Monetary Policy Under Okun's Hypothesis*

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Abstract

The Fed's 2020 framework revision aimed to make monetary policy more *inclusive* by running the economy hot for longer during expansions, building on Okun's (1973) hypothesis that a 'high-pressure economy' persistently improves the labor market outcomes of low-wage workers. We evaluate this conjecture in a Heterogeneous Agent New Keynesian model with a three-state frictional labor market in which, consistent with micro evidence, low-skilled workers are more exposed to the business cycle and recessions have a long-lasting impact on their participation and earnings. Under a canonical Inflation Targeting rule, the ZLB induces a deflationary bias and amplifies the scarring effects of recessions at the bottom of the wage distribution. The Lower-for-Longer strategy adopted by the Fed counteracts this ZLB-driven hysteresis, raising the earnings of low-wage workers and reducing earnings inequality. Pursued aggressively, however, it turns the inflation bias positive. We trace the inflation–inclusion trade-off across policy rules and show that the inclusion gains at the bottom of the distribution survive, though at a higher inflation cost, even when expectations adjust to the inflation bias and aggregate unemployment gains vanish.

JEL Codes: E21, E24, E31, E32, E52, J24, J64

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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 aware of this reality and regularly reassess their conduct. The 2020 strategic review conducted by the U.S. Federal Reserve (Fed) 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 would *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 was 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 to the project's final report (Federal Reserve System, 2020), Chair Powell notes: *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 of employment from its maximum level, but only by shortfalls, 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. This strategy revision 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

[1] Interestingly, the European Central Bank's (ECB) most recent monetary policy strategy review also states that, while price stability remains its sole mandate, *when adjusting its monetary policy instruments, the Governing Council will—provided that two configurations of the instrument set are equally conducive [...] to price stability—choose the configuration that best supports the general economic policies of the Union related to growth, employment and social inclusion* (European Central Bank, 2025).

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 of 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 has a long history. 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 the 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 stoking inflationary pressures, he also thought that renouncing these gains for the 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 an *inflation–inclusion trade-off*.

In this paper, we develop a quantitative macroeconomic framework to assess the labor market implications of this monetary policy regime shift, and trace the inflation–inclusion trade-off. 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 three key 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 high 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) than their employed (E) counterparts ($UN \gg EN$), 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, they are also more likely to become unattached during recessions. Third, earnings losses resulting from job displacement are substantial and especially enduring at the lower end of the income distribution, where exit from the labor force makes re-employment even less likely.

These three mechanisms—uneven exposure to aggregate fluctuations, the labor force attachment wedge, and the lasting impact of job separation—give concrete form to Okun's hypothesis. Sustaining a hot economy for longer allows the recovery to reach all workers, including low-income ones, and gives them enough time to recoup the earnings lost during the downturn.

To quantify the aggregate and distributional effects of alternative monetary policy regimes un-

der 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. In the model, workers can be 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 increases on average while they are employed, but gradually diminishes during periods of nonemployment, leading to substantial and persistent earnings losses following job separations.

While we substantially enrich the labor market block of the model to attain a credible quantification of the employment and earnings gains under this monetary framework, on the inflation side we stay firmly within the canonical sticky-wage New Keynesian model, in which nominal wage adjustments are costly. The rest of the model is standard. A wage Phillips curve links inflation to fluctuations in the real economy, a fiscal authority taxes labor to finance spending, a monetary authority sets the nominal rate subject to a Zero Lower Bound (ZLB), and demand and supply shocks drive the business cycle.

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 which Okun's three channels are disciplined by the micro data. In agreement with much of the existing literature, we find that the ZLB gives rise to a small deflationary bias in the model's ergodic distribution: inflation averages 17 bp below target, while mean unemployment is 0.53 ppt above steady state. Relative to this literature, we find that these moderate aggregate effects mask a much larger and very uneven impact on labor earnings—the negative bias in total labor earnings ranges from just 1.7% in the top tercile of the skill distribution to 9% in the bottom tercile. The damage at the bottom reflects labor market hysteresis: by raising unemployment, particularly among low-skilled workers, a recession that pushes the economy into the ZLB sets off a vicious cycle between weaker labor force attachment and skill erosion that leaves these workers scarred well beyond the ZLB period. A decomposition exercise shows that no single channel accounts for more than a small share of the gap between the top and bottom of the skill distribution: it is the *complementarity* among the three that generates it.

The inability of IT to deal with the ZLB opens the door to alternative, potentially more effective policy regimes, like the *Lower-for-Longer* (LfL) strategy embedded in the 2020 framework review. We next ask whether this 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. The answer is yes. In the ergodic distribution, LfL more than offsets the ZLB damage at the bottom: average earnings in the bottom tercile move from 9% below the non-stochastic steady state under

IT to 4% above it under LfL, a swing of 13 percentage points. The gains run through the same channels that generate the losses under IT: the bottom tercile's participation bias moves from −1.7 to +0.7 ppt and its labor productivity bias from −3.5% to +1.7%. Under a Phillips curve slope estimated from "normal times" data, these gains come with average inflation 25 bp above target, against 17 bp below under IT. A counterfactual built around the Great Recession, an episode that combines the very failures the 2020 framework set out to correct, puts these averages in historical perspective: switching to LfL in 2008 would have produced a more inclusive recovery, letting low-wage workers fully recoup their earnings losses at the cost of inflation modestly above target only late in the expansion.

Since the LfL rule bundles the two novelties of the 2020 review, we next ask how much of its gains each component delivers on its own. Taken one at a time, the make-up strategy for past inflation and the asymmetric response to employment shortfalls deliver comparable gains for low-skilled workers, but at different phases of the cycle: the first mainly tempers deep, ZLB-constrained downturns, whereas the second mainly prolongs expansions. Neither component alone, however, attains the full inclusion gains of the new framework. We also compare LfL with conventional remedies for the ZLB and with rules that respond directly to labor-market conditions at the bottom of the skill distribution. Among these, LfL offers the most favorable inflation–inclusion frontier and is the only rule that reaches high-inclusion outcomes. The alternatives, which respond to gaps that close as the recovery matures, stop accommodating just when LfL begins to run the economy hot.

Finally, we test the robustness of LfL's inclusion gains to how inflation expectations are formed. In our baseline solution, which assumes perfect foresight, agents correctly anticipate the asymmetric policy response to current and past shocks, but do not internalize that future shocks will continue to trigger the rule's asymmetries. Inflation expectations therefore stay anchored at target even though realized inflation under LfL runs above it. Although survey evidence suggests that household expectations do remain anchored in the face of a small inflation bias such as the one LfL generates, we relax this assumption in the last part of the paper. Specifically, we re-solve the model with a Stochastic Extended Path method in which households and firms integrate over future aggregate shocks and thus internalize the rule's inflationary bias, increasingly so as the horizon over which they integrate lengthens. Once expectations fully catch up with realized inflation, the aggregate unemployment gains of LfL all but vanish, as the natural-rate hypothesis predicts. Yet more than half of the reduction in the earnings gap between top and bottom skill terciles survives, with LfL still leaving a lasting imprint on the labor force attachment and skills of low-wage workers.

Taken together, these results give quantitative content to Okun's conjecture: in normal times, when the Phillips curve is relatively flat, monetary policy can sustain a high-pressure economy that improves outcomes for disadvantaged workers at a small inflation cost.

1.1 Related Literature and Contribution

Our paper stands at the intersection of several areas in macroeconomics. From a modeling 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, joining an emerging trend calling for a more prominent role of labor supply in this class of models (Huo and Ríos-Rull, 2020; Ferriere and Navarro, 2024). This choice is consistent with the evidence in Graves et al. (2023), who find that "supply-driven" flows (EN and UN) play a quantitatively important role in the employment response to monetary policy shocks. As shown in Alves and Violante (2024), our framework aligns with their evidence on all labor flows.

Second, within this framework we give formal content to Okun's (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 average to business cycle fluctuations.[2] Hobijn and Şahin (2021) measure the 'participation cycle' from workers flows and document that this channel is more pronounced for low-skilled workers, whose labor force attachment is weaker. 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 because 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 modeling of Okun's (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-margin participation decision builds on Krusell et al. (2017). The assumption that frictions depend on individual skills, crucial to obtaining higher exposure for low-wage workers, follows 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 et al., 2025; 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

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

the macroeconomy, a more recent literature has argued that transitory 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 in U.S. time series.

We also connect to recent work within representative-agent models arguing that macroeconomic hysteresis can arise under strict inflation targeting. In Garga and Singh (2021), demand shortfalls depress innovation and potential output, while in Galí (2022), insider–outsider wage setting makes unemployment persistent. We introduce a different source of hysteresis and study its interaction with the ZLB and monetary policy rules in a heterogeneous-agent incomplete-markets economy. Fernández-Villaverde et al. (2024) also study the negative impacts of the ZLB in a HANK environment. They emphasize how 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 on labor market outcomes are disproportionately concentrated among low-wage workers and that only certain monetary policy rules are effective in mitigating such costs.

Motivated by the shift in the Fed's framework, several recent papers study asymmetric monetary policy rules in representative-agent models: Bianchi et al. (2021) show that an asymmetric response to inflation gaps can correct the ZLB's deflationary bias, and Bundick and Petrosky-Nadeau (2021) analyze the business cycle implications of employment shortfall-based rules. Our interest lies instead in how these rules impact low-wage workers, which requires moving beyond the representative-agent framework.

A number of contemporaneous papers also study the impact of monetary policy on racial unemployment, income, and wealth gaps (Bartscher et al., 2022; Bergman et al., 2020; Lee et al., 2021; Nakajima, 2022; Cairó and Lipton, 2026). Our approach differs along several dimensions. First, we focus on a broader notion of skills, whose sources may be unobservable (e.g., innate abilities, specialized knowledge) or observable (e.g., race, gender, education). Second, these papers feature at most the first of our three Okun channels—uneven exposure—while abstracting from human-capital losses during non-employment and from labor-force attachment, both crucial for hysteresis. Third, most study the effects of monetary policy *shocks* to standard Taylor rules on racial inequality, whereas we study how alternative monetary policy *rules* in response to aggregate shocks can generate durable gains for low-income groups (as, for example, in Gornemann et al., 2022). Focusing on systematic rules also lets us quantify the inflation–inclusion trade-off in the ergodic distribution.

2 Model

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 that reflects benefit duration. Non-participants do not engage in active search, but they still receive job offers and can thus transition back into employment, though at a lower rate than the unemployed. The data indicate that the pool of non-participants is heterogeneous in its attachment to the labor force (Hall and Kudlyak, 2019): in our model, this heterogeneity arises endogenously from differences in wealth, skills, and the idiosyncratic disutility of work introduced below.

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

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

When workers are employed ($s_t = e$), skills drift up at rate δ_z^+, and when they are not employed ($s_t = u, n$) they drift down at rate δ_z^-. 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. At any instant individuals can transition between employment states through a combination of exogenous Poisson rates and optimal participation 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 non-participation (rows 1, 2, 3). Similarly, a 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). Upon expiration of UI benefits, at rate $\lambda^{u_1 u_0}$ (common across z) eligible unemployed become ineligible (row 2). Non-participants receive job opportunities at rate λ_{zt}^{ne} and decide whether to accept them or not (row 4).

	e	u_1	u_0	n
e	$\ddots$	λ_{zt}^{eu}	$\times$	$\blacktriangleright$
u_1	$\lambda_{zt}^{ue} \cdot \triangleright$	$\ddots$	$\lambda^{u_1 u_0}$	$\blacktriangleright$
u_0	$\lambda_{zt}^{ue} \cdot \triangleright$	$\times$	$\ddots$	$\blacktriangleright$
n	$\lambda_{zt}^{ne} \cdot \triangleright$	$\times$	$\blacktriangleright$	$\ddots$

Table 1: Transition matrix across the four employment states. Rows index the origin state s, columns the destination state s'. The $\times$ symbol means that the transition cannot happen. The $\blacktriangleright$ symbol means that an endogenous participation decision moves the individual into that state. The $\triangleright$ symbol means that an endogenous job acceptance decision moves the individual into employment. $\lambda_{zt}^{ss'}$ are exogenous Poisson rates capturing job-finding, job-separation and UI termination rates. The diagonal dots stand for the negative of the sum of all the other entries on that line.

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 associated with 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:

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

where $\sigma > 0$ is the Frisch elasticity of labor supply. The effort costs of employment and job search are stochastic, following Krusell et al. (2017): κ^e and κ^u depend on an idiosyncratic disutility state $\eta_t \in \{L, H\}$ that switches from L to H at Poisson rate χ^{LH} and reverts at rate χ^{HL}, independently across individuals and of all other idiosyncratic shocks.

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.

Saving instruments. Households can save through a financial asset a_t with rate of return r_t, and face a zero unsecured credit limit. This asset is a claim on the mutual fund described in Section 2.4, which owns the firms and holds government debt, and a_t is the market value of that claim. When an unanticipated shock hits, the value of the fund jumps and a_t is revalued with it. Newborn workers enter the economy as ineligible unemployed with zero wealth holdings and low disutility

of work. 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.[3]

Household problem. Let $v_t^s(a, z, \eta)$ be the value at date t of an individual with employment state s, wealth a, productivity z, and disutility state η. The dynamic problem solved by the household at time t is a mix of a consumption-savings optimal control problem and two discrete choices: the job acceptance decision $\mathfrak{j}_t^s \in \{0, 1\}$ arising at random Poisson jump times, and the participation decision $\mathfrak{p}_t^s \in \{0, 1\}$ that takes the form of an optimal stopping-time problem.

Consider first the problem of the non-participant (n):

$$
\begin{aligned}
v_0^n\left(a_0, z_0, \eta_0\right) = \max_{\{c_t\}_{t\geq 0}, \mathfrak{t}^*} \quad & \mathbb{E}_0\Bigg[\int_0^{\mathfrak{t}^{\min}} e^{-\rho t}\mathfrak{u}^n\left(c_t, 0\right) dt + \mathbb{I}_{\{\mathfrak{t}^{\min}=\mathfrak{t}^e\}} e^{-\rho \mathfrak{t}^e} \max\left\{v_{\mathfrak{t}^e}^e\left(a_{\mathfrak{t}^e}, z_{\mathfrak{t}^e}, \eta_0\right), v_{\mathfrak{t}^e}^n\left(a_{\mathfrak{t}^e}, z_{\mathfrak{t}^e}, \eta_0\right)\right\} \\
& + \mathbb{I}_{\{\mathfrak{t}^{\min}=\mathfrak{t}^*\}} e^{-\rho \mathfrak{t}^*}\left(v_{\mathfrak{t}^*}^{u_0}\left(a_{\mathfrak{t}^*}, z_{\mathfrak{t}^*}, \eta_0\right) - \xi\right) + \mathbb{I}_{\{\mathfrak{t}^{\min}=\mathfrak{t}^\eta\}} e^{-\rho \mathfrak{t}^\eta} v_{\mathfrak{t}^\eta}^n\left(a_{\mathfrak{t}^\eta}, z_{\mathfrak{t}^\eta}, \eta_{\mathfrak{t}^\eta}\right)\Bigg] \\
s.t. & \\
c_t + \dot{a}_t &= r_t a_t + \phi \\
a_t &\geq 0
\end{aligned}
\tag{3}
$$

where the conditional expectation reflects the uncertainty about the evolution of skills z_t and the Poisson arrival rates that determine transitions across labor market and disutility states. Non-participant workers choose consumption flow c_t at every instant. They also 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 $\left(\mathfrak{p}_t^n = 0\right)$ also chooses whether to re-enter the labor force $\left(\mathfrak{p}_t^n = 1\right)$, in which case they become unemployed, but are not eligible for UI benefits ($u = u_0$). [4] We assume that re-entering the labor force involves a small fixed switching cost ξ.[5] The optimal stopping time $\mathfrak{t}^*$ represents the first instant in which the choice $\mathfrak{p}_t^n$ switches from 0 to 1. At rate χ^{LH} (if $\eta_0 = L$) or χ^{HL} (if $\eta_0 = H$) the worker's disutility state switches to the complementary value $\eta_{\mathfrak{t}^\eta} \neq \eta_0$. Let $\mathfrak{t}^\eta$ denote the arrival time of this event, while $\mathfrak{t}^{\min}$ denotes the time at which the first of all these events occurs. The last two lines of this problem state the law of motion for wealth, which evolves deterministically conditional on the events above, and the no-borrowing limit.

[3] 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.

[4] 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.

[5] The presence of a small switching cost is mostly a technical assumption to avoid "chattering," i.e., infinitely fast switching between n 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.

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

$$
\begin{aligned}
v_0^{u_0}\left(a_0, z_0, \eta_0\right) = \max_{\{c_t\}_{t\geq 0}, \mathfrak{t}^*} \quad & \mathbb{E}_0\Bigg[\int_0^{\mathfrak{t}^{\min}} e^{-\rho t}\mathfrak{u}^u\left(c_t, 0; \eta_0\right) dt + \mathbb{I}_{\{\mathfrak{t}^{\min}=\mathfrak{t}^e\}} e^{-\rho \mathfrak{t}^e} v_{\mathfrak{t}^e}^e\left(a_{\mathfrak{t}^e}, z_{\mathfrak{t}^e}, \eta_0\right) \\
& + \mathbb{I}_{\{\mathfrak{t}^{\min}=\mathfrak{t}^*\}} e^{-\rho \mathfrak{t}^*} v_{\mathfrak{t}^*}^n\left(a_{\mathfrak{t}^*}, z_{\mathfrak{t}^*}, \eta_0\right) + \mathbb{I}_{\{\mathfrak{t}^{\min}=\mathfrak{t}^\eta\}} e^{-\rho \mathfrak{t}^\eta} v_{\mathfrak{t}^\eta}^{u_0}\left(a_{\mathfrak{t}^\eta}, z_{\mathfrak{t}^\eta}, \eta_{\mathfrak{t}^\eta}\right)\Bigg] \\
s.t. & \\
c_t + \dot{a}_t &= r_t a_t + \phi \\
a_t &\geq 0
\end{aligned} \tag{4}
$$

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.[6] At any time $\mathfrak{t}^*$ during the unemployment spell, the individual can quit the labor force $\left(\mathfrak{p}_t^{u_0} = 0\right)$. Finally, as in the non-participant problem, the disutility state switches to its complementary value $\eta_{\mathfrak{t}^\eta}$ upon the arrival of the shock at $\mathfrak{t}^\eta$.

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

$$
\begin{aligned}
v_0^{u_1}\left(a_0, z_0, \eta_0\right) = \max_{\{c_t\}_{t\geq 0}, \mathfrak{t}^*} \quad & \mathbb{E}_0\Bigg[\int_0^{\mathfrak{t}^{\min}} e^{-\rho t}\mathfrak{u}^u\left(c_t, 0; \eta_0\right) dt + \mathbb{I}_{\{\mathfrak{t}^{\min}=\mathfrak{t}^e\}} e^{-\rho \mathfrak{t}^e} \max\left\{v_{\mathfrak{t}^e}^e\left(a_{\mathfrak{t}^e}, z_{\mathfrak{t}^e}, \eta_0\right), v_{\mathfrak{t}^e}^{u_1}\left(a_{\mathfrak{t}^e}, z_{\mathfrak{t}^e}, \eta_0\right)\right\} \\
& + \mathbb{I}_{\{\mathfrak{t}^{\min}=\mathfrak{t}^*\}} e^{-\rho \mathfrak{t}^*} v_{\mathfrak{t}^*}^n\left(a_{\mathfrak{t}^*}, z_{\mathfrak{t}^*}, \eta_0\right) + \mathbb{I}_{\{\mathfrak{t}^{\min}=\mathfrak{t}^{u_0}\}} e^{-\rho \mathfrak{t}^{u_0}} v_{\mathfrak{t}^{u_0}}^{u_0}\left(a_{\mathfrak{t}^{u_0}}, z_{\mathfrak{t}^{u_0}}, \eta_0\right) \\
& + \mathbb{I}_{\{\mathfrak{t}^{\min}=\mathfrak{t}^\eta\}} e^{-\rho \mathfrak{t}^\eta} v_{\mathfrak{t}^\eta}^{u_1}\left(a_{\mathfrak{t}^\eta}, z_{\mathfrak{t}^\eta}, \eta_{\mathfrak{t}^\eta}\right)\Bigg] \\
s.t. & \\
c_t + \dot{a}_t &= r_t a_t + (1-\tau) b\left(z_t\right) + \phi \\
a_t &\geq 0
\end{aligned} \tag{5}
$$

Besides receiving job opportunities and choosing whether to take them, choosing to drop out of the labor force $\left(\mathfrak{p}_t^{u_1} = 0\right)$, and switching disutility state at $\mathfrak{t}^\eta$, the eligible unemployed could lose their entitlement to UI benefits at rate $\lambda^{u_1 u_0}$, with $\mathfrak{t}^{u_0}$ being the first arrival time of this event.

Finally, the problem of the employed household is:

$$
\begin{aligned}
v_0^e\left(a_0, z_0, \eta_0\right) = \max_{\{c_t\}_{t\geq 0}, \mathfrak{t}^*} \quad & \mathbb{E}_0\Bigg[\int_0^{\mathfrak{t}^{\min}} e^{-\rho t}\mathfrak{u}^e\left(c_t, h_t; z_t, \eta_0\right) dt + \mathbb{I}_{\{\mathfrak{t}^{\min}=\mathfrak{t}^u\}} e^{-\rho \mathfrak{t}^u} v_{\mathfrak{t}^u}^{u_1}\left(a_{\mathfrak{t}^u}, z_{\mathfrak{t}^u}, \eta_0\right) \\
& + \mathbb{I}_{\{\mathfrak{t}^{\min}=\mathfrak{t}^*\}} e^{-\rho \mathfrak{t}^*} v_{\mathfrak{t}^*}^n\left(a_{\mathfrak{t}^*}, z_{\mathfrak{t}^*}, \eta_0\right) + \mathbb{I}_{\{\mathfrak{t}^{\min}=\mathfrak{t}^\eta\}} e^{-\rho \mathfrak{t}^\eta} v_{\mathfrak{t}^\eta}^e\left(a_{\mathfrak{t}^\eta}, z_{\mathfrak{t}^\eta}, \eta_{\mathfrak{t}^\eta}\right)\Bigg] \\
s.t. & \\
c_t + \dot{a}_t &= r_t a_t + (1-\tau) w_t z_t h_t + \phi \\
a_t &\geq 0
\end{aligned} \tag{6}
$$

[6] In equilibrium there is a unique wage per effective hour, thus if they did not want to work, they would choose non-participation.

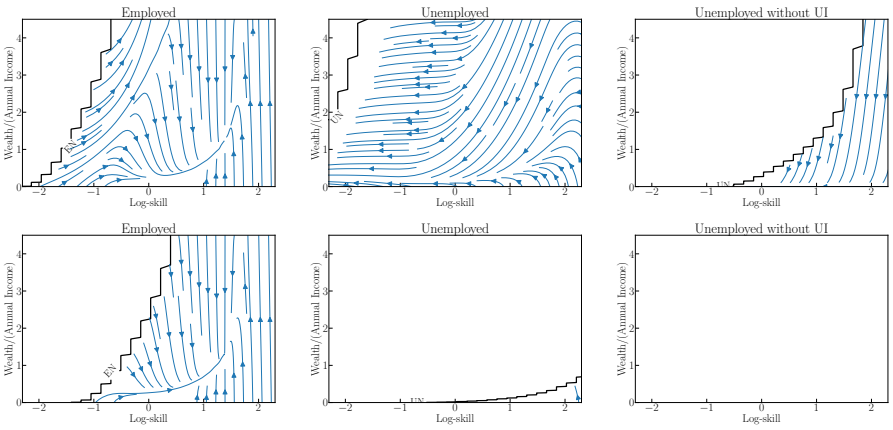


Figure 1: Labor force participation decisions.

Note. Participation decision for the employed, the unemployed with UI, and the unemployed without UI, represented in the state space of log-skills and wealth (in units of annual income). The top row plots the decision under the low disutility state ($\eta = L$), the bottom under the high disutility state ($\eta = H$). In each panel the black line is the participation boundary, and the arrows, drawn only inside the participation region, indicate skill and wealth dynamics in the absence of skill shocks in that employment state. The bottom-right panel is therefore blank: under the high disutility state, the participation region of the unemployed without UI is empty at every level of skills and wealth.

Employed workers (e) can be laid off at rate λ_{zt}^{eu}, in which case they become unemployed eligible for UI benefits ($u = u_1$). Let $\mathfrak{t}^u$ be the first arrival time of this Poisson shock. At any instant $\mathfrak{t}^*$, the employed worker can choose to quit the labor force $\left(\mathfrak{p}_t^e = 0\right)$.[7] In addition, the employed worker's disutility state switches to its complementary value $\eta_{\mathfrak{t}^\eta}$ upon the arrival of the corresponding Poisson shock at $\mathfrak{t}^\eta$.

Each of these four 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.1).

Participation decisions. Figure 1 represents the solution to the labor force participation problem as a function of the individual state (a, z, η). Participation is governed by substitution and income effects and by the current disutility draw: workers are more likely to participate the higher their skills, the lower their wealth, and the lower their disutility of work and search.

Start with the low disutility state $\eta = L$ (top row). Continuous employment moves workers deeper into the participation region: skills grow while employed and, although wealth accumulation pushes them back toward the threshold, target wealth for most skill levels falls well inside the region.[8] Non-employment does the opposite. Skill depreciation pushes the unemployed toward the boundary, slowed only initially by wealth decumulation,[9] and once workers are out of

[7] Quitting into unemployment is never optimal, because the worker would not receive UI benefits, and would pay a higher disutility cost $\kappa_{\eta_0}^u$ for the opportunity to be re-employed at the same wage.

