dt + \mathbb{I}_{\{\mathfrak{t}^{\min}=\mathfrak{t}^e\}} e^{-\rho \mathfrak{t}^e} \max\left\{ v_{\mathfrak{t}^e}^e\left(a_{\mathfrak{t}^e}, z_{\mathfrak{t}^e}\right), v_{\mathfrak{t}^e}^{n_1}\left(a_{\mathfrak{t}^e}, z_{\mathfrak{t}^e}\right) \right\} \\ & + \mathbb{I}_{\{\mathfrak{t}^{\min}=\mathfrak{t}^*\}} e^{-\rho \mathfrak{t}^*} \left(v_{\mathfrak{t}^*}^{u_0}\left(a_{\mathfrak{t}^*}, z_{\mathfrak{t}^*}\right) - \xi \right) + \mathbb{I}_{\{\mathfrak{t}^{\min}=\mathfrak{t}^{n_0}\}} e^{-\rho \mathfrak{t}^{n_0}} v_{\mathfrak{t}^{n_0}}^{n_0}\left(a_{\mathfrak{t}^{n_0}}, z_{\mathfrak{t}^{n_0}}\right) \Bigg] \\ s.t. & \\ c_t + \dot{a}_t &= r_t a_t + \phi \\ a_t &\geq 0 \end{aligned} \tag{4}$$

Active non participants receive job opportunities at rate λ_{zt}^{ne}, with $\mathfrak{t}^e$ being the arrival time of this event. Conditional on receiving this job offer, they decide whether to accept it or not. At every instant, the non-participant chooses whether to remain unattached $\left(\mathfrak{p}_t^{n_1} = 0\right)$

[9] One can also interpret the leisure of nonparticipants as time engaged in home production. Nothing in our analysis would change in that case, except that the total income gains arising from monetary policy rules that boost participation would have to be adjusted for the loss in home production.

or re-enter the labor force $\left(\mathfrak{p}_t^{n_1} = 1\right)$, in which case they become unemployed, but are not eligible for UI benefits ($u = u_0$). We assume that re-entering the labor force involves a small fixed switching cost ξ.[10] The optimal stopping time $\mathfrak{t}^*$ represents the first instant in which the choice $\mathfrak{p}_t^{n_1}$ switches from 0 to 1. Finally, at rate $\eta^{n_1 n_0}$ (with $\mathfrak{t}^{n_0}$ being the arrival time of this shock) active non-participants become passive non-participants. Finally, we let $\mathfrak{t}^{\min}$ denote the time at which the first of these events ocurs and the worker switches employment state.

The problem of an unemployed household who is not eligible for UI benefits is:

$$
\begin{aligned}
v_0^{u_0}(a_0, z_0) = \max_{\{c_t\}_{t\geq 0}, \mathfrak{t}^*} \quad & \mathbb{E}_0 \Bigg[\int_0^{\mathfrak{t}^{\min}} e^{-\rho t} \mathfrak{u}^u(c_t, 0)\, dt + \mathbb{I}_{\{\mathfrak{t}^{\min} = \mathfrak{t}^e\}} e^{-\rho \mathfrak{t}^e} v_{\mathfrak{t}^e}^e(a_{\mathfrak{t}^e}, z_{\mathfrak{t}^e}) \\
& + \mathbb{I}_{\{\mathfrak{t}^{\min} = \mathfrak{t}^*\}} e^{-\rho \mathfrak{t}^*} v_{\mathfrak{t}^*}^{n_1}(a_{\mathfrak{t}^*}, z_{\mathfrak{t}^*}) + \mathbb{I}_{\{\mathfrak{t}^{\min} = \mathfrak{t}^{n_0}\}} e^{-\rho \mathfrak{t}^{n_0}} v_{\mathfrak{t}^{n_0}}^{n_0}(a_{\mathfrak{t}^{n_0}}, z_{\mathfrak{t}^{n_0}}) \Bigg] \\
s.t. & \\
c_t + \dot{a}_t \quad = \quad & r_t a_t + \phi \qquad (5) \\
a_t \quad \geq \quad & 0
\end{aligned}
$$

Ineligible unemployed workers receive a job opportunity at rate λ_{zt}^{ue} (with $\mathfrak{t}^e$ being the arrival time of this event) and always find it optimal to take it. At any time $\mathfrak{t}^*$ during the unemployment spell, the individual can quit the labor force $\left(\mathfrak{p}_t^u = 0\right)$. Finally, at rate $\eta^{n_1 n_0}$ (with $\mathfrak{t}^{n_0}$ being the first arrival rate of this shock) they can become passive non-participants.

The problem of an unemployed household who is eligible for UI benefits is:

$$
\begin{aligned}
v_0^{u_1}(a_0, z_0) = \max_{\{c_t\}_{t\geq 0}, \mathfrak{t}^*} \quad & \mathbb{E}_0 \Bigg[\int_0^{\mathfrak{t}^{\min}} e^{-\rho t} \mathfrak{u}^u(c_t, 0)\, dt + \mathbb{I}_{\{\mathfrak{t}^{\min} = \mathfrak{t}^e\}} e^{-\rho \mathfrak{t}^e} \max\left\{ v_{\mathfrak{t}^e}^e(a_{\mathfrak{t}^e}, z_{\mathfrak{t}^e}), v_{\mathfrak{t}^e}^{u_1}(a_{\mathfrak{t}^e}, z_{\mathfrak{t}^e}) \right\} \\
& + \mathbb{I}_{\{\mathfrak{t}^{\min} = \mathfrak{t}^*\}} e^{-\rho \mathfrak{t}^*} v_{\mathfrak{t}^*}^{n_1}(a_{\mathfrak{t}^*}, z_{\mathfrak{t}^*}) + \mathbb{I}_{\{\mathfrak{t}^{\min} = \mathfrak{t}^{u_0}\}} e^{-\rho \mathfrak{t}^{u_1}} v_{\mathfrak{t}^{u_0}}^{u_0}(a_{\mathfrak{t}^{u_0}}, z_{\mathfrak{t}^{u_0}}) \\
& + \mathbb{I}_{\{\mathfrak{t}^{\min} = \mathfrak{t}^{n_0}\}} e^{-\rho \mathfrak{t}^{n_0}} v_{\mathfrak{t}^{n_0}}^{n_0}(a_{\mathfrak{t}^{n_0}}, z_{\mathfrak{t}^{n_0}}) \Bigg] \\
s.t. & \\
c_t + \dot{a}_t \quad = \quad & r_t a_t + (1 - \tau) b_t(z_t) + \phi \qquad (6) \\
a_t \quad \geq \quad & 0
\end{aligned}
$$

[10] The presence of a small switching cost is mostly a technical assumption to avoid "chattering," i.e., infinitely fast switching between n_1 and u_0, in the optimal solution of the problem. For all other participation decisions, this problem does not arise because switching back can only occur upon the realization of Poisson shocks.

Besides receiving job opportunities and choosing whether to take them, choosing to drop out of the labor force, and exogenously switching to passive non-participant status, the eligible unemployed could lose its entitlement to UI benefit at rate $\lambda_z^{u_1 u_0}$, with $\mathfrak{t}^{u_0}$ being the first arrival time of this event.

Finally, the problem of the employed household is:

$$
\begin{aligned}
v_0^e(a_0, z_0) = \max_{\{c_t\}_{t\geq 0}, \mathfrak{t}^*} \quad & \mathbb{E}_0 \Bigg[\int_0^{\mathfrak{t}^{\min}} e^{-\rho t} \mathfrak{u}^e(c_t, h_t; z_t)\, dt + \mathbb{I}_{\{\mathfrak{t}^{\min} = \mathfrak{t}^u\}} e^{-\rho \mathfrak{t}^u} v_{\mathfrak{t}^u}^{u_1}(a_{\mathfrak{t}^u}, z_{\mathfrak{t}^u}) \\
& + \mathbb{I}_{\{\mathfrak{t}^{\min} = \mathfrak{t}^*\}} e^{-\rho \mathfrak{t}^*} v_{\mathfrak{t}^*}^{n_1}(a_{\mathfrak{t}^*}, z_{\mathfrak{t}^*}) + \mathbb{I}_{\{\mathfrak{t}^{\min} = \mathfrak{t}^{n_0}\}} e^{-\rho \mathfrak{t}^{n_0}} v_{\mathfrak{t}^{n_0}}^{n_0}(a_{\mathfrak{t}^{n_0}}, z_{\mathfrak{t}^{n_0}}) \Bigg] \qquad (7) \\
s.t. \quad & \\
c_t + \dot{a}_t \quad = \quad & r_t a_t + (1 - \tau) w_t z_t h_t + \phi \\
a_t \quad \geq \quad & 0
\end{aligned}
$$

Employed workers (e) can be laid-off at rate λ_{zt}^{eu}, in which case they become eligible for UI benefits ($u = u_1$). Let $\mathfrak{t}^u$ be the first arrival time of this Poisson shock. At every instant $\mathfrak{t}^*$, the employed worker can choose to quit the labor force ($\mathfrak{p}_t^e = 0$).[11] In addition, an employed worker can exogenously switch to passive non-participant status at rate η^{en_0}, with $\mathfrak{t}^{n_0}$ being the first arrival time of this event.

Each of these five problems can be expressed recursively as a Hamilton-Jacobi-Bellman Quasi-Variational Inequality (HJBQVI) which can, in turn, be appropriately discretized to numerically solve the household problem (see Appendix A).

Figure 1 represents the solution to the workers' problem as a function of workers' individual state (a, z) for the cases where the worker is employed, unemployed without UI, and an active nonparticipant. The black line in each panel indicates the participation boundary, while the arrows illustrate the deterministic wealth and skill dynamics in the absence of skill shocks. Participation decisions are determined by substitution and income effects, with workers choosing to participate whenever they are sufficiently productive or wealth-poor. Employment (left panel) tends to move workers deeper into the participation region: workers' skills tend to grow during employment and, despite wealth accumulation pushing them closer to the threshold, it is clear from the plot that workers' wealth target for most skill levels falls well inside the participation region.[12]

[11] Quitting into unemployment is never optimal, because the worker would not receive UI benefits, and would pay a higher disutility cost κ^u for the opportunity to be re-employed at the same wage.

[12] Since skills are stochastic, a sequence of negative productivity shocks can still induce wealthy employed workers to drop out of the labor force.

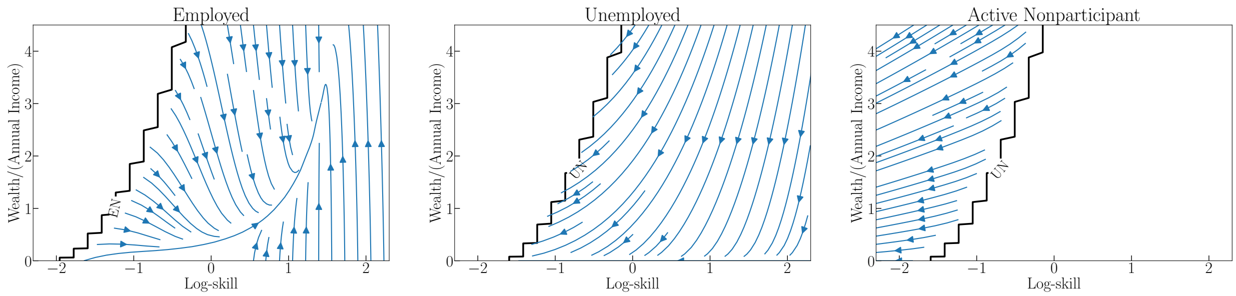


Figure 1: Participation decision for employed, unemployed without UI, and active nonparticipant worker represented in the state space of log-skills and savings. The arrows indicate skill and wealth dynamics in the absence of skill shocks in that particular employment state.

Unemployment (middle panel) does the opposite: while wealth decumulation keeps unemployed workers initially attached, skill depreciation eventually pushes them out of the labor force. Finally, once workers are pushed out of the labor force (right panel), further skill depreciation aggravates their detachment.[13]

The dynamics in Figure 1 illustrate why low-skilled workers are more weakly attached to the labor market in our model. Not only are these workers closer to the participation threshold when they happen to be employed, but they are also more at risk of experiencing unemployment, which, over time, drives down their skills and forces them out of participation.

2.2 Firms

Final-goods producers. A competitive representative final-good producer aggregates a continuum of intermediate inputs indexed by $j \in [0, 1]$ into aggregate output Y_t using a constant returns to scale (CRS) technology with constant elasticity of substitution across inputs $\nu > 0$. Let P_t be the price of the final good and the numeraire of the economy, and let $\pi_t = \dot{P}_t / P_t$ denote the inflation rate.

Intermediate goods producers. A continuum of measure one of monopolistically competitive firms produce the intermediate goods. Production requires hiring labor on a continuum of tasks indexed by $k \in [0, 1]$. Each firm j hires labor services (efficiency-weighted hours) ℓ_{jkt} on every task k by taking the task-specific wage w_{kt} as given, combines them into a labor input ℓ_{jt} using a Dixit-Stiglitz aggregator with elasticity of substitution $\varepsilon > 0$, and produces the intermediate good according to the linear technology $y_{jt} = \alpha \ell_{jt}$.[14] We

[13] Besides these endogenous participation dynamics, recall that both employed and non-employed workers can also drop out participation exogenously through the η^{en_0} and η^{un_0} shocks.

[14] An alternative structure, which gives rise to the same allocations, would be to assume that there is a

allow the government to subsidize labor hired by these firms at rate τ^{ℓ}, with the subsidy partially financed by a lump sum tax ϕ^{ℓ} levied on the same firms, in order to offset the steady-state monopolistic distortion to the quantity produced.

The optimal price setting decisions of firms yields that the relative price p_{jt}/P_t equals a markup over the marginal cost of production, in turn equal to the ratio between the after-subsidy real aggregate wage index $w_t = \left[\int_0^1 w_{kt}^{1-\varepsilon} dk\right]^{\frac{1}{1-\varepsilon}}$ and labor productivity. Because of the CRS technology, in absence of shocks to markups ν and productivity α, imposing a symmetric equilibrium ($p_{jt} = P_t$) implies that the equilibrium aggregate real wage per effective hour is constant over time, i.e.

$$w_t = \alpha \tag{8}$$

and thus, price inflation equals wage inflation at every t. Appendix B contains the full statement of the optimization problems of final and intermediate goods producers, and their solution.

2.3 Wage Setting

This block of the model adapts the wage setting mechanism of Erceg et al. (2000) —i.e., the standard New Keynesian *sticky wage* model— to an heterogeneous-agent economy. We follow closely the approach of Auclert et al. (2024b, 2023), with the necessary modifications due to our continuous time formulation and the presence of the extensive margin in labor supply.

The *nominal* wage ω_{kt} per effective hour worked on task k is set by a union that represents all workers on that particular task. By adhering to the union, each employed worker agrees to supply, at that wage, the same number of hours h_{kt} to intermediate good producers.[15] This number equals whichever total amount of effective hours is demanded by the firms for that task, ℓ_{kt}, divided uniformly across all employees' efficiency units, or $h_{kt} \int_{s_{it}=e} z_{it} di = \ell_{kt}$.[16] The union sets the nominal wage in order to maximize the welfare

competitive labor intermediary that hires task-specific labor services for all tasks $k \in [0, 1]$ and packages into a CES aggregate labor input sold to firms.

[15] As detailed in Appendix C, to offset the steady-state hours distortion generated by the union monopoly power, the government sets a wage subsidy fully financed by a lump sum tax levied on households.

[16] Huo and Ríos-Rull (2020) raise a valid criticism to the RANK model featuring nominal wage rigidity. In that model, along the equilibrium path workers may end up being forced to supply hours against their will, violating the principle of voluntary exchange. They propose a resolution based on a different equilibrium concept. Here, we have a different solution: in our model, unions propose all workers an employment contract that specifies a non-negotiable pair of wage and hours, but workers can always voluntarily choose

of its current members (all individuals employed at date t) subject to a Rotemberg-style quadratic costs of adjusting the nominal wage, in utility terms, with scaling parameter $\Theta \geq 0$. This cost is expressed in terms of deviations of nominal wage growth from the central bank's inflation target, the deterministic steady-state trend inflation rate π^*.[17] We note that, because the union is oblivious to the welfare of the non-employed, this wage setting mechanism is reminiscent of insider-outsider models (Galí, 2022).

In Appendix C we show that the solution to this problem yields the wage Phillips curve

$$\rho(\pi_t - \pi^*) - \dot{\pi}_t = \frac{\epsilon}{\Theta}\left[h_t \int_{s_{it}=e} \partial_c u^e(c_{it}, h_t; z_{it}) z_{it} di\right]\left(\psi h_t^{\frac{1}{\sigma}} - (1-\tau)\alpha\right). \tag{9}$$

The right hand side of equation (9) indicates that whenever the marginal disutility of an extra hour exceeds the marginal utility of an extra unit of after-tax real wage income for households, each union will push up its nominal wage in order to reduce labor demand for their own type. If prices were rigid, the upward pressure on nominal wages would translate in higher real wages and a fall in labor demand. In our environment with flexible prices, and hence a constant real wage, this reduction in labor demand occurs through the monetary policy tightening in response to inflation.

We now return briefly to our preference specification (2). Note that steady-state hours per worker determined by (9), $h^* \equiv \psi^{-1}[(1-\tau)\alpha]^{\sigma}$, are equal to what each employed worker would choose if wages were set competitively. Therefore, the union's imposition that all workers supply the same hours is consistent with worker optimization.[18]

2.4 Mutual Fund

Households wealth is invested in shares of a competitive risk-neutral mutual fund.[19] The fund owns all intermediate good firms and invests in real debt issued by the government as well as in a nominal bond in zero net supply. Holding real and nominal bonds carries a liquidity premium (or convenience yield) $\bar{\iota}$ which, as we will explain in Section 2.7, is a source of aggregate shocks. Let X_t^f denote the shares of the intermediate good producers

not to participate in it and, in fact, in equilibrium some do and quit employment.

[17]Our interpretation of this adjustment cost technology is therefore that wage setters can freely index nominal wage growth to π^*. They understand that inflation in the long-run always converges to that value, and they can take advantage of this information in making their wage setting plans. It is only costly for them to set a value for nominal wage growth which deviates from it. A consequence of this assumption is that changes in the inflation target have no real effects, unless the ZLB binds.

[18]Under preferences displaying income effects (Auclert et al., 2024b), instead, the union's equal-hour restriction gives rise to an additional distributional distortion both in and out-of steady state, relative to its representative agent counterpart.

[19]The set up in this section follows closely Alves et al. (2020).

held by the mutual fund, q_t the unit share price, Π_t per-share dividends (or profits), B_t^f the amount of real government bonds held by the fund, r_t^b the real interest rate on government bonds, M_t^f the real value of the nominal bond, and r_t^m the real rate of return on the nominal bond. Let A_t be the real value of the fund and $\tilde{r}_t$ the total real rate of return of the fund.

In Appendix D, we solve the problem of the fund and show its value satisfies $A_t = q_t X_t^f + B_t^f + M_t^f$. In addition,

$$\tilde{r}_t = \frac{\Pi_t + \dot{q}_t}{q_t} = r_t^b + \bar{\iota} = r_t^m + \bar{\iota}. \tag{10}$$

These relationships determine the real return on the household financial asset a_t (wealth invested in the mutual fund), and establish a no-arbitrage condition between firm equity, real bonds, and nominal bonds which holds at every t, except when a shock hits the economy, in which case the price q_t features a jump. Note that, because of the absence of trading frictions or short-sale constraints, the mutual fund is willing to absorb any amount of each asset. Recall that, because of the annuity markets, the total rate of return on saving to households is $r_t = \tilde{r}_t + \varrho$.

