

# How Should Unemployment Insurance Vary over the Business Cycle?

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## Abstract

We study optimal unemployment insurance (UI) policy over the business cycle, using a heterogeneous agent job-search model with aggregate risk and incomplete markets. We validate the model-implied micro and macro labor market elasticities to changes in the generosity of UI benefits against existing estimates and we reconcile divergent empirical findings. We show that generating the observed demographic differences between UI recipients and non-recipients is critical for determining the magnitudes of these elasticities. We find that the optimal UI policy features countercyclical replacement rates with an average generosity that is close to current U.S. policy but that it adopts drastically longer payment durations reminiscent of European policies.

*Bank topic: Business cycles and fluctuations; Labour markets; Fiscal policy*

*JEL codes: E24, E32, J64, J65*

# 1 Introduction

The sharp increase in unemployment during the Great Recession triggered dramatic expansions of the unemployment insurance (UI) program to provide additional insurance to the large pool of jobless individuals. Whether UI played a quantitatively significant role in slowing the recovery of employment, however, remains at the center of discussion: As it stands, there is no consensus on the magnitude of the impact UI policies have on unemployment. Given that this elasticity is a key consideration for UI policy design, the divergence of estimates has led to equally mixed prescriptions on the optimal UI policy over the business cycle.

Our contribution to the literature on the optimal UI policy over the business cycle is twofold. First, we reconcile divergent empirical estimates of labor market elasticities with respect to the generosity of UI benefits. Using micro-data, combined with each state’s UI laws, we document that UI recipients and non-recipients exhibit significantly different demographic characteristics, most strikingly so with respect to their wealth holdings. In particular, UI recipients are predominantly from low-wealth households, implying that the aggregate labor market response to UI changes is driven by this subgroup’s elasticities. We show that the degree to which a model accounts for these differences ultimately determines whether labor market responses are sizable. Second, we develop a framework that is capable of reproducing the wealth heterogeneity among the unemployed and find that the optimal policy is countercyclical; importantly, it is drastically more generous in recessions compared with the findings of previous studies (Jung and Kuester 2015; Mitman and Rabinovich 2015; Landais et al. 2018).

The countercyclical optimal policy is rationalized by the dampening of incentive costs and the rise of insurance benefits during recessions. This pattern emerges from the cross-sectional and cyclical dynamics of UI recipients’ wealth distribution, both of which are shaped by heterogeneous unemployment risk and UI eligibility, take-up rates, and replacement rates—features that previous studies have largely abstracted from. Low-income households face relatively higher unemployment risk; among them, low-wealth households with the least ability to

self-insure elect to claim benefits. Generous UI has limited effects on the labor market behavior of these households because they attribute a high marginal value to the higher income they would earn from employment. In recessions, when unemployment spells are prolonged, the wealth distribution of these UI recipients further deteriorates as they draw down their savings and quickly approach their borrowing constraint. At this point, a wealth effect induces them to intensify their efforts to search for low-wage jobs that are easier to find. While the incentive costs are smaller in recessions, insurance benefits rise because generous UI cushions the drop in consumption of the wealth-poor unemployed. Moreover, the cyclicity of benefits under the optimal policy alters households' timing of take-up and induces substantially higher claim rates in recessions, precisely the period during which the consumption-smoothing gains of UI benefits are highest.

Underlying these results is a heterogeneous-agent directed-search model with aggregate fluctuations and incomplete markets. Agents are heterogeneous in terms of their labor productivity, which endogenously affects job-finding rates, job-separation rates, and earnings. Unemployed individuals of a given level of productivity direct their job-search efforts toward a specific wage submarket. Eligibility for UI depends on a household's previous earnings. Those who are eligible for UI benefits may elect to claim these benefits but they incur a utility cost of take-up. These features allow the model to generate observed empirical patterns in the micro data that are relevant for policy evaluation, among which include lower UI eligibility rates, higher UI replacement rates, and higher job-separation rates for low earners, and higher take-up rates for wealth-poor households.

The calibrated model is also able to match key untargeted moments that are informative of the level of self-insurance heterogeneous agents have against the risk of job loss and how severe the consequences of unemployment are for these agents. These moments are important because they determine the strength of the insurance benefits and incentive costs of UI. An important indicator of self-insurance is the distribution of wealth across households and how take-up decisions differ across this distribution. Combining both micro data on labor market histories and records of state UI eligibility laws, we find that among the unemployed who are eligible for benefits, recipients have markedly lower wealth holdings than non-recipients. Meanwhile, the severity of unemployment can be

measured through the magnitudes of the consumption drops upon job loss, the difference in the marginal propensities to consume out of transfers between the unemployed and the employed, and the distribution of unemployment-spell durations over the business cycle. We show that model predictions for these moments are in line with the micro evidence.

We then benchmark the model against the empirical literature that estimates the response of re-employment wages and the aggregate unemployment rate to changes in UI generosity. Importantly, we use these estimates not only to validate the model predictions but also to provide an explanation for the wide range of estimates studies have generated. Under the baseline specification and calibration of the model, the predicted responses of the re-employment wages and unemployment in the model align more with studies that estimate small elasticities. The reason why the model predicts these limited elasticities lies within the labor market response that is unique to the demographic of UI recipients. While generous UI certainly induces households to look for higher wages and reduce their search intensities, those who actually take up UI are predominantly wealth-poor individuals who are mostly inelastic to changes in UI policy because jobs are more valuable to them. This is especially true in recessions when the unemployed rapidly deplete their savings, due to prolonged unemployment spells, and consequently intensify their search for lower-wage jobs that are easier to find. In this sense, the presence of borrowing constraints self-disciplines the job-search behavior of the unemployed. In contrast, we show that in an alternative model where job-loss risk is homogeneous across employed agents and all eligible unemployed take up UI benefits, the micro and macro effects of changes in UI generosity approach the upper range of the estimates in the data. This is because in an environment where the unemployed are relatively wealthier and take-up is universal, UI recipients can afford to remain unemployed for longer durations and supplement their savings with UI while they look for the high-wage jobs that are difficult to find.

Having validated the model against empirical elasticities, we proceed with optimizing the UI policy instruments: the levels and cyclicalities of both the UI replacement rate and duration, as well as the replacement-rate heterogeneity across wages. The optimal UI policy is countercyclical. When aggregate produc-

tivity is at its mean, it features a 43 percent replacement rate, for 24 months, for the median wage earner; when depressed by 3.5 percent, it offers more generous benefits of a 49 percent replacement rate for 40 months. In contrast, the UI policy that mimics the historical patterns of the policy implemented in the U.S. provides a 52 percent acyclical replacement rate to the same worker for 6 months during normal times and up to 24 months during deep recessions. Hence, the optimal replacement rates are close to U.S. levels, albeit countercyclical, but the UI durations are reminiscent of European UI policies.<sup>1</sup> Finally, replacement rates decline more steeply with wages under the optimal policy than under the U.S. policy. Overall, relative to the U.S. policy, the optimal policy represents ex-ante welfare gains of around 0.3 percent in additional lifetime consumption. The ex-post welfare gains are heterogeneous. The highest gains accrue to the poor but not to the borrowing-constrained eligible unemployed, due to a drastic increase in their take-up rate. Importantly, employed households also enjoy substantial welfare gains since not only do they face countercyclical unemployment risk but they are also relieved of the need to build a buffer stock of savings due to the more generous public insurance during recessions.

Finally, we analyze the role of heterogeneity in take-up rates, job-separation risk, and UI eligibility on the determination of the optimal policy. To do so, we evaluate the welfare gains of the optimal policy under alternative models that abstract from the aforementioned features. We find that assuming full take-up and uniform job-separation rates lowers the welfare gains of the optimal policy due to the higher incentive costs. This is because, in such a model, relatively wealthier households, whose labor market behavior is more elastic to policy reform, flow into the pool of benefits recipients. On the other hand, assuming uniform UI eligibility across all job losers raises the welfare gains. This is because the poorest and most inelastic households, which would have otherwise been excluded from claiming benefits due to insufficient earnings, are now able to access UI benefits.

**Related Literature** There is a growing literature on optimal UI over the business cycle (Jung and Kuester 2015; Mitman and Rabinovich 2015; Landais et al.

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<sup>1</sup>For example, the UI payment durations in Belgium, France, Spain, Denmark, and Finland are longer than 24 months.

2018; Pei and Xie 2019; and McKay and Reis 2019).<sup>2</sup> Our paper is the first to study the optimal design of UI over the business cycle in a framework with incomplete markets. This advances the literature by focusing on the role of both precautionary-savings motives and the underlying wealth heterogeneity among the unemployed in determining the optimal policy. Wealth holdings affect not only the insurance value of UI but also its incentive costs because job-search behavior is a function of wealth. While the insurance benefits are larger for the borrowing-constrained unemployed, the incentive costs are smaller for them because borrowing constraints discipline search behavior. The crucial implication is that since these households are more likely to claim UI benefits, the moral hazard costs of generous UI are limited in our framework. This rationalizes why the optimal UI policy turns out to be more generous compared to previous findings. Furthermore, unlike these papers, our model incorporates endogenous UI take-up decisions and generates the observed heterogeneity in UI eligibility, benefits take-up, and replacement rates that is observed in the micro data. We show that abstracting from such heterogeneity drastically alters the aggregate implications of policy reform.

Another strand of literature studies positive and normative questions pertaining to UI policy under the presence of incomplete markets but without aggregate risk (Hansen and Imrohoroglu 1992; Acemoglu and Shimer 2000; Shimer and Werning 2008; Chetty 2008; Krusell, Mukoyama, and Sahin 2010; Koehne and Kuhn 2015; Eeckhout and Sepahsalari 2018; Braxton et al. 2018; and Kekre 2019).<sup>3</sup> Among these papers, our framework is closer to those of Eeckhout and Sepahsalari (2018) and Braxton et al. (2018), who also investigate the optimal

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<sup>2</sup>McKay and Reis (2019) use a framework that features a degenerate wealth distribution and partial equilibrium in the labor market to solve for optimal average replacement rates. Our approach emphasizes the importance of replicating wealth differences between UI recipients and non-recipients to assess the effects of UI policies on equilibrium wages and unemployment. Moreover, we solve for the optimal level and cyclicity of UI replacement rates and durations.

<sup>3</sup>Although the baseline model of Krusell, Mukoyama, and Sahin (2010) incorporates aggregate fluctuations, they study the welfare effects of UI policy reform in a steady-state experiment. Kekre (2019) evaluates the effects of discretionary UI extensions during the Great Recession, using a model where UI benefits interacts with aggregate demand but without business cycle dynamics in the real business cycle tradition. We solve for the optimal UI policy over the business cycle and find that it is countercyclical even when business cycles are exogenous and UI policy has no role in smoothing these fluctuations through aggregate demand.



level of UI in a directed-search model. The main difference is that we solve for the optimal cyclicality of UI replacement rates and duration in a model with aggregate shocks, where the strength of precautionary-savings motives significantly varies with the level of unemployment risk over the business cycle. Finally, Nakajima (2012) studies extensions to UI benefits during the Great Recession, using a model with business cycle dynamics. He measures the effect of these extensions on the unemployment rate but does not evaluate the welfare effects of these changes in UI policy. We extend his model to a general equilibrium model in which the government finances UI benefits and we study how UI must vary over the cycle. To overcome the computational difficulties encountered in a model with rich heterogeneity and aggregate shocks, we show that the model's market structure admits a block recursive equilibrium, which is a subset of recursive equilibria where the endogenous distributions are not part of the state space (Menzio and Shi 2010, 2011).

Our paper also contributes to the empirical literature that estimates the effects of changes in UI generosity on wealth holdings (Engen and Gruber 2001), re-employment wages (Card, Chetty, and Weber 2007; Schmieder et al. 2016; Nekoei and Weber 2017; and Johnston and Mas 2018), and the aggregate unemployment rate (Rothstein 2011; Farber and Valletta 2015; Chodorow-Reich et al. 2019; and Hagedorn et al. 2019). We provide an explanation for the differential magnitudes of the estimates obtained in the literature. In particular, we show that a model that assumes homogeneous unemployment risk across workers with different wages or full take-up among the UI-eligible unemployed will overstate the elasticities of re-employment wages and the aggregate unemployment rate with respect to changes in UI generosity.

This paper is organized as follows. Section 2 presents our model. Section 3 provides calibration details, and Section 4 compares our model's predictions to micro evidence. Section 5 discusses the main results. Section 6 provides a list of robustness checks, and Section 7 concludes.

## 2 Model

In this section, we first describe the model environment and layout the household and firm problems. We then discuss details of the government-run UI program.

### 2.1 Environment

Time is discrete and denoted by  $t = 0, 1, 2, \dots$ . Individuals are ex-ante identical, with preferences given by

$$U(c_t, s_t, d_t) = u(c_t) - \nu(s_t) - \phi d_t,$$

where  $u(\cdot)$  is a strictly increasing and strictly concave utility function over consumption  $c$ ;  $\nu(\cdot)$  represents the disutility associated with search effort and is a strictly increasing and strictly convex function of search effort  $s \in [0, 1]$ ; and  $d \in \{0, 1\}$  represents the binary decision to take-up UI benefits, which incurs a utility cost of  $\phi$ . Agents discount the future at rate  $\beta$  and die with probability  $\omega$ .

The labor market features directed search. An agent can be a worker  $W$ , unemployed and eligible for UI  $B$ , or unemployed and not eligible for UI  $NB$ . Unemployed individuals direct their job search toward submarkets that are indexed by their idiosyncratic labor productivity  $y$  and firms' wage offer  $w$ . Once matched with a firm within submarket  $(w, y)$ , the household is paid a fixed wage  $w$  until the match exogenously dissolves at rate  $\delta(y, p) \in [0, 1]$ , where  $p$  is the aggregate labor productivity. A fraction  $g(w, p) \in [0, 1]$  of job losers who were previously earning  $w$  become ineligible for UI benefits. An eligible unemployed agent who decides to take up benefits receives a fraction  $b(w, p) \in [0, 1]$  of their previous wage  $w$ . Finally, their eligibility for UI benefits stochastically expires at rate  $e(p) \in [0, 1]$ .<sup>4</sup>

Households pay a fraction  $\tau$  of their wages or benefits to the government. They have access to incomplete asset markets where they can save or borrow at

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<sup>4</sup>The U.S.'s UI policy is such that the benefits duration is determined by the level of aggregate unemployment. Ideally, the UI policy instruments should depend on the unemployment rate. However, as we explain in Section 2.5, this would make the model intractable. Instead, we define policy instruments to be a function of aggregate productivity—a good approximation since in our model, unemployment is driven by aggregate productivity.

an exogenous interest rate  $r$ .<sup>5</sup> On the other side of the labor market, firms decide the submarket in which to post a vacancy. Once matched, the firm-worker pair converts one unit of labor into final goods, the amount of which is determined by the worker's productivity  $y$  and the aggregate productivity  $p$ .