[8] A sequence of negative productivity shocks, or a realization of the high-disutility shock, can still induce wealthy employed workers to drop out of the labor force.

[9] Wealth decumulation keeps unemployed workers initially more attached, but assets are depleted fast.

the labor force further depreciation deepens their detachment: only the skilled and wealth-poor re-enter. A high disutility draw (bottom row) shifts every participation boundary inward, but its bite is markedly asymmetric across employment states. The employed retain a wide participation region as the wage more than compensates for the higher disutility—for skill levels high enough, they keep working at any wealth level. For the unemployed, who beyond any UI benefit participate only for the option value of finding a job, the same draw is nearly decisive: those still eligible keep searching only when they hold almost no wealth, while for the ineligible the participation region disappears altogether.

Finally, we note that skill depreciation and labor disutility shocks are two distinct forces pushing workers out of participation, and they differ in how long they keep them out. In our calibration, the high disutility state $\eta = H$ reverts quickly, producing short, transitory spells of non-participation. Skill depreciation lowers the return to participating persistently, and can therefore generate long-lasting exits, especially at the bottom of the skill distribution, where workers are closest to the boundary.

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 produces 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 $y_{jt} = \alpha \ell_{jt}$. We 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 yield 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 the 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.,

$$w_t = \alpha \tag{7}$$

and thus, price inflation equals wage inflation at every t. Appendix A.2 contains the full statement of the optimization problems of final and intermediate goods producers, and their solution.

2.3 Nominal Wage Setting

This block of the model adapts the nominal wage-setting mechanism of Erceg et al. (2000)—i.e., the standard New Keynesian *sticky wage* model—to a 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.[10] 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 $h_{kt}\int_{s_{it}=e} z_{it}di = \ell_{kt}$.[11] The union sets the nominal wage in order to maximize the welfare of its current members (all individuals employed at date t) subject to a Rotemberg-style quadratic cost 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^*.[12] 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 A.3 we show that the solution to this problem yields the wage Phillips curve

$$\rho(\pi_t - \pi^*) - \dot{\pi}_t = \frac{\epsilon}{\Theta}\left[h_t \int_{s_{it}=e} \partial_c \mathfrak{u}^e(c_{it}, h_t; z_{it}, \eta_{it}) z_{it} di\right]\left(\psi h_t^{\frac{1}{\sigma}} - (1-\tau)\alpha\right). \tag{8}$$

The right-hand side of equation (8) 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 its own type. If prices were rigid, the upward pressure on nominal wages would translate into higher real wages and a fall in labor demand. In our environment with flexible prices and a constant real wage, this

[10] As detailed in Appendix A.3, 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.

[11] Huo and Ríos-Rull (2020) raise a valid criticism of 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 offer all workers an employment contract that specifies a non-negotiable pair of wage and hours, but workers can always voluntarily choose not to participate in it and, in fact, in equilibrium some do and quit employment.

[12] 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 that deviates from it. A consequence of this assumption is that changes in the inflation target have no real effects, unless the ZLB binds.

reduction in labor demand occurs through the monetary tightening in response to inflation.

We now return briefly to our preference specification (2). Note that steady-state hours per worker determined by (8), $h^* \equiv [(1-\tau)\alpha/\psi]^{\sigma}$, are equal to what each employed worker would choose if wages were set competitively. In addition, the union's imposition that all workers supply the same hours is consistent with worker optimization.[13]

2.4 Mutual Fund

Households' wealth is invested in shares of a competitive risk-neutral mutual fund.[14] 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 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. 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.

In Appendix A.4, 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,

$$\tilde{r}_t = \frac{\Pi_t + \dot{q}_t}{q_t} = r_t^b + \bar{\iota} = r_t^m + \bar{\iota}. \tag{9}$$

These relationships determine the real return on households' wealth invested in the mutual fund and establish a no-arbitrage condition between firm equity, real bonds, and nominal bonds.[15] Along a perfect foresight path the condition holds at every $t > 0$. At $t = 0$, when an unanticipated shock hits, the share price q_t jumps instead: the revision to the expected path of profits and discount rates is capitalized at once into the value of equity, hence into the value of the fund A_t and into the wealth a_t of every household, in proportion to its holdings. We describe this one-time revaluation in Appendix A.5.

2.5 Fiscal Authority

The fiscal authority faces the following intertemporal budget constraint:

$$G_t + \Psi_t^{\ell} + \phi + (1-\tau)\int_{s_{it}=u^1} b(z_{it})di + r_t^b B_t^g = \tau w_t h_t \int_{s_{it}=e} z_{it} di + \dot{B}_t^g \tag{10}$$

[13] 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.

[14] The setup in this section follows closely Alves et al. (2020).

[15] Recall that, because of the annuity markets, the total rate of return on saving to households is $r_t = \tilde{r}_t + \varrho$.

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

$$G_t = G^* - \beta_B(B_t^g - B^*), \quad \beta_B > 0 \tag{11}$$

Thus, after 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 i_t according to an Inflation Targeting (IT) rule that reacts to deviations of inflation and the unemployment rate from their targets with some inertia. If we let i^* be the steady-state nominal rate, then the IT rule is defined as

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

where the reaction function to inflation and unemployment is

$$\mathcal{R}_t = \beta_\pi(\pi_t - \pi^*) + \beta_u(u_t - u^*). \tag{12}$$

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.[16]

The demand shock ζ^d is a perturbation to the bonds' liquidity premium $\bar{\iota}$, which shows up as a time-varying wedge between the rate of return on equity and the return on bonds in the

[16] 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 U.S. economy (see, e.g., Smets and Wouters, 2007; Galí et al., 2012).

no-arbitrage equation (9):

$$\tilde{r}_t = \frac{\Pi_t + \dot{q}_t}{q_t} = r_t^b + \bar{\iota} + \zeta_t^d = r_t^m + \bar{\iota} + \zeta_t^d. \tag{13}$$

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 labor, 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 is clear from the wage Phillips curve derivation (Appendix A.3), the shock shows up as a wedge in (8), whose linearized version (recall that the real wage is constant) becomes

$$\rho(\pi_t - \pi^*) - \dot{\pi}_t = \theta_w \left[\frac{1}{\sigma}(\log h_t - \log h^*) + \zeta_t^s \right] \tag{14}$$

where $\theta_w := \frac{\epsilon}{\Theta} \left[\int_{s_{it}=e} \partial_c \mathfrak{u}^e(c_{it}, h_t; z_{it}, \eta_{it}) z_{it} di \right] \psi(h^*)^{\frac{1+\sigma}{\sigma}}$. A positive shock to unions' desired markup ($\zeta_t^s > 0$) raises nominal wages, which puts upward pressure on inflation. A central bank following (12) 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 and the latter is the "slack" variable entering the Phillips curve, we posit that job offer arrival and separation rates shift with fluctuations in average hours per worker h_t. Specifically, we assume that

$$\log\left(\lambda_{zt}^{ss'}\right) = \log\left(\lambda_z^{*\,ss'}\right) + \vartheta^{ss'} \log\left(\frac{h_t}{h^*}\right), \qquad \text{for } ss' \in \{eu, ue, ne\} \tag{15}$$

where $\vartheta^{ss'}$ determines the elasticity with respect to hours.[17]

To gauge the distortions from aggregate fluctuations, and hence the scope for monetary stabilization, consider a benchmark with flexible, competitive nominal wages. This is the limiting case with a vertical wage Phillips curve ($\theta_w \to \infty$) and no wage markup shocks ($\zeta_t^s = 0$). Employed

[17] 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 two-state model: $u_z = \frac{\lambda_z^{eu}}{\lambda_z^{eu} + \lambda_z^{ue}}$. Differentiating with respect to the log of the separation rate $\frac{\partial u_z}{\partial \lambda_z^{eu}/\lambda_z^{eu}}$ yields $u_z(1 - u_z)$, and the same expression with the negative sign holds when we differentiate with respect to the job-finding rate. 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 the 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 fluctuations in the flows.

workers are then always on their labor supply curves, supplying constant hours h^* regardless of demand shocks. Since h^* equals steady-state hours, unemployment is also approximately constant at its steady-state level.[18] This benchmark with flexible and competitive wages provides the rationale for the strict IT rule (12). In response to a demand shock, inflation and unemployment move in opposite directions and elicit the same response from the IT rule that 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.

Crucially, though, 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 *temporarily* 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.

Equilibrium. Appendix A.5 contains the formal definition of a *perfect foresight equilibrium*.

2.8 Numerical Solution

We solve for the stationary equilibrium of our model globally using standard continuous-time finite-difference methods as described in Achdou et al. (2022) 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 allow for aggregate nonlinearities as in Holden (2016). In practice, this method keeps the model linear with respect to aggregate shocks (so we can still rely on the sequence-space Jacobians), while allowing for nonlinear policy constraints— the occasionally binding ZLB and asymmetric monetary policy rules. A detailed description of all these solution methods is contained in Appendix B.

In our baseline simulations, following an aggregate shock, agents expect no further shocks. This captures the policy response to the current shock but ignores how future shocks, and the policy responses they trigger, affect expectations. While commonly made, this assumption matters under policy asymmetries such as the ZLB and LfL. Anticipated future ZLB episodes create deflationary pressure even when rates are unconstrained (e.g., Adam and Billi, 2007), whereas anticipation of LfL raises current inflation expectations even when employment and inflation are

[18] In the model, as in the data, unemployment moves mainly through fluctuations in job-separation and job-finding rates. Constant hours imply, through (15), constant separation and finding rates.

not below target (e.g., Eggertsson and Kohn, 2023). Our baseline omits these offsetting effects. Section 7 presents a robustness exercise using the Stochastic Extended Path method (Adjemian and Juillard, 2025), where agents form expectations over future aggregate shocks up to a finite, potentially long, horizon.

3 Parameterization

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

Table 2 summarizes the model parameter values, Table 3 reports empirical and model's values of the targeted moments, and Table D1 presents the model performance along some non-targeted dimensions. Overall, our calibration targets a broad set of earnings and employment moments that discipline the three Okun channels—exposure, attachment, and persistence. The model captures (i) the level of labor-market stocks and flows on average and across the earnings distribution; (ii) the cyclicality of stocks and flows; (iii) earnings losses after displacement and life-cycle earnings growth; and (iv) the distributional effects of monetary policy shocks.

3.1 Parameters Determining the Steady State

The model period is set to one month. Some parameters are set externally, while those governing labor-market frictions and skill dynamics are calibrated internally to targeted moments.

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 (8) in steady state. We discuss fixed costs κ^s separately below.[19]

The effective discount rate ρ is set to target a ratio of mean wealth to annual earnings of 0.56 under an (annual) real interest rate r^* of 3%. This corresponds to the amount of liquid wealth among U.S. 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 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.[20]

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

[20] An alternative way of interpreting this calibration strategy is to say 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%.

Description	Parameter	Value
Demographics and Preferences		
Death rate	ϱ	$1/432$
Effective discount rate	ρ	0.0048
Labor supply elasticity	σ	1
Utility weight on hours	ψ	1
Fixed cost of working	κ^e	0.8140
Fixed cost of searching	κ^u	0.1617
Labor disutility shock	$\eta^H, \bar{\eta}$	2.1352
Labor disutility $L \to H$ rate	χ^{LH}	0.0456
Labor disutility $H \to L$ rate	χ^{HL}	0.1205
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 diffusion coefficient	σ_z	0.0332
Skill mean reversion	γ_z	0.0017
Skill drift while employed	δ_z^+	0.0023
Skill drift while non-employed	δ_z^-	0.0157
Labor market frictions		
Job-separation rate out of E	λ_z^{eu}	Table C2
Job-finding rate out of U	λ_z^{ue}	Table C2
Job-finding rate out of N	λ_z^{ne}	Table C2
Interest Rates and Liquidity		
Real return (including annuities)	r	0.0025
Nominal rate	i	0.000625
Liquidity premium	$\bar{\iota}$	0.0012
Real return on bonds	r^b	-0.0010
Technology		
Elast. of subst. between goods	ν	10
Elast. of subst. between tasks	ε	10
Firm productivity	α	1.25

Description	Parameter	Value
Taxes, transfers and expenditures		
Lump-sum transfer	ϕ	0.062
Government debt	B^g	1.812
Government expenditures	G	0.197
Labor income tax rate	τ	0.20
UI replacement rate	$\bar{b}$	0.33
UI expiration rate	$\lambda^{u_1 u_0}$	0.167
Phillips Curve and Frictions Elasticity		
Slope of the wage Phillips curve	θ_w	0.0075
Elasticity of (λ_z^{eu}) to hours	ϑ^{eu}	- 11
Elasticity of $(\lambda_z^{ue}, \lambda_z^{ne})$ to hours	$\vartheta^{ue}, \vartheta^{ne}$	24
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	β_u	- 0.15
Govt. expenditures response to debt	β_B	0.10
Aggregate Fluctuations		
Demand shock drift	γ_d	0.02
Demand shock diffusion	σ_d	0.0001875
Supply shock drift	γ_s	0.02
Supply shock diffusion	σ_s	0.0016

Table 2: Model parameter values expressed in monthly frequency.

Skill Dynamics. The mean of the initial skill distribution $\bar{z}_0$ is set so that the average skill in levels $\exp\left(\bar{z}_0 + \frac{1}{2}\sigma_{z_0}^2\right)$ 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.

The parameters in the skill dynamics process (1) are set as follows. The skill diffusion σ_z is set to match the P90–P50 wage ratio for the 2019 CPS.[21] 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 55, and (ii) the average earnings losses of laid-off workers 10 years after separation, as computed in Davis and von Wachter (2011).[22] Notably, while the calibration targets only the *average* loss,

[21] 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 to skill variation, whereas the extensive margin of labor supply plays a bigger role at the bottom of the distribution.

[22] 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 keep workers with zero earnings, 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), and restrict the control group to workers who remain employed for at least two

the model also reproduces its *cyclicality*—earnings losses are larger and more persistent during recessions, just as in the data—an untargeted dimension we return to in Section 3.3.

Generating earnings losses consistent with the data requires an average skill depreciation of 1.57% per month of unemployment. This value is at the lower end of the available U.S. estimates of the impact of an additional month in non-employment on workers' starting wages upon re-entry, which range from 1.0% to 3.5% (Table 3, Addison and Portugal, 1989; Tables 3 and 4, Neal, 1995; Table 2, Braxton et al., 2025).

Labor Market Frictions and Fixed Costs of Searching and Working. The fixed costs of searching κ^u and working κ^e in the two disutility states, which regulate workers' desire to participate in the labor market, are set jointly with $\lambda_z^{ss'}$. After some innocuous normalizations and a parsimonious choice of functional forms, we are left with eight parameters that we pick in order to match as closely as possible the six average worker flows (EU, UE, EN, UN, NU, NE) and the participation rates at the top (T3) and bottom (T1) terciles of the weekly earnings distribution (our proxy for skills) from the Basic Monthly CPS.

Overall, the model fits all average flows and stocks reasonably well (see Table 3).[23] Notably, our estimation leads to substantial heterogeneity in job-offer and job-separation rates across the skill distribution: workers in the bottom tercile face a monthly job-separation rate of nearly four times that of the top tercile ($\lambda_{T1}^{eu} = 0.050$ versus $\lambda_{T3}^{eu} = 0.014$), and their job-offer rate is considerably lower ($\lambda_{T1}^{ue} = 0.171$ versus $\lambda_{T3}^{ue} = 0.285$). In addition, the model replicates the large attachment wedge between unemployed and employed workers ($UN \gg EN$), which is key to generating the participation-cycle dynamics that reduce labor force participation at the bottom of the wage distribution during recessions (Hobijn and Şahin, 2021).

Finally, we emphasize that in the model flows are not mechanical, but are the result of the interaction between exogenous frictions and endogenous participation decisions. For instance, NE flows depend as much on job-offer rates as on non-participants' willingness to accept job offers. Similarly, a large share of EN flows would not occur without an exogenous lay-off. Appendix C contains a detailed description of the data, this parameterization strategy, and the decomposition of flows into exogenous and endogenous components.

Technology. Firm productivity α is set to normalize after-tax hourly wage per efficiency unit $(1-\tau)w^*$ to 1 in steady state. The elasticities of substitution across labor types (ε) and across intermediate goods (ν) are set to 10, which implies wage and price markups around 10%.

Steady-State Fiscal Policy. We assume that UI benefits are given by $b(z_{it}) = \bar{b}\, w^* h^* z_{it}$, and set the replacement rate $\bar{b}$ to 1/3. UI payments as a share of total earnings are 0.7% in the model, close

years following separation of the treatment group.

[23] The one exception is the NU flow, which the model understates substantially. This is not a serious concern for our purposes. Part of the empirical NU rate reflects residual U/N misclassification that the correction of Elsby et al. (2015) does not fully remove, and in the model nonparticipants who want to work typically receive an offer before re-entering the pool of searchers, so re-entry occurs mostly through NE, which the model matches.

Stationary Equilibrium

	Data	Model		Data	Model
Liquid wealth to annual earnings[1]	0.560	0.578	EU[6]	0.013	0.015
Lump-sum transfer to total earnings[2]	0.053	0.046	UE[6]	0.247	0.204
90-50 wage ratio (entrants)[3]	2.000	1.953	NE[6]	0.070	0.063
90-50 wage ratio (all workers)[3]	3.000	3.042	EN[6]	0.017	0.012
55/25 log earnings difference[4]	0.700	0.768	UN[6]	0.133	0.128
10-Year earnings losses upon displacement[5]	[-0.15,-0.08]	-0.096	NU[6]	0.027	0.003
Employment[6]	0.764	0.748	Non-participation (T1)[6]	0.572	0.583
Unemployment rate[6]	0.055	0.051	Non-participation (T3)[6]	0.024	0.021

Out of Steady State

	Data	Model		Data	Model
Standard deviation of total hours	3.45	3.60	$Cov(E_t, H_t)/Var(H_t)$	0.70	0.74
Inflation and unemployment correlation	-0.32	-0.34	$SD(UE_t)/SD(EU_t)$	1.15	1.20
Inflation response to MP shock	0.30	0.36	ZLB frequency	0.15	0.15

Table 3: Targeted empirical moments and baseline model fit.

Stationary Equilibrium. [1]Kaplan and Violante (2022); [2]Authors' calculations from Tables 3.12 and 2.1 of NIPA for 2019; [3]Wage ratios from the 2019 CPS, as reported in 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 (-0.08); [6]Employment, unemployment, labor force participation and all six gross worker flows are computed from the Basic Monthly CPS for 1989–2019. Labor market transition rates are constructed using "deNUNified" data as in Elsby et al. (2015). See Appendix C 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 between inflation and unemployment, 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 logs 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 B for a description of the simulation procedure.

to the data average of 0.76% over 1989–2019. We set $\lambda^{u_1 u_0}$ 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 calibrated to match 5% of average earnings in steady state.[24] 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.

[24]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, 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).

3.2 Parameters Determining Out of Steady State Dynamics

The model's out-of-steady-state dynamics are driven by two aggregate shocks, a demand shock ζ_t^d and a supply shock ζ_t^s, each following an Ornstein–Uhlenbeck diffusion process

$$d\zeta_t^k = -\gamma_k \zeta_t^k \, dt + \sigma_k \, d\mathcal{W}_t^k, \tag{16}$$

where $d\mathcal{W}_t^k$ is a standard Wiener process, γ_k governs the shock's mean reversion, and σ_k its volatility. For both shocks in (16) we set the mean-reversion parameter $\gamma_k = 0.02$, corresponding to a monthly persistence of 0.98.

The parameters governing the shock process and out-of-steady-state dynamics fall into two groups. A first group—comprising the parameters of the monetary and fiscal policy rules together with the persistence of the aggregate shock processes (γ_d, γ_s)—is set externally to values standard in the literature. The remaining six parameters—the slope of the Phillips curve θ_w, the diffusion coefficients (σ_d, σ_s), the elasticities of frictions to hours $(\vartheta^{eu}, \vartheta^{ue})$, and the liquidity premium $\bar{\iota}$—are calibrated internally to match a set of relevant business-cycle moments (see bottom of Table 3). We discuss each group in turn.

Monetary and Fiscal Policy Rules. 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 (11) to 0.1, as in Auclert et al. (2020).

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 -0.10 and -0.20 at quarterly frequency, in line with the estimates reported by Furlanetto and Lepetit (2024).

Volatility of Aggregate Shocks. The diffusion coefficients (σ_d, σ_s) in (16) are set to match the empirical correlation between the 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.

Elasticities of Frictions to Hours. The elasticities $(\vartheta^{eu}, \vartheta^{ue})$ are chosen to replicate the share of the variance in total hours coming from fluctuations in the extensive margin of employment (70%) and the ratio of flow volatilities $SD(UE_t)/SD(EU_t)$ (1.15).[25]

[25] In 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 $\vartheta^{ne} = \vartheta^{ue}$.

ZLB Frequency. By shifting the steady-state value of the nominal interest rate, the mutual fund's "liquidity premium" of holding bonds $\bar{\iota}$ allows us to target how frequently the ZLB binds in our simulations without affecting the moments of our stationary equilibrium. The model's ZLB frequency is consistent with that observed in the data.[26] The mean duration of ZLB episodes is 8.5 quarters, with a median duration of 5 quarters.[27]

3.3 Untargeted 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 D1 in the Appendix.

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 job-separation rates (which depend 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 (0.38 in the model against 0.51 in the data) and the rise of earnings inequality over the life cycle (from 0.52 at age 25 to 1.07 at age 55 in the model, against 0.60 to 0.91 in the data, respectively).[28] Moreover, we can also reproduce, at least qualitatively, the higher-order moments of the (log) earnings 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 56% (31%) at the 25th (75th) percentile of the recent earnings distribution, close to the 50% (30%) losses reported by Guvenen et al. (2017, Figure 1).[29] More-

[26] We measure the empirical ZLB frequency from monthly central bank policy rates in the BIS Central Bank Policy Rates database (Bank for International Settlements, 2026), covering 1995–2026 for 39 economies, with the euro area entering as a single unit. Counting a month as constrained whenever the policy rate is at or below 0.25%, the average frequency across all economies is 10%; across the 16 advanced economies—which account for 20 of the 22 episodes in the sample—it is 20%. Our target of 15% is the midpoint of these two figures.

[27] These episodes are somewhat shorter than the long, rare ZLB spells documented in the post-war U.S. data, where the average duration is closer to 16 quarters (Bank for International Settlements, 2026). In Appendix G.1 we report a robustness exercise that replaces the AR(1) demand shock with a three-state regime-switching process à la Dordal-Carreras et al. (2016), which lengthens the average ZLB spell to 11.1 quarters. Our headline conclusions about the bottom-tercile hysteresis and the LfL inclusion gains survive under this alternative assumption for the shock process.

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

[29] 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.

over, 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.

Business Cycle Properties of Stocks and Flows. Our calibration disciplines the volatility of total hours and the share of that volatility running through the extensive margin, and so it pins down how much employment fluctuates over the cycle. However, it places little restriction on the division of employment fluctuations between the unemployment rate and participation, and on the dynamics of worker flows—save for the volatility of the EU and UE flows, which is pinned down by our assumed elasticity of frictions to hours. Table D1 shows the model matches well the cyclical movements in both labor market stocks and flows. Employment 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 procyclical, response in participation. Notably, the model also matches closely the standard deviation and cyclicality for all six labor market flows, further evidence of the model's success at capturing the dynamics of both labor market frictions and participation decisions (Krusell et al., 2017; Cairó et al., 2022).[30]

Cyclicality of Earnings Losses. Our calibration of the skill process also reproduces the *cyclicality* of earnings losses for displaced workers and labor-market entrants.[31] First, Davis and von Wachter (2011) document that workers displaced in recessions suffer larger and more persistent earnings losses than those displaced in expansions: 10-year-ahead losses of 15.3% versus 8.7% of predisplacement annual earnings. Replicating their experiment in the model generates 10-year-ahead losses of 12.7% in recessions against 7.7% in expansions, closely tracking their cyclical gap. Second, entering the labor market in a recession has significant and persistent effects on workers' earnings, particularly for those in less-advantaged groups (see von Wachter, 2020, for a summary of the empirical evidence). The model replicates this fact: a 1 ppt higher unemployment rate at entry lowers earnings by 5.2 log points one year after entry and by 1.7 log points five years after (see Figure 5a).

Monetary Policy Shocks and Inequality. Figure D1 plots the response of earnings and consumption inequality—as measured by 90–10 ratios and Gini—to an expansionary monetary policy shock that lowers unemployment by 0.35 percentage points. Both earnings and consumption inequality fall in the model: the earnings 90–10 ratio and Gini by 3% and 0.2, and the consumption 90–10 ratio and Gini by 0.17% and 0.10. As we discuss in more detail in Appendix D, overall monetary policy's scope to compress inequality in our model is roughly in line with the available empirical evidence on its distributional effects (Coibion et al., 2017; Chang and Schorfheide, 2024).

Together with the ability to replicate salient labor market facts both on average and over the business cycle, this result suggests that the model provides a credible laboratory for studying how

[30] The only exception is the standard deviation of the NU flow. This shortcoming follows from the fact that the model struggles to generate as many NU transitions as in the data (see Table 3), so the model volatility is excessively large but starting from a small base.

[31] Both measures are computed out of the same cycle: a demand-driven recession that triggers the ZLB, as in Figure 4.