2.5 Fiscal Authority

The fiscal authority faces the following intertemporal budget constraint:

$$G_t + \Psi_t^\ell + \phi + (1-\tau)\int_{s_{it}=u^1} b_t(z_{it})di + r_t^b B_t^g = \tau w_t h_t \int_{s_{it}=e} z_{it} di + \dot{B}_t^g \tag{11}$$

where $\Psi_t^\ell = \tau^\ell w_t \ell_t - \phi^\ell$ is the net subsidy which undoes the monopolistic distortions of intermediate producers. Finally, government purchases of the final good G_t outside of steady-state follow the policy rule:

$$G_t = G^* - \beta_B(B_t^g - B^*), \quad \beta_B > 0 \tag{12}$$

where the superscript * denotes steady-state values. Thus, following an aggregate shock, debt adjusts to satisfy the government budget constraint, and government expenditures respond to deviations of debt from its steady-state level to keep debt from growing or shrinking too quickly.

2.6 Monetary Authority

In our baseline, the monetary authority sets the nominal interest rate according to an Inflation Targeting (IT) rule that reacts to deviations of inflation and unemployment rate from their targets with some inertia. If we let i_t denote the shadow policy instrument not subject to the zero lower bound (ZLB) and i^* the steady-state nominal rate, then the IT rule is defined as

$$\frac{di_t}{dt} = \begin{cases} -\beta_i(i_t - i^* - \mathcal{R}_t) & \text{if } i_t > 0 \\ \\ \max\Big\{ -\beta_i(i_t - i^* - \mathcal{R}_t),\ 0 \Big\} & \text{if } i_t = 0 \end{cases}$$

where the reaction function to inflation and unemployment is

$$\mathcal{R}_t = \beta_\pi(\pi_t - \pi^*) + \beta_u(u_t - u^*). \tag{13}$$

The coefficients $\beta_\pi > 1$ and $\beta_u \leq 0$ capture the strength of the policy response to deviations of inflation from target π^* and of unemployment from its steady-state value u^*, while $\beta_i > 0$ measures the degree of interest rate smoothing. The monetary authority is constrained by a ZLB on nominal rates which forces i_t to be weakly above zero at all times.

Finally, a standard Fisher equation states that the real financial return on the nominal bond must equal the nominal policy rate minus inflation at every t, or $r_t^m = i_t - \pi_t$.

2.7 Sources of Aggregate Fluctuations

Aggregate dynamics in our economy are driven by two shocks denoted by ζ_t^k, labeled demand ($k = d$) and supply ($k = s$) shocks.[20]

The demand shock ζ^d is a perturbation to the bonds' liquidity premium $\bar{\imath}$ which shows up as a time-varying wedge between the rate of return on equity and the return on bonds in the no-arbitrage equation (10)

$$\tilde{r}_t = \frac{\Pi_t + \dot{q}_t}{q_t} = r_t^b + \bar{\imath} + \zeta_t^d = r_t^m + \bar{\imath} + \zeta_t^d. \tag{14}$$

[20] Our two disturbances are akin, respectively, to a "risk-premium" shock and a "cost-push" shock, both common in the literature on estimated New Keynesian DSGE models, and routinely found to contribute significantly to the overall fluctuations of total hours worked in the US economy (see, e.g. Smets and Wouters, 2007; Galí et al., 2012).

An unanticipated increase in ζ^d reduces q_t, the value of equity, relative to bonds and raises the rate of return to household wealth. These two forces contract household demand for consumption of the final good and firms' demand for labor to produce it. Facing lower demand for their labor task, unions lower nominal wages which pushes down inflation. Thus, output, hours, and inflation comove positively under this shock, which is why we label it a demand shock.

The supply shock ζ^s is a disturbance to the union's desired markup $\varepsilon/(\varepsilon-1)$. As clear from the wage Phillips curve derivation (C9), the shock shows up as a wedge in (9), whose linearized version (recall that the real wage is constant) becomes

$$\rho(\pi_t - \pi^*) - \dot{\pi}_t = \theta_w \left[\frac{1}{\sigma}(\log h_t - \log h^*) + \zeta_t^s \right]. \tag{15}$$

where $\theta_w \equiv \frac{\epsilon}{\Theta}\left[\int_{s_{it}=e} \partial_c u^e(c_{it}, h_t; z_{it}) z_{it} di\right] \psi(h^*)^{\frac{1+\sigma}{\sigma}}$. A positive shock to unions' desired markup ($\zeta_t^s > 0$) raises nominal wages, which puts upward pressure on inflation. A central bank following (13) reacts to the inflation by raising real rates, which lowers household demand for consumption of the final good and thus firm demand for hours. Thus, output and hours comove negatively with inflation under this shock, which is why we label it a supply shock.

It only remains to specify how labor market frictions $\lambda_{zt}^{ss'}$ adjust out of steady state. Because employment and hours per worker are tightly correlated in the data, we posit that job offer arrival and separation rates shift with fluctuations in average hours per worker h_t. Specifically, we assume that

$$\log\left(\lambda_{zt}^{ss'}\right) = \log\left(\lambda_z^{*\,ss'}\right) + \vartheta^{ss'} \log\left(\frac{h_t}{h^*}\right), \quad \text{for } ss' \in \{eu, ue, ne\} \tag{16}$$

where $\vartheta^{ss'}$ determines the elasticity with respect to hours.[21]

[21] Under this specification, the ratio $\lambda_{zt}^{ss'}/\lambda_z^{*\,ss'}$ is the same for all z, i.e., aggregate shocks shift frictions proportionately along the workers' skill distribution. This proportional shift, however, implies changes to unemployment that are *not* proportional in level. To understand this property, consider the expression for steady-state unemployment in a simple 2-state model: $u_z = \frac{\lambda_z^{eu}}{\lambda_z^{eu}+\lambda_z^{ue}}$. Differentiating with respect to the log of the separation rate $\frac{\partial u_z}{\partial \lambda_z^{eu}/\lambda_z^{eu}}$ (and similarly when we differentiate with respect to the job finding rate) yields $u_z(1-u_z)$. As long as the unemployment rate is below 0.5 (an upper bound that is never reached for any plausible model calibration), the response of unemployment rate to a given percentage change in frictions is increasing in the level of steady-state unemployment u_z. Since in the data, and in the calibrated model, low z workers experience higher unemployment on average, they end up also displaying a stronger response to fluctuation in the flows.

To understand the distortions caused by aggregate fluctuations in our model, and, thus, the potential scope for monetary stabilization policy, it is useful to consider a benchmark version of our economy where nominal wages are flexible and set competitively. This configuration corresponds to a limit case of our economy where the wage Phillips curve is vertical ($\theta_w \to \infty$) and wage markup shocks are absent ($\zeta_t^s = 0$ for all t). In this benchmark, employed workers are always on their labor supply curves for hours, which specifies a constant number of hours worked h^* independently of the realization of demand shocks. Since h^* coincides with hours worked at our non-stochastic steady state, this condition also translates into a roughly constant unemployment rate, equal to its steady-state value.[22]

This benchmark with flexible and competitive wages provides the rationale for the strict IT rule (13). In response to a demand shock, inflation and unemployment move in opposite directions and elicit the same response from the IT rule which stabilizes deviations of both hours and inflation from that baseline. In response to a supply shock instead, this rule trades off stabilizing inflation around its target versus minimizing deviations of unemployment—and, by consequence, hours— from that benchmark allocation.

However, the presence of the ZLB adds another layer to the central bank's stabilization objectives. As we show below, recessions that trigger the ZLB in our model lead to *temporary* worse inflation and unemployment outcomes but leave *long-lasting* scars on labor force attachment and productivity, especially among workers at the bottom of the distribution. In this scenario, a policy that deviates from strict inflation and unemployment stabilization following recessions (e.g., a policy that lets the economy run hot during expansions) might be desirable because it has the benefit of allowing workers to re-enter participation, regain employment, and recuperate the earnings losses they endured in the recession.

2.8 Equilibrium

We now formally state the definition of a perfect foresight equilibrium for our economy, which is the relevant one for all our experiments given our solution method outlined in Section 2.9.[23]

For any given initial distribution of households $\mu_0^s(a, z)$, with $s \in \{e, u, n\}$, and a

[22] Unemployment in our model, as it is the case in the data, moves primarily in response to fluctuations in job-separation and job-finding rates. A constant level of hours leads, through (16), to a constant job-separation and job-finding rate.

[23] A stationary equilibrium (or steady-state) is a particular case of our definition where all decisions, prices, aggregate variables, and distributions are constant over time.

time path for shocks $\{\zeta_t^k\}_{t\geq 0}$, with $k \in \{s, d\}$, a perfect foresight equilibrium is defined as time paths for household consumption, participation and job offer acceptance decisions $\{c_t^s(a,z), \mathfrak{p}_t^s(a,z), \mathfrak{j}_t^s(a,z)\}_{t\geq 0}$, unions' nominal wage setting $\{\omega_{kt}\}_{t\geq 0}$, intermediate producers' hiring decisions $\{\ell_{kt}\}_{t\geq 0}$, mutual fund allocations $\left\{X_t^f, B_t^f, M_t^f\right\}_{t\geq 0}$, real rates of return on the mutual fund, real and nominal government bonds $\left\{\tilde{r}_t, r_t^b, r_t^m\right\}_{t\geq 0}$, firms' share price $\{q_t\}_{t\geq 0}$, fiscal variables (UI benefits, expenditures, and debt) $\left\{b_t(z), G_t, B_t^g\right\}_{t\geq 0}$, nominal interest rates $\{i_t\}_{t\geq 0}$, aggregate output, consumption, profits, contractual hours worked, and inflation $\{Y_t, C_t, \Pi_t, h_t, \pi_t\}_{t\geq 0}$, and measures of households $\left\{\mu_t^s(a,z)\right\}_{t>0}$ such that at every t: (i) households solve problems (3)-(7); (ii) final good and intermediate good producers solve (B2) and (B4), respectively; (iii) unions solve (C6) and inflation satisfies the Phillips curve in (9) (iv) the mutual fund solves (D1); (v) the government budget constraint (11) holds; (vi) the fiscal and monetary authorities follow their policy rules (12) and (13); (vii) aggregate profits are given by (B8); (viii) the sequence of distributions satisfies aggregate consistency conditions, (ix) asset and annuity markets clear, and (x) all goods markets clear.

There are four asset markets in our economy: the intermediate firms' shares market, the two government bond markets, and the mutual fund shares market which clear when, respectively,

$$
\begin{aligned}
X_t^f &= 1 \\
B_t^f &= B_t^g \\
M_t^f &= 0 \\
\sum_{s\in\{e,u,n\}} \int a_t d\mu_t^s &= A_t = q_t + B_t^g
\end{aligned}
$$

where, without loss of generality, we normalized the measure of firms' shares to 1. These equations, together with the no-arbitrage conditions (10), determine firm share prices and real interest rates. Market clearing in the continuum of intermediate goods' markets requires

$$
y_{jt} = Y_t, \text{ for all } j
$$

and the final good market clears by Walras law. Given the set of employed workers, average hours per worker h_t required by final good producers is determined by

$$Y_t = \alpha h_t \int_{s_{it}=e} z_{it} di.$$

Lastly, we note that the labor market is frictional and the evolution of the distribution of employed, unemployed, and non participants is implicit in the KFEs for μ_t^s.

2.9 Numerical Solution, Simulation and Asymmetric Rules

We solve globally for the stationary equilibrium of our model using standard continuous-time finite-difference methods as described in Achdou et al. (2021) and compute the economy's perfect foresight linearized response to aggregate shocks using the sequence-space approach of Auclert et al. (2021). To simulate the ergodic distribution of our economy, we extend the procedure in Boppart et al. (2018) to incorporate an occasionally binding ZLB and asymmetric monetary policy rules, as in Holden (2016). This procedure maintains the model's linearity with respect to aggregate shocks, but allows for aggregate nonlinearities coming from monetary policy rules. We compute our policy counterfactuals following the insights of Hebden and Winkler (2024) and McKay and Wolf (2023). In essence, one can use monetary policy "news" shocks, computed under any baseline rule, to construct the economy's counterfactual trajectory under different alternative rules. This approach sidesteps the need to solve the full model for every alternative rule and fits nicely with the way we dealth with asymmetries from the ZLB and alternative rules. We leave the details of the solution method to Appendix E.

By retaining linearity with respect to aggregate shocks, our solution method abstracts from potentially important forces that would arise in the—currently unfeasible—fully nonlinear approach. Ex-ante, the direction and magnitude of the error are unclear. Take, for instance, the effect of future aggregate uncertainty on the direction of the inflation bias. On the one hand, agents in our model don't internalize that the ZLB might bind in the future when it is not binding today. This channel would exacerbate the deflationary bias. On the other hand, agents also don't internalize the Lower for Longer's promise to run a hot economy during booms when the economy is at other points of the business cycle. This channel would, instead, amplify the inflationary bias. A robustness exercise based on the stochastic extended path method (Adjemian and Juillard, 2013) described in the Appendix indicates that the numerical error we make by ignoring future uncertainty is very small.

3 Parameterization

We organize our discussion of the parameterization in three parts. Section 3.1 explains our calibration strategy for parameters which determine the model's stationary equilibrium, and Section 3.2 does it for parameters which determine out-of-steady-state dynamics. Section 3.3 validates our calibration along a series of micro and macro untargeted moments.

Overall, our calibration targets include a wide set of earnings and employment distribution moments that are meant to discipline the strength of the three Okun's channels: (i) exposure, (ii) attachment, and (iii) persistence. Among these, we show that the model does a good job of capturing (i) the high unemployment and weak participation at the bottom of the skill distribution, (ii) the level and cyclicality of labor market stocks and flows, and (iii) statistics of earnings losses upon displacement and earnings growth over the life cycle. Table 2 summarizes the model parameter values. Table 3 reports empirical and model's values of the targeted moments.

3.1 Parameters Determining the Steady State

Some parameters are set externally, and others internally to match a set of targeted moments. Generally, the internally calibrated parameters affect all targeted moments, but some moments are more informative for a subset of the parameters than others. Our presentation and discussion of the calibration strategy reflects this logic. The model period is set to one month.

Demographics and Preferences. We set the monthly mortality rate ϱ so that workers' average lifespan is 36 years (25 to 60). The Frisch elasticity on the intensive margin of labor supply is set to $\sigma = 1$. Working entails a variable and a fixed cost. The variable disutility parameter ψ is set so that $h^* = 1$ satisfies (9) in steady state. The flow utility of non-participation κ^n is normalized to zero. The fixed costs of searching κ^u and working κ^e , which regulate workers' desire to participate in the labor market, are set jointly with frictional parameters to match labor market moments as we discuss below.[24]

The effective discount rate ρ is set to target a ratio of mean wealth to annual earnings of 0.56 under a (annual) real interest rate r^* of 3%. This corresponds to the amount of liquid wealth among US households immediately available for consumption smoothing (Kaplan and Violante, 2022). In equilibrium, total savings by households must be equal to the value of the mutual fund, which includes the value of government bonds and firm

[24] The switching cost ξ is set to a very small number to make the optimal stopping problem well behaved.

Steady State		
Parameter		Value
Demographics and Preferences		
Death rate	ϱ	$1/432$
Effective discount rate	ρ	0.0053
Labor supply elasticity	σ	1.00
Utility weight on hours	ψ	1.00
Disutility of nonparticipation	κ^n	0
Disutility of searching	κ^u	0.33
Disutility of working	κ^e	1.05
Skill dynamics		
Mean of initial skill distribution	$\bar{z}_0$	$\log(0.68) - \sigma_{z_0}^2/2$
S.D. of initial skill distribution	σ_{z_0}	0.50
Skill mean reversion	γ_z	0.0017
Skill drift while employed	δ_z^+	0.0024
Skill drift while non-employed	δ_z^-	0.0214
Skill diffusion coefficient	σ_z	0.0467
Labor market frictions		
Job-separation rate out of E	λ_z^{eu}	Table F2
Job-finding rate out of U	λ_z^{ue}	Table F2
Job-finding rate out of N	λ_z^{ne}	Table F2
Passive nonparticipation rate during E	η^{en_0}	0.0075
Passive nonparticipation rate during U/N	$\eta^{un_0}, \eta^{n_1 n_0}$	0.0750
Passive nonparticipation exit rate	$\eta^{n_0 n_1}$	0.2500
Technology		
Firm productivity	α	1.25
Elast. of subst. between goods	ν	10
Elast. of subst. between tasks	ε	10
Liquidity premium	ι	0.001
Taxes, transfers and expenditures		
Government debt	B^g	1.69
UI replacement rate	$\bar{b}$	0.50
UI expiration rate	$\lambda^{u_1 u_0}$	0.167
Labor income tax rate	τ	0.20
Lump-sum transfer	ϕ	0.068
Government expenditures	G	0.17
Intermediate firms labor subsidy	τ^ℓ	0.10
Intermediate firms net subsidy	Ψ^ℓ	0.001

Out of Steady State		
Parameter		Value
Monetary and Fiscal Policy		
Trend inflation	π^*	$0.02/12$
Taylor rule persistence	β_i	0.07
Taylor rule reaction to inflation	β_π	2.25
Taylor rule reaction to unemployment rate	β_u	-0.15
Government expenditures response to debt	β_B	0.10
Phillips Curve		
Slope of the wage Phillips curve	θ_w	0.01
Aggregate Fluctuations		
Demand shock drift	γ_d	0.0200
Demand shock diffusion	σ_d	0.0001
Supply shock drift	γ_s	0.0200
Supply shock diffusion	σ_s	0.0008
Elasticity of (λ_z^{eu}) to hours	ϑ^{eu}	-11.00
Elasticity of $(\lambda_z^{ue}, \lambda_z^{ne})$ to hours	$\vartheta^{ue}, \vartheta^{ne}$	24.00

Table 2: Model parameter values expressed in monthly frequency. See Section 3 in the main text for a discussion of parameter choices and targets.

equity. We set government debt B^g to be 1/4 of total equity (2019 Flow of Funds, Table B.101.h Balance Sheet of Households) and adjust the value of the net subsidy Ψ^ℓ, which determines aggregate profits, so that the value of equity held by the fund, plus the value of bonds, equals workers' demand for savings.[25]

Skill Dynamics. The mean of the initial skill distribution $\bar{z}_0$ is set so that the average skill in levels $\exp\left(\bar{z}_0 + 0.50\sigma_{z_0}^2\right)$ equals 0.68, reflecting the average wage of age group 23-27 relative to the pool of all workers in the 2019 Current Population Survey (CPS) (Heathcote et al., 2023). Its dispersion σ_{z_0} is set to match the group's P90-P50 hourly wage ratio of 2.00.

The parameters in the skill diffusion process (1) are set as follows. The skill diffusion

[25] An alternative way of interpreting this calibration strategy is to say is that we choose Ψ^ℓ and B^g so that, given the household demand curve, the annual real interest rate that clears the asset market is 3%.

σ_z is set to match the P90-P50 wage ratio for the 2019 CPS.[26] The mean reversion γ_z is set to 0.0017, corresponding to an annual autocorrelation of $\exp(-12 \times \gamma_z) = 0.98$, while the positive δ_z^+ and negative δ_z^- drifts are chosen to match (i) the average worker log earnings growth between ages 25 and 60, and (ii) the average earnings losses of laid-off workers 10 years after separation as computed in Davis and Von Wachter (2011).[27] Table 3 shows that our calibration does a good job matching these targets with earnings losses 10-years after displacement falling at the low end of the range of estimates in Davis and Von Wachter (2011). Like in the data, earnings losses in the model are cyclical and larger during recessions.

In order to generate earnings losses consistent with the data, the average skill depreciation during a month of unemployment in the model is 2.1%.[28] This is roughly in the middle of the available U.S. estimates of the impact of an additional month in non-employment on workers' starting wages upon re-entry, which ranges from 1.0% to 3.5% (Table 3, Addison and Portugal, 1989; Table 3 and 4, Neal, 1995; Table 2, Braxton and Herkenhoff, 2021).

Labor Market Frictions, Nonparticipation Shocks, and Participation Costs. Search frictions, passive nonparticipation shocks, and participation costs are disciplined by data on flows between employment states, in the aggregate and across the weekly earnings distribution (our proxy for skills), computed from the Basic Monthly CPS. We organize our discussion below according to the different labor flows. See Appendix F for a description of the data and more details on our calibration strategy.