The timing of the model is as follows. At the beginning of each time period  $t$ , the idiosyncratic labor productivity  $y$  for each agent and the aggregate labor productivity  $p$  are realized. These determine i) the UI policy instruments  $b(w, p)$ ,  $e(p)$ , and  $g(w, p)$  and ii) the exogenous job-separation rate  $\delta(y, p)$ . After the realization of the exogenous shocks, there are two stages where agents make endogenous decisions. First, in the labor market stage, firms decide the submarket in which to post a vacancy, while unemployed individuals choose a wage submarket  $w$  within which to look for a job. The unemployed can only direct their search toward submarkets that are appropriate for their own labor productivity  $y$ . Second, the production and consumption stages open, where each firm-worker pair produces, wages are paid to workers, UI benefits are paid to the eligible unemployed who decide to take them up, and all of the unemployed receive a monetized value of their non-market activities  $h$ .<sup>6</sup> Households then make their savings or borrowing decisions. Finally, prior to time  $t + 1$ , unemployed households decide the search-effort level  $s$  they will exert in the labor market stage of time  $t + 1$ , where the utility cost of that search effort is incurred at time  $t$ .

## 2.2 Household Problem

A household's individual state vector consists of the household's current employment status  $l \in \{W, B, NB\}$ , net assets level  $a \in \mathcal{A} \equiv [a_l, a_h] \subseteq \mathbb{R}$ , wage level  $w \in \mathcal{W} \equiv [w_l, w_h] \subseteq \mathbb{R}_+$ , and idiosyncratic labor productivity  $y \in \mathcal{Y} \equiv [y_l, y_h] \subseteq \mathbb{R}_+$ .

The aggregate state is denoted by  $\mu = (p, \Gamma)$ , where  $p \in \mathcal{P} \subseteq \mathbb{R}_+$  denotes the aggregate labor productivity and  $\Gamma : \{W, B, NB\} \times \mathcal{A} \times \mathcal{W} \times \mathcal{Y} \rightarrow [0, 1]$  denotes

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<sup>5</sup>In Section 6, we explore the quantitative and welfare implications of allowing interest rates to vary over the business cycle.

<sup>6</sup>The variable  $h$  encompasses both the value of leisure or home production and other income, such as spousal and family income and other transfers. Our results would be similar if  $h$  were a utility value instead of a monetary value.

the distribution of agents across states. The laws of motion for the aggregate states are given by  $\Gamma' = H(\mu, p')$  and  $p' \sim F(p' | p)$ , respectively, and the law of motion for the idiosyncratic labor productivity is given by  $y' \sim Q(y' | y)$ .

The recursive problem of the worker is given by

$$\begin{aligned}
V^W(a, w, y; \mu) = \max_{c, a' \geq a_l} & u(c) + \beta(1 - \omega) \mathbb{E} \left[ (1 - \delta(y', p')) V^W(a', w, y'; \mu') \right. \\
& + \delta(y', p') \left[ (1 - g(w, p')) V^B(a', w, y'; \mu') \right. \\
& \left. \left. + g(w, p') V^{NB}(a', y'; \mu') \right] \middle| y, \mu \right] \quad (1)
\end{aligned}$$

subject to

$$\begin{aligned}
c + a' &\leq (1 + r)a + w(1 - \tau) \\
\Gamma' &= H(\mu, p'), \quad p' \sim F(p' | p), \quad y' \sim Q(y' | y).
\end{aligned}$$

Notice in the above problem that the worker may not qualify for UI benefits with probability  $g$  after losing their job due to an exogenous job separation, which captures both voluntary and involuntary reasons for job loss in our model. This feature intends to capture the fact that, according to current UI policy in the U.S., not all workers who are transitioning into unemployment qualify for UI benefits. In particular, individuals do not qualify for benefits if they voluntarily quit their job or if they do not meet certain work/earnings requirements, both of which we will discuss in detail in Section 3. Notice also that we keep track of previous wages  $w$  for only the unemployed who become eligible for UI benefits, as some  $b(w, p)$  fraction of that wage is paid to them as UI benefits in case they decide to take up these benefits.

The unemployed direct their job search toward a wage submarket  $w$ , based on their productivity  $y$ , with an associated market tightness given by  $\theta(w, y; \mu)$ , which is an equilibrium object that will be defined later. Let  $f(\theta(w, y; \mu))$  be the job-finding probability for the unemployed who visit submarket  $(w, y)$  when the aggregate state is  $\mu$ . Then the recursive problem of the eligible unemployed

is given by

$$\begin{aligned}
V^B(a, w, y; \mu) = & \max_{c, a' \geq a_1, s, d} u(c) - \nu(s) - \phi d \\
& + \beta \mathbb{E} \left[ \max_{\tilde{w}} \left\{ sf(\theta(\tilde{w}, y'; \mu')) V^W(a', \tilde{w}, y'; \mu') \right. \right. \\
& + (1 - sf(\theta(\tilde{w}, y'; \mu'))) \left[ (1 - e(p')) V^B(a', w, y'; \mu') \right. \\
& \left. \left. \left. + e(p') V^{NB}(a', y'; \mu') \right] \right\} \middle| y, \mu \right] \tag{2}
\end{aligned}$$

subject to

$$\begin{aligned}
c + a' & \leq (1 + r)a + h + db(w, p)w(1 - \tau) \\
\Gamma' & = H(\mu, p'), \quad p' \sim F(p' | p), \quad y' \sim Q(y' | y),
\end{aligned}$$

where the eligible unemployed who decide to take up benefits receive UI benefits  $b(w, p)w$  and pay  $\tau$  fraction as tax but may lose their eligibility with probability  $e$ .<sup>7</sup> The wage submarket choice is influenced by a trade-off between the level of surplus (determined by the wage) and the fact that there are fewer vacancies posted for higher-paying jobs, resulting in lower job-finding probabilities.

The problem of the ineligible unemployed is similar except for the absence of a take-up choice and benefits. Ineligible agents are also unable to regain their eligibility for UI benefits if their job search fails. This captures the fact that, according to current UI policy in the U.S., the unemployed receive UI benefits only for a certain number of weeks—which varies over the business cycle—and once that threshold is reached, the unemployed cannot continue to collect UI benefits. We lay out the recursive problem of this agent in Appendix A.

### 2.3 Firm Problem

Firms post vacancies for jobs that offer fixed-wage contracts in different submarkets. The labor market tightness of submarket  $(w, y)$  is defined as the ratio of the vacancies  $v$  posted in the submarket to the aggregate search effort  $S$  exerted by

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<sup>7</sup>The benefit expiration rate  $e$  is stochastic, as in Mitman and Rabinovich (2015). This assumption simplifies the solution of the model because we do not need to carry the unemployment duration as another state variable for the eligible unemployed.

all of the unemployed who are searching for a job within that particular submarket. The labor market tightness is denoted as  $\theta(w, y; \mu) = \frac{v(w, y; \mu)}{S(w, y; \mu)}$ . Let  $M(v, S)$  be a constant-returns-to-scale matching function that determines the number of matches in a submarket with aggregate search effort  $S$  and vacancies  $v$ . We can then define  $q(w, y; \mu) = \frac{M(v(w, y; \mu), S(w, y; \mu))}{v(w, y; \mu)}$  to be the vacancy-filling rate and  $f(w, y; \mu) = \frac{M(v(w, y; \mu), S(w, y; \mu))}{S(w, y; \mu)}$  to be the job-finding rate. The constant-returns-to-scale assumption on the matching function guarantees that the equilibrium object  $\theta$  is sufficient to determine job-finding rates  $f(\theta) = \frac{M(v, S)}{S} = M(\theta, 1)$  and vacancy-filling rates  $q(\theta) = \frac{M(v, S)}{v} = M\left(1, \frac{1}{\theta}\right)$ .

First, consider a firm that is matched with a worker in submarket  $(w, y)$  when the aggregate state is  $\mu$ . The pair produces  $py$  units of output until the match dissolves with some probability  $\delta(y, p)$ . The value of this firm is given by

$$J(w, y; \mu) = py - w + \frac{1}{1+r} (1 - \omega) \mathbb{E} \left[ (1 - \delta(y', p')) J(w, y'; \mu') \mid y, \mu \right]$$

subject to (3)

$$\Gamma' = H(\mu, p'), \quad p' \sim F(p' | p), \quad y' \sim Q(y' | y).$$

Meanwhile, the value of a firm that posts a vacancy in submarket  $(w, y)$  under aggregate state  $\mu$  is given by

$$V(w, y; \mu) = -\kappa + q(\theta(w, y; \mu)) J(w, y; \mu), \tag{4}$$

where  $\kappa$  is a fixed cost of posting a vacancy that is financed by the risk-neutral foreign entrepreneurs who own the firms.

When profit-maximizing firms decide on which wage and productivity submarket to post vacancies in, they face a trade-off between the probability of filling a vacancy and the level of surplus from a possible match. A firm that is posting a vacancy in a high-wage submarket would enjoy a higher probability of filling the job at the expense of extracting a lower surplus from the match. On the other hand, a firm that is posting a vacancy in a high-productivity submarket would enjoy a higher match surplus but face a higher vacancy-unemployed ratio and, thus, find it more difficult to fill the vacancy.

The free-entry condition implies that the firm's profits are just enough to

cover the cost of filling a vacancy in expectation. As a result, the owner of the firm makes zero profits in expectation. Thus, we have  $V(w, y; \mu) = 0$  for any submarket such that  $\theta(w, y; \mu) > 0$ . Then, we impose the free-entry condition to Equation (4) and obtain the equilibrium market tightness:

$$\theta(w, y; \mu) = \begin{cases} q^{-1}(\kappa/J(w, y; \mu)) & \text{if } w \in \mathcal{W}(\mu) \text{ and } y \in \mathcal{Y}(\mu) \\ 0 & \text{otherwise.} \end{cases} \quad (5)$$

The equilibrium market tightness contains all of the relevant information households need to evaluate the job-finding probabilities in each submarket.

## 2.4 Government Policy

The UI policy is characterized by  $\{b(w, p), e(p), g(w, p), \tau\}$ , where UI benefit amount  $b$  and UI eligibility risk  $g$  are allowed to be heterogeneous across wages to capture the differences in the replacement rates and the UI eligibility rates across various income groups in the data, respectively, and  $b$ ,  $e$ , and  $g$  are allowed to vary with aggregate labor productivity to capture the cyclicity of UI replacement rates, their duration, and the eligible fraction of job losers.<sup>8</sup>

The government balances the following budget constraint in expectation:<sup>9</sup>

$$\begin{aligned} \sum_{t=0}^{\infty} \sum_i \left( \frac{1}{1+r} \right)^t \times \left( \mathbf{1}_{\{l_{it}=W\}} \times w_{it} + \mathbf{1}_{\{l_{it}=B \text{ and } d_{it}=1\}} \times b_{it} w_{it} \right) \times \tau & \quad (6) \\ = \sum_{t=0}^{\infty} \sum_i \left( \frac{1}{1+r} \right)^t \times \mathbf{1}_{\{l_{it}=B \text{ and } d_{it}=1\}} \times b_{it} w_{it}, & \end{aligned}$$

where the left-hand side of Equation 6 is the present discounted value of the tax revenues collected from the workers' labor income and from the eligible unem-

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<sup>8</sup>We restrict the UI policy to depend on the aggregate state of the economy  $\mu$  only through aggregate labor productivity  $p$  and not through the distribution of individuals across states  $\Gamma$ . This restriction allows our model to retain block recursivity, which we explain below.

<sup>9</sup>This assumption is motivated by the fact that, according to the current UI system in the U.S., states are allowed to borrow from a federal UI trust fund when they meet certain federal requirements and, thus, are allowed to run budget deficits during some periods. Nevertheless, we explore the implications of this assumption on our main results in Section 6.

ployed who take up benefits, and the right-hand side is the present discounted value of the UI payments that go to the eligible unemployed who take up benefits.

## 2.5 Equilibrium

### Definition of the Recursive Equilibrium:

Given UI policy  $\left\{ b(w, p), e(p), g(w, p), \tau \right\}_{p \in \mathcal{P}}$ , a recursive equilibrium for this economy is a list of household policy functions for decisions on assets, wages, search effort, and UI take-up, a labor market tightness function  $\theta(w, y; \mu)$ , and an aggregate law of motion  $\mu' = (p', \Gamma')$  such that

1. Households' policy functions solve their respective problems.
2. Labor market tightness is consistent with the free-entry condition (5).
3. The government's budget constraint (6) is satisfied.
4. The law of motion of the aggregate state is consistent with the household policy functions.

In order to solve the recursive equilibrium defined above, one must keep track of an infinite dimensional object  $\Gamma$ , making the solution of the model infeasible. To address this issue, we exploit the structure of the model and use the notion of the block recursive equilibrium (BRE) developed by Menzio and Shi (2010, 2011).

**Definition of the block recursive equilibrium:** A BRE for this economy is an equilibrium in which the value functions, policy functions, and labor market tightness depend on the aggregate state of the economy  $\mu$ , only through aggregate productivity  $p$  and not through the aggregate distribution of agents across states  $\Gamma$ .

**Proposition:** *If i) utility function  $u(\cdot)$  is strictly increasing, strictly concave, and satisfies Inada conditions and  $v(\cdot)$  is strictly increasing and strictly convex; ii) choice sets  $\mathcal{W}$  and  $\mathcal{A}$  and sets of exogenous processes  $\mathcal{P}$  and  $\mathcal{Y}$  are bounded; iii) the matching function  $M$  exhibits constant returns to scale; and iv) the UI policy is restricted to being only a function of current aggregate labor productivity, then there exists a unique BRE for this economy.*



**Proof:** See Appendix A.

This proposition is useful because it allows us to solve the model numerically without keeping track of the aggregate distribution of agents across states  $\Gamma$ . We discuss more details about block recursivity and the computational algorithm employed to solve this model in Appendix A.

### 3 Calibration

We calibrate our model to match historical patterns of UI policy as well as important labor market moments in the U.S. Table 1 summarizes the internally calibrated parameters, while Table A.1 in Appendix B provides a list of externally calibrated parameters.

**Demographics and preferences** The model period is a month. We set the probability of death to  $\omega = 0.21$  percent so that the expected duration of an agent’s working lifetime is 40 years.

The period utility function is specified to be

$$U(c_t, s_t, d_t) = u(c_t) - \nu(s_t) - \phi d_t = \frac{c_t^{1-\sigma}}{1-\sigma} - \frac{s_t^{1+\chi}}{1+\chi} - \phi d_t.$$

The coefficient of relative risk aversion  $\sigma$  is set to be equal to 2.

Importantly, we choose the curvature parameter of the search cost function  $\chi$  to match the elasticity of the non-employment duration with respect to the changes in duration of UI benefits. Several papers estimate this elasticity using cross-state or over-time differences in the duration of UI benefits.<sup>10</sup> The magnitudes of the estimated elasticities range from an average change of 0.08 months (Card and Levine 2000) to 0.3 months (Johnston and Mas 2018) in response to a one-month change in the UI duration. We take a median value of 0.16 as the calibration target. In the model, we implement a sudden and unexpected increase in the UI expiration rate  $e(\cdot)$  so that the implied maximum UI duration becomes one month shorter for any realization of aggregate labor productivity. Taking into

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<sup>10</sup>Examples of these studies include Moffitt (1985), Katz and Meyer (1990), Card and Levine (2000), Valletta (2014), and Johnston and Mas (2018).

account the effect of this policy change on equilibrium wages and market tightness, we choose  $\chi$  to generate the same change in the time in non-employment for UI recipients as in the data.<sup>11</sup>

Finally, we use the disutility of the UI take-up parameter  $\phi$  to match the average take-up rate among those eligible for UI benefits. We explain our methodology for measuring take-up rates in the data below when we discuss the UI policy instruments.