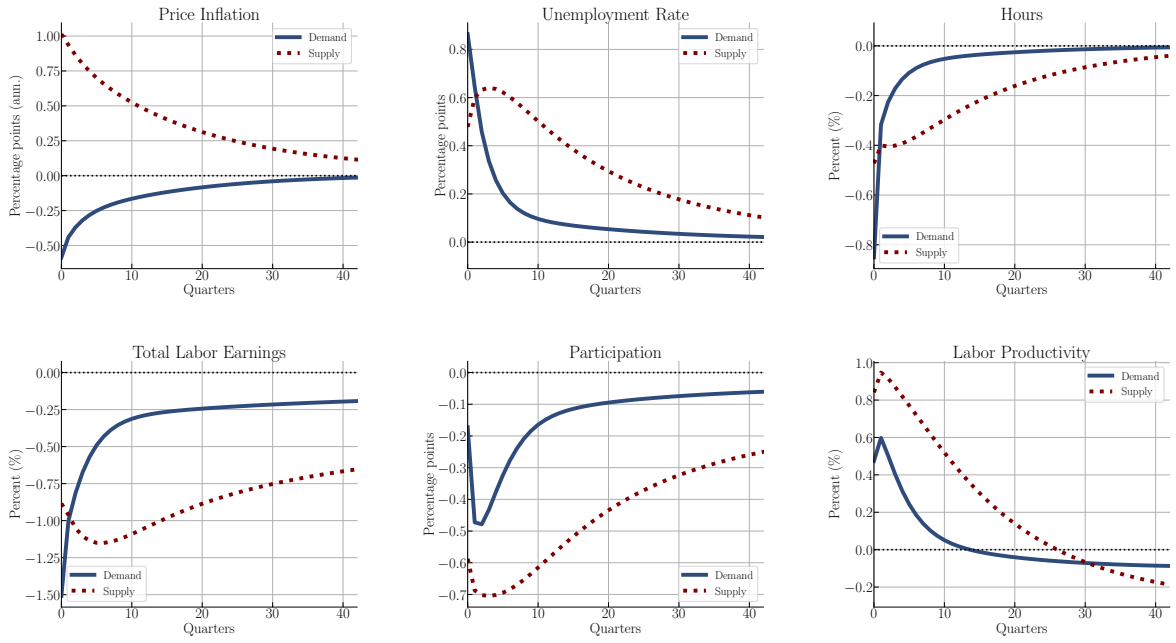


Figure 2: Aggregate responses to demand and supply shocks under inflation targeting.

Note. Responses to contractionary demand (solid blue) and supply (dotted maroon) shocks under IT with a nonbinding ZLB. Each shock is normalized to reduce total labor earnings by 1% on average over the first four quarters. Responses are deviations from the non-stochastic steady state: annualized percentage points for inflation, percentage points for unemployment and participation, and percent for other variables. The horizontal axes measure quarters after the shock.

monetary policy shapes inclusiveness over the cycle —the question we turn to next.

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 (12). 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). Second, we turn to the case of a large negative demand shock that triggers the ZLB (Section 4.2). Third, we simulate the model under repeated demand and supply shocks to recover the ZLB-induced biases in the ergodic distribution (Section 4.3).

The upshot of 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.

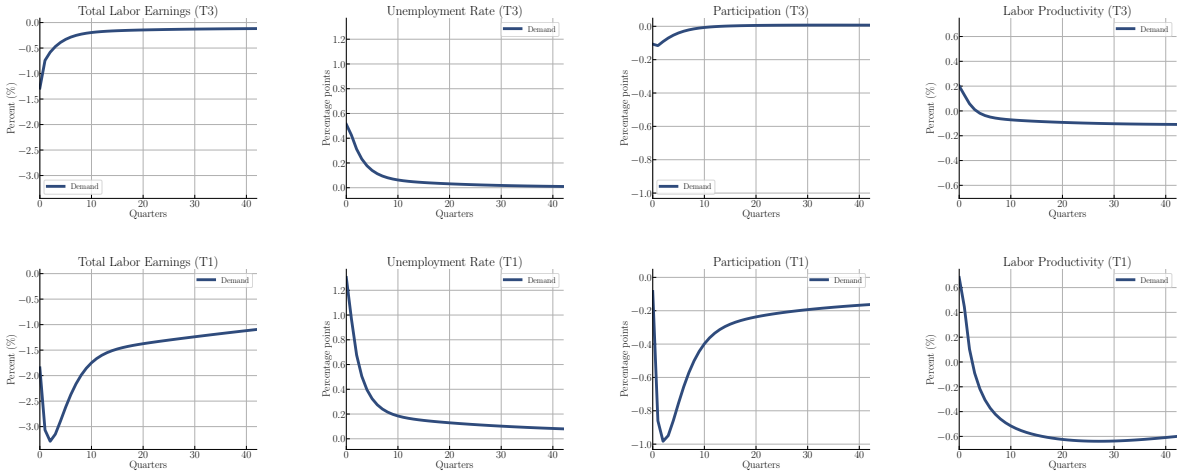


Figure 3: Labor market responses to a demand shock by skill tercile.

Note. Responses to a contractionary demand shock under IT, with a nonbinding ZLB. The top and bottom rows show the top (T3) and bottom (T1) skill terciles, respectively. The shock is normalized to reduce aggregate total labor earnings by 1% on average over the first four quarters, as in Figure 2. Responses are deviations from the non-stochastic steady state, expressed in percentage points for unemployment and participation and in percent for total labor earnings and labor productivity. The horizontal axes measure quarters after the shock.

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 opposite (the same) directions following a demand (supply) shock. Notably, variables in the first and second rows display markedly different long-run dynamics. Inflation, unemployment, and hours (first row) revert to steady state as demand and supply shocks dissipate. By contrast, total earnings and participation (second row) fall and remain persistently depressed, staying well below steady state even after ten years. Productivity rises initially as low-skill workers are disproportionately displaced, but later falls persistently below steady state as unemployment recovers. This persistent decline in participation and productivity following a transitory aggregate shock is the hallmark of labor market hysteresis in our model.[32] Crucially, these long-run scarring effects are not felt equally across the distribution, as we show next.

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

	Year 1		Year 10	
	$\mathbb{E}$	(%)	$\mathbb{E}$	(%)
T3 Total Labor Earnings	-0.770	—	-0.121	—
T3 Hours	-0.392	(50.9)	-0.008	(6.9)
T3 Unemployment rate	0.370	(49.3)	0.012	(10.5)
T3 Participation rate	-0.096	(12.8)	0.007	(-6.1)
T3 Labor productivity	0.100	(-13.0)	-0.108	(88.7)
T1 Total Labor Earnings	-2.838	—	-1.147	—
T1 Hours	-0.392	(13.8)	-0.008	(0.7)
T1 Unemployment rate	0.863	(34.5)	0.087	(8.6)
T1 Participation rate	-0.719	(61.8)	-0.173	(36.7)
T1 Labor productivity	0.285	(-10.0)	-0.618	(53.9)

Table 4: Decomposing earnings responses by skill tercile at 1- and 10-year horizons.

Note. Responses to a demand shock under the IT rule with the ZLB not binding. T1 and T3 denote the bottom and top terciles of the skill distribution. For each tercile, the $\mathbb{E}$ column reports the deviation from the non-stochastic steady state 1 and 10 years after the shock, in percentage points for unemployment and participation and in percent otherwise. The (%) column reports the share of the earnings response accounted for by each channel: log-linearizing (17) gives $\ln W_t^g \approx \ln(wh_t) + \ln(1-u_t^g) + \ln P_t^g + \ln Z_t^{e,g}$, and each share is the log-deviation of a component as a percent of the log-deviation of W_t^g, so shares sum to 100. Hours per worker are common across skill terciles, so their response is identical in the two blocks.

4.1.2 Distributional Implications

Figure 3 plots the impact of a demand shock on earnings at the bottom (T1) and top (T3) terciles.[33] 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 nearly half of the first-year impact, while earnings at the top have all but recovered. Earnings hysteresis, therefore, disproportionately affects low-wage workers.

The model mechanism behind these protracted earnings losses at the bottom involves a vicious cycle between skill erosion, labor market frictions, and participation decisions. Skills erode fast during non-employment and recover only slowly on the job, persistently lowering labor productivity upon re-employment (fourth column). Longer (and repeated) unemployment spells (second column) combined with lower wages upon re-employment ultimately discourage participation altogether, pushing marginal workers out of the labor force (third column).

To better understand the margins of earnings response at the bottom and top of the distribution, we rely on an accounting exercise. We can write total labor earnings for each group g:

$$W_t^g = wh_t \times (1-u_t^g) \times P_t^g \times Z_t^{e,g} \tag{17}$$

where $(1-u_t^g)$ is the employment rate, P_t^g is labor force participation, and $Z_t^{e,g}$ is average labor

[33] We choose terciles (of the steady-state skill distribution) because they roughly correspond to shares of workers with a high-school degree or less, with some college education, and with a college degree or more in the data.

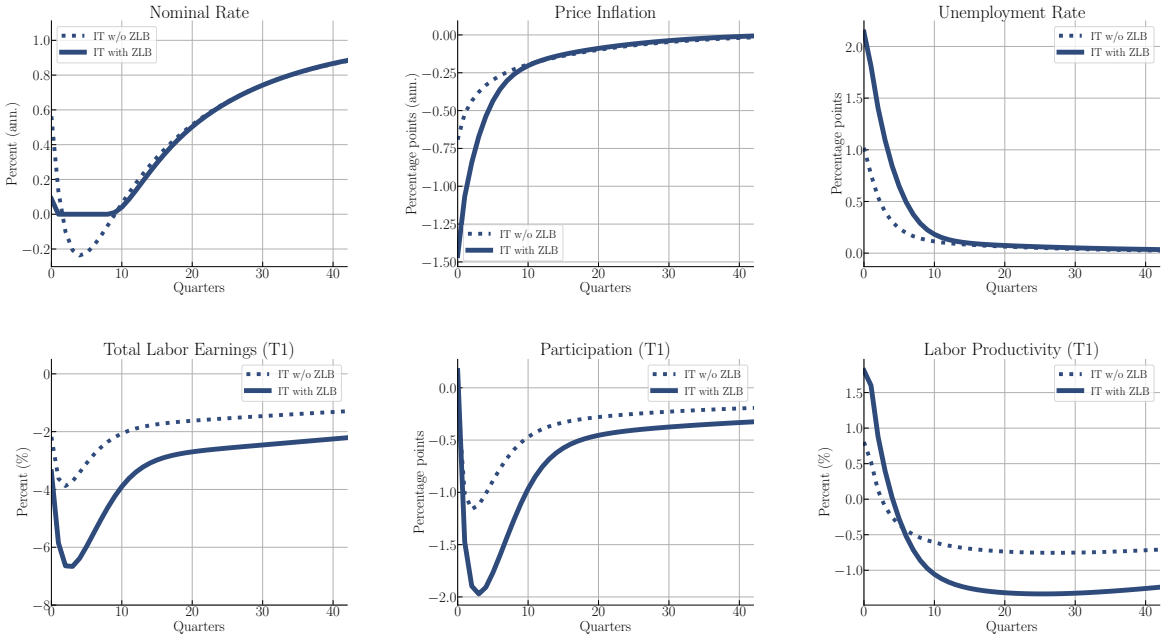


Figure 4: Responses to a demand shock with and without the ZLB.

Note. Responses under IT to the same contractionary demand shock, which initially raises the liquidity premium by 1.2 annualized percentage points. Solid lines impose the ZLB; dotted lines abstract from it. The ZLB binds for approximately ten quarters. The top row reports aggregate nominal interest rates, inflation, and unemployment; the bottom row reports total labor earnings, participation, and labor productivity for the bottom skill tercile (T1). Responses are deviations from the non-stochastic steady state: annualized percentage points for nominal rates and inflation, percentage points for unemployment and participation, and percent for earnings and productivity. The horizontal axes measure quarters after the shock.

productivity at time t, all three conditional on skill group g.

Table 4 decomposes the observed total labor earnings 1 and 10 years after the shock into the right-hand side terms of equation (17). Not surprisingly, we find that movements in hours and unemployment only matter for the short-run response of total labor earnings, whereas the dynamics of participation and labor productivity account for most of the long-lasting earnings losses. At the top of the skill distribution, the responses of unemployment and participation are minimal and dissipate quickly; labor productivity shows some persistence even among high-skilled workers. In contrast, low-skilled workers experience stronger and significantly more persistent movements in all three components, with participation and productivity accounting for approximately 37% and 54%, respectively, of the 10-year decline in earnings observed at the bottom.[34]

[34] While this accounting decomposition identifies participation and productivity as the proximate sources of earnings hysteresis at the bottom, it cannot disentangle how much of each response is driven by heterogeneous exposure, endogenous participation, and skill scarring, since all three channels operate simultaneously and feed back on one another. In Section 4.4, we perform a sequence of nested calibrations that isolate the structural contribution of each Okun's channel.

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.[35] The dotted 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, our model also predicts worse outcomes in terms of both aggregate unemployment and inflation (see Williams, 2009; Kiley and Roberts, 2017; Bernanke et al., 2019). The novel feature, relative to this earlier body of work, however, is that the presence of labor market hysteresis renders the ZLB's adverse effects far more persistent, particularly at the bottom of the skill distribution (second row of Figure 4). For this group, earnings, labor force attachment, and skill losses are exacerbated while the economy is constrained by the ZLB, and remain deeply depressed well after the constraint ceases to bind.

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 will accommodate 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.[36] The next section measures this impact by computing average biases in the model's ergodic distribution in the presence of the ZLB.

4.3 Ergodic Distribution

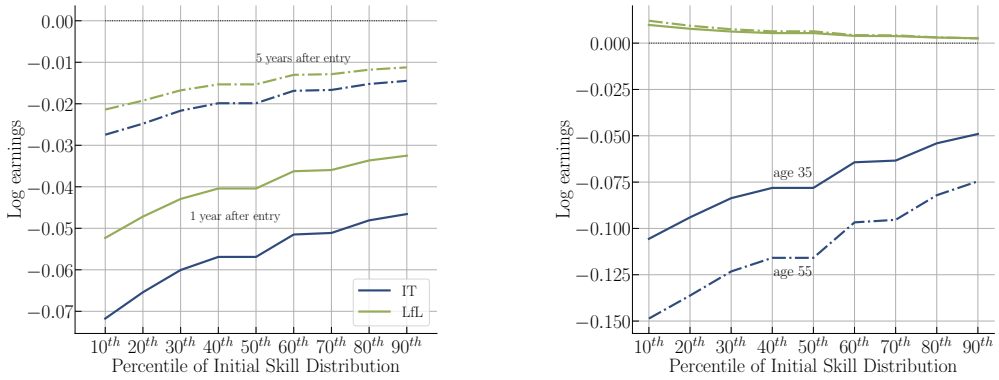
Table 5 summarizes the ergodic distribution results. The first notable feature is that the presence of a binding ZLB skews the ergodic distribution toward adverse outcomes with the economy spending 14.0% of the time in recessions but only 2.1% in booms—recessions become almost seven times more frequent than booms.This asymmetry produces a recessionary bias across the board relative to the non-stochastic steady state: inflation is 17 bp lower, the unemployment rate 0.53 ppt higher, and—far more severely—the labor force participation rate 0.71 ppt lower and total earnings 2.36% lower.[37]

These biases are amplified at the bottom of the skill distribution—a direct consequence of the

[35] Appendix B.2 explains how we solve for IRFs under an aggregate policy constraint.

[36] We note that our model features both positive hysteresis (uplifting effects) following expansions and negative hysteresis (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.

[37] This strong negative earnings bias emerges even though monetary policy is constrained during a relatively small share of time—the ZLB binds in 15.2% of periods, in episodes lasting 8.5 quarters on average. This reflects our earlier analysis of the IRFs, where we highlighted that the deleterious effects of the ZLB persist far beyond the period where the constraint is effectively binding.



(a) Entering in a recession.

(b) Life-cycle earnings gaps.

Figure 5: Earnings at labor market entry and over the life cycle.

Panel (a): Log-earnings losses one year (solid lines) and five years (dash-dotted lines) after entering the labor market during a demand-driven recession, by initial skill percentile. Blue and green lines denote IT and LfL, respectively. Each rule's earnings losses are expressed per one-percentage-point increase in unemployment at entry under that rule, relative to entry in the stationary equilibrium.
Panel (b): Log-earnings gaps at ages 35 (solid lines) and 55 (dash-dotted lines), by initial skill percentile. Blue and green lines denote IT and LfL with the ZLB, respectively. Gaps are measured relative to the life-cycle log-earnings profile in the stationary equilibrium under IT. Outside the stationary equilibrium, we compute the log of mean annual earnings for each initial skill group and average across simulated histories.

hysteresis mechanism documented in the previous sections. The magnitudes are large: total labor earnings in the bottom tercile display a negative bias of 9.0%, against 1.7% for the top tercile.[38] The ZLB also raises overall inequality. The Gini coefficient of earnings among all workers rises from 58.2 to 59. Consistent with the unequal exposure to the cycle documented above, the increase in inequality is concentrated in the lower half of the distribution: the 50–10 ratio of earnings increases by 7.4%, while the 90–50 ratio rises by only 0.65%. The increase in earnings inequality is also accompanied by an increase in consumption inequality, with the consumption Gini increasing from 52.4 to 53.1.

Upward Mobility. 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 compute workers' expected life-cycle earnings profiles over the ergodic distribution under IT. Figure 5b plots the expected earnings gap—i.e., the difference in expected log earnings in the ergodic distribution versus in 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.

[38] Repeating our decomposition (17) confirms that earnings losses at the bottom stem primarily from declines in participation and labor productivity. These contribute 4.04 and 3.51 log points, respectively, to the earnings loss.

	Inflation Targeting		Lower for Longer	
Business Cycle Features				
Boom frequency (%)	2.1		16.4	
Recession frequency (%)	14.0		6.4	
ZLB frequency (%)	15.2		6.6	
Shadow rate at the ZLB	-0.59		-0.16	
Unemployment rate at the ZLB	3.05		1.14	
	Deviations from steady state			
Aggregates	$\mathbb{E}$	std	$\mathbb{E}$	std
Price inflation	-0.17	1.09	0.25	0.46
Unemployment rate	0.53	1.43	-0.15	0.81
Total hours	-1.74	3.60	0.58	2.31
Participation	-0.71	1.04	0.28	0.78
Labor productivity	-0.62	1.35	0.10	0.95
Total labor earnings	-2.36	2.55	0.68	1.55
Distributional	$\mathbb{E}$		$\mathbb{E}$	
T3 Total labor earnings	-1.71		0.43	
T3 Participation	-0.03		0.00	
T3 Labor productivity	-1.07		0.27	
T1 Total labor earnings	-9.00		3.85	
T1 Participation	-1.66		0.70	
T1 Labor productivity	-3.51		1.65	
Total labor earnings 90–10 (Part)	8.02		-3.07	
Total labor earnings 90–50 (Part)	0.65		-0.21	
Total labor earnings 50–10 (Part)	7.37		-2.86	
Total labor earnings Gini (Part)	0.50		-0.15	
Total labor earnings Gini (All)	0.77		-0.27	
Consumption Gini (All)	0.66		-0.25	

Table 5: Ergodic distribution under IT and LfL.

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 at the ZLB" denotes the nominal rate the monetary authority would set if it were not constrained by the ZLB, averaged over periods in which the ZLB binds. "Unemployment rate at the ZLB" denotes the average unemployment rate gap during the ZLB. In the aggregate and distributional panels, $\mathbb{E}$ reports mean deviations from the non-stochastic steady state, while std reports standard deviations in the same units. Inflation, unemployment, and participation are expressed in percentage-point deviations. Gini coefficients are expressed in point deviations on a 0–100 scale. All other variables are in percent deviations. T1 and T3 refer to average outcomes for the bottom and top terciles of the workers' skill distribution. "Part" denotes labor-force participants and "All" the full population. The 90–10, 90–50, and 50–10 measures are log earnings differences between the indicated percentiles.

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 13.6 (8.2) log points lower than their average earnings in the stationary equilibrium.

Taking stock, the main insight of this section is that a monetary policy rule that fails to mitigate the ZLB opens the door to enduring scars on labor force participation and productivity at the bottom of the skill distribution. Alternative rules that reduce the frequency of the ZLB or let the economy run hot during recoveries thus 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, had precisely this flavor.

4.4 From RANK to HANK Augmented by Okun's Hypothesis: A Decomposition

Our baseline model includes four additional ingredients relative to the standard RANK model: market incompleteness, which—through heterogeneous MPCs and precautionary saving—affects the transmission of shocks; and the three channels of Okun's hypothesis—higher exposure to shocks at the bottom, endogenous participation, and skill scarring during non-employment.

This section asks which of these four ingredients contributes the most to our results. To answer it, we study counterfactual economies that add the four ingredients one at a time to a RANK model. In RANK, a representative family pools the income of its workers, who remain heterogeneous in skills and supply labor to the unions, and assigns the same consumption to all of its members. We put these economies through two exercises: we hit each of them with the same demand shock and compare impulse responses, and we compare their ergodic distributions. Appendix E reports both exercises in detail. The main takeaway of the exercise is that the ingredients are strongly complementary: no single channel accounts for a substantial share of the earnings gap between the top and bottom of the skill distribution in our baseline model.

5 Economic Outcomes Under Lower for Longer

We model the LfL strategy by changing the Taylor rule reaction function $\mathcal{R}_t$ in (12) to

$$\mathcal{R}_t = 2.25(\pi_t - \pi^*) + 8.00(\pi_t^{MA} - \pi^*)^- - 0.15(u_t - u^*)^+, \tag{18}$$

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 (18) is meant to capture the asymmetric Average Inflation Targeting (AIT) component of the new framework.[39] Mechanically, following periods where inflation falls persistently below 2 percent,

[39] We incorporate the AIT term inside an inertial monetary-policy rule with interest-rate smoothing, following the specification used in the Federal Reserve's background notes on alternative monetary-policy strategies (e.g., Arias et al.,

the average inflation term adds 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 rule, the LfL rule (18) prescribes 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 the ZLB's negative hysteresis we found under IT. However, letting the economy run hot following a recession might push inflation above target.

The rest of this section illustrates this inclusion-inflation trade-off in different ways. We begin by analyzing 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 recoveries of participation and earnings offer an ideal laboratory to evaluate the LfL, as these features 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 (Section 5.3). 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 F1 in the Appendix shows the model's impulse responses to demand and supply shocks under the IT and LfL strategies.[40] In a demand-driven recession, the LfL strategy provides substantially stronger stabilization: unemployment and inflation deviate by less than half of the response under IT causing the ZLB to bind only briefly. The opposite happens in response to a positive demand shock: by not responding to falling unemployment, the LfL policy lets the economy run hotter, resulting in a much stronger boom than under IT. Similarly, a supply-driven expansion triggers a markedly stronger expansion under LfL than under IT: unemployment falls three times more than under IT, while inflation, which declines sharply under IT, displays a small positive response under LfL.[41]

2020; Hebden et al., 2020; Chung et al., 2025). Our baseline parameterization targets a 4-year average-inflation window. We have explored robustness to longer averaging windows and a stronger response to unemployment and find that our results are largely unchanged. These results are available upon request.

[40] Appendix B.3 explains how we solve for IRFs under asymmetric policy rules.

[41] This reversal in the inflation response reflects two opposing forces of the supply shock: the direct (disinflationary) effect of the shock and the indirect (inflationary) demand effect from higher hours and lower unemployment. Under IT, the monetary authority raises rates in response to low unemployment, containing the rise in hours so that the direct dis-

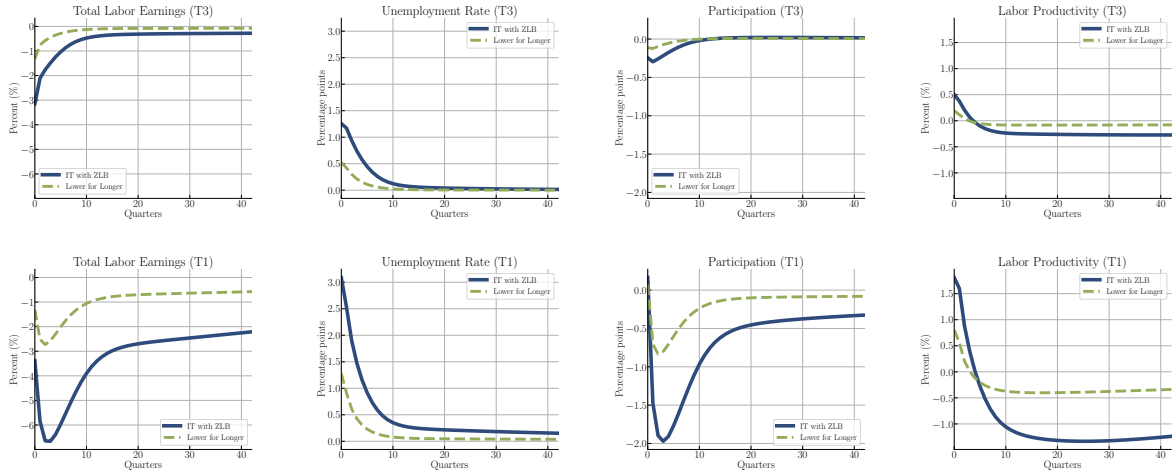


Figure 6: Labor market responses under IT and LfL.

Note. Responses to the contractionary demand shock in Figure 4 under IT (solid blue) and LfL (dashed green), with the ZLB imposed under both rules. The top and bottom rows report outcomes for the top (T3) and bottom (T1) skill terciles, respectively. Responses are deviations from the non-stochastic steady state, expressed in percentage points for unemployment and participation and in percent for total labor earnings and labor productivity. The horizontal axes measure quarters after the shock.