EU and UE flows for each skill level z are linked to the job-separation λ_z^{eu} and job-finding λ_z^{ue} rates: all EU transitions are forced separations from employment, while UE transitions are the outcome of an accepted job offer out of unemployment. Given this tight relation between search frictions and the measured flows, we calibrate λ_z^{eu} and λ_z^{ue} to match the EU and UE flows across workers' skill distribution.

[26] We target the P90-P50 ratio—here and for the initial skill dispersion—because wage variation at the top of the distribution is more directly tied with skill variation, whereas the extensive margin of labor supply plays a bigger role at the bottom of the distribution.

[27] We compute average earnings losses upon displacement in the model by comparing the earnings profile of a random sample of employed workers in the scenario where they are displaced at time zero (treatment group) against a scenario where they do not separate (control group). As in Davis and Von Wachter (2011), we restrict our sample in the treatment and control groups to high-tenure workers (i.e., workers with expected tenure at the job of at least 3 years), we condition admittance to the control group only to workers that remain employed for the entire first year of the simulation, and we keep workers with zero earnings in the treatment group.

[28] Given our estimate for skill depreciation $\delta_z^- = 0.0214$ and the average (log) skill among employed workers of -0.13, an additional month in non-employment in our model lowers individual skills by $0.021 = 0.0214 + 0.0017 * (-0.13)$ on average.

EN and UN flows occur either because workers suddenly find working or searching too costly given their skills (e.g., following a skill decay shock) or following an exogenous passive nonparticipation shock η^{sn_0} for $s = e, u$. We use information along the skill distribution to distinguish between these two motives. Specifically, we set η^{en_0} and η^{un_0} to match the empirical transition rates among high-skilled workers—who, otherwise, rarely exit the labor force in the model—and rely on the average EN and UN to inform the fixed costs κ^e and κ^u regulating participation decisions.

Finally, NE and NU flows arise from workers in nonparticipation who desire to move back into employment. Besides the parameters determining workers' incentives to participate, three other parameters regulate workers' ability to rejoin employment: the arrival rate of passive nonparticipation shock for active nonparticipants $\eta^{n_1 n_0}$, its exit rate $\eta^{n_0 n_1}$, and the job-finding out nonparticipation λ_z^{ne}. First, we assume that active nonparticipants transition into passive nonparticipation at the same rate as the unemployed, i.e., we set $\eta^{n_1 n_0}$ equal to η^{un_0}. Next we use $\eta^{n_0 n_1}$ and λ_z^{ne} to target the two flows out of nonparticipation.[29]

The model matches the average flows reasonably well (see Table 3). In particular, the model generates a large attachment wedge between unemployed and employed workers (i.e., $EN >> UN$), which, as we argue in the introduction, is essential to capture the strong 'participation cycle' present in the data (Hobijn and Şahin, 2021).

Technology. Firm productivity α is set to normalize after-tax hourly wage per efficiency units $(1 - \tau)w^*$ to 1 in steady state. The elasticities of substitution across labor types (ε) and across intermediate goods (ν) are set to 10, which imply wage and price markups around 10 percent. Finally, we set the mutual fund's "liquidity premium" of holding bonds ι to 10bp so that the steady-state (annual) nominal interest rate $i^* = r^m + \pi^*$ is equal to 1%.[30]

Steady-State Fiscal Policy. We assume that unemployment benefits are given by $b_t(z_{it}) = \bar{b}\, w_t h_t z_{it}$, and set the UI replacement rate $\bar{b}$ to 0.5 of individual earnings. We make $\lambda_z^{u_1 u_0}$ constant across skill z and equal to 0.167 to reflect an average UI benefits duration of 6 months. The proportional tax rate τ is set to 0.2 and the lump-sum transfer ϕ is cali-

[29]As we discuss in Appendix F, participation decisions and time aggregation create a wedge between the job-finding out of nonparticipation λ_z^{ne} and NE flows across the skill distribution. Since this wedge can vary across the skill distribution, we don't rely on NE to capture the shape of λ_z^{ne}. Instead, we assume that λ_z^{ne} shares the same shape across z as λ_z^{eu}, i.e., $\lambda_{z_1}^{ne}/\lambda_{z_2}^{ne} = \lambda_{z_1}^{ue}/\lambda_{z_2}^{ue}$ for any skill levels z_1 and z_2.

[30]The main role of the "liquidity premium" parameter is to vary how frequently the ZLB binds in our simulations without affecting the calibration of the stationary equilibrium.

Table 3: Targeted moments.

Stationary Equilibrium	**Data**	**Model**		**Data**	**Model**
Liquid wealth to annual earnings[1]	0.560	0.576	Employment[6]	0.764	0.732
Lump-sum transfer to total earnings[2]	0.060	0.055	Unemployment rate[6]	0.055	0.062
90-50 wage ratio (entrants)[3]	2.000	1.954	EU[6]	0.013	0.013
90-50 wage ratio (all workers)[3]	3.000	3.042	UE[6]	0.248	0.260
55/25 log earnings difference[4]	0.700	0.684	NE[6]	0.069	0.023
10-Year earnings losses upon displacement[5]	[-0.15,-0.10]	-0.096	EN[6]	0.017	0.010
			UN[6]	0.133	0.090
			NU[6]	0.027	0.027

Out of Steady State	**Data**	**Model**		**Data**	**Model**
Standard deviation of total hours	3.45	3.44	$Cov(E_t, H_t)/Var(H_t)$	0.70	0.75
Inflation and unemployment correlation	-0.32	-0.26	$SD(UE_t)/SD(EU_t)$	1.15	1.14

Stationary Equilibrium. [1]Kaplan and Violante (2022); [2]Authors calculations from Table 3.12 and 2.1 of NIPA for 2019; [3]Heathcote, Perri, Violante, and Zhang (2023); [4]Difference in mean log income at ages 55 and 25 for the US as reported in the Global Repository of Income Dynamics (GRID); [5]Davis and Von Wachter (2011) 10-year ahead earnings losses as a percent of predisplacement annual earnings during recessions (-0.15) and expansions (-0.10); [6]Employment, unemployment, labor force participation and all six gross worker flows are computed directly from the CPS (see Appendix F for a detailed description of our data and sample selection).

Out of Steady State. Data is quarterly from 1989 to 2019. Total hours H and hours per worker h are computed from the BLS-CES. To calibrate the correlation of inflation and unemployment and inflation, we consider data from 1995 to 2019. UE and EU flows are quarterly averages of monthly data computed directly from the CPS. All series are in log and are detrended using a linear trend. The model based statistics are simulated at quarterly frequency to match the frequency of the data. See Appendix E for a description of the simulation procedure.

brated to match 6% of average earnings in steady-state.[31] The subsidy to labor hired by intermediate firms is set to $\tau^{\ell} = 1/\nu$ in order to undo the distortion caused by monopolistic competition. Government expenditures are set residually to satisfy the government budget constraint in steady state.

3.2 Parameters Determining Out of Steady State Dynamics

Monetary and Fiscal Policy. We assume a steady-state (trend) inflation rate π^* of 2%. We set the interest rate smoothing to $\beta_i = 0.07$, corresponding to a quarterly persistence of 0.81. Values for the coefficient on inflation $\beta_\pi = 2.25$ and the coefficient on the unemployment gap $\beta_u = -0.15$ are consistent with estimates from Bayer et al. (2024). We set β_B in our fiscal rule (12) to 0.1 as in Auclert et al. (2020).

[31]This number is obtained by dividing Government Social Benefits by Wages and Salaries. Transfers are computed as: Workers' compensation, SNAP, Supplemental security income, Refundable tax credits, Temporary disability insurance, Workers' compensation, Family assistance, General assistance, Energy assistance, Employment and training, Other benefits, and 0.4*Medicaid (Table 3.12 of NIPA). Wages and salaries are taken from Table 2.1 of NIPA for 2019. The share of Medicaid expenditures that are effective transfers to households (0.4) is obtained from Finkelstein et al. (2019).

Slope of the Phillips curve. The slope of the linearized Phillips curve θ_w is set to match the peak response of inflation to high-frequency identified monetary policy shocks as reported in McKay and Wolf (2022), i.e., approximately 30bp for a 100bp change in the nominal rate. In terms of the empirical Phillips curve relating inflation, future inflation and unemployment, by simulating a demand shock we verified that our calibration of θ_w translates into a slope somewhere between -0.15 and -0.20 at quarterly frequency, in line with the estimates reported by Furlanetto and Lepetit (2024).

Aggregate Fluctuations. The aggregate demand and supply shocks ζ_t^d and ζ_t^s both follow an Ornstein-Uhlenbeck diffusion process

$$d\zeta_t^k = -\gamma_k \zeta_t^k dt + \sigma_k d\mathcal{W}_t^k, \tag{17}$$

where $d\mathcal{W}_t^k$ is a standard Wiener process. For both shocks we set γ_k to 0.02, corresponding to a monthly persistence of 0.98. The values of the demand and supply diffusion coefficients (σ_d, σ_s) are set to match the empirical correlation between unemployment rate and inflation (-0.32) and the standard deviation of total hours $H_t = E_t \times h_t$ (3.45), both at quarterly frequency. The elasticities of frictions to hours ($\vartheta^{eu}, \vartheta^{ue}$) are chosen to replicate the share of the variance in total hours coming from fluctuations in the extensive margin of employment (70%) and the relative volatility of *eu* and *ue* flows (1.15).[32] The bottom of Table 3 reports the model's performance along these targeted business cycle moments.

3.3 Untargeted Labor Market Moments

In this section we explore the ability of our model to match some other important, but untargeted, empirical patterns of workers' earnings and employment dynamics. The model and data moments are shown in Table G1 in the Appendix.

Marginal Propensity to Consume and to Earn. The average quarterly marginal propensity to consume in the model is close to 0.10. In addition, our parameterization is consistent with recent U.S. micro evidence on the impact of lottery wins on worker's labor supply with an annual marginal propensity to earn (the dollar reduction in earnings for an additional dollar of non-earned income) around -0.02 (Golosov et al., 2023).

Participation and Unemployment for Low-skilled Workers Low-skilled workers in our model experience lower participation and higher unemployment rates, as in the data. Participation and unemployment rates among workers at the bottom tercile of the skill

[32] Keeping with the steady-state calibration strategy, we set the elasticity of λ_{zt}^{ne} with respect to hours equal to the elasticity of λ_{zt}^{ue}, or $\vartheta^{ne} = \vartheta^{ue}$.

distribution are, respectively, 41% and 12% in the model against 43% and 15% in our data.

Earnings Dynamics. Individual earnings dynamics in our model arise from the interplay between an exogenous stochastic process for skills (conditional on workers' employment status), job finding and separation rates (which depends on workers' skills), and an endogenous participation decision (which depends on workers' wealth and skill levels). This rich interaction allows our model to jointly match the large cross-sectional dispersion of annual log-earnings changes (0.437 in the model against 0.51 in the data) and the rise of earnings inequality over the life cycle (from 0.53 at age 25 to 0.977 at age 55 in the model, against 0.595 to 0.905 in the data, respectively).[33] Moreover, we can also reproduce, at least qualitatively, the higher-order moments of the (log) earning growth distribution—a negative skewness and a high kurtosis—even though these patterns are not as stark as in the data.

Earnings Losses Across the Distribution. The earnings losses due to long nonemployment spells (full-year of nonemployment) in the model are comparable to evidence documented by Guvenen et al. (2017) across the worker earnings distribution. Comparing future earnings of workers experiencing a full-year of nonemployment against a control group that is employed at least part of the year, we find 10-year ahead losses of 45% (27%) at the 25th (75th) percentile of the recent earnings distribution, close to the 50% (30%) losses reported by Guvenen et al. (2017, Figure 1).[34] Moreover, consistent with what the authors find (Guvenen et al., 2017, Figure 2), these larger long-run earnings losses at the bottom are mostly due to the extensive margin. In the model, a full year of nonemployment is associated with a 18 ppt higher nonemployment rate 10 years ahead at the 25th percentile of the skill distribution, compared to an increase of only 3 ppt at the 75th percentile.

Effect of Unemployment Rate at Entry on Future Earnings. A number of papers find that joining the labor market during recessions leads to significant and persistent effects on the earnings of entrants workers, particularly those belonging to less-advantaged groups (see von Wachter, 2020, for a summary of the empirical evidence). Our model replicates this fact with an estimated effect of a 1 ppt unemployment rate at entry on earnings equal to -0.041 and -0.016 log-points, respectively, 1 and 5 years following entry, in line with the

[33] As demonstrated by Heathcote et al. (2010), the traditional linear Gaussian model for earnings dynamics struggles to jointly match these two facts.

[34] For this exercise, we follow Guvenen et al. (2017) in defining a worker as nonemployed in a year t if their annual earnings fall below a minimum earnings threshold.

estimates in Schwandt and von Wachter (2019).[35]

Business Cycle Properties of Stocks and Flows. The volatility and cyclicality of employment, unemployment, and labor force participation match the business cycle properties of the data. mployment dynamics in our model are, just as in the data, the combination of a strong countercyclical reaction in the unemployment rate together with a weaker, but procycylical, response in participation. Notably, our calibration also yields the right cyclicality for all six labor market flows, both unconditionally (Krusell et al., 2017; Cairó and Lipton, 2023) and conditional on a monetary policy shock (Graves et al., 2023), as discussed in detail in Alves and Violante (2024).

4 Economic Outcomes Under Inflation Targeting

We now analyze the aggregate and distributional outcomes of our economy when monetary policy follows a traditional Inflation Targeting (IT) rule as specified in equation (13). We proceed in three steps. We first study aggregate and distributional impacts of small demand and supply shocks for which the ZLB is not binding (Section 4.1). Next, we turn to the case of a large negative demand shock that triggers the ZLB (Section 4.2). Last, we simulate the model under demand and supply shocks to recover the ZLB-induced biases in the ergodic distribution (Section 4.3).

Altogether, the main takeaway from this section is that the three Okun's channels—exposure, attachment, and persistence—combine to give rise to a form of negative labor market hysteresis for low-skill workers which is severely amplified by the ZLB when the monetary authority adheres to an IT rule.

4.1 Shocks that Do Not Trigger the ZLB

4.1.1 Aggregate Implications

The impulse response functions (IRFs) to contractionary aggregate demand and supply shocks are illustrated in Figure 2. The responses of inflation and unemployment look standard: unemployment and inflation move in the opposite (same) directions following a demand (supply) shock. Notably, the shocks have very different predictions on the long-run behavior of inflation, unemployment, and hours (first row) versus total earnings, participation, and labor productivity (second row). Inflation, unemployment, and

[35] The effect of the unemployment rate on log-earnings in the model is computed out of a demand-driven recession that triggers the ZLB, as in Figure 4.

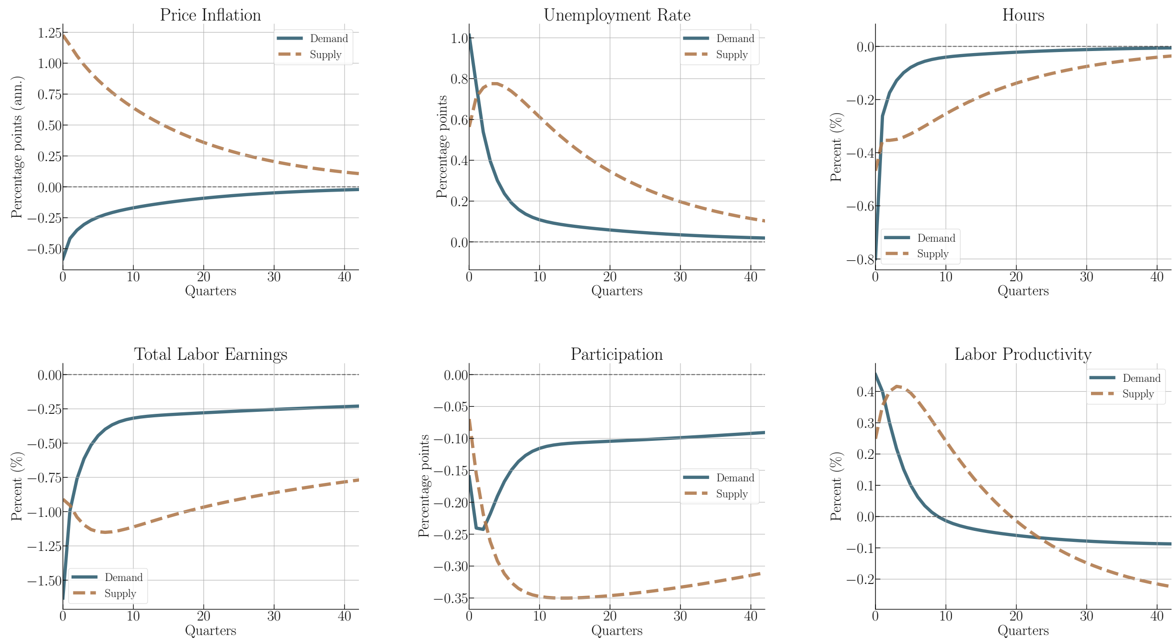


Figure 2: Impulse response of aggregate variables to demand and supply shocks under IT when the ZLB is not binding.

hours revert to steady state as the driving demand and supply shocks dissipate from the economy. In contrast, earnings, participation, and productivity remain depressed for much longer, with their values still significantly below steady state even after 10 years.[36]

The mechanism behind these hysteresis is that an increase in unemployment, albeit transitory, triggers adverse long-lasting effects on total earnings. First, skill losses during non-employment recover only slowly when workers regain their jobs and drive down labor productivity persistently.[37] Second, lower skills make job opportunities less likely to arrive and push down potential wages, driving marginal workers out of participation. It is through these two channels that hysteresis arises in our model. Crucially, these hysteresis do not affect all workers the same way, as we discuss in the next section.

[36]While these hysteresis effects are extremely persistent, they are not permanent in our model. Equivalently, our economy eventually returns to its stationary steady state in the very long run.

[37]Labor productivity displays a short-lived increase due to a selection effect—as low-productivity workers are more exposed to layoffs, a spike in separations shifts the composition of employed workers toward high-productivity individuals.

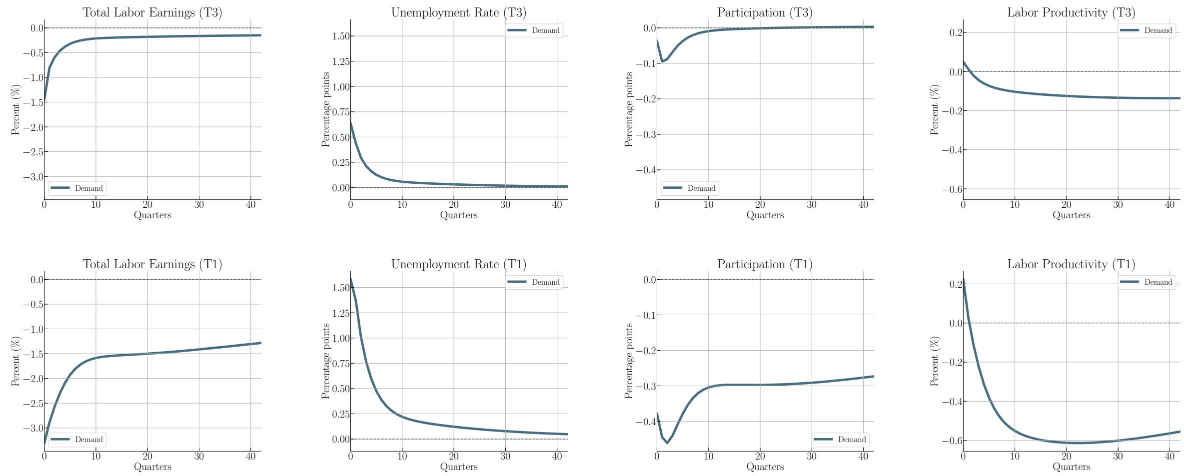


Figure 3: Impulse response of labor market outcomes for the top (T3) and bottom (T1) skill terciles to a demand and supply shocks when the ZLB is not binding.