**Aggregate and idiosyncratic labor productivity** The logarithm of aggregate labor productivity  $p_t$  follows an AR(1) process:  $\ln p_{t+1} = \rho^p \ln p_t + \sigma^p \epsilon_{t+1}$ . We take  $p_t$  as the mean real output per person in the non-farm business sector, using quarterly data constructed by the Bureau of Labor Statistics (BLS) for the period 1951 and 2007. Estimating the AR(1) process at a monthly frequency yields  $\rho^p = 0.9183$  and  $\sigma^p = 0.0042$ .

Similarly, the logarithm of the idiosyncratic labor productivity  $y_t$  follows an AR(1) process:  $\ln y_{t+1} = \rho^y \ln y_t + \sigma^y \nu_{t+1}$ . We choose  $\rho^y = 0.9867$  to achieve a 40-year expected duration of maintaining the same productivity level. We use the standard deviation of the error term  $\sigma^y$  to match the earnings dispersion, specifically, the ratio of the 90th to the 10th percentiles of the labor earnings distribution among the employed individuals included in the Survey of Income and Program Participation (SIPP) data. Appendix B provides details about our sample with the SIPP data.

**Labor market** Following Shimer (2005), we use a process for the job-destruction rate that depends on aggregate labor productivity  $p$  and we modify it to incorporate heterogeneity across idiosyncratic labor productivity levels  $y$ :  $\delta(y, p) = \bar{\delta} \times \exp(\eta_p^\delta (p - \bar{p})) \times \exp(\eta_y^\delta (y - \bar{y}))$ , where i)  $\bar{\delta}$  is the average job-destruction rate over time,  $\bar{p}$  and  $\bar{y}$  are the mean aggregate and idiosyncratic labor productivities, respectively; ii)  $\eta_p^\delta$  captures the volatility of the job-destruction rate over

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<sup>11</sup>Notice that when agents change the wage submarkets in which they look for a job in response to a change in the UI policy, they face a different market tightness in the new wage submarket. For this reason, although changes in the UI policy do not affect the menu of market tightness across wage submarkets, once households change their wage choices in response to changes in the the UI policy, they in turn face different labor market tightness.

time; and iii)  $\eta_y^\delta$  captures the variation of the job-destruction rate across income groups.<sup>12</sup> We jointly choose these parameters to match i) the average monthly job-separation rate, ii) its standard deviation, and iii) its heterogeneity across the earnings distribution in the data. The first two moments are obtained from the monthly transition rates for the period 1976 to 2005 calculated by Fujita and Ramey (2006). For the last moment, we use the SIPP for the period 1996 to 2007 to calculate the ratio of the job-separation rate of workers below the first quintile to that of those above the fifth quintile of the labor-earnings distribution.

The labor market matching function is specified as

$$M(v(w, y; \mu), S(w, y; \mu)) = \lambda(y, p) \frac{v(w, y; \mu) S(w, y; \mu)}{[v(w, y; \mu)^\gamma + S(w, y; \mu)^\gamma]^{1/\gamma}},$$

where  $\lambda(y, p) = \bar{\lambda} \times \exp(\eta_p^\lambda (p - \bar{p})) \times \exp(\eta_y^\lambda (y - \bar{y}))$ .<sup>13</sup> This incorporates time-varying matching efficiency and cross-sectional heterogeneity in matching efficiency  $\lambda(\cdot)$  into an otherwise standard CES matching function, as in den Haan et al. (2000).<sup>14</sup> We jointly choose  $\bar{\lambda}$ ,  $\eta_p^\lambda$ , and  $\eta_y^\lambda$  to match i) the average monthly job-separation rate, ii) its standard deviation, and iii) its heterogeneity across the earnings distribution in the data. For the last moment, we use the SIPP for the period 1996 to 2007 to calculate the ratio of the job-finding rate of the unemployed below the first quintile to that of those above the fifth quintile of the distribution of previous employment earnings.

Shimer (2005) shows that a standard search-and-matching model fails to generate the observed volatility of the unemployment rate. In our model, changes in aggregate labor productivity generate exogenous variations in both the job-separation rates and the matching function efficiency. We calibrate the param-

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<sup>12</sup>These separation shocks can be interpreted as idiosyncratic match-quality shocks that drive down the productivity of a match to a low enough level so that the match endogenously finds it optimal to dissolve, as in Lise and Robin (2017).

<sup>13</sup>Based on this functional form of the matching function, the job-finding and vacancy-filling rates are given by  $f(\theta(w, y; \mu)) = \lambda(y, p) \theta(w, y; \mu) (1 + \theta(w, y; \mu)^\gamma)^{-1/\gamma}$  and  $q(\theta(w, y; \mu)) = \lambda(y, p) (1 + \theta(w, y; \mu)^\gamma)^{-1/\gamma}$ , respectively.

<sup>14</sup>Time-varying matching efficiency can be interpreted as being changes in the aggregate recruiting intensity over the business cycle, as is recently documented by Mongey and Violante (2019). In our work, we do not model the firm's recruiting decisions, but the above specification captures the cyclical variation in the aggregate matching efficiency through  $\eta_p^\lambda$  in reduced form.

eters of these processes to match the observed levels and volatilities of both the separation and job-finding rates. This enables the model to generate the magnitude of the unemployment-rate volatility in the data, as shown in Table A.2 in Appendix B.

We set the cost of vacancy creation to  $\kappa = 0.58$ , following Hagedorn and Manovskii (2008), who estimate the combined capital and labor costs of vacancy creation as being 58 percent of labor productivity.

When agents experience a job separation, they lose earnings but receive a monetary value  $h$  of nonmarket activity, which can be interpreted as income support from family, relatives, or government transfers other than UI benefits. Hence, the magnitude of  $h$  controls the magnitude of the budgetary loss upon job separation. For this reason, we use  $h$  to match what the data shows as being the average drop in consumption upon a job loss. Several papers in the literature use various data sources to estimate the average consumption drop upon job losses.<sup>15</sup> The resulting estimates are between 8 and 21 percent in the data, and we take 14 percent as our data target.

**Savings** We choose the discount factor  $\beta$  to match the fraction of the population in the SIPP with non-positive net liquid wealth. We discuss the calculation of this moment in Section 4.1. The borrowing limit  $a_l$  is set to match a median value of the credit limit to the quarterly labor-income ratio of 74 percent found in the Survey of Consumer Finances. Finally, we set  $r = 0.33$  percent, which generates an annual return on assets of around 4 percent.

**UI policy** Motivated by the current design of UI policies, we assume the following functional forms for the UI policy instruments:

$$1/e(p) = \begin{cases} m_0^e + m_p^e p & \text{if } p < \bar{p} \\ 1/e_{cap} & \text{otherwise} \end{cases}$$

$$b(w, p) = m_0^b + m_w^b w + m_p^b p \tag{7}$$

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<sup>15</sup>See, for example, Browning and Crossley (2001), Aguiar and Hurst (2005), Saporta-Eksten (2014), and Chodorow-Reich and Karabarbounis (2016).

$$g(w, p) = m_0^g + m_w^g w + m_p^g p.$$

Here, the slope parameter  $m_p^j$  captures the cyclicality of policy instrument  $j$ , while  $m_w^b$  and  $m_w^g$  capture the income-group differences in the UI replacement rates that are attributable to the maximum benefit amounts as well as the differences in the eligibility requirements that are attributable to the work and earnings requirements of the various state UI laws. Finally,  $e_{cap}$  captures the maximum duration of UI payments during non-recessions. Below, we explain how we discipline these UI policy parameters.

First, we calibrate the parameters of the UI expiration rate. We set  $e_{cap} = 4/26$  to match the maximum duration of 26 weeks of UI payments during non-recessionary periods; i.e.,  $p_t \geq 1$ . Historically, the maximum duration of UI payments was extended during recessions, when the unemployment rate is higher. For example, during the Great Recession, this duration was extended to up to 99 weeks. We pick  $m_0^e$  and  $m_p^e$  so that the maximum UI duration ( $1/e$ ) is linearly increasing from 26 weeks, when aggregate labor productivity is at its mean, to 99 weeks, when it is at its lowest value. The resulting UI expiration policy closely replicates the maximum UI duration observed in the data that covers recessionary periods.

Second, we calibrate the parameters for replacement rate  $b$  and eligibility rate  $g$ . Recall that in the model i) only a fraction of job losers are eligible for UI benefits; ii) among those eligible, UI is paid only to those who elect to take up these benefits; and iii) UI replacement rates vary across those who take up benefits.

To discipline these aspects of our model, we need data on the replacement rate, eligibility status, and take-up decisions of benefits-eligible unemployed individuals. While the SIPP provides information on respondents' earnings, employment statuses, and the amount of UI received, it does not collect information on respondents' UI eligibility statuses. To overcome this, we construct a program that combines the SIPP data with state-level UI laws for the period 1996 to 2006 to predict a respondent's eligibility.<sup>16</sup> State laws impose a variety of eligibility

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<sup>16</sup>Detailed information on state UI eligibility rules and weekly benefit amounts are obtained from the Department of Labor Employment and Training Administration (<https://oui.doleta.gov/unemploy/pdf/uilawcompar/>).

requirements. First, they require that applicants meet certain wage and employment requirements during a base period—the first four of the last five completed calendar quarters preceding the applicant’s claim for benefits.<sup>17</sup> Second, benefit eligibility is also conditional on the reason for unemployment, with individuals unemployed as a result of quitting or being fired due to misconduct or negligence being ineligible. Finally, UI eligibility expires once an individual claims benefits beyond a certain number of weeks. Given these rules, we use the SIPP data on employment status, earnings, reason for job separation, and state of residence to predict the eligibility statuses of unemployed individuals. This allows us to compute the fraction of the eligible unemployed (FEU)  $\frac{\text{Eligible Unemployed}}{\text{Unemployed}}$ . Together with information on self-reported UI benefit receipt, we then calculate the take-up rate (TUR)  $\frac{\text{UI Recipients}}{\text{Eligible Unemployed}}$ .

Finally, in the data, we calculate job losers’ base-period earnings and use state-specific weekly benefits-amount formulas to arrive at individual-specific replacement rates. The predicted replacement rate for an eligible unemployed is measured as the ratio of their predicted UI weekly benefits amount to their average weekly wages during the months in the base period where they earned positive wages.<sup>18</sup> We then compute the average replacement rate for any given month as the average predicted replacement rate of all unemployed deemed eligible. This implies that the average replacement rate we produce is a measure of the generosity of the UI replacement rate offered by the government and not the actual replacement rates among claimants, as the latter will naturally depend on the distribution of individuals who take up benefits. We discuss this further in Section 4.1.

This analysis allows us to calibrate the parameters of UI replacement rates  $m_0^b$ ,  $m_w^b$ ,  $m_p^b$  and UI eligibility rates  $m_0^g$ ,  $m_w^g$ ,  $m_p^g$  as well as the utility cost of taking

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<sup>17</sup>The formula for wage and employment requirements varies across states. For example, some states impose a flat amount, while others impose varying amounts based on the quarter with the highest wages, multiple quarters, or the entire base-period earnings. Furthermore, the maximum UI duration also varies across states and over time.

<sup>18</sup>There are a few instances where the program classifies an unemployed individual as ineligible based on UI state laws but the respondent reports receiving UI benefits. In these instances, we consider the self-reported UI receipt as an indication of eligibility and use this as the basis for the replacement rate. The results remain similar when we consider these individuals as ineligible.

Table 1: Internally calibrated parameters

| Parameter                                     | Explanation                                    | Value  | Target  | Model | Data  |
|---|--|--------|---|-------|-------|
| <b><i>Preferences and borrowing limit</i></b> |  |        |   |       |       |
| $\beta$                                       | Discount factor                                | 0.9928 | Frac. non-pos. net liq. wealth  | 0.27  | 0.26  |
| $\chi$  | Curvature of utility cost of job-search        | 1.52   | Elasticity of nonemp. duration with respect to UI duration  | 0.15  | 0.16  |
| $\phi$  | Take-up utility cost                           | 1.41   | UI take-up rate among eligible  | 0.57  | 0.55  |
| $a_l$   | Borrowing limit                                | -2.09  | Median credit limit/income  | 0.73  | 0.74  |
| <b><i>Labor market</i></b>                    |  |        |   |       |       |
| $\bar{\delta}$                                | Ave. job-sep. rate                             | 0.021  | Ave. monthly job sep. rate  | 0.02  | 0.02  |
| $\eta_p^\delta$                               | Cyc. job-sep. rate                             | -6.4   | Standard dev. of job sep. rate  | 0.058 | 0.058 |
| $\eta_y^\delta$                               | Heterogeneity of job-sep. rate                 | -0.94  | Ave. job sep. rate ratio of low- (< p20) vs high-income (> p80) workers                             | 3.24  | 3.28  |
| $\bar{\lambda}$                               | Ave. of matching efficiency                    | 1.01   | Ave. monthly job-finding rate   | 0.34  | 0.34  |
| $\eta_p^\lambda$                              | Cyc. of matching efficiency                    | 5.4    | Standard dev. of job-finding rate   | 0.078 | 0.077 |
| $\eta_y^\lambda$                              | Heterogeneity of matching efficiency           | -0.94  | Ave. job-finding rate ratio of low- (< p20) vs high-previous-employment earnings (> p80) unemployed | 0.85  | 0.96  |
| $\sigma^y$                                    | Dispersion of id. labor prod.                  | 0.077  | Ave. ratio of 90th to 10th percentile of labor earnings dist.                                       | 4.50  | 6.30  |
| $h$   | Value of nonmarket activity                    | 0.04   | Ave. consumption drop upon job loss   | 0.13  | 0.14  |
| <b><i>UI policy</i></b>                       |  |        |   |       |       |
| $m_0^b$                                       | UI rep. rate level                             | 0.75   | Ave. UI rep. rate   | 0.52  | 0.52  |
| $m_w^b$                                       | Heterogeneity of UI replacement rate           | -0.24  | Ave. ratio of rep. rate of low- (< p20) vs high-income (> p80) workers                              | 1.91  | 1.89  |
| $m_0^g$                                       | Fraction of job losers who are eligible for UI | 0.42   | Ave. frac. of unemployed eligible for UI  | 0.58  | 0.58  |
| $m_w^g$                                       | Heterogeneity of UI eligibility risk           | -0.14  | Ave. ratio of frac. of unemp. eligible for UI of low- (< p20) vs high-income (> p80) workers        | 0.74  | 0.53  |

*Note:* This table provides a list of model parameters that are calibrated using our model. Please refer to main text for a detailed discussion. Data sources for each moment are described in the text.

up UI  $\phi$ . We jointly choose  $m_0^b$ ,  $m_w^b$ , and  $m_p^b$  to match i) the average replacement rate of the eligible unemployed, ii) the p20/p80 ratio of the replacement rate when the unemployed are ranked according to their base-period average weekly wages, and iii) the variation of the UI replacement rate over time. In the data, we find that the average replacement rate among the benefits-eligible unemployment is 52 percent and that the average p20/p80 ratio of the predicted replacement rate is 1.89. Given that states very rarely (if ever) changed their formula to calculate their UI benefit amounts, except for inflation-related adjustments of minimum and maximum benefit amounts, we set  $m_p^b = 0$ . Figure A.1 in Appendix B compares the heterogeneity of the replacement rates across previous average weekly wages in the data and the model that resulted from our calibration. The linearity of the UI replacement rate in previous wages well approximates the replacement rates in the data.<sup>19</sup>

Next, we discipline the parameters of the UI eligibility rate. We use parameter  $m_0^g$ , which is the parameter that controls the level of UI benefits, to match an average FEU of 58 percent; the slope parameter with respect to the wage,  $m_w^g$ , to match a p20/p80 FEU ratio of 0.53 when the unemployed are ranked according to their base-period average weekly wages; and the slope parameter with respect to aggregate labor productivity,  $m_p^g$ , to match the variations in the eligibility rules over time.<sup>20</sup> Based on state UI laws over the period 1996 to 2019, we see that the minimum wages required to qualify for UI sometimes change but do not exhibit differential changes in recessions. Hence, we also set  $m_p^g = 0$ .