By alleviating labor market disruptions at the ZLB and allowing expansions to be stronger and longer, the LfL rule can alter the shape of business cycles in ways that may especially benefit low-wage workers. Figure 6 confirms this conjecture. While the differential impact of the LfL rule relative to IT is minimal at the top, at the bottom of the skill distribution LfL offsets the bulk of the persistent earnings losses, by dampening the long-run impact of the recession on participation and labor productivity. To better assess the inclusion-inflation trade-off implicit in the LfL strategy, we need to evaluate it under a realistic sequence of aggregate shocks and over a sufficiently long horizon. The next sections set out to do this.

5.2 Great Recession Under Lower-for-Longer

How would the U.S. labor market and inflation dynamics have looked during the Great Recession and its recovery, had the Fed followed a LfL strategy instead of IT? To run 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 (see Appendix B.4 for details). Figure B1 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 im-

inflationary effect dominates and inflation falls. Under LfL, the monetary authority instead chooses to "look through" the improvement in labor market conditions, which allows the indirect demand effect to overcome the deflationary effect, pushing inflation slightly above target.

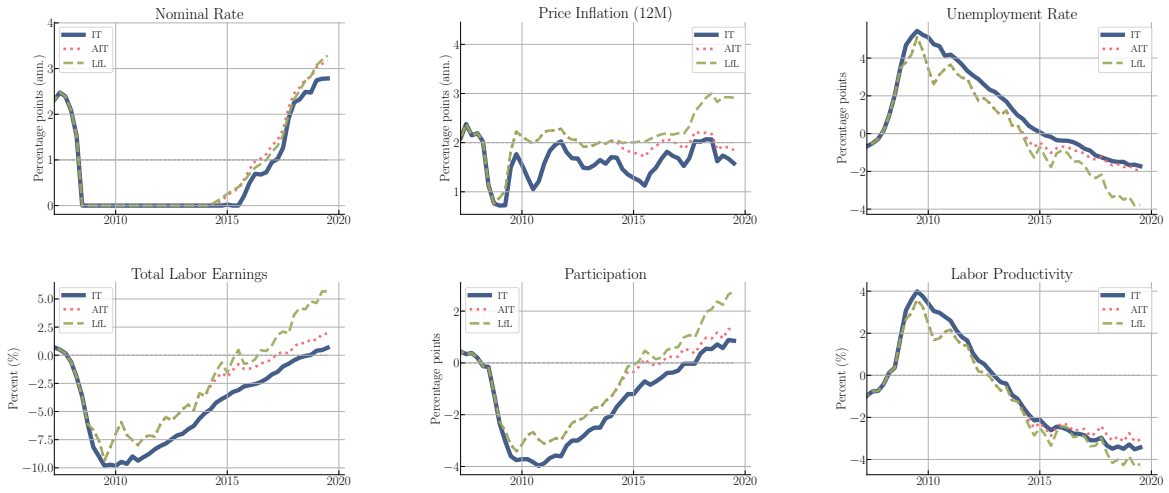


Figure 7: Aggregate dynamics during the Great Recession and recovery.

Note. Model paths under IT (solid blue), asymmetric AIT (dotted pink), and LfL (dashed green), using a common sequence of demand and supply shocks inferred from U.S. inflation and unemployment under IT. Nominal interest rates and twelve-month inflation are shown in percent; unemployment and participation are percentage-point deviations from the non-stochastic steady state, and total labor earnings and labor productivity are percent deviations. See Table H1 in the Appendix for the specification of the different monetary policy rules.

portant dimensions of the Great Recession and its recovery, such as the prolonged period at the ZLB, the rise in labor productivity around 2008–2010, and the protracted reduction in labor force 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, just before the economy plunges into recession. We also present the economy's dynamics under a counterfactual where the Fed follows a rule that includes the average inflation targeting (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.[42]

The LfL's commitment to keep rates lower in response to the low inflation significantly reduces the costs at the outset of the Great Recession, when the economy first hits the ZLB in 2008: inflation doesn't fall as much as it does under IT, and unemployment comes 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 rise even further: by 2019, under the LfL rule, unemployment is 2 ppt lower, participation is almost 2 ppt higher, and earnings are 5% higher compared to the economy under IT.

Figure 8 shows the impact of the LfL rule along the workers' skill distribution. Compared to

[42] Table H1 in the Appendix contains the exact specification of the AIT and SR rules.

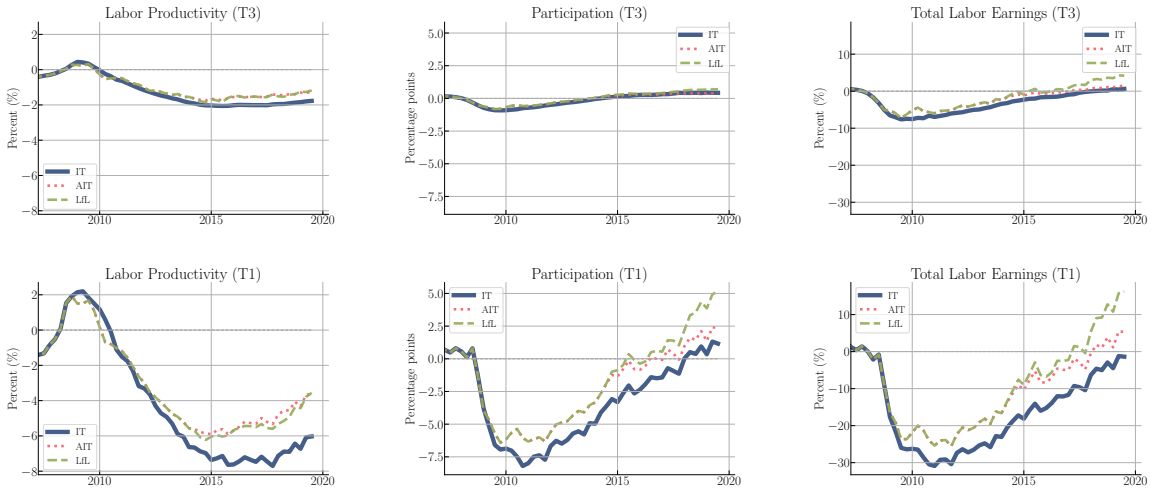


Figure 8: Distributional dynamics during the Great Recession and recovery.

Note. Model paths under IT (solid blue), asymmetric AIT (dotted pink), and LfL (dashed green), using the same sequence of filtered demand and supply shocks as in Figure 7. The top and bottom rows report outcomes for the top (T3) and bottom (T1) skill terciles, respectively. Participation is shown in percentage-point deviations from the non-stochastic steady state; labor productivity and total labor earnings are shown in percent deviations. See Table H1 in the Appendix for the specification of the monetary policy rules.

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 mitigates 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.

The inflationary cost of the new strategy appears in Figure 7: inflation averages 0.5 ppts below target under IT but 0.7 ppts above it under LfL. Most of this bias is caused by the SR component during the last two years of the boom.

Altogether, the Great Recession counterfactual indicates 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. The next section verifies whether these conclusions also hold in the model's ergodic distribution.

5.3 Ergodic Distribution Under Lower-for-Longer

Table 5 shows the impact of the LfL strategy on the ergodic distribution. The rule affects both ends of the business cycle: it tames ZLB episodes and lets the economy run hotter during expansions. Relative to IT, the LfL rule lowers the ZLB frequency from 15.2% to 6.6% and reduces its intensity: during ZLB episodes, the average unemployment gap relative to steady state falls from 3.1 to 1.1 ppt, while the average shadow rate rises from −59 bp to −16 bp. It also increases the share of time spent in booms from 2.1% to 16.4%. The recession–boom asymmetry reverses: recessions

outnumber booms by almost seven to one under IT (14% versus 2.1%), while booms outnumber recessions by more than two to one under LfL (16.4% versus 6.4%). By these business cycle metrics, the LfL rule delivers on its promise to run the economy hot for longer. Doing so confronts the policymaker with Okun's inflation–inclusion trade-off whose two sides we quantify next.

Inclusion Gains. On the inclusion side, the disproportionate losses at the bottom of the skill distribution documented under IT are reversed under LfL. Total labor earnings in the bottom tercile display a positive bias of 3.8%, compared with a negative bias of 9% under IT—a swing of 12.8 percentage points. These gains reflect stronger labor force attachment and higher labor productivity: participation rises by 2.4 ppt, from a bias of −1.7 to +0.70 ppt, while productivity rises by 5.2%, from a bias of −3.5% to +1.7%. Relative to IT, the Gini coefficient of total labor earnings among all workers falls by 1.04 points and the consumption Gini falls by 0.90 points.

Inclusion gains also translate into greater upward mobility—one of the key dimensions Okun singled out in his 1973 article.[43] In line with Okun's conjecture, Figure 5b shows that the LfL leads to stronger life-cycle earnings growth for all workers, but especially so at the bottom of the skill distribution where it fully reverses the large negative earnings gap we found under IT. Gains of the LfL strategy are also reflected in a strong reduction of the earnings losses for low-skilled young workers entering the labor market in a recession, as displayed in Figure 5a.

Inflation Costs. These inclusion gains come at the cost of a modest average long-run inflationary bias of 25 bp. In addition, this bias is not the result of a higher incidence of inflation spikes (see the ergodic inflation distribution in Figure F2). Under IT, the ZLB pulls the ergodic mean of inflation 17 bp *below* target and it leaves behind a thick deflationary left tail: 9.3% of quarters see inflation more than 1 ppt below target. The LfL rule all but erases that tail—its mass falls to 0.8%—while leaving the right tail where it was: the share of quarters with inflation more than 1 ppt above target edges down from 6.4% to 6.1%. The right tail is largely untouched because an inflationary cost-push shock engages neither of the LfL rule's two asymmetries, so the rule responds to it exactly as IT does—which is what the impulse responses in Section 5.1 showed. Instead of getting a heavier right tail, mass piles up just above the target: nearly two thirds of quarters (64%, against 47% under IT) land within 1 ppt above target. This asymmetric reshaping is why the inflationary bias arrives with *less*, not more, inflation volatility—the ergodic standard deviation of inflation drops from 1.09 to 0.46 ppt (Table 5).

[43] In Okun (1973), Okun conjectured that, by fostering stronger attachment and faster skill growth, a high-pressure economy could engineer a steeper life-cycle earnings profile for low-skilled workers. To assess this hypothesis, we repeat the life-cycle earnings computation of Section 4.3, now shifting from an IT to a LfL strategy.

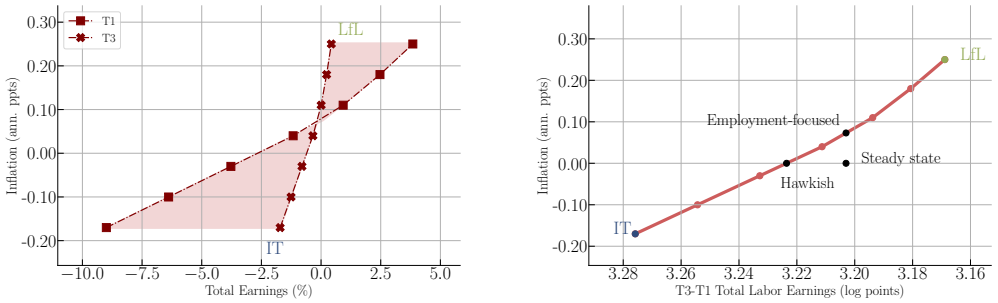


Figure 9: Okun's cones and the inflation–inclusion trade-off.

Note. Each marker corresponds to a parameterization of the LfL rule along the sweep from the IT benchmark to the headline LfL calibration (Section 5.4); all values are averages over the ergodic distribution. **Left panel:** average total labor earnings at the bottom (T1) and top (T3) terciles of the skill distribution (x-axis, percent deviations from the non-stochastic steady state) against average annual price inflation (y-axis, ppt deviations from target). **Right panel:** the same sweep in terms of the T3–T1 differential in log total labor earnings (x-axis, decreasing to the right). Black dots mark the non-stochastic steady state, the zero-inflation-bias parameterization ("Hawkish"), and the parameterization that restores the steady-state differential ("Employment-focused"). The rightward region of the figure represents a more favorable inflation–inclusion trade-off, where policies deliver larger reductions in the T3–T1 earnings gap at a lower inflation cost.

5.4 Okun's Cones: A Menu for Policymakers

The previous section quantified the long-run inflation–inclusion trade-off for a single parameterization of the LfL rule. Here we map the full frontier, which allows us to ask: what is the cost in terms of inflation for any given reduction in earnings inequality? To compute this frontier we vary the reaction coefficients of the LfL rule continuously from the IT benchmark to the main LfL parameterization, storing the ergodic distribution for each case. For every parameterization we then record, jointly, the average inflation bias and the average total earnings at the bottom and top terciles of the skill distribution. This mapping from inflation to tercile earnings—which, because of its shape, we denote by "Okun's cones"—is plotted on the left panel of Figure 9 (Figure F3 in the Appendix shows a similar figure for unemployment and participation).

As expected, the cones show a stronger response at the bottom than at the top. In the right panel we summarize these effects in terms of T3–T1 earnings differential. The line traces out the *long-run inflation–inclusion trade-off* embedded in the LfL strategy, i.e., the additional average inflation required to achieve a persistent reduction in the T3–T1 earnings differential. The slope summarizes how favorable the trade-off is: flatter curves deliver more inclusion per unit of additional inflation.

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 0.50 ppt, 1.2 ppt, and approximately

5 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 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 7 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.

5.5 Decomposing the LfL into its AIT and Shortfall Components

To understand the distinct role played by the AIT and Shortfall components of the LfL rule we computed ergodic averages for a number of outcomes separately for the AIT and SR components. Findings are summarized in Table H2 in the Appendix. Individually, each component reduces ZLB frequency from 15.25% in the baseline to 9.62% under SR and 6.85% under AIT. Bottom-tercile earnings improve by 7.89 percentage points under SR, leaving them 1.11% below their steady-state value, and by 9.52 percentage points under AIT, turning the bias positive at 0.52%. Both components push inflation modestly above target.

Despite producing similar average effects, however, the two components act through very different mechanisms. AIT acts primarily by limiting the damage from severe downturns, whereas SR keeps policy accommodative for longer during recoveries and expansions, allowing low-skilled workers to rebuild lost human capital. Consistent with this contrast, AIT reduces recession frequency from 14.0% under IT to 6.5%, while SR increases the share of time spent in booms from 2.1% to 15.3%.

Crucially, neither component reproduces the LfL gains on its own, as is clear from the last two columns of Table H2. Figure H1 in the Appendix makes the point in terms of the inflation–inclusion frontier. The SR frontier is steeper than the LfL frontier: undoing scarring only during expansions costs more in terms of inflation than the mixed approach of the LfL that acts on both expansions and recessions. The AIT frontier has almost the same slope as LfL but is truncated near the steady state.[44] This is because the AIT policy is inherently self-limiting: a stronger reaction to inflation deficits closes the gap faster during the downturn so that, by the time the recovery is under way, the rule ends up prescribing little extra accommodation.

5.6 Robustness Analysis

The preceding analysis shows how the bottom of the distribution suffers disproportionately from recessions, especially when the ZLB binds, and how LfL can promote economic inclusion by sustaining stronger expansions that make up for scarring effects. Here we examine whether these two key findings are robust to changes in (i) the frequency and duration of ZLB episodes, (ii)

[44] The truncation occurs even when we consider a more aggressive parameterization of the AIT than the one embedded in the LfL.

the baseline monetary and fiscal rules, and (iii) agents' understanding of the new LfL policy. We summarize the exercises below, with details reported in Appendix G. The lesson is the same in all three cases. Under IT earnings losses at the bottom remain substantial, they deepen when the ZLB binds more often or for longer, and the inclusion gains from LfL remain substantial throughout. The gains survive even with very limited understanding of the LfL rule, though attenuated.

ZLB frequency and duration. Because the ZLB amplifies recessions and prolonged unemployment compounds earnings scarring, Appendix G.1 examines sensitivity to how often the bound binds and how long episodes last. The exercises vary the bond liquidity premium to alter ZLB frequency and replace the baseline demand-shock process with a regime-switching specification that generates longer ZLB spells.

Policy rules. The extent of recessionary scarring may depend on monetary stabilization and fiscal accommodation. Appendix G.2 considers stronger monetary responses to inflation or unemployment, debt stabilization through taxes rather than government spending, and slower fiscal adjustment to debt.

Limited understanding. The stabilization power of LfL at the ZLB rests partly on agents' anticipation that interest rates will remain lower for longer. Appendix G.3 assesses the robustness of these gains when agents have only a limited understanding of the LfL rule and internalize only part of its forward-looking promises.

6 Alternative Rules that Address the ZLB or Inclusion Directly

Our baseline measures the inflation–inclusion trade-off implied by the LfL rule. Here, we ask whether alternative monetary policy strategies can deliver a comparable menu of outcomes.

We consider two families of rules. The first family collects standard remedies to the ZLB—a symmetric AIT rule (labeled SYMAIT) and a higher inflation target (HIGHIT). While these rules are not designed to engineer more inclusion, they are leading conventional options for dealing with the ZLB. They thus provide a benchmark for how far conventional solutions can mitigate the negative scarring at the bottom that arises under IT. The second family, in the spirit of Baek (2021) and Nakajima (2022), consists of strategies with an explicit inclusion mandate: they respond directly to labor-market outcomes at the bottom of the skill distribution. Specifically, rule INCL-U replaces aggregate unemployment with bottom-tercile unemployment in the baseline IT rule, and rule INCL-P augments the IT rule with a participation-gap term, which explicitly targets one of the sources of hysteresis in our model.[45]

[45] Group-level unemployment and participation gaps are measured with lags and sizable revisions, so these rules are informationally more demanding than LfL, which conditions only on aggregate outcomes.

The right panel of Figure H1 overlays the inflation–inclusion frontier of each alternative rule against the LfL frontier. The conventional ZLB remedies push the economy close to eliminating the negative inclusion bias, but they differ sharply in their implications for inflation. The SYMAIT rule closes approximately four fifths of the T3–T1 earnings-differential bias, but only half of the deflationary bias. HIGHIT delivers similar inclusion gains, but reaching near-steady-state inclusion requires an inflation bias of approximately +40 bp. Insuring against the ZLB through a permanently higher target is inefficient because the inflation cost is paid in every period, whereas make-up strategies incur it only when a shortfall calls for it.[46] Rules that target the bottom of the distribution improve upon IT along a frontier nearly as favorable as the LfL one: at their most aggressive calibration, they shrink the negative bias in T1 earnings from −9% under IT to −3.8% and −2%, respectively, while keeping average inflation close to target (+0.4bp and +7bp).

None of these alternative rules, however, reaches the high-inclusion region attained by LfL over the parameter ranges considered. Since these rules all respond to *gaps*, which close as the recovery matures, the accommodation they prescribe vanishes precisely where the LfL rule begins to run the economy hot.

7 Inflation Expectations and the Robustness of Inclusion Gains

All results so far maintain that inflation expectations stay anchored at the 2% target in the very long run, even though average inflation under the LfL rule runs systematically above target. A natural concern is that the favorable inflation–inclusion trade-off we documented in Section 5.3 leans on this specific anchoring of inflation expectations which is inconsistent with rational expectations. In this section, we ask how much of the inflation–inclusion trade-off survives once agents (both households and firms) internalize the LfL rule's inflationary bias.

7.1 Stochastic Extended Path

To study this question, we extend our solution method along the lines of the Stochastic Extended Path (SEP) of Adjemian and Juillard (2025), which lets agents form expectations over the realization of future aggregate shocks up to a finite horizon of $H \geq 0$ quarters. At $H = 0$ we recover our perfect-foresight baseline: agents anticipate the asymmetric path implied by current and past shocks, but fail to foresee that future shocks will also trigger the rule's asymmetric behavior. For $H > 0$, agents also integrate over the distribution of future aggregate innovations up to H quarters ahead, and thereby internalize the inflationary bias embedded in the rule's asymmetric reaction to all future shocks up to that horizon (see Appendix B.7 for a description of the method).

[46] This result is in line with the findings of the optimal-inflation-target literature (Coibion et al., 2012; Bernanke et al., 2019; Mertens and Williams, 2019).

Because of the computational burden of the SEP algorithm, we only simulate the model without the ZLB. Abstracting from the ZLB has two additional advantages. First, the model under IT is linear, so ergodic biases are zero up to first order, a useful benchmark. Second, removing the ZLB isolates the "run-it-hot" component of the LfL rule which is the key improvement, relative to IT, in dealing with labor market hysteresis.[47]

7.2 Results

Table I1 presents the results of our simulations. We begin with the $H = 0$ benchmark, which corresponds to our perfect-foresight solution for the baseline economy, but without the ZLB. Just as in Section 5.3, the LfL rule runs the economy hot for longer: average inflation is 33 bp above steady state (the target), unemployment is 0.24 pp lower, and bottom-tercile earnings are nearly 6% higher. At $H = 0$ expectations are strongly anchored: one- and five-year-ahead expected inflation stand at 25 and 11 bp above target, that is, still 8 and 22 bp *below* average realized inflation. Increasing H closes the gap between expected and realized inflation. Between $H = 0$ and $H = 24$, average inflation rises from 33 to 54 bp, but one- and five-year-ahead expected inflation rise even faster, from 25 and 11 bp to 56 and 55 bp. We stop at $H = 24$, where expected inflation has fully caught up with realized average inflation at both horizons.

Aggregate Unemployment-Inflation Trade-Off. As expectations catch up, the aggregate trade-off deteriorates sharply, in line with Friedman's classic view. The unemployment gap shrinks from -0.24 pp at $H = 0$ to less than -0.04 pp at $H = 24$, steepening the implied unemployment-inflation relation from -1.4 to roughly -15. This near-neutrality of the *aggregate* trade-off mirrors the rational-expectations result of Bundick et al. (2025) for a shortfall rule in a RANK model: once expectations take the rule's inflationary bias into account, the *average unemployment* gains from asymmetric accommodation all but vanish.

Inclusion-Inflation Trade-Off. When we zoom in on the distribution, however, we find that inclusion gains in the baseline model largely survive the expectations catch-up. Compared to an unemployment gain retention of just 15% at $H = 24$ (0.037/0.24), the top–bottom tercile earnings gap retains 55% of its $H = 0$ value. Looking across the skill distribution, top-tercile earnings retain almost nothing, while the bottom keeps half of its gains. Notice that this is not a feature of the final horizon alone: even at $H = 16$ the earnings gap retains most of its $H = 0$ gains. Figure I1 plots the full ergodic distributions under IT, LfL with perfect foresight (H=0), and LfL with SEP (at H=24). Under LfL, as we approach rational expectations and the distribution of inflation bias

[47] Omitting the ZLB therefore leads to a conservative assessment of the gap between IT and LfL under aggregate uncertainty: anticipation of future ZLB episodes deepens the deflationary bias under IT via precautionary saving (Fernández-Villaverde et al., 2024). Since the LfL can weaken these effects, incorporating expectations of future shocks with the ZLB would, if anything, widen the gap between the two rules.

shifts to the right, the distribution of unemployment bias recenters around zero but, crucially, the distribution of the T3-T1 earnings gap remains centered around negative numbers.

To dig into the sources of this result, we apply the SEP method to a version of the model discussed in Appendix E (which we called the HA-E model) that keeps heterogeneous exposure, but shuts off participation and skill-scarring, the two channels driving earnings hysteresis in our baseline model. With these two mechanisms switched off, the distributional outcomes track the aggregate closely: both the aggregate unemployment gain and top- and bottom-tercile earnings, and hence the gap between them, retain only around 12% of their $H = 0$ value at $H = 24$.

This finding suggests that the attachment and persistence/scarring channels are responsible for the long-run survival of inclusion gains at the bottom of the distribution even when households re-align their long-run inflation expectations. The reason is that the aggregate labor market slack variable in the model's Phillips curve is average hours worked. Unemployment, and its frictional inflow and outflow, are largely determined by fluctuations in hours through (15), thus one would expect the long-run trade-off in terms of hours and unemployment to disappear. Although the ergodic Phillips curve is nearly vertical, this does not imply long-run neutrality of monetary policy across the entire distribution of earnings. LfL leaves average unemployment essentially unchanged but alters workers' labor-market histories and their decisions, reducing labor-force detachment and labor productivity scarring. As a result, the ergodic distribution of earnings improves at the bottom even in the absence of a long-run unemployment gain.

How plausible is the full realignment of expectations in the $H = 24$ experiment? A growing literature finds that household expectations are sticky and respond only once inflation crosses a salience threshold of roughly 3.5–4% (Korenok et al., 2026; Weber et al., 2025; Pfauti, 2024). In fact, even once inflation surpassed that threshold during the recent surge, five-year-ahead expectations showed little sign of unanchoring (Hajdini et al., 2025). The inflation bias generated by LfL in our simulations is an order of magnitude smaller than any such threshold, and the forecast errors that perfect foresight imposes on agents are correspondingly modest: only -8 (-22) bp at the one-year (five-year) horizon. Expectation formation in practice therefore appears to lie close to our $H = 0$ baseline. At the same time, large and salient shocks do raise households' attention and move their longer-run expectations (Coibion et al., 2023; Coibion and Gorodnichenko, 2025; Candia et al., 2021), so the $H = 24$ results are best read as an upper bound on the expectations channel, corresponding to counterfactually attentive agents.

Either way, our conclusion stands: the aggregate inflation–unemployment trade-off is fragile to how expectations are formed, but the inclusion gains are far more robust, surviving even when expectations fully realign to a very modest gap between average inflation and the target.