4.1.2 Distributional Implications

To highlight the heterogeneous hysteresis effects across the distribution, Figure 3 plots the impact of a demand shock at the bottom and top terciles of the skill distribution.[38] The reduction in earnings (first column) at the bottom is not only more severe but significantly more persistent—10 years after the shock, total earnings at the bottom are still depressed by roughly half of the first-year impact, while earnings at the top have all but recovered.

To better understand the sources of this earnings gap response, we rely on a simple decomposition of total labor earnings for each group g

$$W_t^g = wh_t \times (1 - u_t^g) \times P_t^g \times Z_t^{e,g} \tag{18}$$

where $(1 - u_t^g)$ is the employment rate, P_t^g is labor force participation, and $Z_t^{e,g}$ is average labor productivity at time t, all three conditional on skill group g. Intuitively, each component of (18)—displayed in the second, third and fourth columns of Figure 3—captures one of the Okun's channels of exposure, attachment, and persistence.

Table 4 displays the contribution of each channel to the observed total labor earnings 1 and 10 years after the shock. Not surprisingly, we find that movements to hours and unemployment drive most of the short-run response of total labor earnings, whereas its long-lasting scars arise from the dynamics of participation and labor productivity. At

[38] We choose terciles because they roughly correspond to the share of workers with a high-school degree or less, those with some college education, and those with a college degree or more.

Table 4: Total Labor Earnings and its Sources 1 and 10 Years After a Demand Shock

	Year 1		Year 10	
	$\mathbb{E}$	(%)	$\mathbb{E}$	(%)
T3 Total Labor Earnings	-0.82	—	-0.15	—
Hours	-0.341	0.36	-0.007	0.05
Unemployment rate	0.395	0.50	0.013	0.08
Participation rate	-0.072	0.12	0.003	-0.01
Labor productivity	-0.001	0.02	-0.136	0.88
T1 Total Labor Earnings	-2.76	—	-1.33	—
Hours	-0.341	0.11	-0.007	0.01
Unemployment rate	1.182	0.48	0.057	0.05
Participation rate	-0.431	0.39	-0.281	0.51
Labor productivity	-0.023	0.02	-0.575	0.43

Note. Expected values ($\mathbb{E}$) are expressed in terms of deviations from the non-stochastic steady state. Unemployment and participation are denoted in percentage points deviations. All other variables are in percent deviations. The (%) measures the channel's contribution to the total labor earnings bias. T1 and T3 refer to average outcomes for the bottom and top terciles of the worker's skill distribution. See (18) for a decomposition of group's g total earnings W_t^g into the contribution of hours h_t, unemployment rate $(1-u_t^g)$, labor force participation P_t^g, and labor productivity $Z_t^{e,g}$.

the top of the skill distribution, the responses across all three channels are minimal and tend to dissipate relatively quickly. While labor productivity shows some persistence even among high-skilled workers, its overall movement remains small. In contrast, low-skilled workers experience responses that are 2-4 times stronger, with a greater initial exposure to rising unemployment and significantly larger, more persistent declines in both labor force participation and productivity, which account for approximately 50% and 43%, respectively, of the 10-year decline in earnings observed at the bottom. Earnings hysteresis, therefore, disproportionately affects low-wage workers in our model.

4.2 Shocks that Trigger the ZLB

The solid line in Figure 4 plots the economy's response to a one-time large negative demand shock that triggers the ZLB for around 10 quarters. The dashed line plots the economy's response abstracting from the constraint on nominal rates. The difference between the two lines thus captures the impact of the ZLB on aggregate and distributional outcomes.

Similar to other studies on the deleterious effects of the ZLB (e.g., Williams, 2009; Kiley and Roberts, 2017; Bernanke et al., 2019), our model also predicts worse outcomes in terms of both aggregate unemployment and inflation when the economy is at the constraint. Compared to this earlier body of work, however, the presence of labor market

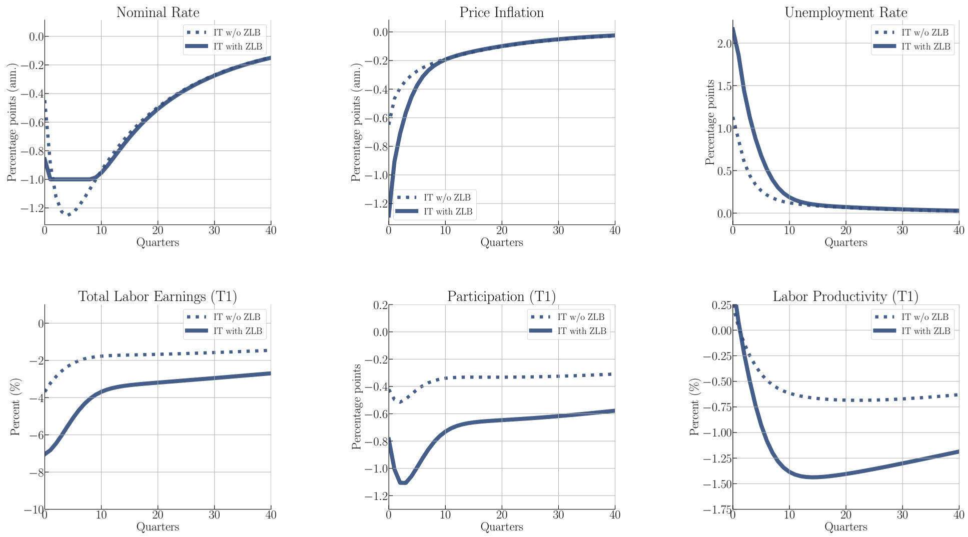


Figure 4: Impulse responses of aggregate variables and bottom terciles (T1) to a large negative demand shock that triggers the ZLB constraint.

hysteresis in our environment yields a lot of endogenous persistence to the negative effects of the ZLB, particularly at the bottom of the skill distribution (second row of Figure 4). Earnings, labor force attachment and skills losses for this group are all deeply exacerbated by the ZLB. In addition, the ZLB continues to impair this group's recovery long after the constraint ceases to be binding, up to 10 quarters following the shock. Crucially, these large negative biases in earnings and participation don't elicit a correction from the monetary authority since unemployment and inflation, the two variables entering the IT rule, revert much faster to their steady-state values. As a result, a central bank following an IT rule over a long horizon can end up with a significant downward bias in the earnings of low-skill workers, even if it is successful at keeping unemployment and inflation close to their targets. The next section looks exactly at this scenario.

4.3 Ergodic Distribution

The previous section highlighted the long-lasting effects of a single visit to the ZLB under an IT rule. In this section, we examine what happens when aggregate shocks repeatedly hit the economy and workers undergo multiple of these episodes, i.e., we compute the model's ergodic distribution.

Table 5 summarizes our results for both aggregate and distributional outcomes. The first notable feature is that the presence of the ZLB skews the ergodic distribution toward adverse outcomes: the share of time spent in recessions (defined as periods when unem-

Table 5: Business Cycle Statistics of the Ergodic Distribution Under Alternative Rules

	Inflation Targeting		Lower for Longer		Shortfall		AIT		Higher IT	
Business Cycle Features										
Boom frequency	0.059		0.238		0.229		0.095		0.071	
Recession frequency	0.165		0.101		0.132		0.101		0.103	
ZLB frequency	0.143		0.057		0.084		0.062		0.053	
Shadow rate at the ZLB	-0.66		-0.21		-0.62		-0.19		-0.13	
Statistics	$\mathbb{E}$	std	$\mathbb{E}$	std	$\mathbb{E}$	std	$\mathbb{E}$	std	$\mathbb{E}$	std
Output	-2.54	2.70	1.06	1.79	-0.13	2.63	-0.10	1.27	-0.44	1.35
Price inflation	-0.19	1.15	0.33	0.55	0.22	0.86	0.11	0.54	0.33	0.74
Total Hours	-1.96	3.43	0.83	2.21	-0.08	3.28	-0.07	1.55	-0.34	1.70
Unemployment rate	0.55	1.70	-0.23	1.08	0.03	1.61	0.02	0.76	0.10	0.84
Participation	-0.89	0.76	0.38	0.54	-0.03	0.76	-0.03	0.39	-0.15	0.39
Labor productivity	-0.58	1.06	0.23	0.70	-0.04	1.00	-0.02	0.49	-0.10	0.53
T3 Total Labor Earnings	-1.79	2.13	0.74	1.38	-0.10	2.05	-0.07	0.96	-0.31	1.06
T1 Total Labor Earnings	-12.17	9.99	5.20	7.13	-0.47	10.06	-0.39	5.20	-2.11	5.14

Note. "Boom frequency" denotes the share of time in the simulation where the aggregate unemployment rate is at least 1.0 ppt below its non-stochastic steady state. "Recession frequency" denotes the share of time in the simulation where the aggregate unemployment rate is at least 1.0 ppt above its non-stochastic steady state. "Shadow rate" denotes the gap between the nominal rate under the ZLB and the rate monetary authority would want to set if it was not constrained. Expected values ($\mathbb{E}$) are expressed in terms of deviations from the non-stochastic steady state. Inflation, unemployment and participation are denoted in percentage points deviations. All other variables are in percent deviations. T1 and T3 refer to average outcomes for the bottom and top terciles of the worker's skill distribution.

ployment is 1 ppt above the non-stochastic steady state) is 16.5%, much larger than the 6% spent in booms (periods when unemployment is 1 ppt below the non-stochastic steady state). This asymmetry results in a deflationary bias of nearly 20 bp and a sizable negative bias for aggregate labor market outcomes: the unemployment rate is 0.55 ppt higher, and the labor force participation rate is 0.9 ppt lower. More striking, though, is the unequal effect of the ZLB across the skill distribution. For example, total labor earnings in the bottom tercile display a negative bias that exceeds 12% compared to less than 2% for the top tercile.[39]

Using decomposition (18) to disentangle the total earnings bias into the contributions of various Okun channels, Table G3 in the Appendix reveals that the substantial earnings bias at the bottom primarily stems from reduced participation (accounting for 50% of the total earnings bias) and lower labor productivity (contributing 37% of the total earnings bias) Notably, this large negative bias among low-skilled workers emerges even though monetary policy is constrained during a relatively small share (14%) of time. This is be-

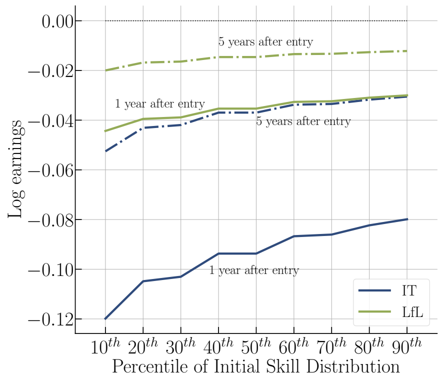
[39]We note that our model features both positive hysteresis (uplifting effects) following expansions and negative ones (scarring effects) following recessions, which, absent the ZLB, would tend to offset each other and lead to virtually no bias in either aggregate or distributional outcomes in the ergodic distribution (in fact exactly so, under our linear solution method). It is the ZLB, and its amplifying effect on negative labor market hysteresis, that gives rise to a negative bias.

cause, as we pointed out in our earlier analysis of the IRFs, the deleterious effects of the ZLB at the bottom of the distribution persist far beyond the period where the constraint is effectively binding.[40]

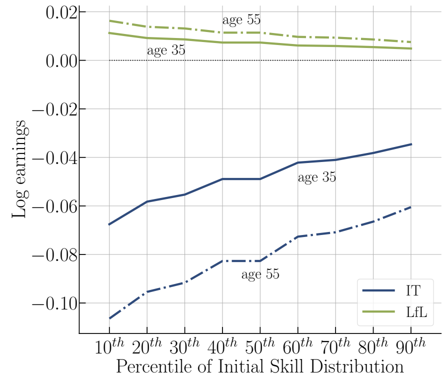
While the measures by skill terciles are informative of the effect of the ZLB on cross-sectional earnings inequality, they do not reveal how the constraint shapes the labor market prospects of individual workers. To address this, we perform two exercises. First, we compute the earnings losses of entrant workers joining the labor market during a demand-driven recession that triggers the ZLB (we use the same shock as in Figure 4). We express these losses relative to workers' earnings trajectories in the stationary equilibrium as a function of their position in the initial skill distribution at the time of labor market entry. Results are shown in Figure 5a. In line with the empirical evidence documented by von Wachter (2020), we find that it is the workers at the lower end of the skill distribution who experience the largest losses when entering the labor market during a recession. Second, we compute workers' expected life-cycle earnings profiles over the ergodic distribution under IT. Figure 5b plots the expected earnings gap (relative to the stationary equilibrium) for workers aged 35 and 55 along the initial skill distribution. Overall, we find that the presence of the ZLB reduces life-cycle earnings growth over the entire skill distribution, with those who initiate their careers at the bottom of the skill distribution suffering the most. For instance, a worker who joins the labor market in the 20th (80th) percentile of the initial skill distribution experiences average earnings at age 55 that are 10% (6.5%) lower than their average earnings in the stationary equilibrium.

Taking stock, the main insight of this section is that a monetary policy rule that does not mitigate the ZLB opens the door to enduring scars on labor force participation and productivity at the bottom of the skill distribution. Alternative monetary policy rules that tackle these hysteresis, by either reducing the frequency of the ZLB or letting the economy run hot during recoveries, have the potential to persistently improve labor market outcomes of low-wage workers. The monetary policy framework introduced by the Fed in 2020, which promises to keep rates lower for longer following recessions, has precisely this flavor.

[40]To appreciate this point even further, consider the following simple back-of-the-envelope calculation: if all the negative bias in total earnings at the bottom tercile in Table 5 came purely from harsher recessions during ZLB episodes—and not from persistent negative effects that outlast these episodes—total labor income at the bottom would fall by roughly 86% (0.12/0.14). Instead, our simulations show that total labor income at the bottom tercile only falls by 30% on average during ZLB episodes, implying that earnings also remain depressed even when the ZLB is not binding.



(a) Entering in a Recession.



(b) Life-cycle Earnings Gaps.

Figure 5: **Panel (a):** Earnings losses from joining the labor market in a recession, 1 and 5 years after entry, by deciles of the initial skill distribution. The worker's losses are computed out of a demand-driven recession that triggers the ZLB, as in Figure 4. **Panel (b):** Log-earnings gap at ages 35 and 55 by decile of the initial skill distribution under IT (blue line) and LfL (green line) rules. The gap denotes the difference between expected life-cycle earnings growth in the ergodic distribution and in the stationary equilibrium under IT.

5 Economic Outcomes Under Lower for Longer

We model the Lower for Longer (LfL) strategy by changing the Taylor rule reaction function $\mathcal{R}_t$ in (13) to

$$\mathcal{R}_t = 2.25(\pi_t - \pi^*) + 5.00(\pi_t^{MA} - \pi^*)^- - 0.15(u_t - u^*)^+, \tag{19}$$

where π_t^{MA} is the exponential moving average of past inflation $\int_0^\infty (1/48)\ e^{-(1/48)\tau}\pi_{t-\tau}d\tau$ with a smoothing factor $1/48$ to target a window of 4 years, x^+ is the shorthand for $\max\{x, 0\}$, and x^- for $\min\{x, 0\}$. The addition of the deficit between past average inflation π^{MA} and the target into (19) is meant to capture the asymmetric Average Inflation Targeting (AIT) component of the new framework. Mechanically, following periods where inflation falls persistently below 2 percent, the average inflation term adds a downward pressure on nominal rates, which persists until average inflation goes back to target. The Shortfall (SR) component is modeled by making the response to unemployment fluctuations asymmetric. Instead of reacting to all unemployment deviations, as in the baseline IT, the LfL rule (19) predicts that the monetary authority should not raise rates when unemployment goes below steady state but inflation remains close to the target.

The LfL rule has two main goals. First, it aims to handle the ZLB more effectively and alleviate some of its most harmful consequences at the bottom of the distribution. Second, it seeks to promote a strong labor market during recoveries, allowing low-skilled workers to re-enter participation, find jobs, and, over time, improve their skills. If successful in these two objectives, this rule can act as an 'antidote' to ZLB's negative hysteresis we found under IT. As we previewed in the Introduction, however, running a LfL strategy also carries the risk of pushing inflation above target.[41]

The rest of this section is focused on measuring this trade-off. We first analyze how the LfL strategy changes the IRFs to demand and supply shocks (Section 5.1). Second, we study the counterfactual where we ask how the recovery from the Great Recession would have developed had the Fed followed a LfL strategy early in the downturn (Section 5.2). The Great Recession's extended ZLB, persistently below-target inflation, and sluggish recovery of participation and earnings offer an ideal laboratory to evaluate the LfL, as these were all "failures" that the new framework was designed to correct. Third, we study the impact of the LfL rule on aggregate and distributional outcomes in the ergodic distribution of our model (Section 5.3).[42] We also compare the LfL rule to an increase in the inflation target. Finally, we trace out the menu of inflation and labor market outcomes available to a policymaker interested in running some version of the LfL strategy (Section 5.4).

5.1 IRFs Under Lower-for-Longer

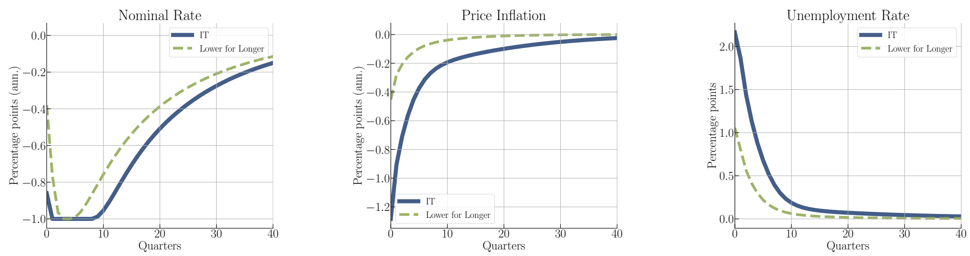
Figure 6 presents the model's impulse responses under the IT and LfL strategies. To highlight the differences between the two policy rules, we focus on the IRFs to a large negative demand shock (a demand-driven recession) and a positive supply shock (a supply-driven expansion).[43] Shifting from an IT to a LfL rule significantly alters the economy's response to these two shocks. In the case of a demand-driven recession, the LfL strategy greatly

[41]Strictly speaking, inflation is a concern only under a demand-driven expansion, since, in the case of supply-driven expansions, inflation is below target under IT. In this latter scenario, pushing for a stronger response in the labor market actually moves the economy closer to price stability. When comparing alternative policy rules, however, what matters is the average trade-off faced by monetary policy over the business cycle. Our calibration—as the data—displays a positive correlation between hours and inflation, meaning that, during expansions, the monetary authority faces, on average, inflationary rather than deflationary pressures.

[42]Similarly to our discussion regarding the ZLB, our solution method ignores how the LfL's promise to run the economy hot can alter households expectations even when the economy is not in a boom. Appendix E goes through some of the ways that this missing expectation channel could impact our assessment of the inflation-inclusion trade-off under the LfL, and offers some suggestive evidence that the "mistake" of our solution is unlikely to change any of our conclusions about the trade-off.

[43]The IRFs of other shocks, like demand-driven expansions and supply-driven recessions, are shown in the appendix H.

(a) Demand-driven recession



(b) Supply-driven expansion

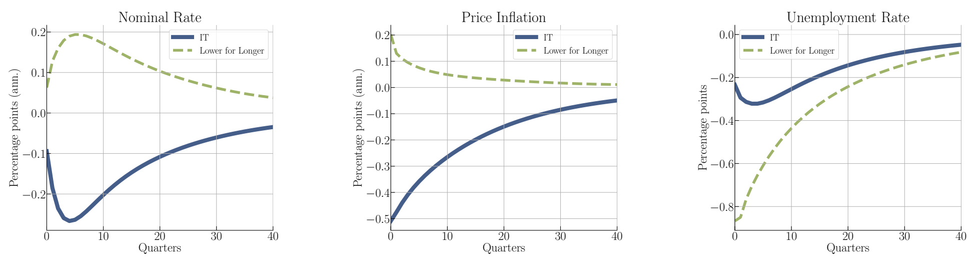


Figure 6: Impulse responses to demand and supply shocks under IT and LfL.

helps to stabilize unemployment and inflation, whose deviations are less than half of those under IT. As a result, the economy under LfL also spends less time at the ZLB, which binds only for a few quarters. In a supply-driven expansion, the economy undergoes a much stronger expansion under a LfL strategy. Unemployment falls 3 times more than under IT, while inflation, which falls significantly under IT, displays a small positive response under LfL. Somewhat counterintuitively, nominal rates are actualy higher under the LfL strategy than IT. This has to due with the LfL rule's feedback response to inflation and unemployment, which pushes up nominal rates in equilibrium despite the rule's promise to keep rates lower *given* the inflation and unemployment paths under IT. Under both shocks, however, the LfL approach delivers a lower path for real rates (see Figure H1), which is what matters for the transmission of monetary policy to the real economy.