Finally, we estimate that the average TUR in the data is 55 percent. We use the disutility of UI take-up parameter  $\phi$  to match the same value in the model. Under this joint calibration of the model parameters, the income tax rate  $\tau$  that satisfies Equation (6) in equilibrium is 0.765 percent.<sup>21</sup>

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<sup>19</sup>The realized average replacement rate, which is obtained by setting to 0 the replacement rate of the eligible unemployed who do not claim benefits, is 0.27 in the data and 0.33 in the model.

<sup>20</sup>An average FEU p20/p80 ratio of 0.53 means that job losers whose previous wages are in the top quintile of the wage distribution are around two times more likely to be eligible for UI benefits upon job loss than job losers in the bottom quintile.

<sup>21</sup>This income tax is much lower than U.S. income tax levels because the government in this model only needs to finance the UI payments. Nevertheless, in Section 6, we incorporate a higher level of government expenditures to account for other forms of government spending and transfers, which implies higher levels of income taxes. Then, we check the implications of



The calibration exercise reveals substantial heterogeneity in job-separation risk, the UI replacement rate, and the UI eligibility rate across income groups. Low-income workers experience much higher job-separation risk, and they are less likely to be eligible for UI upon job loss than high-income workers. However, if they become eligible, then they receive larger replacement rates than high-income workers. Our model is designed to match these dimensions of heterogeneity, as they will be critical in determining labor market responses to UI reform.

## 4 Model Predictions

In Section 4.1, we compare the predictions of the baseline economy for several untargeted data moments. In Section 4.2, we calculate the elasticity of wealth holdings, the re-employment wages of UI recipients, and the aggregate unemployment with respect to changes in the UI generosity and we compare them to the available estimates from microeconomic studies. The results of these two sections show that our model successfully replicates most of the relevant untargeted data moments, which makes it an appropriate environment in which to study the optimal design of UI policy. Finally, in Section 4.3, we sequentially explore the implications of abstracting from several features of the model that allow us to capture UI recipients' demographics. We emphasize the importance of these channels in generating the observed empirical elasticities and provide an explanation for the differentials in the magnitudes of the elasticities that are found in various microeconomic studies.

### 4.1 Baseline economy

**Wealth holdings of UI take-up vs non-take-up** Previously, we documented that, among UI-eligible job losers, only a fraction apply for benefits. In this section, we use the SIPP 2004 Panel to understand the differences in wealth holdings between those who take up benefits and those who do not. First, we construct a sample of benefits-eligible job losers. We consider a job loser as having taken up benefits if they reported receiving benefits during any month

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this assumption for our main results.

Table 2: Assets-to-income distribution, take-up vs. non-take-up

| Percentile | Data    |             | Model   |             |
|------------|---------|-------------|---------|-------------|
|            | Take-up | Non-take-up | Take-up | Non-take-up |
| 10th       | -2.34   | -1.89       | -2.33   | -2.14       |
| 25th       | -0.34   | -0.19       | -1.37   | -0.46       |
| 50th       | 0.42    | 0.41        | -0.29   | 1.02        |
| 75th       | 1.73    | 2.61        | 0.72    | 3.09        |
| 90th       | 7.80    | 14.31       | 1.90    | 5.09        |
| Mean       | 2.15    | 5.43        | -0.06   | 1.94        |

*Note:* This table shows the net liquid assets to monthly labor income distribution among UI-eligible unemployed individuals, both in the model and the data, who take up benefits vs those who do not take up benefits. We calculate the empirical distribution using the SIPP 2004, where we first construct a sample of job losers who are benefits eligible based on their earnings and employment histories. We then consider a job loser as having taken up benefits if they reported receiving benefits during any month within their unemployment spell.

within their unemployment spell. We then calculate the net liquid assets to monthly labor-income ratio distribution of each group. Details of this calculation are presented in Appendix B.

The first two columns of Table 2 compare the distribution of the ratio between the net liquid wealth and the monthly labor income between the benefits-eligible job losers who take up benefits and those who do not. It shows that, in the data, job losers who take up UI benefits have a substantially lower capacity to self-insure compared to those who decide not to receive benefits despite being eligible.<sup>22</sup> The final two columns of Table 2 suggest that the model is able to generate similar differences in the self-insurance profiles of takers and non-takers. As a result, the realized UI replacement rate in the model will be higher for UI-eligible unemployed individuals with a lower capacity to self-insure, as in the data.

**Economy-wide wealth distribution** We also compare the economy-wide distribution of the ratio of agents' net liquid wealth to their monthly labor-income in the model to that in the data. The wealth distribution is a moment of interest,

<sup>22</sup>Mean values of these distributions are statistically different from each other at the 5 percent significance level.

Table 3: Assets-to-income distribution

|       | Percentiles |       |      |      |       | Fraction of population<br>with non-positive wealth |
|-------|-------------|-------|------|------|-------|--|
|       | 10th        | 25th  | 50th | 75th | 90th  |  |
| Data  | -1.88       | 0.00  | 1.36 | 4.28 | 11.84 | 0.26   |
| Model | -1.18       | -0.09 | 2.34 | 3.42 | 5.07  | 0.27   |

*Note:* This table shows the net liquid assets to monthly labor-income distributions in both the data and the model. We calculate the empirical distribution using the SIPP 2004 Panel.

as it directly influences the insurance benefits of UI programs. Table 3 shows that while the model is calibrated to match only the fraction of the population with non-positive wealth, it comes close to matching other percentiles of the empirical distribution, especially its left tail. Matching the left tail of the distribution is relevant for our analysis because the agents in this region of the distribution are more likely to be UI recipients.<sup>23</sup>

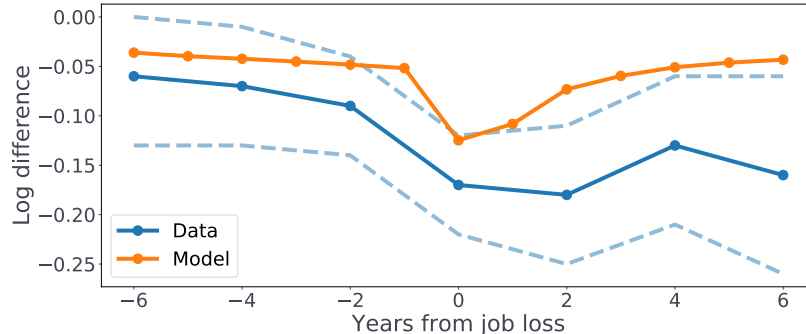
**Consumption drop upon job loss** Another critical indicator of UI’s insurance benefits is the degree by which consumption falls upon job loss. Overstating the drop in consumption would exaggerate the severity of unemployment and, thus, the consumption-smoothing benefits of UI. To make the comparison, we estimate the following distributed lag regression on the model-generated data:

$$\log(c_{it}) = \iota_i + \xi_t + \sum_{k=-6}^6 \psi_k D_{it}^k + \epsilon_{it},$$

where the outcome variable  $\log(c_{it})$  is the logarithm of the consumption of individual  $i$  in period  $t$ ,  $\iota_i$  and  $\xi_t$  are individual and time fixed effects, and  $\epsilon_{it}$  represents the random factors. The indicator variables  $D_{it}^k$  identify all individuals  $k$  periods prior to or after a job loss, where  $k = 0$  is the period in which the job loss occurs. For instance,  $D_{it}^2 = 1$  for individual  $i$  who experiences a job loss at time  $t - 2$ , and zero otherwise. The treatment group consists of individuals who experience at least one job loss during the simulation period, while the control

<sup>23</sup>In the absence of an exogenous stochastic discount factor as in Krusell and Smith (1998) or an exogenous income process calibrated to match the Lorenz coordinates for income and wealth inequality as in Castaneda et al. (2003), the model is less capable of generating households with very high levels of wealth.

Figure 1: Consumption drop upon job loss



*Note:* This figure plots the consumption drop upon job loss in the model and the data. Empirical estimates are obtained from Saporta-Eksten (2014), who uses PSID data from 1999-2009 biannually.

group consists of those with no job loss during the sample period.

Figure 1 plots the estimated values for  $\{\psi_k\}_{k \in \{-6, \dots, 6\}}$ , which measures the effect of a job loss on consumption  $k$  periods prior to or after the incident relative to the control group.<sup>24</sup> This is compared with estimates found by Saporta-Eksten (2014), who implements the same regression using Panel Study of Income Dynamics (PSID) data for the period 1999 to 2009. Given that low-income households face a higher unemployment risk, the model is able to generate the lower consumption of job losers even prior to a job loss, as seen in the data. Moreover, both the model and the data exhibit roughly an 8 percentage-point decline in consumption between the year of a job loss and two years prior. However, the consumption profile after a job loss is much less persistent in the model than in the data. This is because the model does not incorporate features that generate the scarring effects of unemployment; say, through the loss of human capital during unemployment.

**Marginal propensity to consume** Beyond looking at average consumption dynamics, we also consider the model’s performance in generating the heterogeneous marginal propensities to consume (MPC) observed in the data. This moment is informative about the differential effects temporary government transfers have on the consumption behavior of unemployed and employed households. In

<sup>24</sup>The regression is run on yearly data, which is constructed by aggregating monthly data.

Table 4: Marginal propensities to consume

|   | Model | Data        |
|---|-------|-------------|
| Aggregate quarterly MPC                                       | 0.12  | 0.12 – 0.30 |
| Annual MPC difference between the unemployed and the employed | 0.29  | 0.25        |

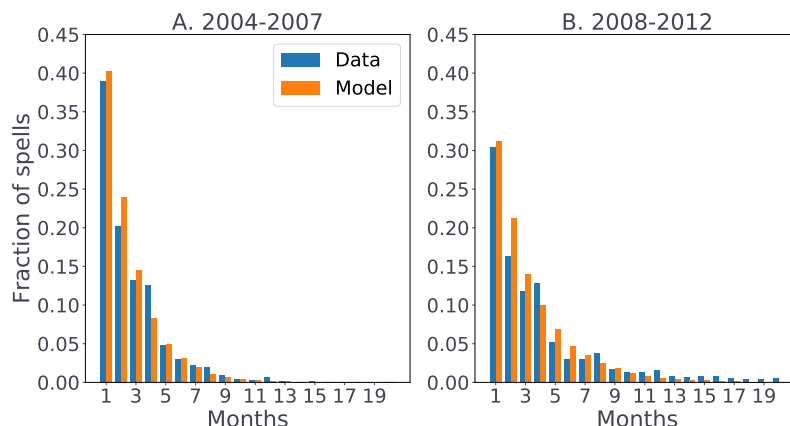
*Note:* This table shows the difference between the aggregate quarterly MPC and the annual MPC of the unemployed and employed. Individual MPCs are calculated by computing the fraction consumed out of an unexpected US\$500 transfer. Then, the aggregate MPCs are obtained by integrating over the distribution of agents. These model-implied MPC values are then compared to the empirical estimates that are available in the literature.

the model, we compute an agent’s MPC by calculating the fraction of an unexpected and temporary transfer—scaled to be equivalent to US\$500—spent on consumption. As in Kaplan and Violante (2014), this is implemented as a tax rebate in order to ensure consistency with the available empirical estimates.

Table 4 shows that the aggregate quarterly MPC in the model is 12 percent, which is comparable to the estimates found by Parker et al. (2013), who find that households spend between 12 and 30 percent of unexpected tax rebates in the quarter in which they are received. Furthermore, the model predicts that the difference in the annual MPCs between the unemployed and employed is 29 percent, which is reasonably close to the results of Kekre (2019), who finds the difference to be 25 percent when using the 2010 Survey of Household Income and Wealth.

**Unemployment-spell duration over the cycle** The duration of an unemployment spell also determines the extent to which UI can provide insurance against income risk. A model where unemployment spells are shorter than those in the data will underestimate the severity of the unemployment and thus the insurance benefits of UI. We compare the distributions of the completed unemployment-spell durations between periods of nonrecession and recession, using the SIPP 2004 Panel, which covers the period from October 2003 through December 2007, and the 2008 Panel, which covers the period from December 2007 through November 2013. To make a comparison using model-generated data, we simulate the roughly 10-year period that spans both SIPP panels by picking the realizations of aggregate labor productivity to match the unemployment rate for

Figure 2: Distribution of unemployment-spell durations



*Note:* This figure plots the distributions of the completed unemployment-spell durations before and after the Great Recession in both the model and the data. We calculate the empirical distribution using SIPP 2004 (Panel A) and SIPP 2008 (Panel B) panels. The model distributions are obtained from the simulated data where we pick the realizations of aggregate labor productivity to match the unemployment rate for the given period.

the period between October 2003 and November 2013. Figure A.2 in Appendix B shows the resulting series in this experiment and compares the unemployment rate that is generated by the model with that in the data for this time period.

Figure 2 shows that in both the model and the data, there is a marked shift toward longer unemployment spells during and after the Great Recession. In the data, 72 percent of the spells in the 2004 Panel did not exceed one quarter in length, compared to just 59 percent in the 2008 Panel. The model predicts similar patterns: 78 percent for the 2004 Panel simulation and only 66 percent for the 2008 Panel simulation.

## 4.2 Micro and Macro Effects of Changes in UI Policy

Using quasi-experimental methods and cross-sectional variations in UI policy instruments, several studies estimate the effect of the generosity of UI benefits on household savings, the re-employment wages of the unemployed, and the aggregate unemployment rate. Given that our model is capable of replicating the same experiments that are used to measure these empirical elasticities, our model-implied elasticities are directly comparable to them. Table 5 summarizes the results of this comparison.

Table 5: Micro and macro elasticities with respect to UI generosity

|                        | Model | Data         |
|------------------------|-------|--------------|
| Assets                 | -0.16 | -0.18        |
| Re-employment wages    | 0.07  | -0.13 - 0.25 |
| Aggregate unemployment | 0.10  | 0.10 - 2.15  |

*Note:* This table summarizes the magnitudes of the elasticities of assets, re-employment wages of UI recipients, and the aggregate unemployment with respect to changes in UI generosity in both the model and the data. For assets, the values in the table show the estimated average percentage-point change in the assets-to-income ratio in response to a 5-percentage-point increase in the replacement rate. For re-employment wages, the values show the estimated average percent change in the re-employment wages of UI recipients in response to a one-month increase in the potential UI duration. Finally, for aggregate unemployment, the values show the estimated percentage-point increase in the aggregate unemployment rate during the Great Recession due to the extensions to UI benefits implemented by the U.S. government during that period. The main text provides the details of these calculations.

**Assets** Households have access to both private and public insurance against labor income risk. The degree to which households substitute away from private insurance when public insurance is more generous will have important implications for their labor market behavior and welfare.