8 Conclusions

This paper formalizes and quantifies Arthur Okun's conjecture that a high-pressure economy persistently lifts the labor market trajectories of low-wage workers, possibly at the cost of higher inflation. To do so, we extend the canonical HANK framework with a rich labor market in which recessions scar low-skilled workers through a vicious cycle of job loss, labor-force exit, and skill erosion. Under Inflation Targeting, the ZLB severely amplifies this hysteresis at the bottom of the distribution. The Lower-for-Longer strategy adopted by the Fed in 2020 neutralizes these effects by promising to run the economy hot for longer during recoveries, with disproportionate benefits for low-wage workers. Because policymakers may differ in their tolerance for above-target inflation, we trace out the inflation–inclusion frontier this strategy implies.

The inclusion-inflation trade-off we study is, at its core, a statement that how a central bank stabilizes the business cycle also determines who bears its costs. Heterogeneous-agent models make this link unavoidable: the clear-cut distinction between stabilization and redistribution policies, inherited from the neoclassical synthesis and embodied in the representative-agent construct, vanishes (Sargent, 2024). Redistribution policies spill over to the business cycle, and stabilization policy is always, to some extent, redistributive. Our paper offers a stark illustration of this latter link. Much remains to be learned about how these two dimensions of macroeconomic policy, traditionally analyzed in isolation, interact.

Finally, our analysis speaks to normal times when capacity constraints are slack and the Phillips curve is relatively flat, so that monetary policy can stretch expansions, drawing marginal workers back into employment, without much pressure on wages and prices. The post-pandemic recovery was not such a time, and it starkly illustrates what is at stake when these conditions fail. Guided by its new framework, the Fed delayed liftoff much longer relative to labor market and inflation conditions than it had after the Great Recession. The payoff for inclusion was the one our model predicts: employment and earnings of low-educated and minority workers reached historic highs, and the wage distribution compressed notably for the first time in decades (Autor et al., 2023). With binding capacity constraints and a steeper Phillips curve, however, the same strategy coincided with the largest inflation surge in four decades, an experience that was likely instrumental in the Fed's decision to abandon the 2020 framework in its 2025 review (Powell, 2025). In follow-up work that builds on this paper (Alves and Violante, 2026), we study how the inflation–inclusion trade-off deteriorates when capacity constraints bind. The lesson of the pandemic, then, is not that Okun's hypothesis was wrong but that the low price of a high-pressure economy we find in normal times can rise sharply when supply is constrained. As long as recessions keep scarring workers at the bottom of the distribution, stabilization policy remains, in Okun's words, a question of whether to renounce these inclusion gains *as insurance against inflation*.

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Appendix

The Appendix is organized as follows. Appendix A provides additional model details and derivations; Appendix B describes the numerical solution method; Appendix C describes the worker-flow data and calibration of labor market frictions; Appendix D reports untargeted moments; Appendix E presents the decomposition into the three Okun's channels; Appendix F reports additional LfL results; Appendix G presents robustness checks; Appendix H presents alternative monetary policy rules; and Appendix I reports results under the stochastic extended path method.

A Additional Model Details and Derivations

A.1 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. (2025) and their notation with the max operator which we find intuitive. We use the symbol $\mathcal{Z}^s$ to denote the infinitesimal generator of the joint process of skills—defined in (1), transformed in levels—and of the disutility state η, in employment state s. Then:

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

where η' denotes the disutility state complementary to η, so that $\chi^{\eta\eta'}$ equals χ^{LH} when $\eta = L$ and χ^{HL} when $\eta = H$.

The problem of the employed household in (6) at time t can be written as:

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

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

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

The problem of the non-eligible unemployed in (4) becomes:

$$\rho v_t^{u_0} = \max \left\{ \max_{c_t} \left\{ \mathfrak{u}^u \left(c_t, 0; \eta_t \right) + \partial_a v_t^{u_0} \left(r_t a_t + \phi - c_t \right) \right\} + \lambda_{zt}^{ue} \left(v_t^e - v_t^{u_0} \right) \right. \\ \left. + \mathcal{Z}^{u_0} v_t^{u_0} + \partial_t v_t^{u_0}, \rho v_t^n \right\}$$

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

$$\rho v_t^{u_1} = \max \left\{ \max_{c_t} \left\{ \mathfrak{u}^u \left(c_t, 0; \eta_t \right) + \partial_a v_t^{u_1} \left(r_t a_t + \phi + (1-\tau) b \left(z_t \right) - c_t \right) \right\} + \lambda_{zt}^{ue} \max \left\{ v_t^e - v_t^{u_1}, 0 \right\} \right. \\ \left. + \lambda^{u_1 u_0} \left(v_t^{u_0} - v_t^{u_1} \right) + \mathcal{Z}^{u_1} v_t^{u_1} + \partial_t v_t^{u_1}, \rho v_t^n \right\}$$

The four HJBQVIs above, jointly with the four first-order conditions at every t

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

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

A.2 Problem of the Final and Intermediate Goods Producers

A.2.1 Final good sector

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

$$Y_t = \left(\int_0^1 y_{jt}^{\frac{\nu-1}{\nu}} dj \right)^{\frac{\nu}{\nu-1}} \tag{A1}$$

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

$$\max_{\{y_{jt}\}} P_t Y_t - \int_0^1 p_{jt} y_{jt} dj \tag{A2}$$

subject to (A1). Cost minimization implies that demand for intermediate good j at price p_{jt} is

$$y_{jt}(p_{jt}) = \left(\frac{p_{jt}}{P_t} \right)^{-\nu} Y_t, \quad \text{where} \quad P_t = \left(\int_0^1 p_{jt}^{1-\nu} dj \right)^{\frac{1}{1-\nu}} \tag{A3}$$

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

A.2.2 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

$$\begin{aligned} \max_{p_{jt},\{\ell_{jkt}\}_k} \quad & \left(\frac{p_{jt}}{P_t}\right) y_{jt} - (1-\tau^{\ell}) \int_0^1 w_{kt}\ell_{jkt}dk - \phi^{\ell} \\ s.t. \quad & \\ y_{jt} &= \alpha \ell_{jt} \\ \ell_{jt} &= \left[\int_0^1 \ell_{jkt}^{\frac{\varepsilon-1}{\varepsilon}} dk\right]^{\frac{\varepsilon}{\varepsilon-1}} \\ y_{jt} &= \left(\frac{p_{jt}}{P_t}\right)^{-\nu} Y_t \end{aligned} \tag{A4}$$

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:

$$\ell_{jkt} = \left(\frac{w_{kt}}{w_t}\right)^{-\varepsilon} \ell_{jt}, \tag{A5}$$

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:

$$\frac{p_{jt}}{P_t} = \left(\frac{\nu}{\nu-1}\right) \frac{(1-\tau^{\ell})w_t}{\alpha}. \tag{A6}$$

This price corresponds to 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 (A6) implies that the equilibrium aggregate real wage per effective hour is equal to the marginal product of labor, or

$$w_t = \alpha. \tag{A7}$$

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

$$\Pi_t = \Psi_t^\ell. \tag{A8}$$

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

A.3 Derivation of the Wage Phillips Curve

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

$$\max_{\{\omega_{kt}\}_{t\geq 0}} \int_0^\infty e^{-\rho t}\left[\int_{s_{it}=e} \mathfrak{u}^e\left(c_{it}, h_{it}; z_{it}, \eta_{it}\right) di - \frac{\Theta}{2}\left(\frac{\dot{\omega}_{kt}}{\omega_{kt}} - \pi^*\right)^2\right] dt \tag{A9}$$

$$s.t.$$

$$h_{it} = \int_0^1 h_{kt} dk \tag{A10}$$

$$c_{it} + \dot{a}_{it} = r_t a_{it} + \left(1 - \tau + \tau^s\right) y_{it} + \phi - \phi_{it}^s \tag{A11}$$

$$y_{it} = \frac{1}{P_t} z_{it} \int_0^1 \omega_{kt} h_{kt} dk \tag{A12}$$

$$h_{kt} = \left(\frac{\omega_{kt}}{\omega_t}\right)^{-\varepsilon} h_t \tag{A13}$$

The first constraint faced by the union states that total hours worked by an employed worker equal the sum of hours 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 the firm's demand for effective labor on task k, ℓ_{kt}. This constraint is equivalent to (A5) 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.

Each task-specific union is "small": there is a continuum of tasks, and union k represents only those of mass dk. This has two implications. First, the union's wage has a negligible impact on individual income and on the firm's total employment, so the union takes as given all individual decisions embedded in the budget constraint, the lump-sum tax ϕ_{it}^s, and the firm's labor demand curves for each task. Second, the union's wage affects members' income and hours only through tasks of mass dk, and we scale its adjustment cost accordingly, $\frac{\Theta}{2}\left(\frac{\dot{\omega}_{kt}}{\omega_{kt}} - \pi^*\right)^2 dk$. Every term in the first-order and envelope conditions below is then proportional to dk, which we cancel throughout, so that the derivatives of y_{it} and h_{it} with respect to ω_{kt} are expressed per unit of dk.

We can write this problem recursively as

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

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

$$\partial_\omega J_t(\omega_{kt})\,\omega_{kt} = \Theta\left(\pi_{kt} - \pi^*\right) \tag{A14}$$

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

where

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

and note that we did not differentiate either consumption or 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

$$\begin{aligned}
\partial_\omega y_{it} &= \frac{1}{P_t} z_{it} h_t (1 - \varepsilon) \\
\partial_\omega h_{it} &= -\varepsilon h_t \omega_t^{-1}
\end{aligned} \tag{A15}$$

and

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

Substituting (A15) into the envelope condition, we obtain

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

Differentiating the first-order condition (A14) with respect to time yields

$$\partial_{\omega t}J_t\left(\omega_t\right)+\partial_{\omega\omega}J_t\left(\omega_t\right)\dot{\omega}_t=\frac{\Theta\dot{\pi}_t}{\omega_t}-\frac{\Theta\left(\pi_t-\pi^*\right)}{\omega_t}\left(\frac{\dot{\omega}_t}{\omega_t}\right) \tag{A16}$$

Substituting (A16) into the envelope condition yields

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

Multiply both sides by ω_t/Θ to arrive at

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

Simplifying this expression and rearranging, we obtain

$$\rho\left(\pi_t-\pi^*\right)=\frac{\varepsilon}{\Theta}h_t\left[-\int_{s_{it}=e}\partial_h \mathrm{u}^e\left(c_{it},h_t;z_{it},\eta_{it}\right)di-\left(\frac{\varepsilon-1}{\varepsilon}\right)\left(1-\tau+\tau^s\right)w_t\int_{s_{it}=e}\partial_c \mathrm{u}^e\left(c_{it},h_{it};z_{it},\eta_{it}\right)z_{it}di\right]+\dot{\pi}_t \tag{A17}$$

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., $\phi^s_{it}=\tau^s z_{it}w_t h_{it}$. As a result, in equilibrium it does not appear in either the household budget constraint or 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 (A7), we arrive at

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

which equals the expression for the Phillips curve (8) 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 (14), note that when linearizing the term in round brackets in (8) around the steady state we have exploited the fact that $\psi(h^*)^{\frac{1}{\sigma}+1}=(1-\tau)\alpha h^*$.

A.4 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 that carries 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 the 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:

$$\begin{aligned}\tilde{r}_t A_t\left(X^f, B^f, M^f\right) = \max_{\dot{X}^f, \dot{B}^f, \dot{M}^f} \quad & \Pi_t X^f - q_t \dot{X}^f + (r_t^b + \bar{\iota}) B^f - \dot{B}^f + (r_t^m + \bar{\iota}) M^f - \dot{M}^f \\ & + \partial_X A_t\left(X^f, B^f, M^f\right) \dot{X}^f + \partial_B A_t\left(X^f, B^f, M^f\right) \dot{B}^f \\ & + \partial_M A_t\left(X^f, B^f, M^f\right) \dot{M}^f + \partial_t A_t\left(X^f, B^f, M^f\right)\end{aligned} \tag{A18}$$

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 (A18), 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

$$\tilde{r}_t = \frac{\Pi_t + \dot{q}_t}{q_t} = r_t^b + \bar{\iota} = r_t^m + \bar{\iota}, \tag{A19}$$

which is the expression (9) in the main text.

A.5 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 2.8.[48]

For any given distribution of households over wealth, skills, and disutility state the instant before the shock, $\mu_{0^-}^s(a, z, \eta)$, with $s \in \{e, u, n\}$, and a time path for shocks $\{\zeta_t^k\}_{t \geq 0}$, with $k \in$

[48] 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.

$\{s,d\}$, a perfect foresight equilibrium is defined as time paths for household consumption, participation and job offer acceptance decisions $\left\{c_t^s\left(a,z,\eta\right),\mathfrak{p}_t^s\left(a,z,\eta\right),\mathfrak{j}_t^s\left(a,z,\eta\right)\right\}_{t\geq 0}$, 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 $\left\{q_t\right\}_{t\geq 0}$, fiscal variables (expenditures and debt) $\left\{G_t, B_t^g\right\}_{t\geq 0}$, 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 $\left\{\mu_t^s\left(a,z,\eta\right)\right\}_{t\geq 0}$ such that at every t: (i) households solve problems (3)-(6); (ii) final good and intermediate good producers solve (A2) and (A4), respectively; (iii) unions solve (A9) and inflation satisfies the Phillips curve in (8); (iv) the mutual fund solves (A18); (v) the government budget constraint (10) holds; (vi) the fiscal and monetary authorities follow their policy rules (11) and (12); (vii) aggregate profits are given by (A8); (viii) the sequence of distributions satisfies aggregate consistency conditions; (ix) asset and annuity markets clear; and (x) all goods markets clear.

The post-shock distribution $\mu_0^s(a,z,\eta)$ is obtained from the initial condition $\mu_{0^-}^s(a,z,\eta)$ by revaluing each household's wealth at the post-shock value of the fund, $a_0 = a_{0^-}\left(A_0/A_{0^-}\right)$. There are four asset markets in our economy: the intermediate firms' shares market, the two government bond markets, and the mutual fund shares market. These 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 (9), 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.

B Numerical Solution Method

B.1 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. (2022).[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 in the bottom tercile of the skill distribution).

Out of steady state, we discretize our continuous-time economy over T_m 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). We set $T_m = 600$ (or 50 years) to accurately capture the persistent effects operating in the model. 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 Appendix A.5.

In what follows, we use boldface to denote vectors that stack time paths and matrices that map between these vectors. For each endogenous variable X, the sequence-space solution delivers general equilibrium Jacobians $\mathbf{G}^{x,k}$, $k \in \{d, s\}$, mapping changes in the paths of the structural shocks ζ^k into changes in the path of X. The analogous Jacobian $\mathbf{G}^{x,m}$ maps changes in the path of auxiliary monetary policy adjustments, introduced below, into changes in the path of X.

For simulations, let ϵ_t^k denote the innovations to the discretized demand and supply shock processes. We write $d\boldsymbol{\zeta}^k$ for the vector stacking the response of the shock process to a unit innovation and $d\mathbf{X}^k = \mathbf{G}^{x,k} d\boldsymbol{\zeta}^k$ for the corresponding vector of equilibrium impulse responses. Thus, $d\mathbf{X}^k \epsilon_t^k$ gives the contribution of the date-t innovation to the projected path of X.

While we calibrate and solve for the model's IRFs at monthly frequency, we perform simulations and counterfactuals of the model at quarterly frequency.[50] In the expressions below, T denotes the number of quarters retained in each projected path, including the current quarter. Path vectors therefore have T entries, indexed by horizons $h = 0, \ldots, T-1$, and the corresponding general equilibrium Jacobians have dimension $T \times T$. Unless otherwise noted, all the remaining exercises are conducted after aggregating shocks and IRFs from months to quarters.

B.2 Model Simulation with 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

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

[50] This choice facilitates comparison of the model's business-cycle moments with the empirical targets and reduces the computational cost of the ergodic simulations.

shocks, while allowing for nonlinearities coming from occasionally binding aggregate constraints, like the ZLB.

For simulations, we denote the projected path of X formed at date t by

$$\mathbf{X}_{(t)} = (X_t, \mathbb{E}_t[X_{t+1}], \ldots, \mathbb{E}_t[X_{t+T-1}])'.$$

We truncate deviations from steady state beyond the retained horizon. The forward-shift operator $\mathcal{F}$ drops the first entry and appends the steady-state value:

$$\mathcal{F}\mathbf{X}_{(t)} = (\mathbb{E}_t[X_{t+1}], \ldots, \mathbb{E}_t[X_{t+T-1}], X^*)'.$$

When applied to an impulse-response vector or an auxiliary policy-adjustment vector, the operator instead appends zero. Throughout this subsection, expectations are formed under the assumption that all future demand and supply innovations are zero. The resulting paths are thus perfect-foresight projections.

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

$$\mathbf{X}_{(t)} = X^* \mathbf{1}_T + \sum_{j=0}^{T-1} \sum_{k=d,s} \left(\mathcal{F}^j d\mathbf{X}^k\right) \epsilon_{t-j}^k, \tag{B1}$$

where $\mathbf{1}_T$ is the T-vector of ones. This representation coincides with the expressions in Boppart et al. (2018) and Auclert et al. (2021). Alternatively, we can write (B1) recursively as

$$\mathbf{X}_{(t)} = \mathcal{F}\mathbf{X}_{(t-1)} + \sum_{k=d,s} d\mathbf{X}^k \epsilon_t^k. \tag{B2}$$

In this representation, the time-t projections $\mathbf{X}_{(t)}$ are separated into two objects: (a) the time-$t-1$ projections and (b) the forecast revisions due to shocks hitting the economy at time t.[51]

With the ZLB, we impose nonnegativity on every entry of the projected nominal interest rate path, $\boldsymbol{i}_{(t)} \geq \mathbf{0}$. To this end, we follow Holden (2016) and augment the baseline monetary policy rule with auxiliary policy shocks that are chosen endogenously to enforce the bound on interest rates. We begin by writing the baseline inertial policy rule described in Section 2.6, absent the ZLB, in stacked form as

$$\mathcal{A}\,\hat{\mathbf{y}}_{(t)} - \mathbf{Z}_{(t)}^m = \mathbf{0}, \tag{B3}$$

where $\hat{\mathbf{y}}_{(t)}$ stacks the projected deviations of the nominal interest rate, inflation, and unemployment.

[51] The recursive formulation in (B2) is useful because whether the ZLB binds in the future depends on the history of shocks, whose effects are summarized by the inherited projection $\mathcal{F}\mathbf{X}_{(t-1)}$.

The linear operator $\mathcal{A}$ represents the discretized policy rule, including interest rate smoothing. The vector $\mathbf{Z}^m_{(t)} \equiv (Z^m_t, \mathbb{E}_t[Z^m_{t+1}], \ldots, \mathbb{E}_t[Z^m_{t+T-1}])'$ stacks the current and projected future auxiliary monetary policy shocks. A positive entry at horizon h represents an anticipated policy tightening at $t+h$ relative to the baseline rule. These shocks prevent violations of the ZLB whenever the nominal interest rate path implied by (B3) with $\boldsymbol{Z}^m_{(t)} = \mathbf{0}$ would otherwise fall below zero. The auxiliary-shock path must thus satisfy the complementarity conditions

$$\boldsymbol{i}_{(t)} \perp \boldsymbol{Z}^m_{(t)}, \qquad \boldsymbol{i}_{(t)} \geq \mathbf{0}, \qquad \boldsymbol{Z}^m_{(t)} \geq \mathbf{0}, \tag{B4}$$

which allow positive auxiliary shocks only at horizons where the rate is zero. To determine these shocks, we combine the complementarity conditions with the updating equation for the projected nominal interest rate path:

$$\boldsymbol{i}_{(t)} = \mathcal{F}\boldsymbol{i}_{(t-1)} + \sum_{k=d,s} d\boldsymbol{i}^k \epsilon^k_t + \mathbf{G}^{i,m}\left(\mathbf{Z}^m_{(t)} - \mathcal{F}\mathbf{Z}^m_{(t-1)}\right). \tag{B5}$$

Relative to (B2), this updating equation adds a term in the monetary news, $\boldsymbol{Z}^m_{(t)} - \mathcal{F}\boldsymbol{Z}^m_{(t-1)}$. Each entry of $\mathbf{Z}^m_{(t)}$ is the total monetary policy shock adjustment projected for a given date, including any component already anticipated in earlier periods; the news instead captures the date-t revision to that total, which reflects how the date-t demand and supply innovations, ϵ^d_t and ϵ^s_t, shift the set of horizons at which (and by how much) the ZLB is projected to bind. Different from $\mathbf{Z}^m_{(t)}$ that must be nonnegative, the news can thus take either sign. The general equilibrium Jacobian $\boldsymbol{G}^{i,m}$ maps this news into revisions of the nominal interest rate path: its column associated with horizon h gives the response to a unit revision, announced at date t, in the policy adjustment at $t+h$.

Substituting (B5) into the complementarity conditions (B4), we arrive at a linear complementarity problem (LCP) in $\mathbf{Z}^m_{(t)}$ of the form

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

with

$$\mathbf{Q} = \mathbf{G}^{i,m}, \qquad \mathbf{q} = \mathcal{F}\boldsymbol{i}_{(t-1)} + \sum_{k=d,s} d\boldsymbol{i}^k \epsilon^k_t - \mathbf{G}^{i,m}\mathcal{F}\mathbf{Z}^m_{(t-1)}.$$

Solving the LCP problem for $\mathbf{Z}^m_{(t)}$, we can then update projections of other variables X in a similar fashion:

$$\mathbf{X}_{(t)} = \mathcal{F}\mathbf{X}_{(t-1)} + \sum_{k=d,s} d\mathbf{X}^k \epsilon^k_t + \mathbf{G}^{x,m}\left(\mathbf{Z}^m_{(t)} - \mathcal{F}\mathbf{Z}^m_{(t-1)}\right). \tag{B6}$$

Compared with (B2), the updating rule (B6) features the additional term $\mathbf{G}^{x,m}\left(\mathbf{Z}^m_{(t)} - \mathcal{F}\mathbf{Z}^m_{(t-1)}\right)$, which translates the time-t forecast revisions in the auxiliary monetary shocks into revisions of the projected path of X, with the general equilibrium Jacobian $\mathbf{G}^{x,m}$ defined analogously to $\mathbf{G}^{i,m}$

in (B5). It is through this term that the ZLB—binding today or expected to bind in the future—shapes the dynamics of all variables in the model; whenever neither the $t-1$ nor the t projections are expected to hit the constraints, the updating rule (B6) reduces to (B2).

B.3 Computing Monetary Policy Counterfactuals

We use the baseline IT solution to construct equilibrium paths under alternative monetary policy rules, following Hebden and Winkler (2024) and McKay and Wolf (2023). We first describe this construction under the same assumption of zero future structural innovations used in the baseline simulation. The basic idea is to use the previous section's 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 idea that we can add monetary "news" shocks to the policy rule to study counterfactuals. At each date t, 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 (B5) using shocks $\tilde{\mathbf{Z}}^m_{(t)}$, replicates the interest rate path that would arise under the counterfactual regime, $\boldsymbol{i}^{alt}_{(t)}$.[52] Given $\tilde{\mathbf{Z}}^m_{(t)}$, we compute the IT news-perturbed allocation $\tilde{\mathbf{X}}^{IT}$ for other variables of interest according to

$$\tilde{\mathbf{X}}^{IT}_{(t)} = \mathcal{F}\tilde{\mathbf{X}}^{IT}_{(t-1)} + \sum_{k=d,s} d\mathbf{X}^k \epsilon^k_t + \mathbf{G}^{x,m}\left(\tilde{\mathbf{Z}}^m_{(t)} - \mathcal{F}\tilde{\mathbf{Z}}^m_{(t-1)}\right), \tag{B7}$$

where the term $\left(\tilde{\mathbf{Z}}^m_{(t)} - \mathcal{F}\tilde{\mathbf{Z}}^m_{(t-1)}\right)$ denotes the monetary news *surprises* to the original IT solution that implement the allocation under the alternative rule.

For a given initial state and sequence of structural innovations, the news-perturbed allocation satisfies the same linearized private-sector equilibrium conditions as the counterfactual economy. Because the auxiliary shocks are chosen to make this allocation satisfy the alternative policy rule as well, it constitutes an equilibrium under that rule. When the counterfactual equilibrium is unique, we therefore have $\tilde{\mathbf{X}}^{IT} = \mathbf{X}^{alt}$. 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."*

B.4 Filtering in the Great Recession Exercise

For the Great Recession exercise conducted in Section 5.2, we need to find the sequence of demand and supply innovations that, when fed into our model under the baseline IT rule, reproduce 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 the standard Kalman filter algorithm is that their approach only requires information on the impulse response functions, which we have from above.

[52] 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.

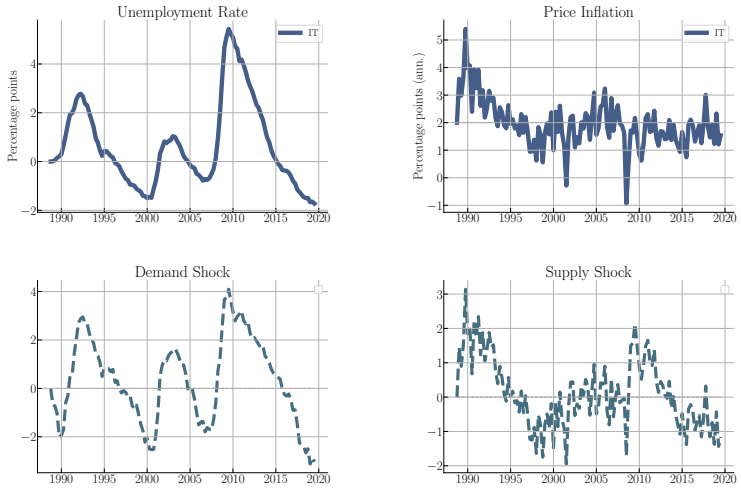


Figure B1: Aggregate dynamics and filtered shocks.