These IRFs suggest that adopting the LfL strategy can contain recessions and prolong expansions, altering the shape of business cycles. To understand whether the rule can also foster inclusion for low-wage workers and, if so, at what costs in terms of inflation, we need to evaluate the consequences of this strategy over a sufficiently long horizon under a realistic sequence of aggregate shocks. The next two sections do precisely this.

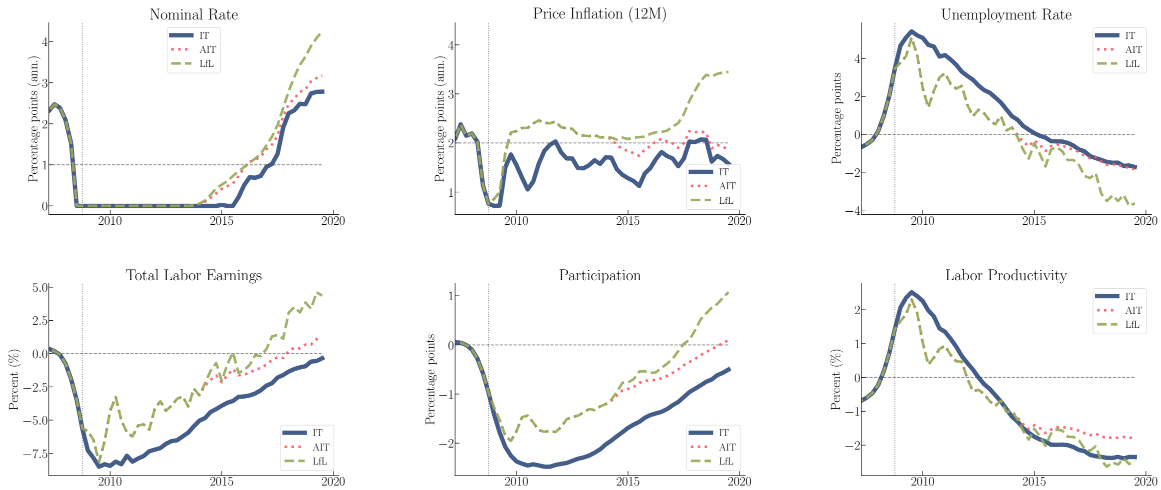


Figure 7: Great Recession dynamics of aggregate variables under IT, AIT, and LfL rule. See Table G2 in the Appendix for the specification of the different monetary policy rules.

5.2 Great Recession Under Lower-for-Longer

How would the US labor market and inflation dynamics have looked like during the Great Recession and its recovery had the Fed followed a LfL strategy? To generate this counterfactual, we first use the model's impulse responses together with unemployment and inflation data from 1990:Q1 to 2019:Q4 to filter the sequence of demand and supply innovations that exactly replicate, under our model with a baseline IT rule, the observed data. Figure H2 in the Appendix reports the filtered shock series. Figures 7 and 8 in the main text depict the implied dynamics for aggregate and distributional outcomes. Beyond matching inflation and unemployment dynamics, which we do by construction, the simulation also captures other important dimensions of Great Recession and its recovery such as the prolonged period at ZLB, the rise in labor productivity around 2008-2010, and the persistent reduction in participation (Christiano et al., 2015).

We then use the sequence of filtered shocks to simulate a counterfactual economy where the Fed shifts from an IT to a LfL rule in 2008:Q4. We also present the economy's dynamics under a counterfactual where the Fed follows a rule that includes the AIT component of the LfL framework, but keeps the reaction to unemployment symmetric as in the baseline IT rule. The difference between LfL and AIT shows the impact of the Shortfall (SR) component (see Table G2 in the Appendix).

The LfL's commitment to keep rates lower in response to the low inflation significantly reduces the costs during the outset of the Great Recession when the economy first hit the ZLB in 2008: inflation doesn't fall as much as it does under IT and unemployment comes

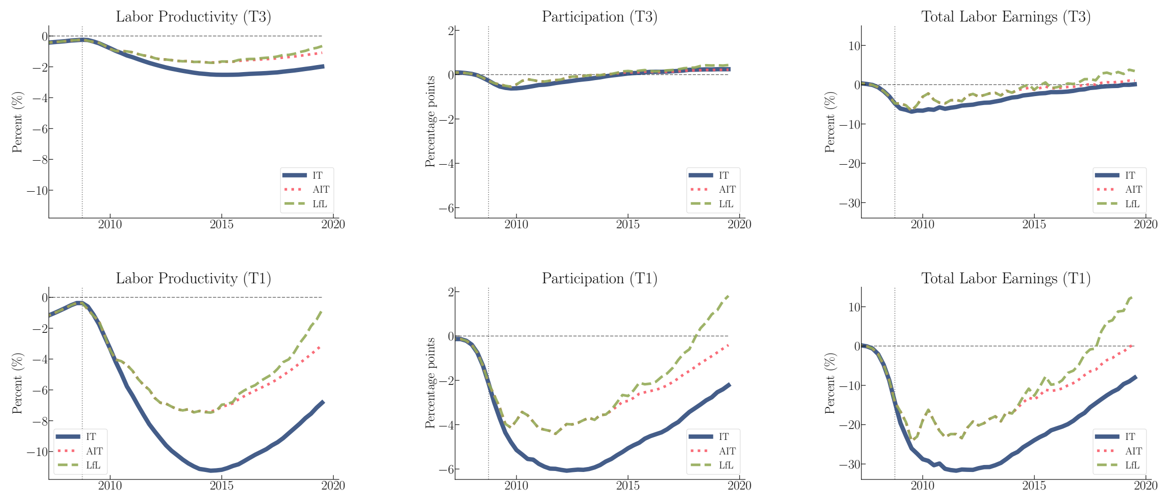


Figure 8: Great Recession dynamics at the top (T3) and bottom (T1) terciles under IT, asymmetric AIT, and LfL rule. See Table G2 in the Appendix for the specification of the different monetary policy rules.

down faster from its peak. As a result, the economy exits the ZLB sooner with beneficial impacts on participation and earnings. Starting from 2016, once the expansion is well under way, the AIT component of the rule becomes moot (past inflation, under LfL, is averaging around 2% at that point) and the SR component takes over. Unemployment keeps falling and participation and earnings go up even further: at the end of the sample period, under the LfL rule, unemployment is 2 ppts lower, participation 1.5 ppt higher, and earnings are 5 ppt higher compared to the economy under IT.

Figure 8 shows the impact of the LfL rule along the workers' skill distribution. Compared to the top tercile (top row), the fluctuations in earnings at the bottom tercile (bottom row) are much more pronounced. As before, the benefits of the LfL rule to this group of workers accrue both in the downturn and in the recovery. At the onset of the recession, the rule prevents the sharp and persistent decline in labor productivity and labor force participation. Later in the recovery, it reinforces and amplifies the gains allowing workers to fully recoup their earnings losses.[44] The inflationary cost of the new strategy shows up in Figure 7: while inflation remained 0.5 ppts below target throughout the recovery under IT, under the LfL rule, inflation is on average 0.7 ppts above it. Noticeably, this bias is caused mostly by the SR component during the last two years of the boom.

[44] It might seem puzzling that, under LfL, by 2020 labor productivity of each tercile has fully recovered, whereas aggregate labor productivity remains depressed (Figure 7). The reason is that the LfL strategy shifts the composition of employment toward low-skill workers who are less productive than the rest. This selection channel imparts more countercyclicality to aggregate productivity.

Altogether, the Great Recession counterfactual suggests that the LfL strategy would have delivered a major short-run boost to low-wage workers with only a modest deviation of inflation from target, except very late in the recovery. Whether these short-run gains of a LfL strategy can be sustained over the long run is the question we try to answer in the next section by looking at the model's ergodic distribution.

5.3 Ergodic Distribution Under Lower-for-Longer

Table 5 reports the model's simulated ergodic distribution results under the LfL strategy. Relative to IT, the LfL rule lowers the ZLB frequency (from 14% to 6%), reduces its intensity (the average shadow rate goes from -66 bp to -21 bp), and increases the share of time the economy spends in expansions (from 6% under IT to 24%). These effects also show up in the ergodic distribution of inflation and unemployment, as illustrated in Figure 9 which depicts the 10th and 90th percentiles of the distribution of these variables under IT and LfL rules. The distribution under IT (blue line) highlights the asymmetric effects of the ZLB: we get a long left tail in the distribution of inflation, and a stretched right tail in the distribution of unemployment. Shifting to a LfL strategy (green line) better stabilizes the economy at the ZLB, reducing much of the mass at the left (right) tail of the inflation (unemployment) distribution. In addition, the LfL rule also succeeds at running the economy hot during expansions, as depicted by the stretched left tail in the distribution of unemployment and the (modest) longer right tail in the inflation distribution. Consequently, the negative inflation and positive unemployment biases under IT—indicated by the blue squares—are fully reversed with an LfL rule, under which unemployment bias is negative (-0.23 ppt), and inflation averages slightly above target (33 bp).

Table G3 in the Appendix summarizes the rule's impacts over the skill distribution. As in the Great Recession counterfactual, labor market gains under an LfL rule are much stronger at the bottom: total labor earnings at the bottom tercile increase by over 17% $\left(5.20\% - (-12.17\%)\right)$ through a combination of stronger labor force attachment $\left(1.09\text{ppt} - (-2.52\text{ppt})\right)$ and higher labor productivity $\left(1.92\% - (-4.54\%)\right)$. As a result, cross-sectional labor market inequality is reduced, with unemployment, participation, and earnings differentials between the top and bottom skill terciles falling by 1.2 ppt, 3.5 ppt, and 14%, respectively.

5.3.1 Improvements in Upward Mobility Under Lower for Longer

In his 1974 article, Okun stressed improvements in upward mobility as one of the major benefits of running a high-pressure economy. His conjecture is that, by fostering stronger attachment and faster skill growth, a hot labor market could also engineer a steeper life-cycle earnings profile for low-skilled workers. To assess this hypothesis, we repeat the computation of workers' expected life-cycle earnings shifting from an IT to a LfL strategy. Results are displayed in Figure 5. In line with Okun's conjecture, we find that the LfL leads to a stronger life-cycle earnings growth for all workers, but specially so at the bottom of the skill distribution where it fully reverts the large negative earnings gap we found under IT.[45].

5.3.2 Lower for Longer versus Higher Inflation Target

An alternative policy available to central banks trying to fight the negative hysteresis of the ZLB is to raise the inflation target π^* (Coibion et al., 2012).[46] Relative to the LfL, this strategy gives rise to a different type of trade-off: it allows the central bank to decrease the frequency of hitting the ZLB, thereby mitigating some of its adverse effects, particularly at the lower end of the distribution, at the cost of permanently higher inflation.

The last column in Table 5 reports the ergodic distribution results for a higher inflation target (Higher IT) strategy with the same small positive inflationary bias of the LfL approach.[47] While the Higher IT reduces the ZLB frequency and increases the shadow rate as much as the LfL strategy, it promotes much smaller gains to labor market outcomes of low-wage workers: compared to a positive bias of 5.2% for total earnings at the bottom tercile under LfL, there is still a −2.3% negative bias under a Higher IT rule. Notably, the outcomes under Higher IT are dominated even by the AIT component of the rule alone, which achieves, with much less volatility, larger labor market gains at the cost of less inflation, as we discuss next.

5.3.3 The Role Played by the AIT and Shortfall Components

What are the separate contributions of the AIT and SR components to the gains of the LfL strategy? Table 5 shows that the two policies, when implemented individually, have a similar impact on average outcomes. Both rules reduce the frequency of ZLB episodes (which binds 8% of the time under SR, and 6% of the time under AIT), significantly

[45] Part of the gains of the LfL strategy can be seen by the fact that the rule reduces significantly the earnings losses for entrants that join the labor market in a recession, as displayed in Figure 5a

[46] An increase in the inflation target translates into higher steady-state nominal rates, making the ZLB less likely to bind in response to shocks.

[47] In line with the approach followed so far, we assume that unions can adjust nominal wage growth to the new inflation target without incurring in any cost. Thus, the ZLB is the only reason that the higher inflation target is not neutral.

Ergodic Distributions of Inflation and Unemployment

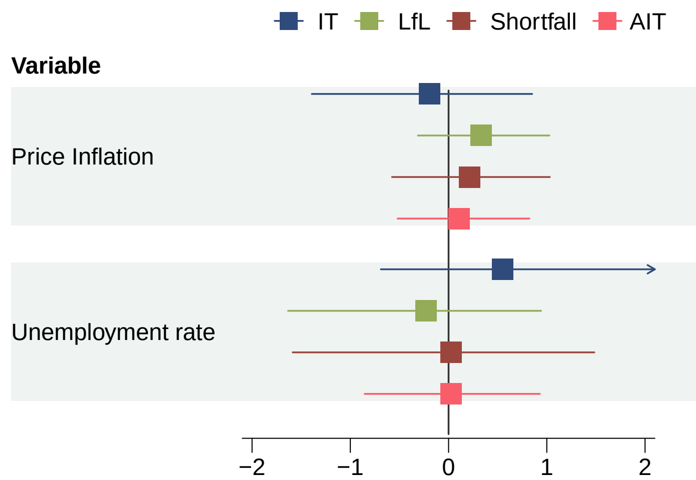


Figure 9: Ergodic distributions of inflation and unemployment under alternative monetary policy rules. The lines plot the distance between the 10^{th} and the 90^{th} percentiles of the ergodic distribution of inflation and unemployment. The square denotes the average.

dampen the negative labor market biases relative to IT, and push inflation slightly above the target (22bp the SR, and 11bp the AIT). However, they vary a lot in terms of their predicted share of booms and recessions, as well as in their implied volatilities.

To understand these differences, compare the 10th and 90th percentiles of unemployment under the IT (blue line), AIT (pink line) and SR (brown line) in Figure 9. It is clear that the AIT's gains come mainly from avoiding extremely low inflation and high unemployment outcomes, i.e., the benefits associated with the AIT rule occur primarily during large recessions. Coherently, Table 5 reports that the AIT rule reduces the share of recessions in the simulation from 16.5% under IT to 10%, lifts the shadow rate at the ZLB from −66bp to −19bp, and curtails the volatility of inflation and real outcomes by a factor of 2. In contrast, the SR rule realizes most of its gains during expansions, as it is clear from its ability to generate periods of very low unemployment rates. In line with this observation, Table 5 reports that the SR rule increases the share of booms in the simulation from 6% under IT to 23%, whereas its impact during downturns, as indicated by the change in the share of recessions and the shadow rate at the ZLB, is much more modest.[48]

The AIT and SR components of the new framework thus seem to operate at very dif-

[48] As seen in Table G3 in the Appendix, labor force participation and labor productivity contribute roughly the same to the negative and positive biases across all rules, and are the two most important channels driving earnings biases at the bottom of the skill distribution.

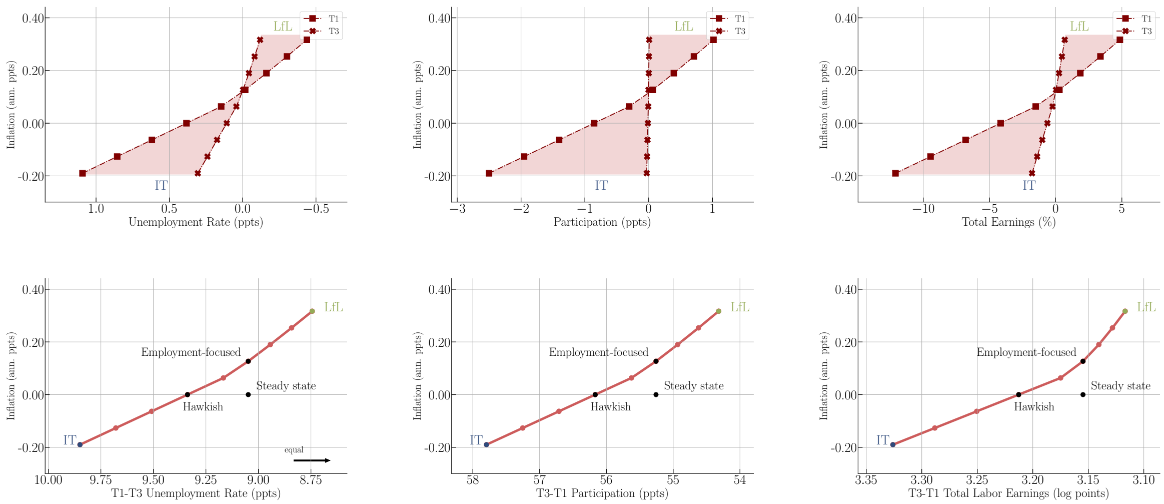


Figure 10: Okun's cones and the inflation-inclusion trade-off. **Top row:** The x and y axis denote deviations from the non-stochastic steady state. The cones' lower and upper limits reproduce the outcomes at the bottom (T1) and top (T3) terciles under IT and the LfL rules as parameterized in Table 5. **Bottom row:** The y axis denotes inflation and the x axis the differential outcome between T1 and T3 for alternative parameterizations of the LfL rule.

ferent points of the business cycle: the AIT shrinks the size of negative hysteresis brought by the ZLB, while the SR component overheats the economy during expansions, thus allowing low skilled workers to recover from the persistent losses incurred at the ZLB. The LfL strategy, which combines the AIT and SR components, realizes gains across the full business cycle.

5.4 Okun's Cones: A Menu for Policymakers

Up to now, we have analyzed and quantified the inflation-inclusion trade-off exclusively for a plausible, but specific, parameterization of the LfL rule. In this section, we try to assess the entire menu of outcomes available to a policymaker interested in exploring some version of the LfL strategy. For this purpose, we repeat the LfL simulations of Section 5.3 while varying the reaction coefficients of the LfL policy rule between the values taken under IT and those under our main parameterization of the LfL rule. For each parameterization, we track the implied average biases for unemployment, participation, and total earnings at the bottom and top terciles of the skill distribution. This mapping—which, because of its shape, we denote by "Okun's cones"—is plotted in the first row of Figure 10. As expected, the cones show a stronger response at the bottom than at the top. Thus, in the second row we summarize the effects in terms of the top-bottom tercile differentials in outcomes. Ultimately, these numbers express the additional average inflation required to achieve a specific reduction to the cross-sectional divergence in a particular labor market outcome (e.g., the T3-T1 participation rate differential).

First, consider a more hawkish central bank interested in the LfL strategy only as a way to close the deflationary bias induced by the ZLB (outcomes corresponding to zero on the Y axis). Implementing this allocation will already deliver sizable gains in labor market outcomes for workers in the bottom tercile. Compared to an IT rule, even this conservative version of the LfL rule shrinks unemployment, participation, and earnings differentials by 0.50ppt, 1.5ppt, and approximately 10 log points, respectively. A more employment-focused central bank that wishes to fully offset the detrimental effect of the ZLB on the labor market outcomes of the low-skilled workers (corresponding to the non-stochastic "Steady State" values on the X axis) would instead have to tolerate a positive, but small, inflation bias of 15 bps. Finally, a more inclusion-focused policymaker who wishes to go beyond this point and push for even greater inclusion, can do so at the cost of a larger inflation bias.