We compare the elasticity of precautionary savings with respect to the generosity of UI benefits implied by the model with existing empirical estimates. Engen and Gruber (2001) estimate the crowding-out effect of UI on financial assets, using SIPP data under the following regression specification:

$$WEALTH_i = \iota_i + \zeta_1 X_i + \zeta_2 RR_i + \zeta_3 \varphi_j + \zeta_4 \xi_t + \epsilon_{ijt}, \quad (8)$$

where  $WEALTH_i$  is the assets-to-income ratio of household  $i$ ;  $X_i$  is a vector of demographic and economic characteristics such as age, sex, marital status, education, and a quartic on wages;  $RR_i$  is the individual's UI replacement rate, and  $\iota_i$ ,  $\varphi_j$ , and  $\xi_t$  are individual-, state-, and year-specific dummies. They find that a 5-percentage-point increase in the replacement rate decreases the assets-to-income ratio by 0.18 percentage points. Using model-generated data, we run the same regression, controlling for a quartic on wages and time and individual fixed effects. The model predicts that the same 5-percentage-point increase in the replacement rate lowers the assets-to-income ratio by 0.16 percentage points.

**Re-employment wages** While the model is calibrated to match the response of non-employment duration to changes in the UI generosity, we do not directly target moments that relate to re-employment outcomes. Here, we compare the elasticity of re-employment wages with respect to the benefit extensions in the model with available empirical estimates. This moment is informative about the extent to which increases in the generosity of the benefits allows workers to match with higher-paying jobs. However, these are potentially more difficult to find.

The empirical literature has mixed findings on this relationship. Card, Chetty, and Weber (2007) and Johnston and Mas (2018) use quasi-experimental designs with administrative data and conclude that the re-employment wage effect of UI benefits is not statistically different from zero. Schmieder, von Wachter, and Bender (2016) find that workers with longer potential UI spells earn *lower* wages: a six-month (one-month) increase in the UI duration leads to a 0.8 (0.13) percent decline in post-unemployment wages. In contrast, Nekoei and Weber (2017) find that a 9-week (one-month) extension of benefits leads to a 0.5 (0.25) percent increase in re-employment wages. They reconcile these mixed results by showing that while increases in the UI duration lead the unemployed to look for higher wages (selectivity margin), they also cause longer unemployment spells and duration dependence due to lower search efforts, leading to a reduction in these people's subsequent wages (search margin).

To benchmark the model against these findings, we compare the average re-employment wages between the baseline economy and the one where the maximum UI duration is extended by one month, taking into account the effect of this policy change on the equilibrium market tightness. We find that this leads to only a 0.07 percent increase in the re-employment wages, a small positive estimate that lies in between the available range of estimates in the microeconomic studies.

The reason why the model finds a small elasticity for re-employment wages is that wealth holdings endogenously affect the job-search behavior of the unemployed. First, UI recipients are predominantly low-wealth households with no self-insurance, so they barely increase their wage choices despite the benefit extensions. For this reason, to begin with, the selectivity margin in our model is not strong. Furthermore, wealth decumulation over the unemployment spell also



leads job seekers to direct their search toward lower-paying jobs with higher job-finding probabilities. Hence, even in the absence of duration dependence in the model, longer unemployment spells generate negative pressure on re-employment wages due to the wealth channel.

**Aggregate unemployment** Finally, we compare the effect of UI-benefits extensions during the Great Recession on the unemployment rate in both the model and the data. The empirical literature presents mixed findings on this moment. Rothstein (2011), Farber and Valletta (2015), and Chodorow-Reich et al. (2019) separately conclude that the macroeconomic effects of extensions to UI benefits are small. According to their results, in the absence of extended benefits, the unemployment rate would have been only around 0.1 to 0.5 percentage points lower. However, Hagedorn et al. (2019) find that unemployment in 2011 would have been 2.15 percentage points lower had benefits not been extended.

To understand the model’s predictions about the aggregate effect of UI extensions on the labor market during the Great Recession, we simulate the model for the period of the Great Recession with and without UI-benefits extensions and measure the time path of the unemployment rate. This is accomplished by picking the realizations of aggregate labor productivity to match the unemployment rate for the period December 2007 to November 2013 under UI extensions implemented by U.S. policy, as shown in Figure A.2 in Appendix B. We find that during the depth of the recession, the model-implied unemployment rate would have been only around 0.1 percentage point lower in the absence of benefits extensions, implying that extending benefits during the Great Recession played a limited role in exacerbating the labor market conditions during that period.

The next section will elaborate on why the model predicts a small response of the unemployment rate to changes in benefits generosity and also on which model elements presented in our model contribute to this result.

### **4.3 Interpreting empirical elasticities with the model**

The goal of this section is to use our model to provide an explanation for the divergent empirical estimates on the elasticities of re-employment wages and the

Table 6: Effect of UI duration on the unemployment rate in different models

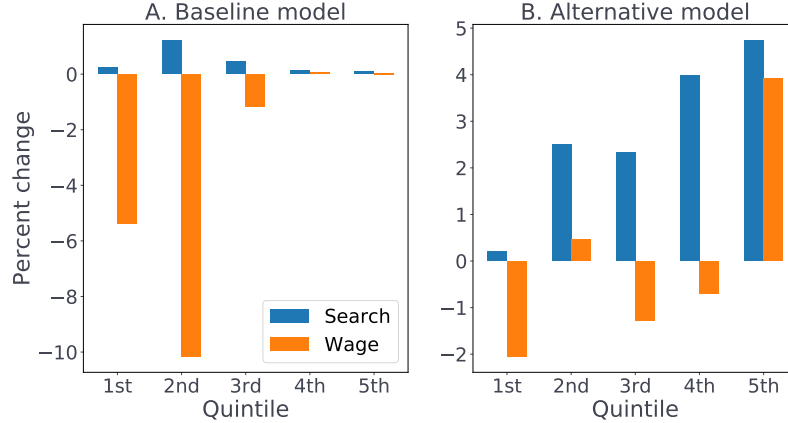
|                               | Baseline | $\phi = 0$ | $\phi = 0$          | $\phi = 0$          | $\phi = 0$          | $\phi = 0$          | $\phi = 0$          |
|-------------------------------|----------|------------|---------------------|---------------------|---------------------|---------------------|---------------------|
|                               |          |            | $\eta_y^\delta = 0$ | $\eta_y^\delta = 0$ | $\eta_y^\delta = 0$ | $\eta_y^\delta = 0$ | $\eta_y^\delta = 0$ |
|                               |          |            |                     | $g = 0.5$           | $g = 0.5$           | $g = 0.5$           | $g = 0.5$           |
|                               |          |            |                     |                     | $b = 0.52$          | $b = 0.26$          | $b = 0.98$          |
| Change in<br>unemp. rate (pp) | -0.01    | -0.17      | -0.46               | -0.34               | -0.55               | -0.16               | -1.93               |

*Note:* In this table, we compare the stochastic steady-state average unemployment rates under our baseline policy and under a policy where the potential benefits duration is cut by half; i.e.,  $\hat{e}(p) = 2e(p) \forall p$ . Values in the table are the percentage-point changes in the unemployment rate (as the alternative policy value minus the baseline policy value) in our baseline model (first column) and in the models (subsequent respective columns) where we shut down the following mechanisms, one by one: i) imperfect and endogenous take-up, ii) heterogeneous separations rates, iii) heterogeneous UI eligibility, and iv) heterogeneous replacement rates.

aggregate unemployment rate with respect to UI generosity. To do so, we sequentially explore the implications of accounting for household heterogeneity in terms of the unemployment risk and of UI receipt in determining the magnitude of these elasticities. Specifically, we focus on the following features in our model: i) imperfect and endogenous take-up, ii) heterogeneous separations rates, iii) heterogeneous UI eligibility, and iv) heterogeneous replacement rates. We compare the stochastic steady-state average unemployment rate under our baseline policy and under a policy where the potential benefits duration is halved; i.e.,  $\hat{e}(p) = 2e(p) \forall p$ . Table 6 presents the percentage-point changes (as the value of the alternative policy minus the value of the baseline policy) of the unemployment rate in our baseline model and in the models where we shut down the above mechanisms, one by one.

We begin with the baseline model. It predicts a limited response of aggregate unemployment to changes in the benefits generosity because wealth-poor households are those that primarily take up UI, as seen in Table 2. These households are inelastic to changes in UI policy because as they are close to the borrowing limit and have almost no access to self-insurance, jobs are most valuable to them. In contrast, the unemployed who possess some degree of self-insurance are more likely to respond to changes to UI generosity because they are more capable of smoothing consumption by drawing from their wealth to supplement the UI benefits they receive. Finally, the richest unemployed exhibit negligible responses

Figure 3: Search and wage choices of unemployed across assets-to-income quintiles



*Note:* This figure compares the stochastic steady-state average search effort and wage choice of the unemployed across assets-to-income quintiles under our baseline policy and under a policy where the potential benefits duration is cut by half; i.e.,  $\hat{e}(p) = 2e(p) \forall p$ , in our baseline model (Panel A) and in an alternative model (Panel B) with full UI take-up and homogeneous job-separation rates, UI eligibility rates, and UI replacement rates across individuals (such that  $\phi = 0$ ,  $\eta_y^0 = 0$ ,  $g = 0.5$ , and  $b = 0.52$ ). Values in the figure are percent changes in the average search effort and the wage choices of the unemployed relative to their values under the baseline policy.

since they enjoy sufficient insurance from their own savings and do not even take up benefits. This inverse U-shape pattern is summarized by Panel A of Figure 3, where we calculate the percent changes in the search effort and the wage choices of the unemployed across the quintiles of the assets-to-income distribution following the change in the UI duration in the baseline model.<sup>25</sup> The result emphasizes that the heterogeneity in the elasticities across the assets-to-income distribution is a critical feature of the model. In this framework, the aggregate response of the unemployment rate is inextricably tied to the underlying wealth distribution of the unemployed. To the extent that the unemployed are typically wealth poor and borrowing constrained, and more so during recessions, these elasticities predict a small response of unemployment.

Next, we shut down several channels in our model, one by one. The second column of Table 6 shows the resulting change in the aggregate unemployment rate when we remove endogenous UI take-up decisions by setting the utility cost of take-up to zero; i.e.,  $\phi = 0$ . Here, effective UI coverage expands

<sup>25</sup>Here, we use the percentiles of the assets-to-income distribution of the model under the baseline UI policy when defining the quintiles of the distribution in this exercise.

to relatively wealthier agents who, under the presence of take-up costs, would have otherwise refused to claim benefits. Since the search and wage choices of such unemployed are more responsive to changes in UI generosity, compared with borrowing-constrained households, as shown in Figure 3, a model with full take-up induces a larger response in the re-employment wages and the unemployment rate. Overall, this exercise highlights the importance of endogenous take-up—where wealth-poor unemployed self-select into the pool of UI recipients. In a model where this channel is absent, the micro and macro effects of the UI extensions are pronounced.

Suppose we assume that the unemployment risk is uniform; i.e.,  $\eta_y^\delta = 0$ . Given that all agents now face an equal probability of losing their jobs, regardless of whether they are high or low income or wealthy, the wealth distribution of the unemployed shifts to the right. Following the same intuition, the inclusion of a larger proportion of agents with better self-insurance into the pool of the unemployed amplifies the elasticity of the wage and search choices and, thus, the elasticity of the unemployment rate to changes in the UI duration.

We then impose that the UI eligibility upon a job loss is independent of past earnings; i.e.,  $m_w^g = 0$ , and set  $g(w, p) = 0.5$  for all agents. Here, severely low-income households that had previously been excluded from UI due to the program’s earnings requirements now enjoy a higher probability of receiving benefits. The inclusion of poorer and inelastic households into the pool of the unemployed dampens the overall response of unemployment to a change in the benefits generosity.

Finally, we further reduce the heterogeneity by introducing a uniform average replacement rate; i.e.,  $m_w^b = 0$ , and set  $b(w, p) = 0.52$ . Relative to the previous model, the rich now enjoy higher replacement and take-up rates. Now that the UI benefits amount is larger for higher earners, their labor market behaviors also become more elastic to changes in the benefits generosity. Panel B of Figure 3 shows that, in this version of our model with full take-up and uniform job-separation risk, UI eligibility, and replacement rates, the wage and search choices of richer agents are responsive to changes in the UI policy. These policy changes lead to a much larger response of the aggregate unemployment rate. Hence, this exercise shows that abstracting from these important dimensions of heterogeneity

in the model results in a larger unemployment response due to the overestimation of the labor market responses of those who are unemployed and have relatively high levels of private insurance.

We also explore the implications of changing the uniform replacement rate down from 52 percent to 26 percent as a simple and reduced-form way to adjust for imperfect take-up without having to endogenize it (under the assumption that around half of the unemployed actually receive UI). Given that UI is no longer as potent in providing insurance to all of the unemployed, the response is markedly weaker but still much higher than in the baseline model. Finally, changing the replacement rate from 52 percent to 98 percent to simulate the effects of raising the opportunity cost of employment results in large changes in unemployment, since the UI program now provides a substantial degree of insurance to all job losers.

## 5 Optimal Policy

In this section, we first use our model to solve for the optimal UI policy instruments. We then discuss the mechanisms through which the optimal policy improves aggregate welfare as well as its heterogeneous welfare effects across different types of individuals in the economy.

### 5.1 Welfare Analysis

**Measurement** The government chooses UI policy instruments  $m_0^b$ ,  $m_w^b$ ,  $m_p^b$ ,  $m_0^e$ ,  $m_p^e$ , and implied tax rate  $\tau$  to maximize the ex-ante lifetime utility of an individual who is born (under the veil of ignorance) into an economy where the baseline policy is being implemented but is subject to the government budget constraint.<sup>26</sup> Put differently, the government maximizes a utilitarian social-welfare function, subject to Equation (6), by choosing a set of policy instruments. The policy reform is unanticipated and permanent. Our welfare analysis takes into

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<sup>26</sup>We focus on both the optimal level and cyclicity of the UI replacement rate and duration, but we keep the UI eligibility parameters ( $m_0^g$ ,  $m_w^g$ ,  $m_p^g$ ) at their values under the current policy. This is because it is computationally infeasible to jointly optimize nine parameters over a broad range. Moreover, we do not consider any cap in the UI duration when testing policy reforms.

account the effects of the transition path from the stationary distribution of the economy under the baseline policy to that under the proposed policy. Appendix C provides formal expressions for the welfare measure and discusses an alternative welfare measure.

**Optimal policy results** The optimal policy is countercyclical in both the replacement rate and the benefits duration and features a higher replacement rate for low-wage earners than for high-wage earners.<sup>27</sup> This policy prescribes that the replacement rate rises from 43 to 49 percent for the median wage earner when labor productivity is depressed by 3.5 percent from its mean. The countercyclical replacement rates under the optimal policy are, however, lower than under the baseline policy, which features a 52 percent acyclical replacement rate for the median wage earner. The optimal policy also offers a longer potential UI duration of 24 months during normal times and 40 months during deep recessions, compared with only 6 months extending to 24 months under the baseline policy. The rate at which replacement rates decline with wages is also higher. The 20th-percentile wage earner receives a replacement rate of 63 percent, while the earner in the 80th-percentile receives only 27 percent of their wages, implying a ratio of 2.4, which is much higher than the baseline ratio of 1.9. The tax required to finance the optimal policy is  $\tau = 0.71$  percent, which is lower than the baseline tax rate of  $\tau = 0.76$  percent. This is explained by the lower average replacement rates and the fact that, despite a rise in the potential duration, benefits recipients typically find jobs before the extensions are utilized. Overall, the optimal replacement rates are close to the U.S. levels, albeit countercyclical, while the optimal durations are reminiscent of UI policies in many European countries. For example, Belgium, France, Spain, Denmark, and Finland prescribe up to an 80 percent replacement rate with potential UI durations of longer than 24 months.