Note. The top row shows unemployment and inflation under the baseline IT rule, fitted to the observed series. Unemployment is expressed in percentage-point deviations from the non-stochastic steady state; inflation is expressed in annualized percent. The unemployment measure is constructed from the CPS (see Appendix C), and inflation is core PCE inflation (FRED series PCEPILFE). The bottom row shows the demand and supply shock processes, ζ_t^d and ζ_t^s, reconstructed using (16) and the filtered innovations. The demand shock is expressed in annualized percentage points; the supply shock is shown as $100\zeta_t^s$.

Abstracting from the ZLB, we can use (B1) to recover the demand and supply innovations $\{\epsilon_t^d, \epsilon_t^s\}$ that are consistent with the observed values of unemployment and inflation. We begin filtering in 1990Q1, assuming that the economy starts at its non-stochastic steady state, and proceed recursively. At t = 1990:$Q1$, this just requires inverting the impact matrix of the impulse response function to find the shocks that match the model's unemployment and inflation responses to the data. For $t >$ 1990:Q1, we apply the same logic to the "surprise" component of the data, $X_t - \mathbb{E}_{t-1}[X_t]$: because only the date-$t$ innovations move outcomes away from the previous period's projection, inverting the impact matrix of the impulse response function maps this surprise vector back into $(\epsilon_t^d, \epsilon_t^s)$. We then update the projection $\mathbf{X}_{(t)}$ using the filtered innovations and proceed to $t + 1$.

With an occasionally binding ZLB, we jointly recover the demand and supply innovations and the auxiliary monetary policy shocks. At each date t, we initialize the structural innovations by inverting the impact matrix using the observed unemployment and inflation surprises. Given these innovations, we solve the complementarity problem (B4)–(B5) for the auxiliary policy path $\mathbf{Z}_{(t)}^m$. We then subtract the contemporaneous effects of the monetary news $\mathbf{Z}_{(t)}^m - \mathcal{F}\mathbf{Z}_{(t-1)}^m$ from the observed surprises and invert the impact matrix again to update the structural innovations. We iterate between these two steps, damping the updates to the structural innovations. This procedure accounts both for newly anticipated interventions and for revisions to interventions anticipated at $t - 1$. Finally, we update the projections using (B6) and proceed to $t + 1$.

Figure B1 reports the paths of the demand and supply shocks implied by the filtered innovations. The demand shock ζ_t^d closely tracks unemployment, rising sharply during 2008–2009 and declining gradually thereafter. The supply shock ζ_t^s is elevated in the early 1990s and again around 2009–2012. In the latter episode, positive supply shocks offset part of the disinflationary pressure associated with weak demand.

B.5 Ergodic Distribution

The model moments reported for the ergodic distribution are computed from averages across 250 simulated samples of 160 quarters each. We discard the first 10 years of each sample and compute moments on the last 30 years of the simulated data.

B.6 Limited Understanding of the LfL Rule

In the background of our LfL counterfactuals lies the assumption that households are fully aware of, and perfectly understand, the shift from IT to the new rule. This justifies using the general-equilibrium Jacobian $\mathbf{G}^{x,m}$ in (B7) to convert a monetary news shock implementing the new rule into its impact on variable x. Since LfL operates in large part through commitments to lower rates far into the future, it is natural to ask how much of the rule's effect on current outcomes survives when households fail to internalize distant policy commitments. Here we take up this question.

We model limited understanding through cognitive discounting by assuming that agents perceive a monetary news surprise at horizon h scaled by θ^h, so that lower values of θ correspond to less of the rule shift being internalized (Gabaix, 2020). Operationally, we implement this by replacing $\mathbf{G}^{x,m}$ with a "behavioral" Jacobian $\mathbf{G}_\theta^{x,m}$ that applies this discount to the news shocks encoding the deviation of LfL from IT,

$$\mathbf{X}_{(t)}^{\theta} = \mathcal{F}\mathbf{X}_{(t-1)}^{\theta} + \sum_{k=d,s} d\mathbf{X}^k \epsilon_t^k + \mathbf{G}_\theta^{x,m}\left(\tilde{\mathbf{Z}}_{(t)}^m - \mathcal{F}\tilde{\mathbf{Z}}_{(t-1)}^m\right).$$

We build $\mathbf{G}_\theta^{x,m}$ from the fake-news representation of the Jacobian (see Auclert et al., 2021, for a discussion of how to add cognitive discounting to the FIRE Jacobian).

Three features are worth emphasizing. First, whereas Gabaix's cognitive discounting friction applies to deviations of all variables from steady state, we adapt it to discount solely the incremental forward-guidance commitments of LfL relative to the familiar IT benchmark—agents continue to internalize the direct impulse responses to demand and supply shocks under IT. This adaptation, which follows de Groot and Mazelis (2020) and de Groot et al. (2021), captures the assumption that agents fully understand the established IT regime but may only partially internalize the novel make-up component of the LfL.[53] Second, we recompute the auxiliary monetary policy ad-

[53] Notice that we hold θ fixed throughout each simulation. The exercise therefore captures persistent attenuation of responses to future policy commitments; it does not model learning about the policy rule over time.

justments using the transformed Jacobians, including those for the variables entering the policy rule. The complementarity problem therefore imposes the LfL rule on the resulting behavioral allocation. Third, households observe current interest rates without discounting. Operationally, the first column of each monetary-policy Jacobian is unchanged, preserving the response to an unanticipated contemporaneous policy disturbance. Current outcomes can nevertheless differ because responses to anticipated future policy adjustments are attenuated.

B.7 Stochastic Extended Path

The baseline and counterfactual simulations described above assume at each date that future demand and supply innovations are zero, updating the projection only when new innovations arrive. In a linear economy with mean-zero innovations, these perfect-foresight projections coincide with conditional expectations that integrate over future uncertainty. With the ZLB or an asymmetric policy rule such as Lower for Longer (LfL), this equivalence generally fails: the projected equilibrium path is a nonlinear function of future innovations. Consequently, imposing the policy rule along the zero-innovation path generally differs from imposing it across possible realizations and taking expectations.

In this subsection we relax that assumption by following the Stochastic Extended Path (SEP) of Holden (2023) and Adjemian and Juillard (2025). Instead of a single perfect-foresight projection at each date t, the method computes expectations by averaging over a (finite) set of possible future realizations of the shocks, with the asymmetric rule imposed separately along each path—enforcing the asymmetry realization by realization and then averaging, rather than at the mean. This restores the anticipatory effects that certainty equivalence misses: if agents assign positive probability to future states in which the LfL threshold binds, today's expected policy path already embeds the promise of accommodation even when the LfL branch is inactive at t. The cost is computational: the expectation integrates over a high-dimensional distribution of future innovations, and each evaluation of the integrand requires solving a complementarity problem. The rest of this subsection describes how we make that integral tractable.

Quadrature over future innovations. We let agents form time-t projections by integrating over the joint distribution of future demand and supply innovations $\{\epsilon^k_{t+h}\}^{k=d,s}_{h=1,\dots,H}$ up to a finite horizon H. The integral runs over $d \equiv 2H$ dimensions and evaluating the integrand at a single node is costly (each node involves solving a complementarity problem enforcing the asymmetric policy rule). This rules out Gauss–Hermite quadrature, whose tensor-product construction requires m^d nodes for m points per dimension—already ($3^{24} \approx 3 \times 10^{11}$) path solves with $m = 3$ points per dimension at a horizon of $H = 12$ quarters. We therefore rely on degree-3 monomial (cubature) rules: node–weight schemes that integrate exactly every polynomial of total degree up to three, thereby matching the mean and the full covariance structure of the innovations with only $N =$

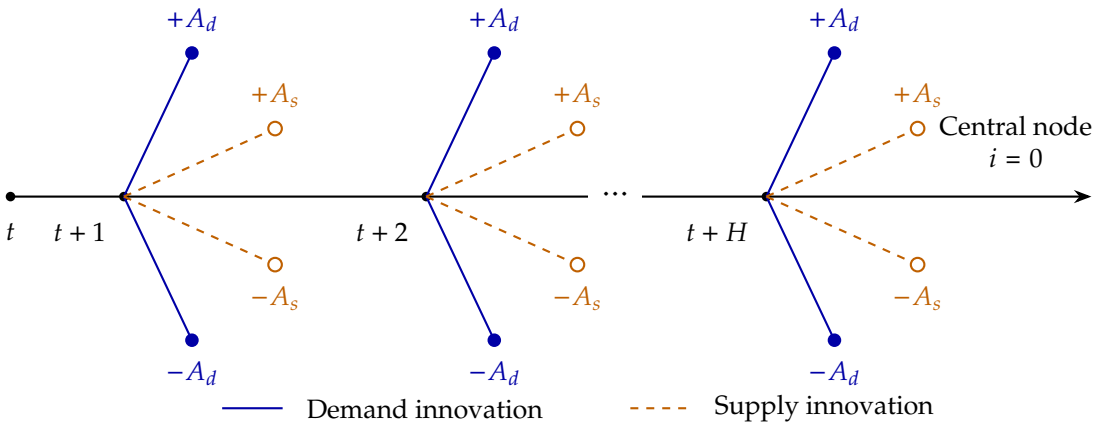


Figure B2: Fishbone quadrature over future innovations.

Note. The horizontal spine represents the central node, at which all future innovations are zero. At each horizon $h = 1, \ldots, H$, the four branches represent nodes with a single nonzero innovation: $\epsilon^d_{t+h} = \pm A_d$ or $\epsilon^s_{t+h} = \pm A_s$, where $A_j = \alpha\sqrt{d}\,\sigma_j$ and $d = 2H$. All other future innovations at that node are zero. The central node has weight w_0 and each branch has weight w_c, giving $N = 4H + 1$ nodes in total. Branch heights are schematic.

$2d + 1$ nodes.

We index the central node by $i = 0$ and the $2d$ non-central nodes by $i = 1, \ldots, 2d$. Each non-central node i is characterized by the triple (s_i, j_i, a_i), with $s_i \in \{1, \ldots, H\}$ the horizon at which the innovation materializes, $j_i \in \{d, s\}$ its type, and a_i its amplitude. The resulting node set coincides with the 'fishbone'-shaped sparse innovation tree of Adjemian and Juillard (2025), illustrated in Figure B2: a central spine along which all future innovations are zero, with four branches at each horizon corresponding to positive and negative demand and supply innovations. Each branch perturbs a single future innovation, leaving all others at zero.[54]

Solving and aggregating conditional paths. Appealing again to the linearity of the economy's response to demand and supply shocks, we can write the projected path of any variable X conditional on node i—prior to enforcing the asymmetric policy rule—as

$$\mathbf{X}^{(i)}_{(t)} = \mathcal{F}\mathbf{X}_{(t-1)} + \sum_{k=d,s} d\mathbf{X}^k \epsilon^k_t + \mathcal{L}^{s_i}\, d\mathbf{X}^{j_i} a_i, \tag{B8}$$

where $\mathcal{L}^s$ denotes the delay operator that pads the IRF $d\mathbf{X}^k$ with s leading zeros. Relative to (B2), the additional term in (B8) captures the response to the innovation associated with node i, arriving at $t + s_i$. At the central node ($a_i = 0$), one recovers the perfect-foresight projection.

[54] We choose a scaled unscented transform with parameter α and scaling $\lambda = \alpha^2 d - d$ (Julier, 2002), which matches the first two moments of the joint Gaussian distribution exactly with $N = 4H + 1$ nodes: a central node at zero carrying weight $w_0 = \lambda/(d + \lambda) = 1 - 1/\alpha^2$, plus $2d$ axis-aligned perturbations with amplitude $\pm\alpha\sqrt{d}\,\sigma_j$, each carrying weight $w_c = 1/\big(2(d + \lambda)\big) = 1/(2\alpha^2 d)$. Our baseline sets $\alpha = 0.25$, which places the nodes at $\alpha\sqrt{d} = 1.22$ standard deviations at the horizon $H = 12$ ($d = 24$).

For each node i, we solve a separate LCP delivering auxiliary shocks $\tilde{\mathbf{Z}}_{(t)}^{m,(i)}$ imposing the alternative rule under the path associated with node i. We then approximate the expected auxiliary policy adjustment using the quadrature sum

$$\bar{\mathbf{Z}}_{(t)}^{m} = \sum_{i=0}^{N-1} w_i \, \tilde{\mathbf{Z}}_{(t)}^{m,(i)}, \tag{B9}$$

and update the projections $\mathbf{X}_{(t)}$ of all remaining variables from (B6) using time-t forecast revisions $\bar{\mathbf{Z}}_{(t)}^{m} - \mathcal{F}\bar{\mathbf{Z}}_{(t-1)}^{m}$. The resulting $\mathbf{X}_{(t)}$ becomes the anchor $\mathcal{F}\mathbf{X}_{(t-1)}$ for the next period's iteration, ensuring that projections are internally consistent across periods under the agents' finite-horizon expectations.

C Data on Worker Flows and Calibration of Labor Market Frictions

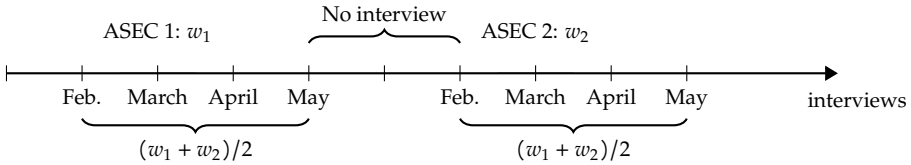


Figure C1: Graphical description of weekly earnings inference for individuals in our sample.

C.1 Sample Selection

We measure worker stocks and flows directly from the Basic Monthly Current Population Survey (CPS) from 1989 to 2019. We exclude 1995 because the Census Bureau scrambled the household identifiers in the public-use files for June through August of that year, so individuals in those months cannot be reliably matched to adjacent months, which prevents the measurement of worker flows (Drew et al., 2014). Our sample includes individuals between 25 and 59 years old and excludes retirees, members of the armed forces, the self-employed, government employees, and unpaid family workers. This selection leaves us with 17,104,781 person-month observations, or 47,513 per month on average, which we use to compute average worker stocks. Worker flows are computed from the 12,127,055 observations that can be matched to the same individual in the following month.

C.2 Measure of Skills

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 to 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 the 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 person-month observations on 942,546 individuals, or 21,264

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 C1: Average labor market flows computed from the CPS. **Left table:** averages using raw transition data. **Right table:** averages using data corrected for misclassification according to the approach described in Elsby et al. (2015). Entries are mean monthly transition rates, reported as fractions. Rows index origin states and columns destination states: employment (E), unemployment (U), and nonparticipation (N). The sample uses the Basic Monthly CPS for 1989–2019, covers individuals aged 25–59, and excludes self-employed, government, and unpaid family workers.

per month on average over the months in which merged observations are available.[55] Figure C1 summarizes our approach to assigning a weekly-earnings (hence skill) level to individuals in the sample.

C.3 Monthly 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.[56] The raw and corrected average worker flows are reported in Table C1.

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 C2 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-loss 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 far more likely to exit the labor force than

[55] 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 June to November are not in our sample.

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

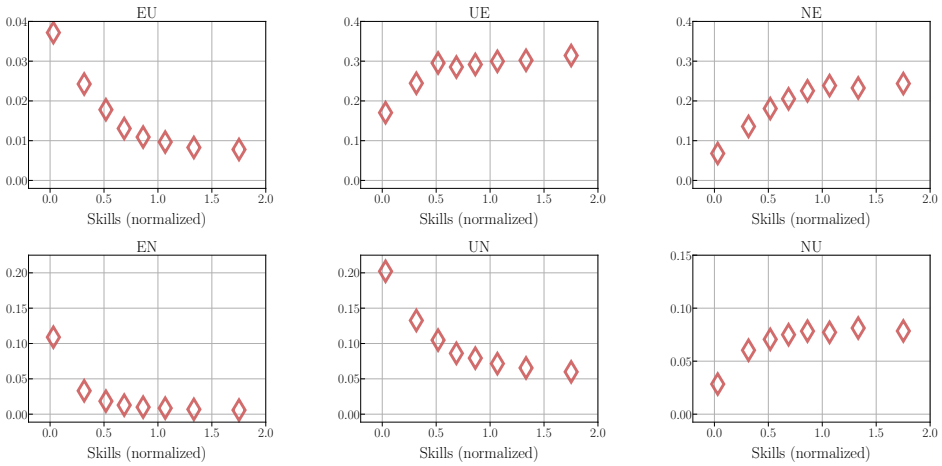


Figure C2: Monthly labor market transitions by skill.

Note. Diamonds show average monthly transition probabilities by decile of the pooled skill distribution, using the Basic Monthly CPS (1989–2019) linked to the ASEC. The sample covers individuals aged 25–59 and excludes self-employed, government, and unpaid family workers. Skills are measured by real weekly earnings relative to the cross-sectional average, so average skill level is normalized to 1 in our sample.

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

C.4 Job Separation and Job Finding Rates across the Skill Distribution

We parameterize the dependence of frictions on skills as:

$$\lambda^{ss'}(z) = \lambda_0^{ss'} + \lambda_1^{ss'} \exp(\lambda_2^{ss'} z) \qquad ss' \in \{eu, ue, ne\}, \tag{C1}$$

a specification where three parameters $\{\lambda_0^{ss'}, \lambda_1^{ss'}, \lambda_2^{ss'}\}$ capture the level and curvature of frictions with respect to z. We pin down these parameters in two steps.

Step 1: Shape. We use the data on EU and UE flows by weekly earnings from Figure C2 to estimate the *shape* of frictions along the skill distribution. Specifically, for $ss' \in \{eu, ue\}$, we estimate $\tilde{\lambda}_0^{ss'}, \tilde{\lambda}_1^{ss'}$, and $\tilde{\lambda}_2^{ss'}$ by minimizing the quadratic distance between the model and the observed transition probabilities at the empirical skill deciles. For the job-finding rate out of nonparticipation, we assume it shares the same shape as the job-finding rate out of unemployment—i.e., $\tilde{\lambda}_i^{ne} = \tilde{\lambda}_i^{ue}$ for $i = 0, 1, 2$. 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). The acceptance decisions of nonparticipants and time aggregation (a measured NE transition can actually be a within-period NU+UE) give rise to this

	Job-separation from E	Job-finding from U	Job-finding from N
$\lambda_0^{ss'}$	0.012	0.286	0.268
$\lambda_1^{ss'}$	0.064	-0.210	-0.196
$\lambda_2^{ss'}$	-2.143	-3.174	-3.174

Table C2: Estimates of the parameters $\{\lambda_0^{ss'}, \lambda_1^{ss'}, \lambda_2^{ss'}\}$ governing job-separation and job-finding frictions in (C1). The shape of each friction is estimated by minimum distance to the decile transition rates in Figure C2, and its level is then calibrated to average flows; the job-finding rate from N is assumed to share the shape of the rate from U. See Appendix C.4.

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.[57]

Step 2: Level. The calibration stage then adjusts the *level* of each friction to match our empirical targets for population average EU, UE, and NE flows. To do so, we scale the first-step estimates by a single shift parameter per transition:

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

for $ss' \in \{eu, ue, ne\}$. Because $c^{ss'}$ multiplies both $\tilde{\lambda}_0$ and $\tilde{\lambda}_1$ but leaves $\tilde{\lambda}_2$ unchanged, this level shift preserves the *relative* frictions faced by workers at different skill levels—i.e., the ratio $\lambda^{ss'}(z_1)/\lambda^{ss'}(z_2)$ for any z_1, z_2 is the same in the model and data. The resulting estimates are shown in Table C2.

C.5 Disutility Costs

Recall that we have two disutility states (H,L) and three employment states, thus six values in total. Without loss of generality, the flow utility of non-participation κ^n is normalized to zero in both states, so the fixed costs of searching and working should be interpreted relative to the utility cost of being out of the labor force. In addition, to keep a parsimonious representation, we assume that the high disutility state H raises the cost of work and search by a common amount $\bar{\eta} \equiv \kappa_H^e - \kappa_L^e = \kappa_H^u - \kappa_L^u > 0$. As a result, we have five parameters to calibrate: $\kappa_L^u, \kappa_L^e, \bar{\eta}$ and the transition probabilities across disutility states χ^{LH}, χ^{HL}. To pin down these parameters we target the following five moments: average EN, UN, and NU flows, and average participation rates in the bottom (T1) and top (T3) terciles of the earnings distribution.

[57] While UE transitions suffer from a similar issue, this is less of a concern 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, this wedge is unlikely to affect our estimation of job-finding rate $\lambda^{ue}(z)$.

	E			U			N		
	total	exo	endo	total	exo	endo	total	exo	endo
E		—		0.015	0.018	(-0.003)	0.012	0.000	(0.012)
U	0.204	0.230	(-0.026)		—		0.128	0.000	(0.128)
N	0.063	0.150	(-0.087)	0.003	0.000	(0.003)		—	

Table C3: Decomposition of steady-state worker flows into exogenous and endogenous components.

Notes: Monthly transition rates across employment (E), unemployment (U), and nonparticipation (N) in the model's stationary equilibrium; rows denote origin states, columns destination states. For each transition, *total* is the equilibrium flow; *exo* is the flow that would obtain if workers made no participation decisions, so that every separated worker enters unemployment and every job offer is accepted; *endo*, in parentheses, is total minus exo and captures participation choices. Negative values indicate that choices offset part of the mechanical flow.

C.6 Endogenous vs Exogenous Contribution of Flows

To get at the contribution of exogenous frictions and endogenous decisions to each labor market flow, we decompose each flow (EU, UE, NE, EN, UN, NU) into two components. The *exogenous* component measures what each flow would be if workers made no active participation decisions—that is, if all separated workers transitioned mechanically into unemployment and all (unemployed, non-participant) workers who received a job offer accepted it. The *endogenous* component, defined as the residual between observed and exogenous flows, captures the role of choices: workers who reject job offers, and workers who voluntarily enter or exit participation.

Table C3 summarizes our findings. Not surprisingly, the endogenous participation component accounts for all observed EN, UN, and NU flows. Interestingly, however, we find that the participation margin also shapes the dynamics of EU, UE, and NE flows, which are more commonly associated with the behavior of job-finding and separation rates. In particular, the participation margin lowers UE and NE relative to the raw offer-arrival rate as some unemployed workers and nonparticipants decline offers. For instance, using the rounded table entries, we find that approximately 11.30%—$(0.230 - 0.204)/0.230$—of unemployed workers who receive a job offer reject it. The participation margin also diverts a portion of the job separations from U to N as marginal workers choose to exit the labor force rather than transitioning into unemployment. We find that 16.67%—$(0.018 - 0.015)/0.018$—of workers who are laid off leave the labor force instead of remaining unemployed.

The presence of these layoff-induced exits is consistent with evidence from Graves et al. (2023) and Ellieroth and Michaud (2024), which show that a large share of EN transitions stems from layoffs rather than direct quits from employment. In general, these layoff-induced exits are very informative about the participation of marginally attached workers since they correspond to the set of individuals who would remain in the labor market if they could keep their jobs, but opt to drop out of participation once they are laid off. Returning to Figure 1, these are workers who find themselves in between the participation regions for the employed and the unemployed when they lose a job.

D Untargeted Moments

	Data	Model
Cross-sectional earnings variance (age 25)[1]	0.595	0.523
Cross-sectional earnings variance (age 55)[1]	0.905	1.070
Standard dev. of one-year earnings change[1]	0.510	0.376
Skewness of one-year earnings change[1]	-1.070	-0.201
Kurtosis of one-year earnings change[1]	14.930	8.844
10-Year earnings losses full-year non-emp. (p25)[2]	-0.500	-0.564
10-Year earnings losses full-year non-emp. (p75)[2]	-0.300	-0.305
10-Year earnings losses during recessions[3]	-0.153	-0.127
10-Year earnings losses during expansions[3]	-0.087	-0.077
Unemployment Rate on Entry Impact on Log-Earnings 1-Year Ahead[4]	-0.041	-0.052
Unemployment Rate on Entry Impact on Log-Earnings 5-Year Ahead[4]	-0.023	-0.017

	Data	Model	Data	Model
	Standard dev.		Correlation	
Employment[5]	2.81	2.69	0.98	0.99
Labor Force Participation[5]	1.38	1.32	0.77	0.88
Unemployment rate[5]	29.74	28.26	-0.91	-0.98
EU[5]	15.91	16.32	-0.82	-0.91
UE[5]	18.25	19.50	0.88	0.88
NE[5]	8.89	8.97	0.84	0.73
EN[5]	6.18	5.09	0.51	0.14
UN[5]	13.25	15.43	0.78	0.97
NU[5]	17.28	91.92	-0.73	-0.92

Table D1: Untargeted moments: empirical estimates and baseline-model counterparts.

Note: [1]Guvenen, Karahan, Ozkan, and Song (2021); [2]Guvenen, Karahan, Ozkan, and Song (2017); [3]Davis and von Wachter (2011); [4]Schwandt and von Wachter (2019); [5]Data are 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 from the CPS. Labor market transition rates are constructed using "deNUNified" data as in Elsby et al. (2015). See Appendix C for a detailed description of our data, sample selection and "deNUNification" procedure. All series are in log and are detrended using a linear trend. Correlations are with total hours.