Clearly, there is a limit to the extent to which this inflation-inclusion trade-off can be exploited in the long run: as the systematic inflationary bias grows larger and larger, it becomes more likely that long-run inflation expectations will become unanchored. Where this limit lies depends on expectation formation. We make two observations that suggest that our results fall well inside this limit. First, in all our simulations the average bias never exceeds 33 bp from the 2% target, with a 90-10 inflation differential close to 150 bp in the ergodic distribution (Figure 9). Such tiny systematic bias would thus require an extremely long sample to be detected. Second, a large literature (e.g. Weber et al., 2023; Pfauti, 2024) argues that inflation expectations are sticky in practice, and households only become more attentive and update their long-run expectations when inflation significantly deviates relative to the status quo. In our simulations, however, inflation remains for the most part (97% of the time) below 3.5-4%, the attention threshold estimated by Korenok et al. (2023) and Pfauti (2024).

6 Conclusions

In this paper we have formalized Arthur Okun's conjecture that a high-pressure economy would lead to a persistent uplifting of labor market trajectories for low-wage workers, possibly at the cost of higher inflation. This step required extending the canonical HANK framework with a rich model of the labor market where heterogeneous workers choose their degree of attachment to the labor force, are unequally exposed to aggregate fluctuations, and upgrade or downgrade their skills depending on their employment status. In this world, recessions are especially detrimental to low-skilled labor through a vicious cycle of job loss, exit to non-participation, and skill deterioration which imparts persistent scars on their lifetime earnings. Within this framework, we have analyzed the stabilization role of monetary policy. We have uncovered that, under a strict Inflation Targeting regime, the ZLB severely amplifies these negative hysteresis at the bottom of the income distribution. Shifting to a Lower-for-Longer strategy, the framework adopted by the Fed in 2020, disproportionately benefits low-wage workers by neutralizing the negative effects of the ZLB through the promise of running a hot economy for longer during recoveries. Because policymakers might have different preferences for inflation vs. inclusion, we showed how to use our framework to quantify the inclusion-inflation frontier implied by the Lower-for-Longer strategy.

In our attempt of measuring the inflation-inclusion tradeoff, we have prioritized achieving a credible quantification of the labor market impact of different monetary policy rules across the distribution. We instead, purposefully, kept the inflation-side of this tradeoff much closer to the canonical HANK framework. A natural next step in this research agenda would be to enrich this block of the model. One possible direction would be to acknowledge that an especially tight labor market could lead to a steepening of the Phillips curve (Benigno and Eggertsson, 2023), or that persistent deviations of inflation from the target may lead to de-anchoring of inflation expectations (Carvalho et al., 2023). Another direction would be to recognize that the costs of inflation are uneven across the distribution and operate through a variety of channels (e.g., via heterogeneity in consumption baskets, nominal net positions, and nominal wage rigidity). Jaravel (2021), Olivi et al. (2023), Del Canto et al. (2024), Afrouzi et al. (2024), and Guerreiro et al. (2024) are recent examples of studies that try to quantify the relative role of these mechanisms.

In HANK models, the clear cut distinction between stabilization and redistribution policies invoked half a century ago by the neoclassical synthesis, and embodied by the representative agent construct, inevitably vanishes (Sargent, 2024). In this class of economies, redistribution policies spill over to the business cycle and stabilization policy is always, to some extent, redistributive. Our paper is a stark exemplification of this latter link.

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Appendix

A Recursive Formulation of the Household Problem

In this section we show how the individual problems can be expressed recursively as a Hamilton-Jacobi-Bellman Quasi-Variational Inequality (HJBQVI). We follow Maxted et al. (2024) and their the notation with the max operator which we find intuitive. We use the symbol $\mathcal{Z}^s$ to denote the infinitesimal generator of the stochastic process defined in (1), transformed in levels, in employment state s. Then:

$$\mathcal{Z}^s v_t = \left(-\gamma_z \log z + \mathbb{I}_{\{s_t = e\}} \, \delta_z^+ - \mathbb{I}_{\{s_t \neq e\}} \, \delta_z^- + \frac{\sigma_z^2}{2} \right) z \, \partial_z v_t^s + \sigma_z \, z \, \partial_{zz} v_t^s$$

The problem of the employed households in (7) at time t can be written as:

$$\begin{aligned} \rho v_t^e = \max \, \Big\{ & \max_{c_t} \left\{ \mathrm{u}^e \left(c_t, h_t; z_t \right) + \partial_a v_t^e \left(r_t a_t + (1 - \tau_t) \, w_t z_t h_t + \phi - c_t \right) \right\} + \lambda_{zt}^{eu} \left(v_t^{u_1} - v_t^e \right) \\ & + \eta^{en_0} (v_t^{n_0} - v_t^e) + \mathcal{Z}^e v_t^e + \partial_t v_t^e, \rho v_t^{n_1} \Big\} \end{aligned}$$

The problem of the passive non-participant in (3) is:

$$\begin{aligned} \rho v_t^{n_0} = \max_{c_t} \, & \left\{ \mathrm{u}^n \left(c_t, 0 \right) + \partial_a v_t^{n_0} \left(r_t a_t + \phi - c_t \right) \right\} + \eta^{n_0 n_1} \left(v_t^{n_1} - v_t^{n_0} \right) \\ & + \mathcal{Z}^{n_0} v_t^{n_0} + \partial_t v_t^{n_0} \end{aligned}$$

The problem of the active non-participant in (4) is:

$$\begin{aligned} \rho v_t^{n_1} = \max \, \Big\{ & \max_{c_t} \left\{ \mathrm{u}^n \left(c_t, 0 \right) + \partial_a v_t^{n_1} \left(r_t a_t + \phi - c_t \right) \right\} + \lambda_{zt}^{ne} \max \left\{ v_t^e - v_t^{n_1}, 0 \right\} + \eta^{n_1 n_0} \left(v_t^{n_0} - v_t^{n_1} \right) \\ & + \mathcal{Z}^{n_1} v_t^{n_1} + \partial_t v_t^{n_1}, \rho v_t^{u_0} - \xi \Big\} \end{aligned}$$

The problem of the non-eligible unemployed in (5) becomes:

$$\begin{aligned} \rho v_t^{u_0} = \max \, \Big\{ & \max_{c_t} \left\{ \mathrm{u}^u \left(c_t, 0 \right) + \partial_a v_t^{u_0} \left(r_t a_t + \phi - c_t \right) \right\} + \lambda_{zt}^{ue} v_t^e + \eta^{un_0} \left(v_t^{n_0} - v_t^{u_0} \right) \\ & + \mathcal{Z}^{u_0} v_t^{u_0} + \partial_t v_t^{u_0}, \rho v_t^{n_1} \Big\} \end{aligned}$$

The problem of the eligible unemployed in (5) becomes:

$$\rho v_t^{u_1} = \max \left\{ \max_{c_t} \left\{ \mathfrak{u}^u \left(c_t, 0\right) + \partial_a v_t^{u_1} \left(r_t a_t + \phi + b\left(z_t\right) - c_t\right)\right\} + \lambda_{zt}^{ue} \max\left\{v_t^e - v_t^{u_1}, 0\right\} \right.$$
$$\left. + \lambda_z^{u_1 u_0}\left(v_t^{u_0} - v_t^{u_1}\right) + \eta^{u n_0}\left(v_t^{n_0} - v_t^{u_1}\right) + \mathcal{Z}^{u_1} v_t^{u_1} + \partial_t v_t^{u_1}, \rho v_t^{n_1} \right\}$$

The five HJBQVI's above, jointly with the five first-order conditions at every t

$$\partial_c \mathfrak{u}^s\left(c_t, h_t; z_t\right) = \partial_a v_t^s \quad s \in \{e, u_0, u_1, n_0, n_1\}$$

can be solved for value functions $\left\{v_t^s\left(a, z\right)\right\}_{t\geq 0}$, consumption decision rules $\left\{c_t^s\left(a, z\right)\right\}_{t\geq 0}$ for $s \in \{e, u_0, u_1, n_0, n_1\}$, participation rules $\left\{\mathfrak{p}_t^s\left(a, z\right)\right\}_{t\geq 0}$ for $s \in \{e, u_0, u_1, n_1\}$, and job acceptance rules $\left\{\mathfrak{j}_t^s\left(a, z\right)\right\}_{t\geq 0}$ for $s \in \{u_1, n_1\}$.

B Problem of the Final and Intermediate Goods Producers

B.1 Final good sector

A competitive representative final-good producer aggregates a continuum of intermediate inputs indexed by $j \in [0, 1]$ with CRS technology

$$Y_t = \left(\int_0^1 y_{jt}^{\frac{\nu-1}{\nu}} dj\right)^{\frac{\nu}{\nu-1}} \tag{B1}$$

where $\nu > 0$ is the elasticity of substitution across inputs. This firm takes prices as given and solves

$$\max_{\{y_{jt}\}} P_t Y_t - \int_0^1 p_{jt} y_{jt} dj \tag{B2}$$

subject to (B1). Cost minimization implies that demand for intermediate good j at price p_{jt} is

$$y_{jt}(p_{jt}) = \left(\frac{p_{jt}}{P_t}\right)^{-\nu} Y_t, \quad \text{where} \quad P_t = \left(\int_0^1 p_{jt}^{1-\nu} dj\right)^{\frac{1}{1-\nu}} \tag{B3}$$

is the price of the final good and the numeraire of the economy.

B.2 Intermediate goods sector

At every date t, the intermediate-good producing firms, indexed by j take the task-specific wage w_{kt} as given, and solve

$$\max_{p_{jt},\{\ell_{jkt}\}_k} \quad \left(\frac{p_{jt}}{P_t}\right) y_{jt} - (1-\tau^{\ell}) \int_0^1 w_{kt}\ell_{jkt}dk - \phi^{\ell} \tag{B4}$$

$$\begin{aligned} s.t. & \\ y_{jt} &= \alpha \ell_{jt} \\ \ell_{jt} &= \left[\int_0^1 \ell_{jkt}^{\frac{\varepsilon-1}{\varepsilon}} dk\right]^{\frac{\varepsilon}{\varepsilon-1}} \\ y_{jt} &= \left(\frac{p_{jt}}{P_t}\right)^{-\nu} Y_t \end{aligned}$$

where w_{kt} is the real wage on task k, τ^{ℓ} is a wage subsidy to producers partially financed by the lump sum tax ϕ^{ℓ} that is set to undo the steady-state monopolistic distortion to production. Cost minimization yields the relative demand of labor for task k

$$\ell_{jkt} = \left(\frac{w_{kt}}{w_t}\right)^{-\varepsilon} \ell_{jt}, \tag{B5}$$

where w_t is the Dixit-Stiglitz real aggregate wage index $w_t = \left[\int_0^1 w_{kt}^{1-\varepsilon} dk\right]^{\frac{1}{1-\varepsilon}}$ that satisfies $\int_0^1 w_{kt}\ell_{jkt}dk = w_t\ell_{jt}$. The profit-maximizing price setting decision yields the standard expression whereby the relative price equals a markup over the after-subsidy marginal cost of production

$$\frac{p_{jt}}{P_t} = \left(\frac{\nu}{\nu-1}\right) \frac{(1-\tau^{\ell})w_t}{\alpha} \tag{B6}$$

This price corresponds an optimal quantity sold and, in turn, to a total amount of labor demanded to produce it which, in the symmetric equilibrium with $p_{jt} = P_t$, satisfies $\ell_{jt} = \ell_t$ with

$$\ell_t = \left(\frac{1}{\alpha}\right) Y_t.$$

Imposing $p_{jt} = P_t$ and setting $\tau^{\ell} = 1/\nu$ in (B6) implies that the equilibrium aggregate real wage per effective hour is equal to the marginal product of labor, or

$$w_t = \alpha. \tag{B7}$$

Finally, we note that because of the CRS assumption and the result that the wage rate equals the marginal product of labor, aggregate profits of the intermediate sector are equal to the net subsidy $\Psi_t^\ell = \tau^\ell w_t \ell_t - \phi^\ell$, thus in equilibrium

$$\Pi_t = \Psi_t^\ell. \tag{B8}$$

As long the tax only partially finances the subsidy, profits will be strictly positive in equilibrium. Profits are paid to the mutual fund which owns all firms as dividends.

C Derivation of the Wage Phillips Curve

The problem of the union representing workers on task k is:

$$
\begin{aligned}
& \max_{\{\omega_{kt}\}_{t\geq 0}} \int_0^\infty e^{-\rho t}\left[\int_{s_{it}=e} u^e\left(c_{it}, h_{it}; z_{it}\right) di - \frac{\Theta}{2}\left(\frac{\dot{\omega}_{kt}}{\omega_{kt}} - \pi^*\right)^2\right] dt && \text{(C1)}\\
& s.t. && \text{(C2)}\\
h_{it} &= \int_0^1 h_{kt} dk && \text{(C3)}\\
c_{it} + \dot{a}_{it} &= r_t a_{it} + \left(1 - \tau + \tau^s\right) y_{it} + \phi - \phi_{it}^s && \text{(C4)}\\
y_{it} &= \frac{1}{P_t} z_{it} \int_0^1 \omega_{kt} h_{kt} dk && \text{(C5)}\\
h_{kt} &= \left(\frac{\omega_{kt}}{\omega_t}\right)^{-\varepsilon} h_t && \text{(C6)}
\end{aligned}
$$

The first constraint faced by the union states that total hours worked by an employed worker equal the sum of hour worked on each task. The second constraint is the budget constraint of employed workers. Note that, symmetrically with the problem of the intermediate producers, we have introduced a wage subsidy τ^s financed by the lump-sum tax ϕ_{it}^s in order to offset the distortion in steady state hours and production caused by the unions' monopoly power. The third line is simply the definition of real pre-tax labor income. The fourth one states that contractual hours worked required by the union from all its workers must satisfy firm's demand for effective labor on task k, ℓ_{kt}. This constraint is equivalent to (B5) because $\ell_{kt} = \left(\int_{s_{it}=e} z_{it} di\right) h_{kt}$ and $\ell_t = \left(\int_{s_{it}=e} z_{it} di\right) h_t$, and because all firms j demand the same amount of labor in a symmetric equilibrium.

Since each task-specific union is "small" (there is a continuum of tasks), the impact of a union's wage on an individual income and the firm's employment is negligible. In addition, the union takes the lump sum tax ϕ_{it}^s as given. As a result, the union takes as given all individual decisions embedded in the budget constraint, and the firm's labor demand curves for each task.

We can write this problem recursively as

$$\begin{aligned}
\rho J_t(\omega_{kt}) &= \max_{\pi_{kt}} \int_{s_{it}=e} \mathrm{u}^e(c_{it}, h_{it}; z_{it})\, di - \frac{\Theta}{2}\left(\pi_{kt} - \pi^*\right)^2 + \partial_\omega J_t(\omega_{kt})\,\omega_{kt}\pi_{kt} + \partial_t J_t(\omega_{kt}) \\
& \quad s.t. \\
c_{it} &= r_t a_{it} + \left(1 - \tau + \tau^s\right) y_{it} + \phi - \phi_{it}^s - \dot{a}_{it} \\
y_{it} &= \frac{1}{p_t} z_{it} \int_0^1 \omega_{kt}\left[\left(\frac{\omega_{kt}}{\omega_t}\right)^{-\varepsilon} h_t\right] dk \\
h_{it} &= \int_0^1 \left[\left(\frac{\omega_{kt}}{\omega_t}\right)^{-\varepsilon} h_t\right] dk
\end{aligned}$$

The first order condition with respect to π_{kt} and the envelope condition are, respectively:

$$\begin{aligned}
\partial_\omega J_t(\omega_{kt})\,\omega_{kt} &= \Theta\left(\pi_{kt} - \pi^*\right) \\
\left(\rho - \pi_{kt}\right)\partial_\omega J_t(\omega_{kt}) &= \int_{s_{it}=e} \left\{\partial_c \mathrm{u}^e(c_{it}, h_{it}; z_{it})\left[\left(1 - \tau + \tau^s\right)\partial_\omega y_{it}\right] di + \partial_h \mathrm{u}^e(c_{it}, h_{it}; z_{it})\,\partial_\omega h_{it}\right\} di \\
& \quad + \partial_{\omega\omega} J_t(\omega_{kt})\,\omega_{kt}\pi_{kt} + \partial_{\omega t} J_t(\omega_{kt})
\end{aligned}$$

where

$$\begin{aligned}
\partial_\omega y_{it} &= \frac{1}{P_t} z_{it}\omega_t^{\varepsilon} h_t (1 - \varepsilon) \int_0^1 \omega_{kt}^{-\varepsilon} dk \\
\partial_\omega h_{it} &= -\varepsilon h_t \omega_t^{\varepsilon} \int_0^1 \omega_{kt}^{-(1+\varepsilon)} dk
\end{aligned}$$

and note that we did not differentiate neither consumption nor participation/job acceptance decisions with respect to ω_{kt} because of the assumption that each individual union has a negligible effect on prices.

Imposing symmetry $(\omega_{tk} = \omega_t)$, we obtain

$$\begin{aligned}
\partial_\omega y_{it} &= \frac{1}{P_t} z_{it} h_t (1 - \varepsilon) \\
\partial_\omega h_{it} &= -\varepsilon h_t \omega_t^{-1}
\end{aligned} \tag{C7}$$

and

$$\begin{aligned}
\partial_\omega J_t(\omega_t) &= \frac{\Theta\left(\pi_t-\pi^*\right)}{\omega_t} \\
\left(\rho-\pi_t\right)\partial_\omega J_t(\omega_t) &= \int_{s_{it}=e}\left\{\partial_c \mathrm{u}^e\left(c_{it},h_{it};z_{it}\right)\left[\left(1-\tau+\tau^s\right)\partial_\omega y_{it}\right]di+\partial_h \mathrm{u}^e\left(c_{it},h_{it};z_{it}\right)\partial_\omega h_{it}\right\}di \\
&\quad +\partial_{\omega\omega}J_t(\omega_t)\,\omega_t\pi_t+\partial_\omega J_t(\omega_t)
\end{aligned}$$

Substituting (C7) into the envelope condition, we obtain

$$\begin{aligned}
\left(\rho-\pi_t\right)\frac{\Theta\left(\pi_t-\pi^*\right)}{\omega_t} &= \left(1-\tau+\tau^s\right)\frac{1}{P_t}h_t(1-\varepsilon)\int_{s_{it}=e}\partial_c \mathrm{u}^e\left(c_{it},h_{it};z_{it}\right)z_{it}di \\
&\quad -\varepsilon\frac{h_t}{\omega_t}\int_{s_{it}=e}\partial_h \mathrm{u}^e\left(c_{it},h_{it};z_{it}\right)di+\partial_{\omega\omega}J_t(\omega_t)\,\omega_t\pi_t+\partial_{\omega t}J_t(\omega_t).
\end{aligned}$$

Differentiating the first-order condition (C7) with respect to time yields

$$\partial_{\omega t}J_t(\omega_t)+\partial_{\omega\omega}J_t(\omega_t)\,\dot{\omega}_t=\frac{\Theta\dot{\pi}_t}{\omega_t}-\frac{\Theta\left(\pi_t-\pi^*\right)}{\omega_t}\left(\frac{\dot{\omega}_t}{\omega_t}\right) \tag{C8}$$

Substituting (C8) into the envelope condition yields

$$\begin{aligned}
\left(\rho-\pi_t\right)\frac{\Theta\left(\pi_t-\pi^*\right)}{\omega_t} &= \left(1-\tau+\tau^s\right)\frac{1}{P_t}h_t(1-\varepsilon)\int_{s_{it}=e}\partial_c \mathrm{u}^e\left(c_{it},h_{it};z_{it}\right)z_{it}di-\varepsilon\frac{h_t}{\omega_t}\int_{s_{it}=e}\partial_h \mathrm{u}^e\left(c_{it},h_{it};z_{it}\right)di \\
&\quad +\frac{\Theta\dot{\pi}_t}{\omega_t}-\frac{\Theta\left(\pi_t-\pi^*\right)}{\omega_t}\pi_t
\end{aligned}$$

Multiply both sides by ω_t/Θ to arrive at

$$\begin{aligned}
\left(\rho-\pi_t\right)\left(\pi_t-\pi^*\right) &= \frac{\omega_t}{\Theta}\left(1-\tau+\tau^s\right)\frac{1}{P_t}h_t(1-\varepsilon)\int_{s_{it}=e}\partial_c \mathrm{u}^e\left(c_{it},h_{it};z_{it}\right)z_{it}di-\frac{\varepsilon}{\Theta}h_t\int_{s_{it}=e}\partial_h \mathrm{u}^e\left(c_{it},h_{it};z_{it}\right)di \\
&\quad +\dot{\pi}_t-\left(\pi_t-\pi^*\right)\pi_t
\end{aligned}$$

Simplifying this expression and rearranging, we obtain

$$\rho\left(\pi_t-\pi^*\right)=\frac{\varepsilon}{\Theta}h_t\left[-\int_{s_{it}=e}\partial_h \mathrm{u}^e\left(c_{it},h_t;z_{it}\right)di-\left(\frac{\varepsilon-1}{\varepsilon}\right)\left(1-\tau+\tau^s\right)w_t\int_{s_{it}=e}\partial_c \mathrm{u}^e\left(c_{it},h_{it};z_{it}\right)z_{it}di\right]+\dot{\pi}_t \tag{C9}$$

To fully undo the union's distortion to hours worked in steady state, we set $\tau^s=(1-\tau)/(\varepsilon-1)$. We also assume that this subsidy is funded by the lump-sum tax, i.e. $\phi_{it}^s=$

$\tau^s z_{it} w_t h_{it}$. As a result, in equilibrium it does not appear in either the household budget constraint nor in the government budget constraint, which is why we have omitted it altogether from the main text. After this substitution, and after setting $w_t = \alpha$ from (B7), we arrive at

$$\rho\left(\pi_t - \pi^*\right) = \frac{\varepsilon}{\Theta} h_t \left[-\int_{s_{it}=e} \partial_h \mathrm{u}^e\left(c_{it}, h_t; z_{it}\right) di - (1-\tau)\,\alpha \int_{s_{it}=e} \partial_c \mathrm{u}^e\left(c_{it}, h_{it}; z_{it}\right) z_{it} di \right] + \dot{\pi}_t$$

which equals the expression for the Phillips curve (9) in the main text, once we use our functional form for u^e in (2).