Previous studies provide mixed prescriptions on the optimal UI policy over the business cycle. In particular, Mitman and Rabinovich (2015) find that the optimal UI replacement rates and payment durations are procyclical in the long run, with replacement rates as high as 44 percent for around 9 months during expansions and as low as 36 percent for around 4 months during recessions.

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<sup>27</sup>We find that  $m_0^b = 1.5$ ,  $m_p^b = -0.78$ ,  $m_w^b = -0.28$ ,  $m_0^e = 451.47$ , and  $m_p^e = -426.87$ .

Jung and Kuester (2015) also find that optimal replacement rates are procyclical, with little variation over the cycle. However, Landais et al. (2018) find that optimal replacement rates are countercyclical, at 33 percent of wages during booms and 50 percent during recessions. Unlike these studies, our framework accounts for the observed wealth heterogeneity among the unemployed. The crucial implication is that since borrowing-constrained households are more likely to claim UI benefits, the aggregate incentive costs of generous UI policies are limited in our framework. This rationalizes why the optimal UI policy turns out to be more generous compared to previous findings.

To illustrate the mechanisms behind this result, we now compare the response of an economy under the optimal policy with an economy under the baseline policy to a sudden 3.5 percent drop in aggregate productivity. When the shock is realized, each economy begins with its respective stationary distribution. Aggregate productivity then returns to its mean after 60 months. Figure 4 shows that under the optimal policy, the recession triggers both a rise in replacement rates and extensions in UI duration.<sup>28</sup> The unemployment rate increases by 40 percent during this deep recession, but its response is almost indistinguishable between the baseline policy and the optimal policy, despite the latter promising a substantially longer UI duration. As discussed in Section 4.3, this is because of the small responses in the wage choice and the search effort of the UI-recipient demographic. Wealth-poor households typically claim UI benefits and the presence of borrowing constraints is a device that disciplines their job-search behavior.

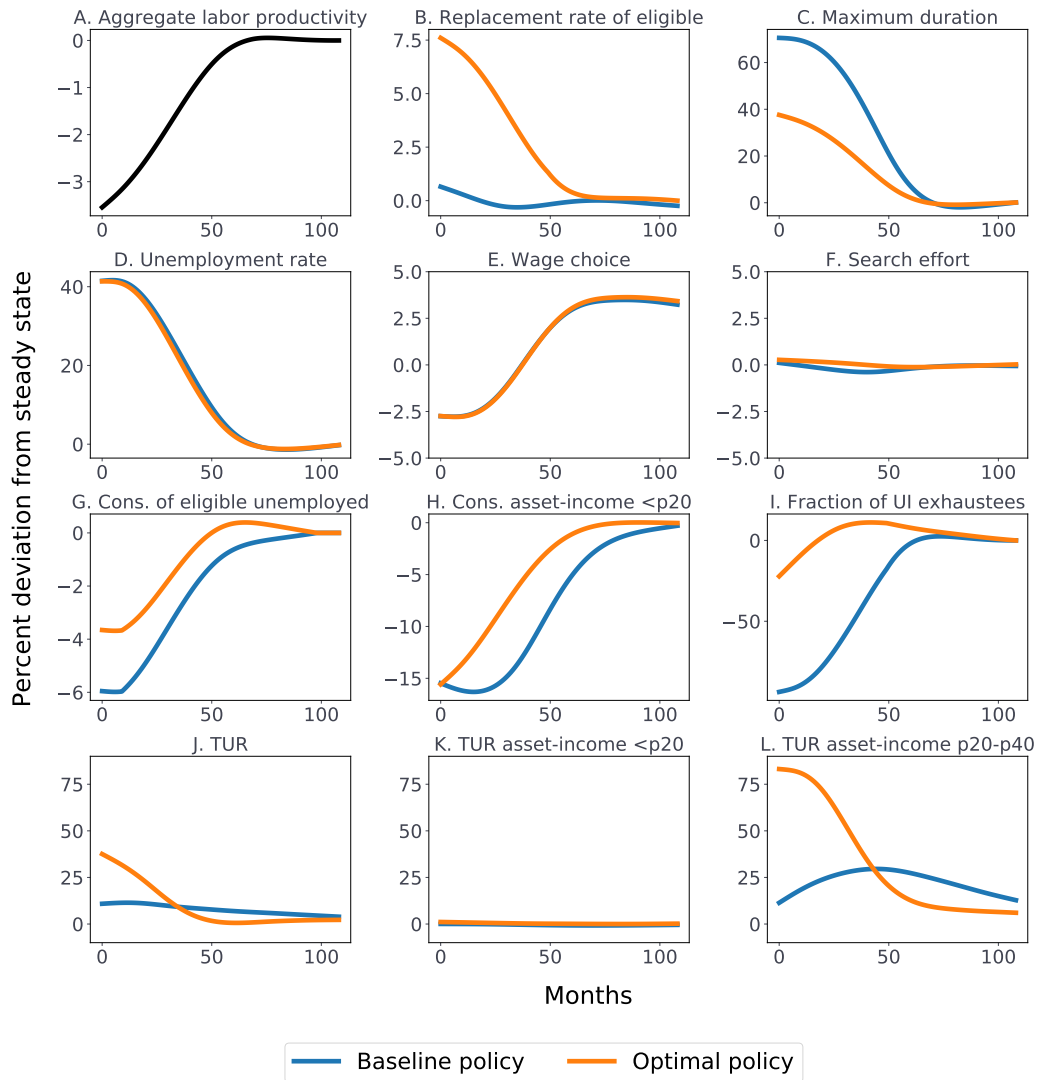
While the moral hazard effects of the optimal policy are smaller during recessions, it provides larger consumption-smoothing benefits in downturns, especially to agents for whom additional insurance is most valuable. The drop in average consumption for the unemployed with assets-to-income ratios below the 20th percentile is markedly lower under the optimal policy. This result is driven by two forms of redistribution. First, the generous UI durations offered by the optimal policy during recessions lowers the probability that the long-term unemployed exhaust their benefits.<sup>29</sup> While incidences of long-term unemployment are low,

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<sup>28</sup>The higher average UI duration under the optimal policy implies that in percentage terms, UI extensions in recessions are much lower under the optimal policy than under the baseline policy.

<sup>29</sup>The percentage change in the fraction of households that exhaust their benefits under the

Figure 4: Impulse-response functions under the baseline and optimal policies



*Note:* This figure compares the response of an economy under the optimal policy with an economy under the baseline policy to a drop in aggregate labor productivity of 3.5 percent below its mean. In this exercise, each economy begins with its respective stationary distribution when the negative shock to labor productivity is realized. Aggregate labor productivity then returns to its mean after around 60 months. Cons. refers to consumption.



these households have the highest marginal utility of consumption. Note that despite longer UI durations under the optimal policy, the average UI take-up duration is very similar under both the baseline and the optimal policies. This means that most of the unemployed are able to find jobs before the extensions become relevant for them. Second, the optimal policy also induces drastically higher take-up rates during recessions. Given much longer UI durations, individuals who would have opted out during periods of expansion now find it beneficial to apply for UI benefits during recessions, when unemployment spells are prolonged. Thus, while the unemployed below the 20th percentile of the assets-to-income distribution exhibit almost no change in UI claims during recessions, those above the 20th percentile drastically increase their take-up. This result emphasizes the importance of modeling endogenous UI take-up decisions, given that the optimal policy’s insurance benefits also manifest through a sizable increase in the number of UI claims during recessions.

**Heterogeneous welfare effects** The optimal policy yields an ex-ante welfare gain of 0.32 percent in lifetime consumption equivalents. In order to understand how welfare gains are distributed across heterogeneous households, we measure the ex-post welfare gains/losses of the optimal policy for subgroups of the population. To do so, we first compute the welfare gains for each individual state. We then group the agents by their employment statuses and assets, based on the stationary distribution under the baseline policy. Finally, for each group, we integrate the individual welfare gains over the agents who belong to the group. This gives us the average ex-post welfare gains/losses of the group.<sup>30</sup> Table 7 summarizes the results.

The highest welfare gains are enjoyed by the unemployed who are eligible for UI benefits. This is unsurprising because, conditional on their take-up decisions, these people are the direct recipients of UI benefits. Within this group, welfare gains exhibit an inverse U shape, with households in the second and third quintiles enjoying the highest welfare gains. The reason behind this can be traced to

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optimal policy is small, as the policy provides much longer UI durations in all states of the economy.

<sup>30</sup>Appendix C provides formal expressions for this calculation.

Table 7: Heterogeneous welfare gains

| Employment            | Asset groups |       |       |       |       |
|-----------------------|--------------|-------|-------|-------|-------|
|                       | $a_1$        | $a_2$ | $a_3$ | $a_4$ | $a_5$ |
| Worker                | 0.28         | 0.39  | 0.31  | 0.29  | 0.15  |
| Eligible unemployed   | 0.40         | 0.59  | 0.60  | 0.44  | 0.34  |
| Ineligible unemployed | 0.38         | 0.43  | 0.41  | 0.36  | 0.25  |

*Note:* This table shows the heterogeneous welfare gains from the optimal policy on various groups, where the columns represent agents that hold various levels of assets and the rows represent agents of differing employment statuses. Welfare gains are in terms of the percentage lifetime equivalent consumption relative to the baseline policy. The asset groups are quintiles of the asset distribution prior to the policy change.

the response of the take-up rates shown in Figure 4. Households in the bottom quintile already have very high take-up rates, even during periods of non-recession and thus benefit only from marginally higher payments for longer durations. As such, welfare gains from the optimal policy arise only along the intensive margin. In contrast, households in the middle quintiles are relatively more insured during non-recessions such that UI benefits are not deemed valuable enough to claim. However, when a recession occurs, their take-up rate drastically increases. Welfare gains from the optimal policy for this group arise along the extensive margin.

The ineligible unemployed do not receive benefits during their current spell but still enjoy large welfare gains. This is because this group is composed of households with low productivity, low wealth, and future labor market outcomes that are characterized by a higher risk of repeated unemployment. Thus, countercyclical benefits with much longer durations are valuable to them.

Importantly, workers also enjoy a sizable welfare gain from the optimal policy. This is because, even in the absence of a job loss, they are now able to maintain a smoother consumption path over the business cycle, afforded by countercyclical benefits with much longer durations that reduce the need for precautionary savings. Furthermore, they also face larger unemployment risk during recessions and, thus, benefit from the additional insurance against it.

## 5.2 Optimal Policy in Alternative Models

In order to understand the role of generating the observed demographic differences between UI recipients and non-recipients in determining the optimal policy, we evaluate the welfare gains of implementing *the* optimal policy when we abstract from the critical features of the model.<sup>31</sup>

In Table 8, we present the welfare gains of the optimal policy relative to the baseline policy under different versions of our model. Recall that the optimal policy provides a 0.32 percent additional lifetime consumption. The second and third columns show that when we introduce full take-up or uniform job-separation rates, the welfare gains of the optimal policy are significantly reduced. As we discussed in Section 4.3, when the model abstracts from these features, the pool of UI recipients becomes relatively wealthier. This increases the aggregate incentive costs of the changes in the UI generosity over the business cycle, as the labor market behavior of the unemployed with some positive level of self-insurance is more elastic to UI. As a result, on one hand, the countercyclical benefits with much longer durations under the optimal policy yield smaller welfare gains. On the other hand, assuming uniform eligibility risk has the effect of slightly raising the optimal policy's welfare gains, as low-income earners who are inelastic now qualify for UI. Overall, these exercises show that modeling the heterogeneity of UI recipients similar to those in the data is critical in determining the welfare effects of any proposed UI policy reform.

## 6 Robustness

We conduct a series of robustness checks to understand the implications of certain assumptions made in the baseline model. First, we relax the assumption of a fixed interest rate  $r$  and consider a version of the model with procyclical interest rates as observed in the data. Second, we relax the assumption of allowing the government to balance its budget in expectation. In particular, we let tax rate  $\tau$  vary with aggregate labor productivity  $p$  and choose parameters of the tax

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<sup>31</sup>While we acknowledge that the optimal policy of the baseline model may no longer be optimal under these alternative environments, this exercise is informative about the importance of various channels in our model in determining the optimal policy.

Table 8: Welfare gains from the optimal policy in alternative models

|                   | Baseline | $\phi = 0$ | $\phi = 0$          | $\phi = 0$          |
|-------------------|----------|------------|---------------------|---------------------|
|                   |          |            | $\eta_y^\delta = 0$ | $\eta_y^\delta = 0$ |
|                   |          |            |                     | $g = 0.5$           |
| Welfare gains (%) | 0.32     | 0.15       | -0.05               | -0.01               |

*Note:* This table shows the welfare gains of the optimal policy in our baseline model (first column) and in models (subsequent respective columns) where we shut down the following mechanisms, one by one: i) imperfect and endogenous take-up, ii) heterogeneous separation rates, and iii) heterogeneous UI eligibility. Welfare gains are in terms of percentage lifetime equivalent consumption.

function such that the government’s period-by-period surpluses/deficits are minimized. Third, we consider the effects of introducing a higher level of government expenditures to account for other forms of government spending and transfers. The intention of this exercise is to understand whether a marginal change in taxes to fund the optimal policy will have different implications, depending on the level of taxes. Finally, we relax the assumption of a constant labor-income tax and introduce progressive taxation. We find that under all modifications, the optimal policy still provides substantial welfare gains. In the model with progressive taxation, however, these welfare gains are much smaller. This is because the progressive income tax diminishes the efficacy of UI as a tool for income redistribution. Detailed explanations on how we implement these exercises can be found in Appendix D.

## 7 Conclusion

We study the optimal unemployment insurance policy over the business cycle, using a tractable heterogeneous-agent job-search model with aggregate risk and incomplete markets, and find that the optimal policy is countercyclical for both the replacement rate and the benefits duration. We argue that accounting for the observed demographic differences between UI recipients and non-recipients is key to this result. UI recipients—who already have little wealth when they start their unemployment spell—quickly drive down their wealth and approach their borrowing limits. The resulting wealth effect induces them to intensify

their efforts to search for easier-to-find jobs. Overall, on one hand, the increase in the aggregate unemployment rate under the more generous optimal policy during recessions is limited, suggesting small moral hazard costs. On the other hand, UI provides substantial insurance, especially in recessions, when the wealth distribution shifts to the left and the long-term unemployment risk is higher. This is supported by a smaller drop in the consumption of the unemployed and a marked increase in their UI take-up rates under the optimal policy, during recessions.

Our main contribution to the growing literature on optimal UI over the business cycle is to study how the aggregate labor market response to policy reform is shaped by the interaction of the heterogeneity in UI receipt and the dynamics of wealth over the cycle. We show that abstracting from such heterogeneity and wealth dynamics results in drastically different aggregate implications of reforms to UI policy. Beyond the insurance-benefit and incentive-cost trade off, the optimal policy may have implications for the occupational choices of UI benefits recipients. Given that optimal UI benefits offer more generous replacement rates for longer durations, UI benefits recipients may be willing to start their own businesses. This is because of the weakened need for precautionary savings, allowing funds to be diverted to finance new businesses. We leave these analyses to future work.