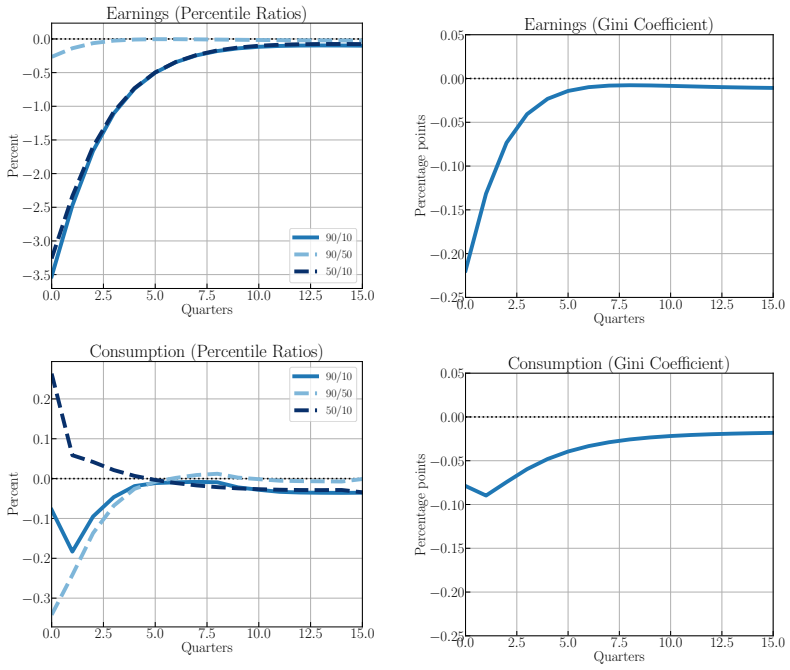


Figure D1: Earnings and consumption inequality responses to a monetary policy shock.

Note. The panels show model impulse responses to an expansionary monetary policy shock. The shock is calibrated to lower the unemployment rate by 0.35 ppt on impact—the midpoint of the shocks identified by Coibion et al. (2017) and Chang and Schorfheide (2024). The top row reports earnings inequality among labor market participants, including zero earnings; the bottom row reports consumption inequality over the full population. Left panels show percentage changes in the 90/10 (solid blue), 90/50 (dashed light blue), and 50/10 (dashed dark blue) percentile ratios. Right panels show changes in Gini coefficients in percentage points.

Comparison with the evidence. For more direct comparability with the literature, we set the size of the shock so that unemployment moves by 0.35 percentage points, the midpoint of estimates in Coibion et al. (2017) and Chang and Schorfheide (2024). To match each study's measurement convention, earnings inequality is computed over labor market participants and includes zero earnings (Chang and Schorfheide, 2024), while consumption inequality is computed over the full population (Coibion et al., 2017).

The model's responses are, overall, in line with the empirical evidence: Chang and Schorfheide (2024) report that a 25 bp expansionary monetary-policy shock reduces the earnings 90–10 ratio by approximately 4% after 36 months and the earnings Gini by 0.10–0.30 points on a 0–100 scale, while Coibion et al. (2017) find a reduction in the consumption 90–10 ratio of about 0.15% following an expansionary shock. The consumption Gini decline in Coibion et al. (2017) is an order of magnitude larger (1–2 percentage points) than our model estimate. Our consumption Gini response is more aligned with Chang and Schorfheide (2024), who find approximately zero median Gini responses for nondurable consumption and services following an expansionary monetary-policy shock.

E From RANK to HANK Augmented by Okun's Hypothesis

As explained in the main text, our baseline model includes four additional ingredients relative to the baseline RANK model: market incompleteness (hence heterogeneous MPCs and precautionary saving motives), uneven exposure to aggregate shocks, endogenous labor force participation decisions, and skill scarring effects during non-employment.

Because all four ingredients operate simultaneously, and feed back on one another, it is hard to distinguish the contribution and importance of each individual channel to our main results. We therefore solve for counterfactual economies that shut the ingredients down one at a time. Our starting point is a representative-agent benchmark with none of Okun's ingredients (RANK). The model retains its idiosyncratic productivity and employment risk, but such risk is fully insured by a representative family planner that pools income across its members—who all supply labor to the unions—and allocates the same consumption to everyone. To this model we add each ingredient one at a time: model HA (+ market incompleteness), model HA-E (+ heterogeneous exposure), model HA-ES (+ scarring), and finally the baseline, which activates all four.[58] We recalibrate every economy in the sequence so that all of them meet the same steady-state targets as the baseline.

We put this sequence of models through two exercises. In Section E.1, we hit every economy with a single common demand shock in order to isolate differences in propagation across the different models. Since all economies share the same linearized wage Phillips curve (14), differences in the IRF reflect only differences in the demand-side transmission of the shocks. In Section E.2, we hold the business-cycle targets fixed across models, and compute the ergodic distribution.

E.1 IRF to a Common Demand Shock

Figure E1 plots the impulse responses to a negative demand shock under the IT rule with the ZLB in all five economies. Each successive layer amplifies the aggregate labor market responses. Market incompleteness alone raises the impact response of the unemployment rate from 0.6pp in the RANK economy to 0.8pp. From there, each additional Okun mechanism contributes to an even stronger response: unemployment goes up by 0.9pp with heterogeneous exposure (model HA-E), 1.1pp with scarring added (HA-ES), and 2.1pp in the baseline where all four ingredients are present simultaneously.

The bottom-tercile (T1) earnings responses reveal substantial differences in the persistence of recession-induced losses across economies. Ten years after the shock, earnings have approximately returned to their steady-state levels in the RANK, HA, and HA-E economies. The same

[58] The contribution of each ingredient depends on which others are active. We therefore also consider model HA-EP, which retains participation and heterogeneous exposure but excludes scarring. Comparing HA-EP with HA-E measures the change associated with adding participation without scarring. Comparing the baseline with HA-EP measures the role of scarring.

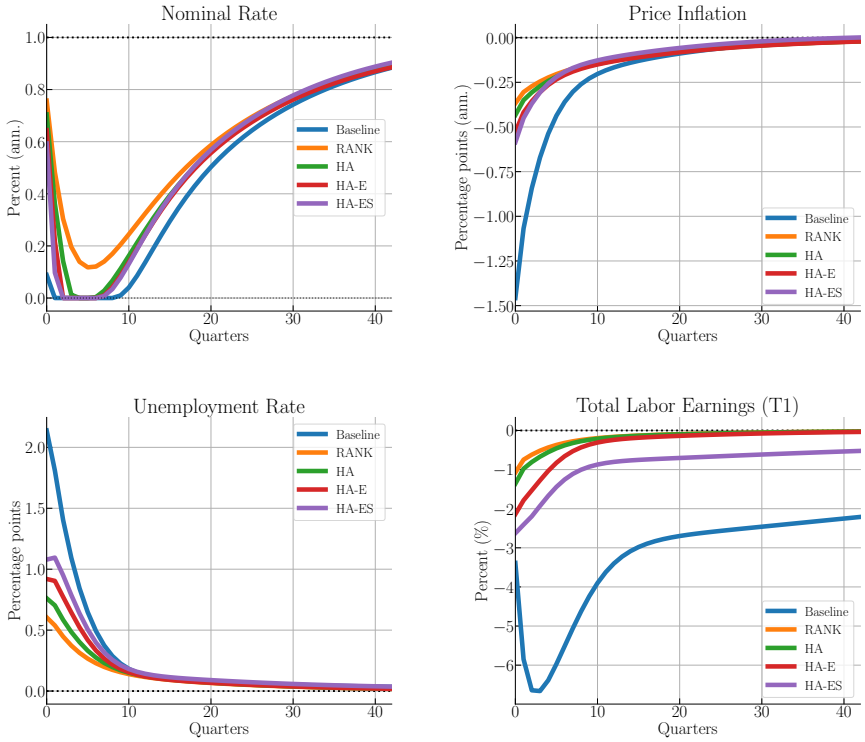


Figure E1: Impulse responses to an identical demand shock across nested economies.

Note. Response to a one-time negative demand shock of equal size in every economy, under the IT rule with the ZLB. Panels: nominal rate (dotted line marks the ZLB), price inflation, unemployment rate, and bottom-tercile gross labor income. Lines: Baseline, RANK, HA, HA-E, and HA-ES.

is true in the HA-EP economy, which adds participation to heterogeneous exposure (not shown in the figure). In HA-ES, which adds scarring to heterogeneous exposure, earnings remain about 0.5% below steady state. The corresponding loss in the baseline is roughly four times as large, at 2.2%. This exercise establishes that the hysteresis at the bottom emerges from the interaction of heterogeneous exposure, skill scarring, and participation.[59]

E.2 Ergodic Distribution

We now recalibrate each HANK economy to match the same aggregate business-cycle targets as the baseline.[60] For each economy, Table E1 reports the ergodic earnings bias at the bottom tercile (T1) under IT and LfL, mirroring the ergodic distribution exercises of Sections 4.3 and 5.3.[61]

In Model HA-E, where heterogeneous exposure is the only active Okun channel, the magnitude of the average earnings bias under IT is about 10% of the baseline bias. Adding participation

[59] IRFs to supply shocks (not shown here) confirm this result.

[60] The RANK economy is not re-calibrated: it runs with the shock process of Model HA. We report it in Table E1 for reference but exclude it from the channel decomposition below.

[61] We follow the same simulation strategy as in the baseline of Section 4.3 for all four alternative HANK economies.

	RANK	HA	HA-E	HA-EP	HA-ES	Baseline
Channels/Ingredients						
Market incompleteness		X	X	X	X	X
+exposure			X	X	X	X
+scarring					X	X
+participation				X		X
IT outcomes						
Price inflation	-0.079	-0.247	-0.173	-0.323	-0.018	-0.170
Unemployment rate	0.174	0.593	0.445	0.638	0.585	0.528
T3 Total labor earnings	-0.238	-0.811	-0.367	-0.705	-1.162	-1.714
T1 Total labor earnings	-0.252	-0.858	-0.904	-1.985	-3.788	-8.997
T3–T1 Total labor earnings	0.014	0.047	0.537	1.280	2.626	7.283
LfL outcomes						
Price inflation	0.249	0.274	0.287	0.280	0.301	0.250
Unemployment rate	-0.170	-0.199	-0.265	-0.159	-0.262	-0.146
T3 Total labor earnings	0.232	0.271	0.219	0.117	0.490	0.431
T1 Total labor earnings	0.246	0.287	0.539	0.464	1.583	3.845
T3–T1 Total labor earnings	-0.013	-0.016	-0.320	-0.348	-1.093	-3.414

Table E1: Nested economies: decomposing Okun's channels

Note. Ergodic means under inflation targeting (IT) and Lower for Longer (LfL), with the ZLB imposed, are reported as deviations from each economy's non-stochastic steady state. T1 and T3 denote the bottom and top terciles of the skill distribution. X indicates that the ingredient is present. The HANK economies are recalibrated to the baseline aggregate business-cycle targets. RANK uses the shock process of Model HA without recalibration to those targets. Comparisons across economies incorporate general-equilibrium effects; channel contributions need not be additive and can depend on the order in which ingredients are introduced.

(Model HA-EP) or skill scarring (HA-ES) raises this share to approximately 22% and 42%, respectively. The two single-channel economies together account for less than two thirds of the baseline bias, even though that sum counts exposure twice; the rest arises only when all three channels operate jointly.

The same logic explains LfL inclusion gains at the bottom. Switching from IT to LfL narrows the top–bottom tercile gap by approximately 0.9 percentage points when heterogeneous exposure is the only active Okun channel (HA-E). The reduction rises to 1.6 points with participation only (HA-EP), 3.7 points with skill scarring only (HA-ES), and 10.7 points when all three channels operate jointly. Once again, the complementarity in the effects of the three mechanisms is central in generating hysteresis at the bottom of the distribution.

F Additional Results on the LfL Rule

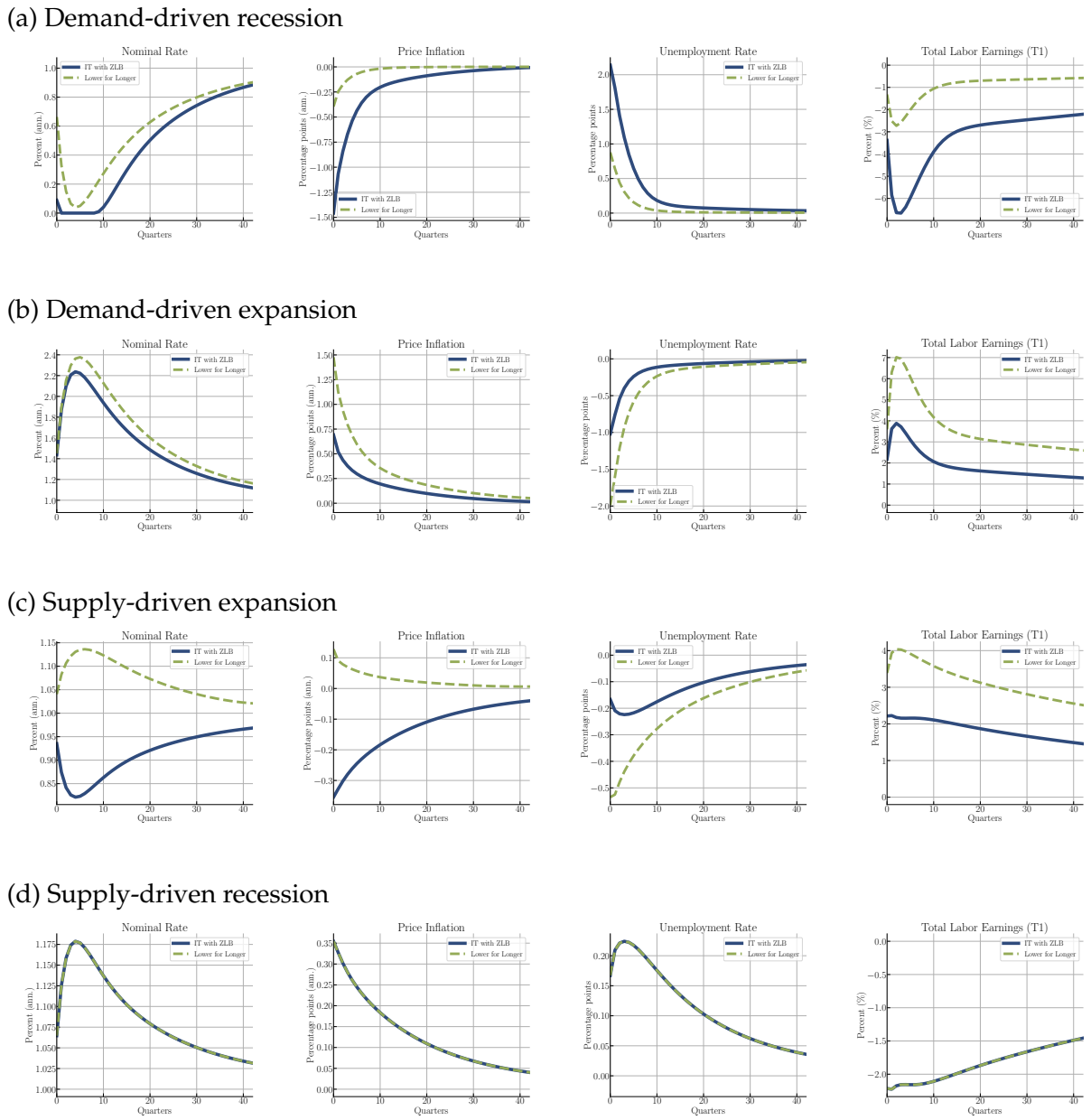
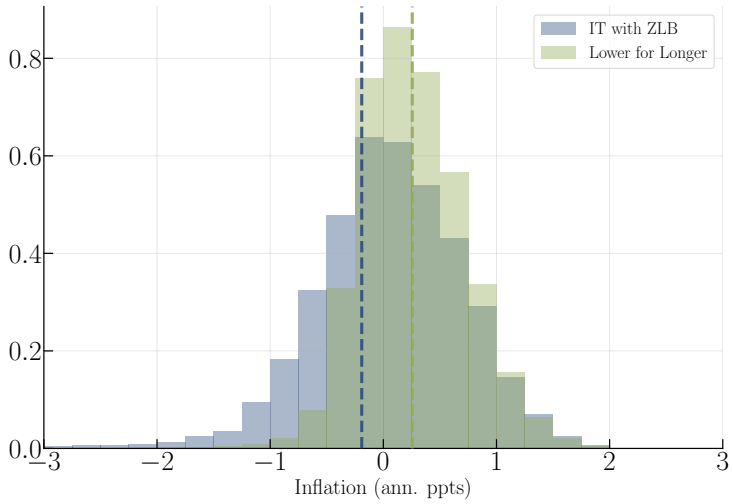


Figure F1: Impulse responses to demand and supply shocks under IT and LfL.

Note. Columns show the nominal interest rate, price inflation, unemployment rate, and total labor earnings of the bottom skill tercile (T1). Solid blue lines denote IT with the ZLB; dashed green lines denote LfL. Responses are deviations from the non-stochastic steady state: interest rates and inflation in annualized percentage points, unemployment in percentage points, and earnings in percent. Horizontal axes show quarters after the shock.



(a) Ergodic distribution of inflation

	IT	LfL
Share of quarters		
$\pi \leq -1$	9.30	0.80
$\pi \in (-1, 0]$	37.41	29.52
$\pi \in (0, 1]$	46.85	63.55
$\pi > 1$	6.44	6.13
Distribution		
p10	-1.28	-0.15
p90	0.91	0.95
mean	-0.17	0.25

(b) Bin shares, tails, and moments

Figure F2: Ergodic distributions of inflation under Inflation Targeting with the ZLB (blue) and the Lower for Longer rule (green).

Note. **Panel (a):** histograms of inflation, expressed in ppt deviations from the non-stochastic steady state and truncated at ±3 ppt, so that zero on the horizontal axis marks the steady-state value. Dashed vertical lines denote the ergodic mean of each distribution. **Panel (b):** share of quarters (in percent) falling in each inflation bin, the mass in the two tails $\pi \leq -1$ and $\pi > 1$, and the 10th percentile, 90th percentile, and mean of each distribution, all in ppt deviations from the non-stochastic steady state, that is, from the inflation targeting economy without the lower bound.

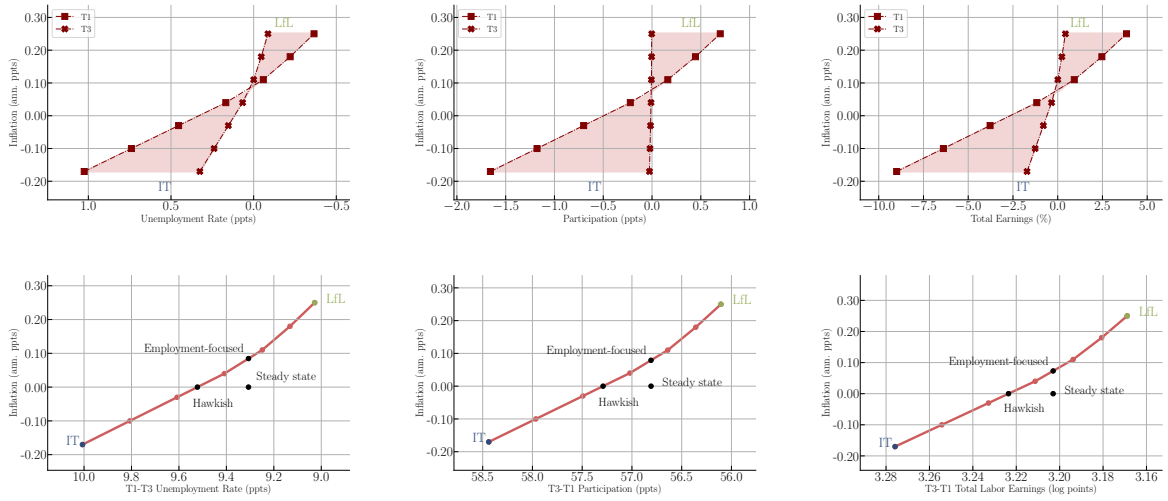


Figure F3: Okun's cones and inflation–inclusion trade-offs: unemployment, participation, and earnings.

Note. As in Figure 9, each marker corresponds to a parameterization of the LfL rule along the sweep from the IT benchmark to the headline LfL calibration (Section 5.4); all values are averages over the ergodic distribution. Columns show unemployment, participation, and total labor earnings, respectively. All vertical axes show annualized inflation in percentage-point deviations from its target. **Top row:** horizontal axes show outcomes for the bottom (T1, squares) and top (T3, crosses) terciles of the skill distribution, expressed as deviations from the non-stochastic steady state: unemployment and participation in percentage points, and earnings in percent. **Bottom row:** horizontal axes show the T1–T3 unemployment differential and the T3–T1 participation differential, both in percentage points, and the T3–T1 differential in log total labor earnings. These differentials are shown in levels, not deviations from their steady-state values; each horizontal axis decreases to the right. Black dots mark the non-stochastic steady state, the zero-inflation-bias parameterization ("Hawkish"), and the parameterization that restores the steady-state differential ("Employment-focused").

Methodology. To obtain the plots in Figure 9 and in this figure, we index the LfL family by a scalar $\lambda \in [0, 1]$ that scales the make-up response to inflation shortfalls up to $\lambda\,\beta_{AIT}$, with $\beta_{AIT} = 8.00$, and the response to unemployment below steady state down to $(1 - \lambda)\,\beta_u$, so that $\lambda = 0$ recovers the IT benchmark and $\lambda = 1$—which switches the latter off entirely—delivers the headline LfL parameterization of Section 5.3. For each value of λ we re-solve the model and simulate its ergodic distribution.

	Baseline	ZLB variants			Monetary rule		Fiscal rule		Limited understanding	
	(1)	$i^* = 1.00\%$ (2)	$i^* = 0.50\%$ (3)	Regime switching (4)	$\beta_u = -0.05$ (5)	$\beta_\pi = 2.75$ (6)	Tax adjustment (7)	Slow debt adjustment (8)	$\theta = 0.25$ (9)	$\theta = 0.75$ (10)
IT outcomes										
Boom frequency (%)	2.1	2.7	1.7	2.9	8.9	3.3	2.6	2.3	2.1	2.1
Recession frequency (%)	14.0	9.8	21.7	12.7	28.8	14.2	10.3	10.1	14.0	14.0
ZLB frequency (%)	15.2	10.0	22.2	15.1	25.2	14.7	14.3	15.7	15.2	15.2
Median ZLB duration	5	5	6	12	7	5	5	5	5	5
Mean ZLB duration	8.5	7.1	10.2	11.1	13.1	8.4	7.1	7.2	8.5	8.5
Unemployment rate at the ZLB	3.050	2.507	3.884	4.599	4.068	2.762	1.607	1.478	3.050	3.050
Price inflation	-0.170	-0.092	-0.292	-0.201	-0.447	-0.165	-0.088	-0.116	-0.170	-0.170
Unemployment rate	0.528	0.284	0.967	0.682	1.012	0.451	0.253	0.261	0.528	0.528
T3 Total labor earnings	-1.714	-0.896	-3.320	-2.252	-2.892	-1.412	-0.716	-0.852	-1.714	-1.714
T1 Total labor earnings	-8.997	-4.699	-17.590	-11.674	-15.044	-7.376	-6.417	-3.519	-8.997	-8.997
T3–T1 Total labor earnings	7.283	3.804	14.271	9.422	12.152	5.964	5.701	2.667	7.283	7.283
LfL outcomes										
Boom frequency (%)	16.4	16.6	16.2	10.5	17.9	14.9	15.2	14.5	16.0	22.8
Recession frequency (%)	6.4	5.3	9.9	7.6	12.7	7.5	6.1	5.5	13.0	11.3
ZLB frequency (%)	6.6	3.3	12.6	12.4	11.8	6.6	7.4	7.1	31.7	19.2
Median ZLB duration	5	4	5	10	5	4	4	4	9	7
Mean ZLB duration	6.0	5.0	7.7	9.2	7.7	5.8	6.0	5.9	17.5	12.2
Unemployment rate at the ZLB	1.144	1.120	1.579	1.606	1.282	1.172	0.852	0.694	0.929	1.305
Price inflation	0.250	0.268	0.204	0.081	0.151	0.196	0.242	0.248	-0.120	0.001
Unemployment rate	-0.146	-0.178	-0.031	-0.056	-0.045	-0.103	-0.141	-0.137	0.242	0.005
T3 Total labor earnings	0.431	0.521	0.114	0.166	0.131	0.303	0.336	0.412	-0.805	-0.080
T1 Total labor earnings	3.845	4.332	2.244	1.398	1.805	2.847	5.235	3.321	-4.414	-0.381
T3–T1 Total labor earnings	-3.414	-3.811	-2.131	-1.232	-1.674	-2.544	-4.899	-2.908	3.609	0.301

Table G1: Robustness of the ergodic distribution.

Note. The two panels report ergodic outcomes under inflation targeting (IT) and Lower for Longer (LfL), with the ZLB imposed. Each column uses the variant indicated in its heading. Aggregate-shock processes retain their baseline specification except in the regime-switching experiment, which replaces the Gaussian innovations with a three-state demand process. The lower- and higher-ZLB columns (columns 2 and 3) vary the liquidity premium to set the annualized steady-state nominal rate i^* to 1.00% and 0.50%, respectively, versus 0.75% in the baseline (column 1). The monetary-rule variants (columns 5 and 6) change β_u from -0.15 to -0.05 or β_π from 2.25 to 2.75. Tax adjustment (column 7) uses the labor income tax rate rather than government spending to stabilize debt, with adjustment coefficient 0.10; slow debt adjustment (column 8) lowers β_B from 0.10 to 0.02. In the final two columns (9 and 10), agents discount policy news associated with departures from IT at horizon h quarters by θ^h. IT outcomes are identical in columns (1), (9), and (10), because limited understanding applies only to departures from IT.