To obtain the linearized expression for the Phillips curve in (15), note that when linearizing the term in round brackets in (9) around the steady-state we have exploited the fact that $\psi(h^*)^{\frac{1}{\sigma}+1} = (1-\tau)\alpha h^*$.

D Problem of the Mutual Fund

Recall that the fund owns all intermediate good firms and holds real debt issued by the government and a nominal bond in zero net supply which carry a liquidity premium $\bar{\iota}$. Let X_t^f denote holdings of shares of the intermediate good producers, q_t the unit share price, Π_t per-share profits, B_t^f holdings of real government bonds, r_t^b the real interest rate on government bonds, M_t^f holdings of nominal bond in real terms, and r_t^m the real rate of return on the nominal bond. Let A_t be the real value of the fund. The problem of the mutual fund, which takes prices as given, entails choosing the optimal portfolio composition between equity, real bonds and nominal bonds:

$$\begin{aligned}\tilde{r}_t A_t\left(X^f, B^f, M^f\right) = \max_{\dot{X}^f, \dot{B}^f,, \dot{M}^f} \quad & \Pi_t X^f - q_t \dot{X}^f + (r_t^b + \bar{\iota}) B^f - \dot{B}^f + (r_t^m + \bar{\iota}) M^f - \dot{M}^f \\ & + \partial_X A_t\left(X^f, B^f, M^f\right) \dot{X}^f + \partial_B A_t\left(X^f, B^f, M^f\right) \dot{B}^f \\ & + \partial_M A_t\left(X^f, B^f, M^f\right) \dot{M}^f + \partial_t A_t\left(X^f, B^f, M^f\right)\end{aligned} \tag{D1}$$

with first-order conditions with respect to $\dot{X}^f$, $\dot{B}^f$, and $\dot{M}^f$

$$\begin{aligned} q_t &= \partial_X A_t\left(X^f, B^f, M^f\right) \\ 1 &= \partial_B A_t\left(X^f, B^f, M^f\right) \\ 1 &= \partial_M A_t\left(X^f, B^f, M^f\right)\end{aligned}$$

These first-order conditions, together with the linear homogeneity of the problem imply that $A_t\left(X^f, B^f, M^f\right) = q_t X^f + B^f + M^f$. Substituting this expression for A_t and the first order conditions into (D1), we arrive at

$$\tilde{r}_t\left(q_t X_t^f + B_t^f + M_t^f\right) = (\Pi_t + \dot{q}_t)X_t^f + (r_t^b + \bar{\iota})B_t^f + (r_t^m + \bar{\iota})M_t^f$$

Finally, by matching coefficients on equity and bonds, we obtain

$$\tilde{r}_t = \frac{\Pi_t + \dot{q}_t}{q_t} = r_t^b + \bar{\iota} = r_t^m + \bar{\iota}. \tag{D2}$$

which is the expression in equation (10) in the main text.

E Numerical Solution Method

Stationary Equilibrium and Impulse Response Functions. We solve for the stationary equilibrium using standard continuous-time finite-difference methods as described in Achdou et al. (2021).[49] This step defines the steady state X^* for any variable of interest X, either aggregate (e.g., unemployment) or distributional (e.g., total earnings at bottom tercile of skill distribution).

Out of steady state, we discretize our continuous-time economy in T monthly time steps and solve for the economy's first-order response to aggregate shocks using the sequence-space approach of Auclert et al. (2021). The most costly step in their method is the computation of the sequence-space Jacobian for the heterogeneous-agent block. For this step, we rely on their fake-news algorithm. We then write the sequence-space representation of the equilibrium of our economy, as described in Section 2.8. For any endogenous variable X and shock Z^k for $k \in \{d, s, m\}$, the sequence-space solution delivers a $(T \times T)$ matrix $\mathbf{G}^{x,k}$—a general equilibrium Jacobian—mapping any change in the path of shocks $d\mathbf{Z}^k \equiv (Z_1^k - Z^*, \ldots, Z_T^k - Z^*)'$ to the impulse responses $d\mathbf{X}^k \equiv (X_1 - X^*, \ldots, X_T - X^*)'$.[50] Notice that the general equilibrium Jacobians $\mathbf{G}^{x,k}$ give the endogenous response to any arbitrary shock vector $d\mathbf{Z}^k$. For the case of demand and supply shocks ($k = d, s$), $d\mathbf{Z}^k$ and $d\mathbf{X}^k$ are the impulse responses to a unit innovation to $\epsilon_t^k \equiv [\mathcal{W}_t^k - \mathcal{W}_{t-1}^k]$ in (17).

While we calibrate and solve for the model's IRFs at monthly frequency, we perform simulations and counterfactuals of the model at quarterly frequency.[51] Unless otherwise

[49] As the authors highlight, these methods generalize to stopping time problems such as the participation choice in our setup.

[50] Note that, besides the two shocks in the main text, demand and supply ($k = d, s$), we have an additional monetary shock $k = m$. This shock will be useful in dealing with the ZLB and asymmetries in monetary policy rules.

[51] This choise makes it easier to compare the model business cycle moments to the empirical targets, and

noticed, all the remaining exercises are conducted after aggregating shocks and IRFs from months to quarters.

Model Simulation and the ZLB. We combine the method of Boppart et al. (2018) with Holden (2016, 2023) to simulate equilibrium dynamics with the ZLB. The idea is to exploit the linearity of the economy's response to aggregate shocks, while allowing for nonlinearities coming from an occasionally binding aggregate constraint, like the ZLB. In what follows, we use boldface $\mathbf{X}_{(t)}$ to denote the expected path of variable X at time t, i.e., $\mathbf{X}_{(t)} = (\mathbb{E}_t[X_{t+0}], \ldots, \mathbb{E}_t[X_{t+T}])'$. Also, we use $\mathcal{F}$ to represent the forward-shift operator, i.e., applying $\mathcal{F}$ to $\mathbf{X}_{(t)}$ delivers $\mathcal{F}\mathbf{X}_{(t)} = (\mathbb{E}_t[X_{t+1}], \ldots, \mathbb{E}_t[X_{t+T+1}])'$.

Suppose we want to perform a simulation for a given a sequence of demand and supply shocks $\{\epsilon_t^d, \epsilon_t^s\}_{t\geq 0}$. We proceed recursively, starting from $t = 0$ until T^{sim}. Absent the ZLB and with linearity, time-t projections are given by the moving-average (MA) process

$$\mathbf{X}_{(t)} = X^* + \sum_{j=0}^{T-1} \sum_{k=d,s} \left(\mathcal{F}^j d\mathbf{X}^k\right)\epsilon_{t-j}^k. \tag{E1}$$

which coincides with the expressions in Boppart et al. (2018) and Auclert et al. (2021). Alternatively, we can write (E1) recursively

$$\mathbf{X}_{(t)} = \mathcal{F}\mathbf{X}_{(t-1)} + \sum_{k=d,s} d\mathbf{X}^k \epsilon_t^k \tag{E2}$$

as the sum of period $t-1$ projections $\mathcal{F}\mathbf{X}_{(t-1)}$ with the impulse responses $d\mathbf{X}^k$ to time-t surprises.[52]

With the ZLB, we must also enforce that the projected path of nominal rates $\boldsymbol{i}_{(t)}$ does not violate the ZLB today or at any point in the future ($h \geq 0$). To this end, we start by representing the baseline monetary policy rule (13) as

$$\mathcal{A}\mathbf{y}_{(t)} + \mathbf{Z}_{(t)}^m = \mathbf{0}$$

where $\mathcal{A}$ is the linear map summarizing the policy rule (13) absent the ZLB, $\mathbf{y}_{(t)}$ collects the time path of variables entering the policy rule (e.g., interest rate, inflation, and unemployment), and $\mathbf{Z}_{(t)}^m$ denotes the date-t "news" shocks to the path of the policy rule

saves us time when computing the ergodic simulation.

[52]The recursive formulation in (E2) is very useful in the presence of the ZLB, as the probability of the ZLB binding or not in the future depends, in general, on the entire past sequence of shocks, which, in formulation (E2), is fully summarized by past projections $\mathcal{F}\mathbf{X}_{(t-1)}$.

at all future horizons. A date-t policy news shock at horizon h, for instance, captures a deviation from the policy rule $\mathcal{A}$ at time $t+h$ announced at time t. The idea is to use positive "news" shocks $\mathbf{Z}^m_{(t)} > 0$ to the interest rate path whenever the interest rate path set according to $\mathcal{A}$ would violate the ZLB constraint. In terms of our notation, this problem can be represented as a complementarity slackness condition on the paths of interest rates $\boldsymbol{i}_{(t)}$ and monetary policy shocks $\mathbf{Z}^m_{(t)}$

$$\boldsymbol{i}_{(t)} \cdot \mathbf{Z}^m_{(t)} = 0, \qquad \boldsymbol{i}_{(t)} \geq 0, \qquad \mathbf{Z}^m_{(t)} \geq 0. \tag{E3}$$

Obviously, $\boldsymbol{i}_{(t)}$ and $\mathbf{Z}^m_{(t)}$ must be solved jointly since the nominal rate path $\boldsymbol{i}_{(t)}$ is itself a function of the monetary "news" shock $\mathbf{Z}^m_{(t)}$, as those affect the interest rate path both directly, and indirectly through the feedback response to inflation and unemployment. Importantly, however, we already know the impact of a monetary "news" at any horizon on interest rates: these are given by the columns of general equilibrium Jacobian $\mathbf{G}^{i,m}$ computed in the first step. Appealing again to linearity, we can write the project interest rate path as

$$\boldsymbol{i}_{(t)} = \mathcal{F}\boldsymbol{i}_{(t-1)} + \sum_{k=d,s} d\mathbf{X}^k \epsilon^k_t + \mathbf{G}^{i,m}\left(\mathbf{Z}^m_{(t)} - \mathcal{F}\mathbf{Z}^m_{(t-1)}\right), \tag{E4}$$

where $\mathcal{F}\boldsymbol{i}_{(t-1)}$ denotes past nominal rate projections, $\left(\sum_{k=d,s} d\mathbf{X}^k \epsilon^k_t\right)$ captures the impact of time t demand and supply shocks, and $\mathbf{G}^{i,m}\left(\mathbf{Z}^m_{(t)} - \mathcal{F}\mathbf{Z}^m_{(t-1)}\right)$ incorporates the surprise news shocks concerning the possibility of the ZLB binding today or in the future.

Substituting (E4) into the complementary slackness (E3), we arrive at a linear complementarity problem (LCP) in $\mathbf{Z}^m_{(t)}$ of the form

$$\left(Q\mathbf{Z}^m_{(t)} + q\right) \cdot \mathbf{Z}^m_{(t)} = \mathbf{0}, \quad \mathbf{Z}^m_{(t)} \geq 0, \quad Q\mathbf{Z}^m_{(t)} + q \geq 0,$$

with $Q = \mathbf{G}^{i,m}$ and $q = \mathcal{F}\boldsymbol{i}_{(t-1)} + \sum_{k=d,s} d\mathbf{X}^k \epsilon^k_t - \mathbf{G}^{i,m}\mathcal{F}\mathbf{Z}^m_{(t-1)}$. Using a LPC solver to find $\mathbf{Z}^m_{(t)}$, we can then update projections of other variables X in a similar fashion

$$\mathbf{X}_{(t)} = \mathcal{F}\mathbf{X}_{(t-1)} + \sum_{k=d,s} d\mathbf{X}^k \epsilon^k_t + \mathbf{G}^{x,m}\left(\mathbf{Z}^m_{(t)} - \mathcal{F}\mathbf{Z}^m_{(t-1)}\right). \tag{E5}$$

Compared with (E2), condition (E5) features the additional term $\mathbf{G}^{x,m}\left(\mathbf{Z}^m_{(t)} - \mathcal{F}\mathbf{Z}^m_{(t-1)}\right)$ that captures the impact of the ZLB constraint (on current or expected future nominal rates) on the projected path of X. Notice that while news shocks are constrained to be nonnegative, $\mathbf{Z}^m_{(t)} \geq 0$, the ZLB surprises $\left(\mathbf{Z}^m_{(t)} - \mathcal{F}\mathbf{Z}^m_{(t-1)}\right)$ can be either positive or negative as the shocks hitting the economy render the ZLB more or less likely to bind.

Computing Monetary Policy Counterfactuals. Our strategy for simulating the economy under the counterfactual monetary policy rules follows Hebden and Winkler (2024) and McKay and Wolf (2023). The basic idea is to use the previous section projections computed under IT, $\mathbf{X}^{IT}$, to obtain the economy's counterfactual trajectory under any alternative monetary policy rule, $\mathbf{X}^{alt}$.

The method again leverages the monetary "news" shocks to the policy rule. In particular, we choose shocks $\tilde{\mathbf{Z}}^{m}_{(t)}$ so that the IT news-perturbed nominal rate path, $\tilde{\boldsymbol{i}}^{IT}_{(t)}$, computed as in (E4) using shocks $\tilde{\mathbf{Z}}^{m}_{(t)}$, mimics exactly the interest rate path that would arise under the counterfactual regime, $\boldsymbol{i}^{alt}_{(t)}$.[53] Given $\tilde{\mathbf{Z}}^{m}_{(t)}$, we compute the IT news-perturbed allocation $\tilde{\mathbf{X}}^{IT}$ for other variables of interest following (E5). As monetary policy only enters other equilibrium conditions through the current and expected future path of nominal rates and we have chosen $\tilde{\mathbf{Z}}^{m}_{(t)}$ so that $\tilde{\boldsymbol{i}}^{IT}_{(t)} = \boldsymbol{i}^{alt}_{(t)}$, the IT news-perturbed equilibrium allocations must coincide with the equilibrium allocations under the alternative monetary policy rule, i.e., $\tilde{\mathbf{X}}^{IT} = \mathbf{X}^{alt}$. As McKay and Wolf (2023) put it, for computing the counterfactuals "it does not matter whether the policy rate path comes about due to systematic conduct of policy or due to policy shocks."

Ergodic Distribution. The previous section described how to perform the simulation given a sequence of demand and supply shocks. The model moments reported for the ergodic distribution are computed from averages across 250 simulated samples. In each sample, we initialize the model at the non-stochastic steady state and simulate the economy for 160 quarters. We discard the first 10 years of each sample and compute moments on the last 30 years of the simulated data.

Filtering in the Great Recession Exercise. For the Great Recession exercise, conducted in Section 5.2, we need to find the sequence of innovations that replicate, in our model under a baseline IT rule, the observed U.S. unemployment and inflation dynamics. To do so we adopt the filtering procedure discussed in McKay and Wieland (2021). The main benefit relative to more standard Kalman filter algorithm is that their approach only requires information on the impulse response functions, which we have from above.

Abstracting from the ZLB, we can use (E1) to recover the demand and supply series of innovations $\{\epsilon^{d}_{t}, \epsilon^{s}_{t}\}$ that are consistent with the observed values of unemployment and inflation. We start the filtering back in 1990:$Q$1 assuming that the economy starts from its non-stochastic steady-state, and proceed recursively. At t = 1990:$Q$1, this just requires

[53] Hebden and Winkler (2024) describe how to compute these monetary "news" surprises for a counterfactual with an asymmetric policy rule like the Lower for Longer strategy we consider in our application.

inverting the impact matrix of the impulse response function to find the shocks that move unemployment and inflation in the model as much as in the data. For $t > 1990{:}Q1$, we can use the same logic to find the shocks that explain the "surprise" movements in inflation and unemployment, i.e., the difference between current realizations and previous period projections $(X_t - \mathbb{E}_{t-1}[X_t])$.

To deal with the ZLB, we rely on monetary news shocks as before. Specifically, at each point t, we verify whether the projected path of nominal rates under the filtered shocks violates the ZLB. If it doesn't, we proceed to $t+1$. If it does, we compute the monetary news shocks to the path of nominal rates that ensure the constraint is satisfied along the projection, i.e., $\mathbb{E}_t[i_{t+h}] \geq 0$. Because the monetary news shocks also affect the economy's response at time t, we need to solve for the news, demand and supply shocks jointly. An iterative algorithm works well in practice.

Discussion of our Solution Method. Our simulations and policy counterfactuals are computed—much like other papers in this literature (e.g., Williams, 2009; Kiley and Roberts, 2017; Bernanke et al., 2019)—under the assumption of perfect foresight, i.e., at each point in time agents in our model form expectations under the assumption that the economy won't be hit with any further aggregate shocks. As a result, agents always expect that inflation will converge back to the target in the long run.

In a fully global rational expectations solution, however, agents would internalize that the ZLB might bind in the future even if it is not binding today (as in Fernàndez-Villaverde et al., 2024), a force that would push down the deflationary bias even further via precautionary saving. At the same time, agents would also internalize the promise to run a hot economy during booms under the Lower for Longer strategy even when the economy is at other points of the business cycle, which pushes inflation expectations, and actual inflation, further up. If this latter force is quantitatively significant, it could raise the concern that our perfect foresight solution might provide a "too favorable" view of the inflation-inclusion trade-off embedded in the Okun's cones of Section 5.4.

While computing the fully rational expectation solution of our model is currently unfeasible, we offer a robustness exercise that lessens this concern. We extend our solution method to take into account future aggregate uncertainty along the lines of the Stochastic Extended Path approach discussed in Adjemian and Juillard (2013). When we incorporate aggregate uncertainty up to 8 quarters ahead, qualitatively the results align with our previous intuition: the possibility of a binding ZLB in the future lowers further the negative inflation bias under IT, while the promise to run the economy hot raises further the positive inflation bias under LfL. However, the implied magnitude of changes in infla-

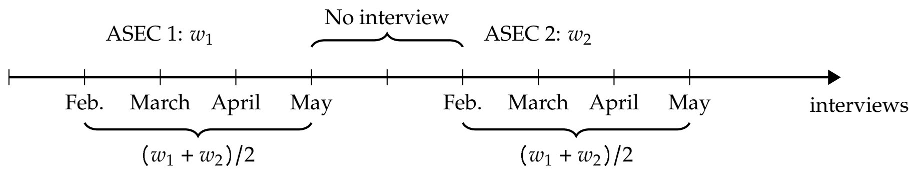


Figure F1: Graphical description of weekly earnings inference for individuals in our sample.

tion and unemployment is tiny, smaller than 1 bp, and does not alter any of our previous findings.