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# Appendix

## A. Model

In this section, we first lay out the recursive problem of the ineligible unemployed. Next, we provide a proof for the existence and uniqueness of the model's block recursive equilibrium. Finally, we discuss the computational algorithm for solving for the BRE.

### A.1 Recursive Problem of the Ineligible Unemployed

The recursive problem of the ineligible unemployed is given by

$$\begin{aligned} V^{NB}(a, y; \mu) = & \max_{c, a' \geq a_l, s} u(c) - \nu(s) + \beta \mathbb{E} \left[ \max_{\tilde{w}} \left\{ sf(\theta(\tilde{w}, y'; \mu')) V^W(a', \tilde{w}, y'; \mu') \right. \right. \\ & \left. \left. + (1 - sf(\theta(\tilde{w}, y'; \mu'))) V^{UI}(a', y'; \mu') \right\} \middle| y, \mu \right] \end{aligned} \quad (\text{A.1})$$

subject to

$$\begin{aligned} c + a' &\leq (1 + r)a + h \\ \Gamma' &= H(\mu, p'), \quad p' \sim F(p' | p), \quad y' \sim Q(y' | y). \end{aligned}$$

Compared with the eligible unemployed, the ineligible unemployed do not receive benefits and are unable to qualify for UI eligibility.

### A.2 BRE

**Proposition:** *If i) utility function  $u(\cdot)$  is strictly increasing, strictly concave, and satisfies the Inada conditions and  $\nu(\cdot)$  is strictly increasing and strictly convex; ii) choice sets  $\mathcal{W}$  and  $\mathcal{A}$  and sets of exogenous processes  $\mathcal{P}$  and  $\mathcal{Y}$  are bounded; iii) the matching function  $M$  exhibits constant returns to scale; and iv) the UI policy is restricted to being only a function of the current aggregate labor productivity, then there exists a unique BRE for this economy.*

**Proof:** The proof presented here follows from Herkenhoff (2017) and Karahan and Rhee (2019), which are extensions of Menzio and Shi (2010, 2011). We extend the formers' proof to a model in which the government finances the time-varying UI benefits and we show that the model still admits block recursivity.

Existence: We prove the existence of BRE in two steps. We first show that the firm value functions and the corresponding labor market tightness depend on the aggregate state of the economy only through aggregate labor productivity. Then, given that the UI policy instruments are restricted to being a function of aggregate labor productivity, we show that the household's value functions do not depend on the aggregate distribution of agents across states. As a result, the solution of the household's problem, together with the solution of the firm's problem and the labor market tightness constitute a BRE.

Let  $\mathcal{J}(\mathcal{W}, \mathcal{Y}, \mathcal{P})$  be the set of bounded and continuous functions  $J$  such that  $J : \mathcal{W} \times \mathcal{Y} \times \mathcal{P} \rightarrow \mathbb{R}$  and let  $T_J$  be an operator that is associated with Equation (3) such that  $T_J : \mathcal{J} \rightarrow \mathcal{J}$ . Then, using Blackwell's sufficiency conditions for a contraction and the assumptions of the boundedness of the sets of exogenous processes  $\mathcal{Y}$  and  $\mathcal{P}$  and the choice set  $\mathcal{W}$ , we can show that  $T_J$  is a contraction that has a unique fixed point  $J^* \in \mathcal{J}$ . Thus, the firm value function satisfying Equation (3) depends on the aggregate state of the economy  $\mu$  only through aggregate labor productivity  $p$ . This means that the set of wages that is posted by the firms in equilibrium  $\mathcal{W}$  for each labor productivity level in the set  $\mathcal{Y}$  is also determined by aggregate labor productivity. Plugging  $J^*$  into Equation (5) yields

$$\theta^*(w, y; p) = \begin{cases} q^{-1}(\kappa/J^*(w, y; p)) & \text{if } w \in \mathcal{W}(p) \text{ and } y \in \mathcal{Y}(p) \\ 0 & \text{otherwise.} \end{cases}$$

Hence, we show that equilibrium market tightness does not depend on the distribution of agents across states.<sup>32</sup>

Next, we collapse the problem of households into one functional equation and

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<sup>32</sup>Notice that the constant-returns-to-scale property of the matching function  $M$  is crucial here so that we can write both the job-finding and vacancy-filling rates as functions of  $\theta$  only. The free-entry condition (5) is also important to pin down market tightness.

show that it is a contraction. Then, we show that the functional equation maps the set of functions that depend on the aggregate state  $\mu$  only through  $p$ .

Let  $\Omega$  denote the possible realizations of the aggregate state  $\mu$  and define a value function  $R : \{0, 1\} \times \{0, 1\} \times \mathcal{A} \times \mathcal{W} \times \mathcal{Y} \times \Omega \rightarrow \mathbb{R}$  such that

$$\begin{aligned} R(l = 1, n = 0, a, w, y; \mu) &= V^W(a, w, y; \mu) \\ R(l = 0, n = 1, a, w, y; \mu) &= V^B(a, w, y; \mu) \\ R(l = 0, n = 0, a, w, y; \mu) &= V^{NB}(a, y; \mu). \end{aligned}$$

Then, we define the set of functions  $\mathcal{R} : \{0, 1\} \times \{0, 1\} \times \mathcal{A} \times \mathcal{W} \times \mathcal{Y} \times \mathcal{P} \rightarrow \mathbb{R}$

and let  $T_R$  be an operator such that

$$\begin{aligned}
(T_R R)(l, n, a, w, y; p) = & l \left[ \max_{c, a' \geq a_l} u(c) + \beta \mathbb{E} \left[ \delta(p') [(1 - g(p')) R(l = 0, n = 1, a', w, y'; p') \right. \right. \\
& + g(p') R(l = 0, n = 0, a', w, y'; p')] \\
& \left. \left. + (1 - \delta(p')) R(l = 1, n = 0, a', w, y'; p') \right] \right] \\
& + (1 - l) n \left[ \max_{c, a', s, d} u(c) - \nu(s) - \phi d \right. \\
& + \beta \mathbb{E} \left[ \max_{\tilde{w}} \left\{ s f(\theta(\tilde{w}, y'; p')) R(l = 1, n = 0, a', \tilde{w}, y'; p') \right. \right. \\
& + (1 - s f(\theta(\tilde{w}, y'; p'))) [(1 - e(p')) R(l = 0, n = 1, a', w, y'; p') \\
& \left. \left. + e(p') R(l = 0, n = 0, a', w, y'; p')] \right\} \right] \\
& + (1 - l) (1 - n) \left[ \max_{c, a', s} u(c) - \nu(s) \right. \\
& + \beta \mathbb{E} \left[ \max_{\tilde{w}} \left\{ s f(\theta(\tilde{w}, y'; p')) R(l = 1, n = 0, a', \tilde{w}, y'; p') \right. \right. \\
& \left. \left. + (1 - s f(\theta(\tilde{w}, y'; p'))) R(l = 0, n = 0, a', w, y'; p') \right\} \right] \left. \right]
\end{aligned}$$

subject to

$$\begin{aligned}
c + a' &\leq (1 + r) a + l w (1 - \tau) \\
&+ (1 - l) n [b(y, p) d (1 - \tau) + h] + (1 - l) (1 - n) h \\
p' &\sim F(p' | p), \quad y' \sim Q(y' | y),
\end{aligned}$$

where we use the result from above that market tightness does not depend on  $\Gamma$ .

Assuming the utility function is bounded and continuous,  $\mathcal{R}$  is the set of continuous and bounded functions. Then, we can show that the operator  $T_R$  maps a function from  $\mathcal{R}$  into  $\mathcal{R}$  (i.e.,  $T_R : \mathcal{R} \rightarrow \mathcal{R}$ ). Then, using Blackwell's sufficiency conditions for a contraction and the assumptions of the boundedness of the sets of exogenous processes  $\mathcal{P}$  and  $\mathcal{Y}$ , and the choice sets  $\mathcal{W}$  and  $\mathcal{A}$ , we can show that  $T_R$  is a contraction that has a unique fixed point  $R^* \in \mathcal{R}$ . Thus, the solution to the household problem does depend on  $\Gamma$ . This constitutes a

BRE, along with the solution to the firm's problem and the implied labor market tightness that does not depend on  $\Gamma$ , given that the UI policy is a function of only of  $p$ .

Uniqueness: We know that the household's policy functions do not depend on  $\Gamma$ . Now, we prove the uniqueness of the policy functions for households' assets, wages, and search effort.

**Wage policy function:** Under the assumptions on  $u(\cdot)$  and  $\nu(\cdot)$ , together with the assumptions of the boundedness of the sets of exogenous processes  $\mathcal{P}$  and  $\mathcal{Y}$ , and the choice sets  $\mathcal{W}$  and  $\mathcal{A}$ , value functions  $V^l$  are strictly concave in  $w$  for  $l = \{W, B\}$  and  $l = NB$  is constant in  $w$ . For simplicity, assume that  $p$  and  $y$  are non-stochastic and  $\delta(y, p) = \delta$ . We then obtain the equilibrium value of a matched firm using Equation (3) as follows:<sup>33</sup>

$$J^*(w, y; p) = \frac{py - w}{r + \delta + \omega(1 - \delta)}(1 + r).$$

Then, we can write the equilibrium labor market tightness as

$$f(\theta^*(w, y; p)) = \theta^*(w, y; p) = \frac{J^*(w, y; p)}{\kappa},$$

where we assume that  $M = \min\{v, S\}$  in the first equality, and the second equality uses the free-entry condition. Using the expression for  $J^*(w, y; p)$  gives

$$f(\theta^*(w, y; p)) = \frac{1 + r}{\kappa[r + \delta + \omega(1 - \delta)]}[py - w] > 0.$$

Thus, the job-finding rate  $f(\cdot)$  is linear and decreasing in  $w$ . Then, rewriting the objective function for the wage choice of the eligible unemployed, we have

$$\begin{aligned} \max_{\tilde{w}} & sf(\theta(\tilde{w}, y; p))V^W(a', \tilde{w}, y; p) + (1 - sf(\theta(\tilde{w}, y; p))) \\ & \times [(1 - e(p))V^B(a', w, y; p) + e(p)V^{NB}(a', y; p)]. \end{aligned}$$

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<sup>33</sup>The following results can be obtained under an  $N$ -state Markov-process assumption for  $p$  and no restrictions on the job-destruction rate.

Using the result that  $V^W$  and  $V^B$  are strictly concave in  $w$ ,  $V^{NB}$  is constant in  $w$ , and  $f(\cdot)$  is linear and decreasing in  $w$ , it is easy to show that the above objective function is strictly concave in  $w$ . This implies that the wage policy function of the eligible unemployed is unique.

Similarly, rewriting the objective function for the wage choice of the ineligible unemployed yields

$$\max_{\tilde{w}} sf(\theta(\tilde{w}, y; p)) V^W(a', \tilde{w}, y; p) + (1 - sf(\theta(\tilde{w}, y; p))) V^{NB}(a', y; p)$$

and using the same reasoning implies that the wage policy function of the ineligible unemployed is also unique.

**Asset policy function:** Under the assumptions on the utility functions  $u(\cdot)$  and  $\nu(\cdot)$  and the choice sets  $\mathcal{A}$ ,  $\mathcal{W}$  and exogenous processes  $\mathcal{Y}$ ,  $\mathcal{P}$ , value functions  $V^l$  are strictly concave in assets. This implies that the objective functions for the asset choice of each employment status are strictly concave in  $a'$  and, thus, assets policy functions are unique for  $l = \{W, NB, B\}$ .

**Search-effort policy function:** Using the same reasoning, the objective functions for the search-effort choices of the eligible and ineligible unemployed are strictly concave in  $s$ . This implies that the search-effort policy functions are also unique.

**Discussion** This proposition demonstrates that the model can be solved numerically without keeping track of the aggregate distribution of agents across states  $\Gamma$ . One should be careful when interpreting this result. Even though we can solve for the policy functions, the value functions, and the labor market tightness independent of  $\Gamma$ , this does not mean that the distribution of agents is irrelevant for our analysis. Notice that the evolution of macroeconomic aggregates, such as the unemployment rate, average spell duration, and the economy's wealth distribution, is determined by household decision rules in both the labor market and the financial market. These decisions, in turn, are functions of individual states whose distribution is determined by  $\Gamma$ . Hence, the evolution of

aggregate variables after a change in the UI policy will depend on the distribution of agents in the economy at the time of the policy change.

Notice that if the UI policy instruments were to depend on the unemployment rate, then this would break the model's block recursivity. This is because agents would need to calculate the next period's unemployment rate to know the replacement rate and the UI duration for the next period. However, this requires calculating the flows in and out of unemployment, the latter of which depends on the distribution of agents across states  $\Gamma$ . Although the changes in the UI policy are triggered by the changes in the unemployment rate, according to the current UI program in the U.S., the assumption that the UI policy depends on aggregate productivity is not restrictive because of the strong correlation between the unemployment rate and the aggregate labor productivity in our model.

### A.3 Computational Algorithm

The model is solved using the following steps:

1. Solve for the value function of the firm  $J(w, y; p)$ .
2. Using the free-entry condition  $0 = -\kappa + q(\theta(w, y; p))J(w, y; p)$  and the functional form of  $q(\theta)$ , we can solve for market tightness for any given wage submarket  $(w, y)$  and aggregate productivity  $p$ :

$$\theta(w, y; p) = q^{-1}\left(\frac{\kappa}{J(w, y; p)}\right),$$

where we set  $\theta(w, y; p) = 0$  when the market is inactive.

3. Given the function  $\theta$ , we can then solve for the household value functions  $V^W$ ,  $V^B$ , and  $V^{NB}$  using a standard value function iteration. In order to decrease the computation time, we implement Howard's improvement algorithm (policy-function iteration).
4. Once the household policy functions are obtained, we are able to simulate the aggregate dynamics of the model.



## B. Data, Calibration, and Validation

In this section, we first provide details about the SIPP data and our calculations of the empirical moments used in the calibration and validation exercises. Then, we present additional tables and figures to supplement our discussion in Sections 3 and 4 of the main text.

### B.1 SIPP Data

We use the SIPP data to discipline the labor market transitions, the assets-to-income distribution, and the UI eligibility and take-up rates. The SIPP is a longitudinal survey that follows individuals for a duration of up to five years, with interviews held in four-month intervals called waves. Each respondent is then assigned to one of four rotation groups. The rotation group determines which month within a wave a respondent is interviewed. Each interview covers information about the four months (reference months) preceding the interview month. For example, when a new SIPP panel starts and Wave 1 (the first four months of the new panel) commences, the first rotation group is interviewed in the first month of Wave 1, the second rotation group is interviewed in the second month of Wave 1, and so on. Once all four rotation groups are interviewed at the end of the fourth month of Wave 1, Wave 2 begins with the second round of interviews with the first rotation group. This way, all four rotation groups and, thus, all of the respondents will have been interviewed at the end of each wave.

In each interview, the respondents are asked questions about their income, employment status, and receipts of government transfers over the previous four months, not including the interview month. In the end, the SIPP provides monthly data on income and government transfers and weekly data on the labor force status. Importantly, the SIPP also contains data on the respondent's asset holdings. In each SIPP panel, the respondents provide information on the various types of assets they held during two or three waves of the panel, usually one year or, equivalently, three waves apart.