G Robustness Analysis

This section examines the robustness of our two headline findings: substantial scarring in the bottom tercile under IT and inclusion gains under LfL. We vary the frequency and duration of ZLB episodes, monetary and fiscal policy rules, and agents' understanding of the LfL rule.[62] For each perturbation, we recompute the ergodic distributions under IT and LfL and report the resulting inflation, unemployment, and earnings biases in Table G1. Except in the regime-switching exercise, we hold the aggregate-shock processes fixed at their baseline values, so differences from the baseline reflect the modeling change under study.

G.1 Frequency and duration of ZLB episodes

We first assess the sensitivity of our results to the share of time the economy spends at the ZLB. We vary the bond liquidity premium $\bar{\iota}$, holding the aggregate-shock processes and the remaining

[62] Robustness with respect to the three Okun channels is examined in Appendix E.

structural parameters fixed, to generate economies with lower and higher ZLB frequencies than in the baseline. Table G1 (columns 2 and 3) shows that, as the share of time spent at the ZLB rises from 10.0% to 22%, mean bottom-tercile earnings under IT fall from 4.7% to 17.6% below their respective deterministic steady-state levels. The corresponding inclusion gains from LfL—the differences between the LfL and IT earnings biases—rise from 9.0 to 19.8 percentage points.

Next, we change the stochastic process of our aggregate shocks. Dordal-Carreras et al. (2016) emphasize that AR(1) shock processes calibrated to match the empirical ZLB frequency generate too many short spells relative to the data. Because scarring in our model accumulates during prolonged unemployment, the duration of ZLB episodes matters for earnings hysteresis at the bottom of the distribution. We therefore replace the AR(1) demand shock with a three-state regime-switching process. The demand shock ζ_t^d takes values

$$\zeta_t^d = \begin{cases} -\bar{\zeta}_B & \text{in state } B \text{ (“boom”)}, \\ 0 & \text{in state } N \text{ (“normal”)}, \\ +\bar{\zeta}_R & \text{in state } R \text{ (“recession”)}, \end{cases} \tag{G1}$$

where $\bar{\zeta}_B, \bar{\zeta}_R > 0$. Only exits from the normal state are stochastic: while in state N, the economy transitions to B or R through two competing Poisson processes with arrival rates $\lambda_B, \lambda_R > 0$. Boom and recession regimes last for deterministic durations of T_B and T_R periods, respectively, after which the economy returns to N.

We use a symmetric specification. Booms and recessions have the same magnitude, $\bar{\zeta}_B = \bar{\zeta}_R = 0.0012$ in monthly rate units, and the same duration, $T_B = T_R = 12$ quarters. The arrival rates out of the normal state are also symmetric, $\lambda_B = \lambda_R = 0.0068$ per month, so that a normal spell lasts about six years on average. The Gaussian demand and supply innovations are switched off in this experiment, so aggregate fluctuations are driven by the regime-switching demand process alone.

Column 4 of Table G1 shows that the regime-switching economy spends essentially the same share of time at the ZLB as the baseline (around 15%), but its spells are longer on average and more concentrated around their typical duration. They last 11.1 quarters on average, with a median of 12, compared with a baseline mean of 8.5 quarters and a median of 5. Conditional on the ZLB binding, unemployment is also further above its steady-state level: 4.6 percentage points, compared with 3.1 in the baseline.

These longer and more severe spells are associated with larger biases under IT: the unemployment bias rises from 0.53 to 0.68 percentage points, the deflation bias from 0.17 to 0.20 percentage points, and the bottom-tercile earnings shortfall from 9.0% to 11.7% of deterministic steady-state earnings.

Importantly, the LfL strategy remains an effective antidote to IT’s bottom hysteresis. Relative to IT, LfL lifts mean bottom-tercile earnings to 1.4% above steady state, delivering an inclusion gain of 13.1 percentage points—essentially the same as in the baseline. The mechanism is also

similar: LfL reduces the ZLB share from 15.1% to 12.4%, shortens average spells from 11.1 to 9.2 quarters, and raises the boom frequency from 2.9% to 10.5%.

G.2 Fiscal and Monetary Policy Rules

The strength of the policy reaction to inflation and unemployment governs how often and how long the economy is at the ZLB and, therefore, the recessionary skew underlying the bottom-tercile bias.

With respect to monetary policy, we consider two separate perturbations of the IT rule: increasing the inflation-response coefficient from 2.25 to 2.75, and weakening the unemployment response by changing its coefficient from -0.15 to -0.05.

Turning to fiscal policy, the choice of fiscal instrument matters in HANK models because it determines who bears the burden of stabilizing government debt: a spending rule triggers indirect general equilibrium effects that matter more at the bottom of the skill distribution, whereas a tax rule places more burden of the adjustment at the top of the skill distribution. We consider two perturbations of the baseline fiscal rule (spending adjustment): (i) a tax rule, in which the labor income tax rate τ stabilizes debt instead of government spending G; and (ii) slow debt adjustment, a lower adjustment speed β_B, which provides more fiscal accommodation in recessions.

Across all four variants (Table G1, columns 5–8), both headline findings survive. A weaker unemployment response amplifies the bottom-tercile bias under IT, while a stronger inflation response dampens it. The first result echoes Gornemann et al. (2022), who show in a HANK model with search frictions that systematic unemployment stabilization benefits households that rely mostly on labor income, because it reduces the countercyclical labor-market risk they bear. In their setting, stabilizing unemployment comes at the expense of price stability; here, the presence of the ZLB is deflationary, so a stronger response to either inflation or unemployment mitigates it and the two strategies work in the same direction.

The largest attenuation, however, occurs under slow debt adjustment, highlighting the quantitative importance of fiscal policy. Greater fiscal accommodation in recessions reduces the magnitude of the bottom-tercile earnings bias under IT by about 60% and the inclusion gain from adopting LfL by about half. Fiscal accommodation thus acts as a partial substitute for monetary accommodation: by mitigating earnings losses already under IT, it reduces the additional inclusion gains that LfL can deliver.

G.3 Limited Understanding of LfL

The ability of LfL to limit scarring at the ZLB rests partly on households and firms anticipating future policy accommodation. Limited understanding of these commitments, or doubts about their implementation, can substantially weaken this expectations channel (Hebden et al., 2020; Dobrew et al., 2025).

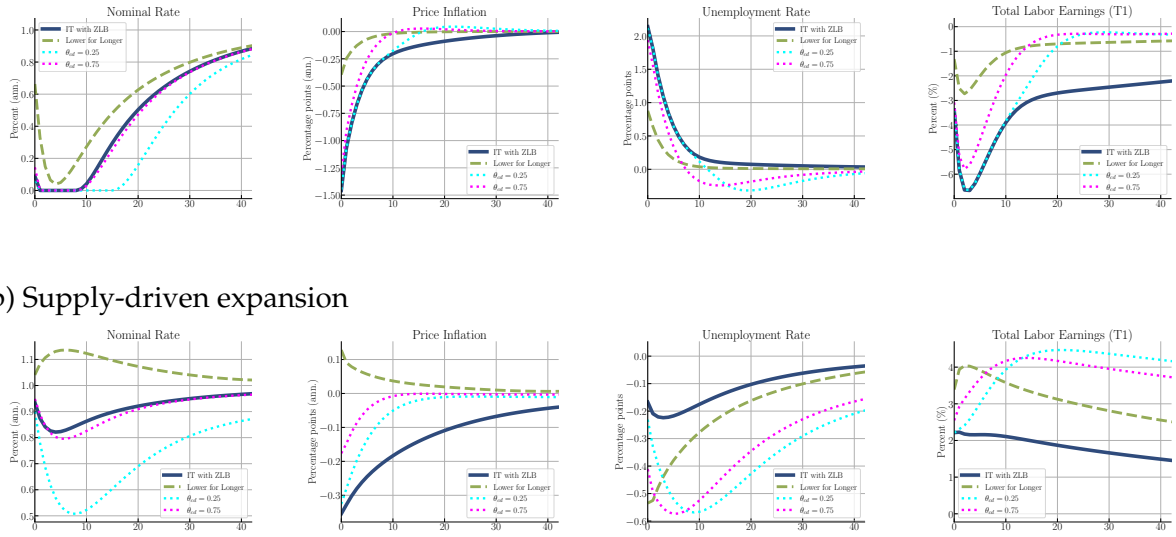


Figure G1: Impulse responses under full and limited understanding of LfL.

Note. The top row shows a demand-driven recession; the bottom row shows a supply-driven expansion. Columns report the nominal interest rate, price inflation, unemployment rate, and total labor earnings of the bottom skill tercile (T1). Solid blue lines denote IT with the ZLB; dashed green lines denote LfL with full understanding. Dotted cyan and magenta lines denote LfL with limited understanding at $\theta = 0.25$ and $\theta = 0.75$, respectively. Agents discount perceived monetary policy news associated with departures from IT by θ^h at horizon h quarters; full understanding corresponds to $\theta = 1$. The panel legends denote this parameter by θ_{cd}. Responses are deviations from the non-stochastic steady state: interest rates and inflation in annualized percentage points, unemployment in percentage points, and earnings in percent. Horizontal axes show quarters after the shock.

Evidence on households' understanding of makeup commitments is mixed. Coibion et al. (2023) find that the Federal Reserve's 2020 announcement of average inflation targeting left U.S. household expectations essentially unchanged. Even households directly informed about AIT revised their expectations no differently from those informed about traditional inflation targeting. In an experiment studying a hypothetical regime change in Germany, however, Hoffmann et al. (2022) find that households significantly raise their inflation expectations following below-target inflation, consistent with the intended effect of AIT.

We model limited understanding by discounting agents' perceived monetary policy news associated with departures from IT by a factor θ^h at horizon h quarters. Full understanding corresponds to $\theta = 1$; lower values imply stronger discounting of future commitments. We consider $\theta \in \{0.25, 0.75\}$ as sensitivity cases—which imply anticipation of approximately 0.004 and 0.316, respectively, at a one-year horizon.[63] Appendix B.6 describes the implementation of the limited understanding simulation.

[63] The empirical findings motivate exploring different degrees of understanding but do not provide a direct calibration of θ.

Impulse responses. Figure G1 compares responses to demand and supply shocks under IT, LfL with full understanding, and the two discounting cases. In the demand-driven recession in the top row, limited understanding leaves the initial inflation and unemployment responses close to IT. The weaker anticipated stimulus induces more persistent accommodation ex post, with rates remaining low for longer than under full understanding. As this accommodation accumulates, unemployment falls below and inflation rises above their IT counterparts, and earnings gains emerge with a delay.

The supply-driven expansion in the bottom row also features more persistent accommodation under limited understanding. Earnings gains build more gradually than under full understanding, while the expansion lasts longer.

Ergodic distribution. Under limited understanding, LfL increases the ZLB frequency relative to IT: weaker forward guidance requires rates to remain low for longer following recessions to provide accommodation. This persistent accommodation continues to sustain expansions, with boom frequency rising from 2.1% under IT to 16.0% at $\theta = 0.25$ and 22.8% at $\theta = 0.75$ under LfL (Table G1). By sustaining these expansions, LfL continues to deliver substantial inclusion gains: the bottom-tercile earnings bias shrinks from -9.0% under IT to -4.4% at $\theta = 0.25$ and -0.4% at $\theta = 0.75$ under LfL, compared with $+3.85\%$ under fully understood LfL. Limited understanding therefore attenuates—but does not eliminate—the inclusion gains from following a LfL rule.

H Alternative Monetary Policy Rules

Rule	*Specification* $\mathcal{R}_t$
IT (Inflation Targeting)	$\mathcal{R}_t = +2.25\,(\pi_t - \pi^*) + \beta_u\,(u_t - u^*)$
LfL (Lower for Longer)	$\mathcal{R}_t = +2.25\,(\pi_t - \pi^*) + \beta_{AIT}\,(\pi_t^{MA} - \pi^*)^- + \beta_{SR}\,(u_t - u^*)^+$
(i) Components of the Lower-for-Longer rule	
SR (Shortfall Rule)	$\mathcal{R}_t = +2.25\,(\pi_t - \pi^*) + \beta_{SR}\,(u_t - u^*)^+$
AIT (Asymmetric AIT)	$\mathcal{R}_t = +2.25\,(\pi_t - \pi^*) + \beta_{AIT}\,(\pi_t^{MA} - \pi^*)^- + \beta_u\,(u_t - u^*)$
(ii) Symmetric strategies for the ZLB	
HIGHIT (Higher Inflation Target)	$\mathcal{R}_t = +2.25\,(\pi_t - \pi^{**}) + \beta_u\,(u_t - u^*), \qquad i^{**} - i^* = \pi^{**} - \pi^*$
SYMAIT (Symmetric AIT)	$\mathcal{R}_t = +2.25\,(\pi_t - \pi^*) + \beta_{AIT}\,(\pi_t^{MA} - \pi^*) + \beta_u\,(u_t - u^*)$
(iii) Rules targeting the bottom of the skill distribution	
INCL-U (Targets Bottom Unemployment)	$\mathcal{R}_t = +2.25\,(\pi_t - \pi^*) + \beta_{T1}\,(u_t^{T1} - u^{T1,*})$
INCL-P (Targets Bottom Participation)	$\mathcal{R}_t = +2.25\,(\pi_t - \pi^*) + \beta_u\,(u_t - u^*) + \beta_P\,(P_t^{T1} - P^{T1,*})$

Table H1: Monetary policy rules traced out along the inflation–inclusion frontier.

Note. π_t is price inflation and π^* the central bank's inflation target, equal to steady-state inflation. u_t is the aggregate unemployment rate; u_t^{T1} and P_t^{T1} are the unemployment and participation rates of workers in the bottom tercile of the skill distribution. Starred values denote steady-state counterparts. π_t^{MA} is the exponential moving average of past inflation with smoothing factor $1/48$, $\pi_t^{MA} = (1 - 1/48)\,\pi_{t-1}^{MA} + 1/48\,\pi_t$, so that it averages inflation over a window of roughly 4 years. $X^+ \equiv \max\{X, 0\}$ and $X^- \equiv \min\{X, 0\}$. In HIGHIT, $\pi^{**} > \pi^*$ is the higher inflation target and i^{**} the associated steady-state nominal rate.
Each rule specifies the reaction component $\mathcal{R}_t$. The policy rate i_t adjusts toward $i^* + \mathcal{R}_t$ ($i^{**} + \mathcal{R}_t$ under HIGHIT) at speed $\beta_i = 0.07$ per month, subject to the zero lower bound $i_t \geq 0$. Throughout, $\beta_\pi = 2.25$ and $\beta_u = -0.15$, as in Table 2. The remaining coefficients ($\beta_{AIT}, \beta_{SR}, \beta_{T1}, \beta_P$) and the target π^{**} are swept to trace each rule's frontier; the values used are reported in the Methodology paragraph above.

Methodology. Every rule-specific frontier starts with IT as the lower bound and is interpolated linearly between successive points of a sweep of the reaction coefficients of the corresponding rule in Table H1; the labeled marker is the last point of the sweep. These endpoints are: LfL $(\beta_{AIT}, \beta_{SR}) = (8, -0.15)$; SR $\beta_{SR} = -0.15$; AIT $\beta_{AIT} = 32$; HIGHIT $\pi^{**} - \pi^* = +41.25$ bp; SYMAIT $\beta_{AIT} = 8$; INCL-U $\beta_{T1} = -0.1875$; and INCL-P $\beta_P = 0.15$.[64]

[64] For SR, we progressively weaken the response to unemployment below steady state while keeping the response above steady state at its baseline IT value. For INCL-U, we gradually replace the aggregate unemployment response with the bottom-tercile response, using the unemployment component $(1 - \lambda)\beta_u(u_t - u^*) + \lambda\beta_{T1}(u_t^{T1} - u^{T1,*})$. As λ increases from zero to one, the rule moves from IT to INCL-U. The response to inflation remains unchanged in both sweeps.

	ZLB frequency (%)	Boom frequency (%)	Recession frequency (%)	Price inflation	Unemployment rate	Total labor earnings	T3 Total labor earnings	T1 Total labor earnings	T3–T1 Total labor earnings
IT (Inflation Targeting)	15.2	2.1	14.0	-0.170	0.528	-2.357	-1.714	-8.997	7.283
LfL (Lower for Longer)	6.6	16.4	6.4	0.250	-0.146	0.679	0.431	3.845	-3.414
(i) Components of the Lower-for-Longer rule									
SR (Shortfall Rule)	9.6	15.3	10.6	0.130	0.134	-0.574	-0.473	-1.108	0.635
AIT (Asymmetric AIT)	6.8	5.3	6.5	0.096	0.017	-0.037	-0.059	0.519	-0.578
(ii) Symmetric strategies for the ZLB									
HIGHIT (Higher Inflation Target)	6.9	2.9	7.6	0.227	0.148	-0.656	-0.478	-2.486	2.008
SYMAIT (Symmetric AIT)	8.9	5.7	10.4	-0.085	0.085	-0.347	-0.233	-1.679	1.446
(iii) Rules targeting the bottom of the skill distribution									
INCL-U (Targets Bottom Unempl.)	15.4	0.3	7.1	0.004	0.278	-1.187	-0.897	-3.822	2.925
INCL-P (Targets Bottom Particip.)	19.8	0.1	6.2	0.073	0.185	-0.780	-0.615	-1.981	1.366

Table H2: Ergodic distribution under Inflation Targeting and alternative monetary policy rules.

Note. Each row is a single parameterization of the corresponding target rule in Table H1, all of them subject to the ZLB: LfL at $(\beta_{AIT}, \beta_{SR}) = (8, -0.15)$; SR at $\beta_{SR} = -0.15$; AIT at $\beta_{AIT} = 8$; HIGHIT at $\pi^{**} - \pi^{*} = +27.5$ bp; SYMAIT at $\beta_{AIT} = 8$ with a 48-month averaging window; INCL-U at $\beta_{T1} = -0.1875$; and INCL-P at $\beta_{P} = 0.15$. "Boom frequency" ("Recession frequency") denotes the share of time in the simulation where the aggregate unemployment rate is at least 1.0 ppt below (above) its non-stochastic steady state; "ZLB frequency" is the share of time the lower bound binds. All remaining entries are expected values expressed as deviations from the non-stochastic steady state, that is, from the inflation targeting economy without the lower bound. Inflation and the unemployment rate are in percentage points; labor earnings are in percent. Inflation deviations are measured relative to the original target π^{*}, including under HIGHIT. T1 and T3 refer to average outcomes for the bottom and top terciles of the workers' skill distribution, and the last column is the difference between the two preceding ones.

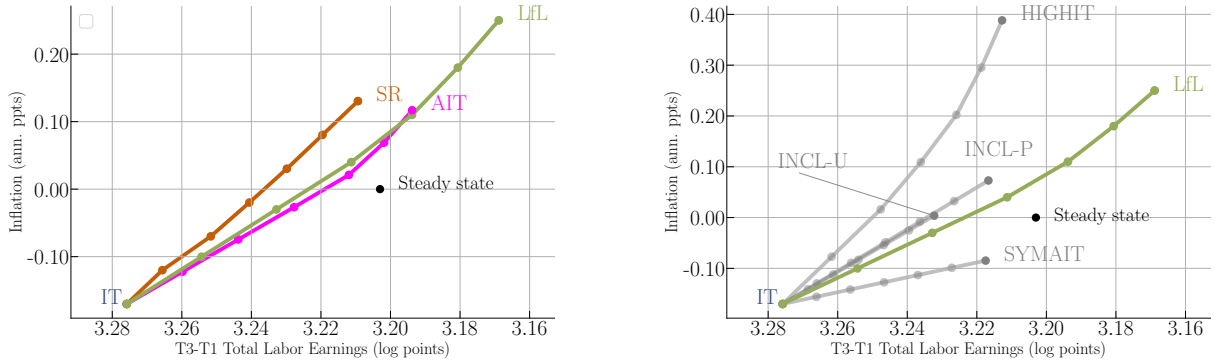


Figure H1: Inflation–inclusion frontiers across monetary policy rules. **Left panel:** LfL and its AIT and Shortfall (SR) components. **Right panel:** LfL compared with SYMAIT, HIGHIT, INCL-U, and INCL-P.

Note. Both panels plot ergodic mean inflation, expressed as annualized percentage-point deviations from target (vertical axis), against the T3–T1 differential in log total labor earnings (horizontal axis, decreasing to the right). T1 and T3 denote the bottom and top terciles of the skill distribution. The black marker denotes the non-stochastic steady state. Markers along each frontier denote the simulated policy parameterizations.

I Ergodic Distribution Under the Stochastic Extended Path

	Horizon H (quarters)						
	$H = 0$	$H = 4$	$H = 8$	$H = 12$	$H = 16$	$H = 20$	$H = 24$
Baseline							
Inflation	0.333	0.392	0.445	0.489	0.519	0.534	0.541
Expected inflation, 1yr ahead	0.250	0.312	0.385	0.455	0.510	0.544	0.560
Expected inflation, 5yr ahead	0.111	0.142	0.184	0.242	0.320	0.424	0.546
Unemployment rate	-0.242	-0.216	-0.163	-0.112	-0.073	-0.048	-0.037
Hours per worker	0.127	0.111	0.081	0.054	0.034	0.022	0.017
Average inflation / unemployment gap	-1.4	-1.8	-2.7	-4.4	-7.1	-11.1	-14.6
T3 Total Labor Earnings	0.755	0.641	0.446	0.268	0.137	0.058	0.025
T1 Total Labor Earnings	5.750	5.727	5.382	4.829	4.188	3.484	2.773
T3–T1 Total Labor Earnings	-4.995	-5.087	-4.936	-4.561	-4.052	-3.426	-2.748
Normalized series (1 at $H = 0$)							
Hours per worker	1.000	0.874	0.638	0.425	0.268	0.173	0.134
Unemployment rate	1.000	0.893	0.674	0.463	0.302	0.198	0.153
T3–T1 Total Labor Earnings	1.000	1.018	0.988	0.913	0.811	0.686	0.550
Model HA-E (heterogeneous exposure only)							
Inflation	0.380	0.443	0.501	0.554	0.598	0.633	0.659
Expected inflation, 1yr ahead	0.301	0.373	0.449	0.524	0.589	0.641	0.679
Expected inflation, 5yr ahead	0.119	0.161	0.219	0.301	0.412	0.551	0.698
Unemployment rate	-0.307	-0.261	-0.200	-0.142	-0.094	-0.058	-0.038
Hours per worker	0.104	0.088	0.068	0.048	0.031	0.020	0.013
Average inflation / unemployment gap	-1.2	-1.7	-2.5	-3.9	-6.4	-10.9	-17.3
T3 Total Labor Earnings	0.254	0.216	0.165	0.117	0.077	0.048	0.031
T1 Total Labor Earnings	0.625	0.531	0.407	0.289	0.190	0.119	0.077
T3–T1 Total Labor Earnings	-0.371	-0.315	-0.242	-0.171	-0.113	-0.070	-0.046
Normalized series (1 at $H = 0$)							
Hours per worker	1.000	0.846	0.654	0.462	0.298	0.192	0.125
Unemployment rate	1.000	0.850	0.651	0.463	0.306	0.189	0.124
T3–T1 Total Labor Earnings	1.000	0.849	0.652	0.461	0.305	0.189	0.124

Table I1: Inflation expectations and long-run outcomes under alternative SEP horizons.

Note. Ergodic means under the LfL rule without the ZLB, for stochastic extended path horizons (H=0,...,24) quarters. The upper panel reports the baseline model; the lower panel reports HA-E, which excludes participation and skill-scarring channels. The row "Average inflation / unemployment gap" divides average inflation above target by the unemployment deviation from steady state. The rows under "Normalized series (1 at $H = 0$)" restate hours per worker, the unemployment rate, and the T3–T1 total labor earnings differential as ratios to their perfect-foresight ($H = 0$) values.

Methodology. The SEP moments are averages over the full path of 150 simulated samples of 300 quarters each, computed without the ZLB and with the same sequence of innovations across policy rules and expectation horizons H. Agents integrate over future innovations with the degree-3 monomial rule of Appendix B.7 ($\alpha = 0.25$, $4H + 1$ nodes). Innovations follow (16) with $\gamma_d = \gamma_s = 0.02$ and diffusion coefficients $\sigma_d = 0.000225$ and $\sigma_s = 0.0016$; relative to the baseline calibration in Table 2, the supply shock is unchanged while the demand shock is 20% larger.

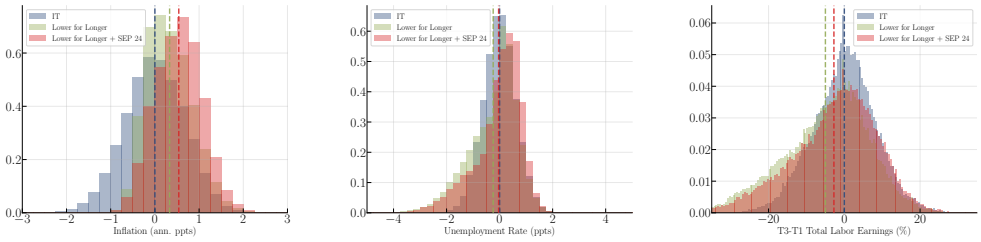


Figure I1: Ergodic distributions under perfect foresight and the stochastic extended path.

Note. The panels show distributions of inflation (left), unemployment (middle), and the T3–T1 total labor earnings differential (right) in the baseline model without the ZLB. Blue, green, and red histograms denote IT, LfL with perfect foresight ($H = 0$), and LfL with stochastic extended path ($H = 24$ quarters), respectively. Dashed vertical lines mark the corresponding means; vertical axes show probability densities. Each variable is centered on its simulated IT mean. Inflation is measured in annualized percentage points and unemployment in percentage points. The earnings differential is top-tercile minus bottom-tercile earnings deviations from steady state, measured in percent.

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