F Data on Worker Flows

F.1 Sample and Measure of Skills

We measure worker stocks and flows directly from the Basic Monthly Current Population Survey (CPS) from 1989 to 2019. Our sample includes individuals between 25 and 59 years old and exclude self-employed, government employees and unpaid family workers. This sample selection leaves us with a sample of $18,697,072$ workers, or $47,215$ individuals per month on average. This is our primary sample to compute average worker stocks and flows.

To estimate the dependence of flows on workers' skill levels z_{it}, we merge the Monthly CPS files with the Annual Social and Economic Supplement (ASEC). The ASEC, which is conducted as a supplement of the March CPS, asks each individual additional questions about past earnings and weeks worked. We use this information to construct a measure of individual weekly earnings, which serves as our proxy for workers' skills. Every individual in our sample is interviewed at most twice in the ASEC supplement. For each interview in which the individual participates, we compute weekly real earnings by dividing annual nominal labor earnings [INCWAGE] by the product of number of annual weeks worked [WKSWORK1] and the Consumer Price Index (CPI-U) for that year. If individuals are interviewed only once, we use the weekly earnings of that interview for the whole period we observe that individual. If individuals are interviewed twice, we use the average of weekly earnings from the two interviews. We express skills z_{it} in relative terms by taking the ratio of individual weekly earnings to cross-sectional average weekly earnings computed for that year. We further drop all individuals who report positive weeks worked but no earnings. as well as all entries that are assigned zero weight in the survey. After this step, we are left with a sample of $3,933,752$ workers/months, or $21,264$ indi-

Data

	E	U	N
E	-	0.0126	0.0170
U	0.2465	-	0.1899
N	0.0696	0.0396	-

Data (deNUN)

	E	U	N
E	-	0.0126	0.0170
U	0.2465	-	0.1326
N	0.0696	0.0267	-

Table F1: Average labor market flows computed from the CPS. Left table shows averages using raw transition data. Right table shows averages using data corrected for misclassification according to the approach described in Elsby et al. (2015).

viduals per month on average.[54] Figure F1 summarizes our approach to assign a weekly earnings, hence skill, level to individuals in the sample.

F.2 Measuring Worker Flows

We measure worker flows from month-to-month changes in individual employment status [EMPSTAT]. A well known concern in this literature is the misclassification of workers' labor market status, especially between unemployment and nonparticipation. We follow the correction approach of Elsby et al. (2015) and re-code some sequences of labor market states to eliminate high-frequency reversals between unemployment and nonparticipation states.[55] The raw and corrected average worker flows are reported in Table F1.

To measure flows across the workers' skill distribution, we divide individuals into deciles based on the distribution of skills in the pooled time sample. For each quantile q and employment status s, we then measure flows from the share of workers that transition to a different employment state s' from t to $t+1$. For instance, to compute EU flows for quantile q, we compute the share of workers whose skills fall in quantile q that are employed at time t and move to unemployment at time $t+1$. Figure F2 plots the average worker flows as a function of skill level.

The EU flow is strongly declining in skills: from a relative skill level of 1/2 to 2 (from half to twice the observed weekly earnings of an average worker), the job losing probability falls by almost a factor of two. The UE and NE flows are much flatter over the same region, trending down only for very low-skill levels. We also observe a strong dependence of EN and UN flows on skills, with workers at the bottom deciles of the distribution being

[54] Because of the rotating nature of the CPS, in which households are interviewed for four months, then left aside for eight months, and finally interviewed again for four months, this leaves many individuals in the Basic Monthly CPS out of our merged sample because they are not part of any ASEC supplement. More specifically, workers interviewed from July to November are not in our sample.

[55] Examples of the latter are recorded sequences 'UUNU' reclassified as 'UUUU' or 'NNUN' reclassified as 'NNNN', and so on.

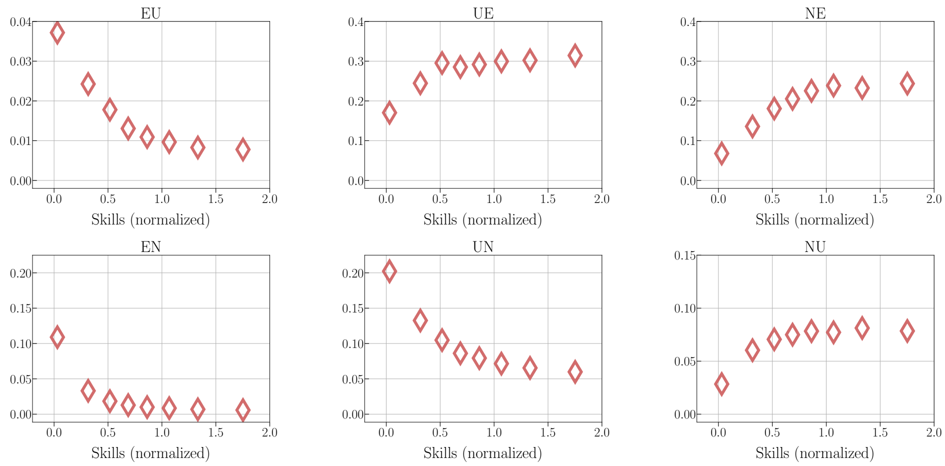


Figure F2: Labor market average transition rates as a function of workers' skill (weekly earnings) levels. The average skill level is normalized to 1 in our sample.

far more likely to exit the labor force than workers at the top deciles. Overall, workers at the bottom of the skill distribution are more likely drop out of participation (EN and UN rates are larger at the bottom deciles) and, conditionally on participating in the labor market, experience less stable employment (EU is high and UE is low at the bottom deciles).

F.3 Job Separation and Job Finding Rates across the Skill Distribution

In the model, we make no restrictions on the dependence of labor market frictions $\lambda_z^{eu}, \lambda_z^{ue}, \lambda_z^{ne}$ on the worker's skill level z. In order to make progress in our estimation, we must parameterize search frictions $\lambda_z^{ss'}$ according to some lower-dimensional object. We adopt the following functional form

$$\lambda^{ss'}(z) = \lambda_0^{ss'} + \lambda_1^{ss'} \exp(\lambda_2^{ss'} z) \qquad ss' \in \{eu, ue, ne\}, \tag{F1}$$

which reduces each friction to three parameters $\{\lambda_0^{ss'}, \lambda_1^{ss'}, \lambda_2^{ss'}\}$ capturing the level and curvature of frictions along z. To get estimates for these parameters in (F1) for $ss' \in \{eu, ue, ne\}$ we proceed in two steps. First, we use the data on EU and UE flows by weekly earnings from Figure F2 to capture the "shape" of the job-separation and job-finding rates along workers' skill level. Specifically, we estimate the values of $\tilde{\lambda}_0^{ss'}, \tilde{\lambda}_1^{ss'}$, and $\tilde{\lambda}_2^{ss'}$ for $ss' \in \{eu, ue\}$ that minimize the quadratic distance between $\lambda^{ss'}(z)$, defined as in (F1), and the observed EU and UE transition probabilities at the empirical skill deciles. In this step, we assume that the job-finding rate out of nonparticipation shares the same shape as the

	Job-separation from E	Job-finding from U	Job-finding from N
$\lambda_0^{ss'}$	0.0087	0.3461	0.2307
$\lambda_1^{ss'}$	0.0457	-0.2531	-0.1687
$\lambda_2^{ss'}$	-2.1433	-3.1738	-3.1738

Table F2: Parameter estimates of for job-separation and job-finding frictions. Frictions are parameterized according to F1. Read the description in the main text for a discussion of the estimation strategy.

job-finding rate out of unemployment—i.e., we set $\tilde{\lambda}_i^{ne} = \tilde{\lambda}_i^{ue}$ for $i = 0, 1, 2$.

The second step, which takes place in the calibration stage, adjusts the "level" of frictions to match our empirical targets for average flows. Specifically, we posit that model parameters are

$$\lambda_0^{ss'} = c^{ss'}\tilde{\lambda}_0^{ss'}, \quad \lambda_1^{ss'} = c^{ss'}\tilde{\lambda}_1^{ss'}, \quad \lambda_2^{ss'} = \tilde{\lambda}_2^{ss'}$$

for $ss' \in \{eu, ue, ne\}$, where the scaling coefficients $c^{ss'}$ serve to target the average EU, UE and NE flows. This guarantees that the relative frictions faced by workers—alternatively, the ratio $\lambda^{ss'}(z_1)/\tilde{\lambda}^{ss'}(z_2)$ for any skill levels z_1 and z_2—are the same in the model and data. The resulting estimates are shown in Table F2.

Note that we avoid using NE transitions across the skill distribution to inform the shape of $\lambda^{ne}(z)$. We make this choice because a number of factors lead to a wedge between job-finding rates out of active nonparticipation (the object we want to parameterize) and NE flows (the object we actually observe in the data). Time aggregation (a measured NE transition can actually be a within period NU+UE), the presence of a stock of passive nonparticipants (who don't receive job offers but add to the measure of nonparticipants), as well as the acceptance decision of nonparticipants, all give rise to this wedge. Given that the strength of these different factors can change systematically along the skill distribution, we prefer to rely on the UE flows to capture the shape of job-finding frictions.[56]

[56]UE transitions also suffer from a similar issue when not all job offers from unemployment are accepted. This is less of a concern in our exercise because unemployed workers almost always accept job offers in our model (all job offers are the same, so unemployed workers don't have an option value of waiting for better offers). The only case when an unemployed worker can reject a job offer in our model is when the worker would be better off leaving the labor force but chooses to remain unemployed to collect their unemployment insurance benefits. Given that UI duration is short in our calibration, the importance of this wedge to our estimation of job-finding rate $\lambda^{ue}(z)$ is not unlikely to affect our results.

G Additional Tables

Table G1: Untargeted moments.

Stationary Equilibrium

	Data	Model
Marginal propensity to consume[1]	0.150	0.100
Marginal propensity to earn[2]	-0.023	-0.020
Unemployment rate bottom tercile[3]	0.150	0.123
Participation rate bottom tercile[3]	0.430	0.410
Cross-sectional earnings variance (age 25)[4]	0.595	0.531
Cross-sectional earnings variance (age 55)[4]	0.905	0.977
Standard dev. of one-year earnings change[4]	0.510	0.437
Skewness of one-year earnings change[4]	-1.070	-0.320
Kurtosis of one-year earnings change[4]	14.930	7.548
10-Year earnings losses full-year non-emp. (p25)[5]	-0.500	-0.452
10-Year earnings losses full-year non-emp. (p75)[5]	-0.300	-0.272
Effect of Unemployment Rate on Entry on Log-Earnings 1-Year Ahead[6]	-0.041	-0.041
Effect of Unemployment Rate on Entry on Log-Earnings 5-Year Ahead[6]	-0.023	-0.016

Out of Steady State (Standard Deviation)

	Data	Model
Employment	2.81	2.61
Labor Force Participation	1.38	0.99
Unemployment rate	29.36	27.61

Out of Steady State (Correlations with total hours)

	Data	Model
Employment	0.98	0.99
Labor Force Participation	0.76	0.78
Unemployment rate	-0.91	-0.97
EU	-0.82	-0.91
UE	0.88	0.91
NE	0.84	0.81
EN	0.51	0.76
UN	0.78	0.94
NU	-0.73	-0.84

Stationary Equilibrium. [1]Kaplan and Violante (2022); [2]Golosov, Graber, Mogstad, and Novgorodsky (2023); [3]Unemployment and participation rates across skill distribution are computed directly from the CPS using earnings data from the March ASEC Supplement (see Appendix F for a detailed description of our data and sample selection). [4]Guvenen, Karahan, Ozkan, and Song (2021); [5]Guvenen, Karahan, Ozkan, and Song (2017); [6]Schwandt and von Wachter (2019);

Out of Steady State. Data is quarterly from 1989 to 2019. Total hours and hours per worker are computed from the BLS-CES. Labor market stocks and flows are quarterly averages of monthly data computed directly from the CPS (see Appendix F for a detailed description of our data and sample selection). All series are in log and are detrended using a linear trend.

Table G2: Monetary policy rules considered in our counterfactual experiments.

For all rules $\mathcal{R}_t$,	$\frac{d\imath_t}{dt} = \begin{cases} -0.07(\imath_t - i^* - \mathcal{R}_t) & \text{if } \imath_t > 0 \\ \max\left\{-0.07(\imath_t - i^* - \mathcal{R}_t), 0\right\} & \text{if } \imath_t = 0 \end{cases}$
Baseline Inflation Target (IT)	$\mathcal{R}_t = 2.25(\pi_t - \pi^*) - 0.15(u_t - u^*)$
Average Inflation Target (AIT)	$\mathcal{R}_t = 2.25(\pi_t - \pi^*) + 5.00(\pi_t^{MA} - \pi^*)^- - 0.15(u_t - u^*)$
Shortfall Rule (SR)	$\mathcal{R}_t = 2.25(\pi_t - \pi^*) - 0.15(u_t - u^*)^+$
Lower for Longer (LfL)	$\mathcal{R}_t = 2.25(\pi_t - \pi^*) + 5.00(\pi_t^{MA} - \pi^*)^- - 0.15(u_t - u^*)^+$

Note. X^+ is the shorthand for $\max\{X, 0\}$, while X^- stands for $\min\{X, 0\}$. π_t^{MA} is the exponential moving average of past inflation $\int_0^\infty (1/48)\ e^{-(1/48)\tau}(\pi_{t-\tau} - \pi^*)d\tau$ with a smoothing factor 1/48 to target a window of 4 years.

Table G3: Total Labor Earnings Bias and Its Sources under Alternative Rules

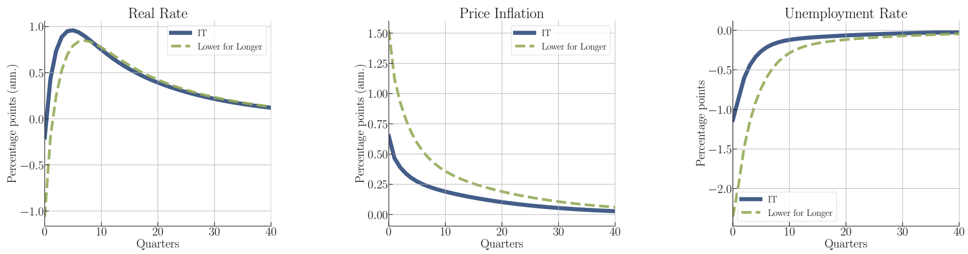
	Inflation Targeting		Lower for Longer		Shortfall		AIT		Higher IT	
	$\mathbb{E}$	(%)	$\mathbb{E}$	(%)	$\mathbb{E}$	(%)	$\mathbb{E}$	(%)	$\mathbb{E}$	(%)
T3 Total Labor Earnings	-1.79	—	0.74	—	-0.10	—	-0.07	—	-0.31	—
Hours	-0.23	2	0.09	3	-0.01	10	-0.01	29	-0.04	11
Unemployment rate	0.31	18	-0.13	18	0.02	20	0.01	14	0.05	19
Participation rate	-0.03	2	0.01	1	-0.01	10	-0.00	0	-0.01	3
Labor productivity	-1.22	68	0.50	68	-0.06	60	-0.04	57	-0.21	67
T1 Total Labor Earnings	-12.17	—	5.20	—	-0.47	—	-0.39	—	-2.11	—
Hours	-0.23	3	0.09	2	-0.01	1	-0.01	3	-0.04	3
Unemployment rate	1.10	10	-0.47	10	0.04	11	0.04	13	0.19	10
Participation rate	-2.52	50	1.09	51	-0.09	45	-0.07	46	-0.44	50
Labor productivity	-4.54	37	1.92	37	-0.20	43	-0.15	38	-0.78	37

Note. Expected values ($\mathbb{E}$) are expressed in terms of deviations from the non-stochastic steady state. Unemployment and participation are denoted in percentage points deviations. All other variables are in percent deviations. The (%) measures the contribution of a particular channel to the total earnings bias. T1 and T3 refer to average outcomes for the bottom and top terciles of the worker's skill distribution. See (18) for a decomposition of group's g total earnings W_t^g into the contribution of hours h_t, unemployment rate $(1 - u_t^g)$, labor force participation P_t^g, and labor productivity $Z_t^{e,g}$.

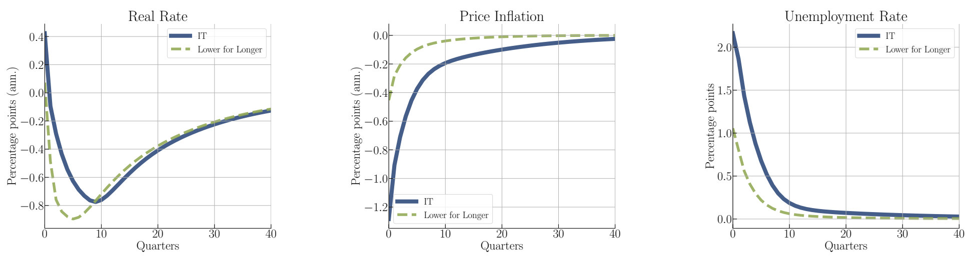
H Additional Figures

H.1 IRFs under Lower-for-Longer

(a) Demand-driven expansion



(b) Demand-driven recession



(c) Supply-driven expansion

(d) Supply-driven recession

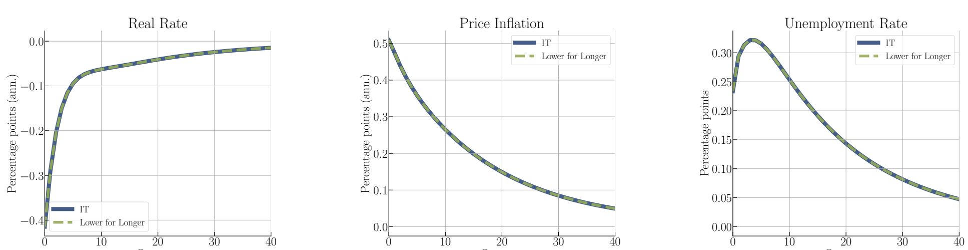


Figure H1: Impulse response under IT and LfL.

H.2 Great Recession

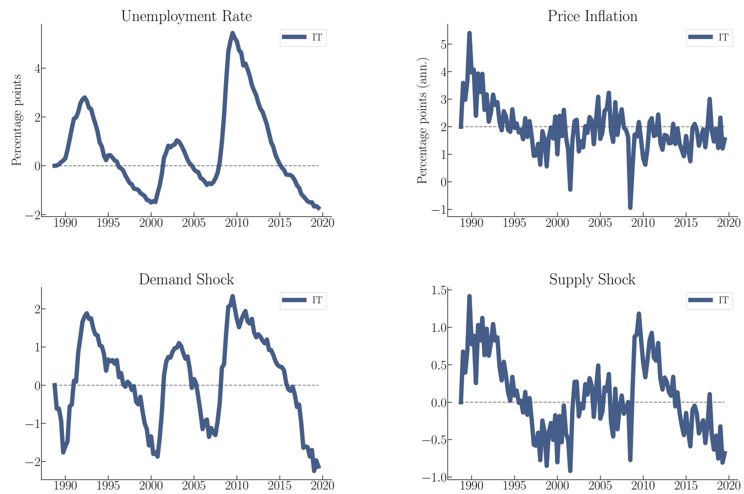


Figure H2: The unemployment rate measure is computed directly from the CPS (see Appendix F for a detailed description of our data and sample selection). Price inflation is headline PCE inflation (Fred Series: PCEPILFE). The aggregate demand ζ^d and supply ζ^s shocks in the model follow the diffusion specification in (17) with innovations filtered to match the inflation and unemployment data.