Below we provide additional details to the discussion provided in the main text on the calculations of the empirical moments from the SIPP data. We restrict our sample to individuals aged 25 to 65 and to those who neither own a business

nor derive income from self-employment.

**Labor market transitions** Using the SIPP’s 1996, 2001, and 2004 panels (covering data for the period 1996 to 2007), we calculate the monthly job-finding and job-separation rates. First, we classify an individual as employed (E) if they report having a job and are either working or not on layoff but are absent without pay in the first week of the month. We classify the individual as unemployed (U) if they report either having no job and being actively looking for work or having a job but currently having been laid off in the first week of the month. Using these definitions, we find that the average E-U and U-E transition rates in the data—where we account for seasonality by removing monthly fixed effects—are 0.02 and 0.34, respectively, which are similar to the estimates of Fujita and Ramey (2006). When calculating the heterogeneity of the job-finding and job-separation rates across the income distribution, we use monthly labor earnings data.<sup>34</sup>

**Heterogeneity in job-separation rates** To measure the heterogeneity in the job-separation rates across the income distribution, we use monthly data from the SIPP for the period 1996 to 2007. First, we calculate the labor earnings distribution of employed individuals for each month. Then, for each month, we separately calculate the job-separation rate of employed individuals who are below the first quintile and above the fifth quintile of the labor earnings distribution, where we account for seasonality by removing the monthly fixed effects. The average ratio of the job-separation rate of low-income workers to that of high-income workers over time is 3.28, implying that workers in the first quintile of the earnings distribution are more than three times more likely to separate from their employers than those in the fifth quintile of the earnings distribution. We use  $\eta_y^\delta$  to match this value for the same moment in the model.

**Heterogeneity in job-finding rates** Calculating the calibration target pertaining to the heterogeneity in the job-finding rates follows a similar procedure. In particular, for each unemployment spell, we record the previous employment

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<sup>34</sup>Variables TPMSUM1 and TPMSUM2 provide the monthly gross labor earnings from up to two jobs. We sum these two variables to obtain the monthly labor-income.

income as the unemployed person’s labor earnings from the month prior to their job loss.<sup>35</sup> Then, for each month, we calculate the distribution of these job losers’ previous employment incomes. Next, for each month, we separately calculate the job-finding rate of the unemployed individuals who are below the first quintile and above the fifth quintile of the previous employment income distribution, where we account for seasonality by removing the monthly fixed effects. The average ratio of the job-finding rate of the low-income to the high-income unemployed over time is 0.96, implying that the bottom and top income quintiles have similar job-finding rates.<sup>36</sup> We use  $\eta_y^\lambda$  to match this value for the same moment in the model.

**Assets-to-income distribution** We use the SIPP’s 2004 panel, which contains 12 waves that cover information for the period January 2004 to December 2007. We use the topical module in Wave 6 to obtain information on the assets holdings.

We focus on individuals’ net liquid assets holdings. The SIPP contains individual-level data on financial liquid assets such as interest-earning financial assets in banks and other financial institutions, amounts in non-interest-earning checking accounts, equity in stocks and mutual funds, and the face value of U.S. savings bonds. Moreover, for married individuals, the survey asks about the amounts of these assets held in joint accounts. Only one spouse is asked about joint accounts; the response is then divided by two and the divided amount is copied to both spouses’ records. The SIPP also contains information about revolving debt on credit card balances at the individual level for both single and joint accounts, in the same fashion. The summation of the amounts in liquid-assets accounts net of

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<sup>35</sup>The result for the heterogeneity in job-finding rates across income groups is similar if we take the previous employment income as the quarterly average of the labor earnings prior to the job loss.

<sup>36</sup>A similar result is documented in Lise and Robin (2017) and Krusell et al (2017). Lise and Robin (2017) use the CPS to calculate the levels and cyclicalities of the labor market transition rates across education groups. They show that the job-finding rates of high school dropouts and college graduates have similar levels and cyclicalities. Krusell et al. (2017) use the SIPP to calculate the labor market transition rates of individuals across quintiles of the asset distribution. They find that the ratio of the job-finding rate of the unemployed individuals from the first quintile of the asset distribution to those from the fifth quintile of the asset distribution is 0.83.

revolving debt gives us the individual’s net financial assets holdings. Finally, the SIPP provides data on equity in cars at the household level. We split that amount between the members of the household who are age 16 or older, and record that value as the amount of equity in cars for each individual within the household. Adding this value to the individual’s net financial assets holdings gives us the measure of net liquid assets holdings for each individual.<sup>37</sup>

The SIPP also provides information about each individual’s monthly labor earnings. If the individual is unemployed during the interview month, then we use labor income associated with their last employment from earlier waves. Finally, dividing each individual’s net liquid-assets-holdings measure by their monthly labor income gives us the ratio of their net liquid assets to their monthly labor income.

**Unemployment-spell duration** Here, we provide additional details on the construction of the distribution of the completed unemployment-spell durations shown in Section 4.1. As in Rothstein and Valletta (2017), we require at least one quarter of employment prior to the spell in order to focus on individuals who have sufficient attachment to the labor market. Spells that are left-truncated and spells with missing information for which we cannot ascertain the respondents’ employment statuses are dropped. Finally, we define spells as being uninterrupted months of unemployment and, thus, do not consider time spent out of the labor force, since we do not model the non-participation margin. For each panel, we then report the duration distribution of the completed unemployment spells.

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<sup>37</sup>Individuals’ net financial assets holdings are calculated by using the following variables in the SIPP data:  
Net financial assets = TALICHA+TALJCHA+TALSBV+TIMIA+TIMJA+TIAITA+TIAJTA+ESMIV+ESMJV-(EALIDAB+EALJDAB), where TALICHA (TALJCHA) is the amount of non-interest-earning checking accounts that are registered in the respondent’s name (joint account); TALSBV is the face value of U.S. savings bonds; TIMIA (TIMJA) is the amount of bonds/securities in the respondent’s name (joint account); TIAITA (TIAJTA) is the amount in an interest-earning account in the respondent’s name (joint account); ESMIV (ESMJV) is the value of stocks/funds in the respondent’s name (joint account); and EALIDAB (EALJDAB) is the amount owed for store bills/credit cards in the respondent’s name (joint account). Then, the net equity in the household’s vehicles is given by THHVEHCL. We divide this value among the members of the household above age 16. Thus, we get the net-liquid-assets holdings of the individual as follows: Net liquid assets = Net financial assets +  $\frac{\text{THHVEHCL}}{\text{Num. of persons in household} > \text{age 16}}$ .

Table A.1: Externally calibrated parameters

| Parameter  | Explanation                                     | Value  | Parameter | Explanation   | Value   |
|------------|---|--------|-----------|---|---------|
| $\omega$   | Probability of death                            | 0.0021 | $\gamma$  | Matching function parameter                                     | 0.5     |
| $\sigma$   | Risk aversion                                   | 2      | $m_0^e$   | Level of UI expiration rate                                     | 507.17  |
| $r$        | Interest rate                                   | 0.0033 | $m_p^e$   | Cyclicalitity of UI expiration rate                             | -500.67 |
| $\kappa$   | Vacancy posting cost                            | 0.58   | $e_{cap}$ | Maximum UI expiration rate during non-recessions                | 4/26    |
| $\rho^y$   | Persistence of idiosyncratic labor productivity | 0.9867 | $m_p^b$   | Cyclicalitity of UI replacement rate                            | 0       |
| $\rho^p$   | Persistence of aggregate labor productivity     | 0.9183 | $m_p^g$   | Cyclicalitity of fraction of job losers who are eligible for UI | 0       |
| $\sigma^p$ | Dispersion of aggregate labor productivity      | 0.0042 |           |   |         |

*Note:* This table provides a list of externally calibrated parameters. Please refer to the main text for a detailed discussion.

## B.2 Calibration and Validation

In this section, we present additional tables and figures to supplement our discussion in Sections 3 and 4 of the main text. Table A.1 provides a list of externally calibrated parameters.

Table A.2 compares the aggregate labor market properties in the data and the model. In our calibration, the volatility of the job-finding and separation rates are targeted moments. As a natural outcome, the model is able to generate the observed magnitude of the unemployment-rate volatility in the data, as shown in Table A.2. The rest of the table shows that the model moments are reasonably close to their empirical counterparts, with the exception that the volatility of the market tightness is much smaller in the model than in the data.

Table A.2: Aggregate labor market properties

|                            | Data   |         |        |            | Model  |         |        |            |
|----------------------------|--------|---------|--------|------------|--------|---------|--------|------------|
| $X_t$                      | $UR_t$ | $JFR_t$ | $SR_t$ | $\theta_t$ | $UR_t$ | $JFR_t$ | $SR_t$ | $\theta_t$ |
| $\sigma_X$                 | 0.096  | 0.077   | 0.058  | 0.216      | 0.106  | 0.078   | 0.058  | 0.066      |
| $\sigma_X/\sigma_p$        | 10.70  | 8.56    | 6.46   | 24.12      | 12.32  | 9.07    | 6.73   | 7.70       |
| $\text{cor}(X_t, X_{t-1})$ | 0.93   | 0.80    | 0.63   | 0.93       | 0.80   | 0.67    | 0.59   | 0.57       |
| $\text{cor}(UR_t, X_t)$    | 1      | -0.90   | 0.72   | -0.98      | 1      | -0.82   | 0.76   | -0.70      |

*Note:* This table compares the aggregate labor market properties in the data and the model. We obtain the monthly times series for the unemployment rate for the period 1975 to 2005 from the Bureau of Labor Statistics. The monthly series for job-finding and separation rates are constructed by Fujita and Ramey (2006). Finally, we use Barnichon’s (2010) monthly composite Help-Wanted index to measure job vacancies. Both for the model and the data, each series is converted to quarterly averages of their respective monthly series, logged, and HP filtered with a smoothing parameter of 1600, and the standard deviation  $\sigma_X$  of each series  $X$  is calculated as the standard deviation of the cyclical component.  $UR$ ,  $JFR$ ,  $SR$ , and  $\theta$  denote the unemployment rate, job-finding rate, separation rate, and market tightness, respectively.

Next, Figure A.1 compares the UI replacement rates in the model and in the data as a function of the wages from previous employment relative to the mean wages. The calibrated UI replacement rate in the model comes close to its empirical counterpart.

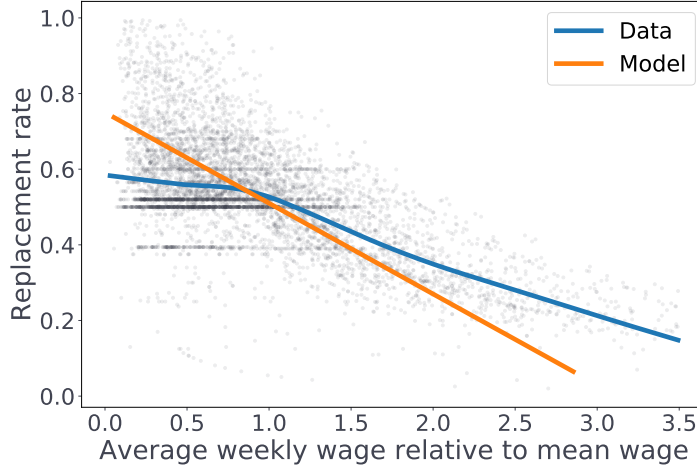
Finally, in Figure A.2, we present the path of the aggregate labor productivity (panel A) that we feed to our model to generate the observed unemployment rate (panel B) before and after the Great Recession. We use this simulation to study i) the distributions of unemployment-spell durations before and after the Great Recession in Section 4.1 and also ii) the aggregate unemployment rates with and without UI extensions during the Great Recession, which we presented in Section 4.2. Here, we pick 10 grid points across the time period and apply a cubic spline to minimize the sum of squared distances between the unemployment rates in the model and those in the data.

## C. Measurement of Welfare

In this section, we provide details on our welfare measures.

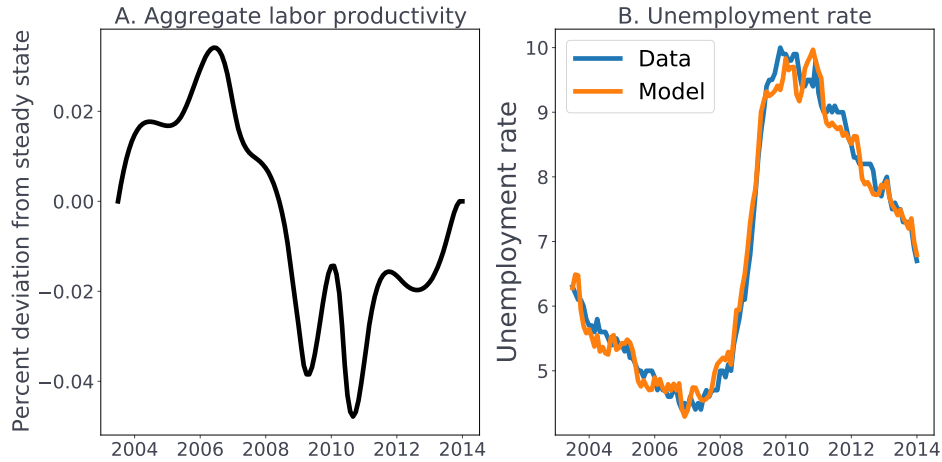
We employ two measures to assess the welfare impact of alternative UI policies relative to the existing policy. The first measure,  $\pi_1(z)$ , is computed separately for each individual state  $z$  that is possible in the economy; i.e.,  $z \in \mathcal{Z} \equiv$

Figure A.1: UI replacement rates in the model vs the data



*Note:* This figure compares the UI replacement rates in the model and in the data across the average weekly wage relative to the mean wage. We calculate the replacement rates of the UI-eligible unemployed across the average weekly wages by creating a program that combines information from the SIPP data and the eligibility rules on state-level UI laws. This allows us to predict whether or not a respondent is eligible for unemployment benefits, based on the observables in our SIPP sample. Each gray dot represents an individual replacement rate in the data. Replacement rates in the model represent the calibrated  $b(w, p)$  function, where we plot each value under the mean level of the aggregate labor productivity; i.e.,  $p = \bar{p}$ .

Figure A.2: Unemployment rate replication before and after the Great Recession



*Note:* This figure shows the series of the aggregate labor productivity (Panel A) that we feed to our model to generate the observed unemployment rate (Panel B) before and after the Great Recession. We use this simulation to study i) the distributions of the unemployment-spell durations before and after the Great Recession in Section 4.1 and ii) the unemployment rates with and without UI extensions during the Great Recession in Section 4.2.

$\{W, B, NB\} \times \mathcal{A} \times \mathcal{W} \times \mathcal{Y}$ . This measure enables us to assess the heterogeneous welfare gains or losses the proposed reform to UI policy may have on different types or subgroups of agents. We can also aggregate this to a summary measure, which we call  $\bar{\pi}_1$ , to arrive at a measure of the average welfare gain/loss for the entire economy. The second measure,  $\bar{\pi}_2$ , is motivated by Lucas (1987). This measure provides one aggregated welfare measure for the entire economy and allows for a better comparison with the existing literature.

We now formally define these two measures. Let  $\{c_t^E(z), s_t^E(z), d_t^E(z)\}_{t=T}^{\infty}$  denote the path allocations of an individual in state  $z$  at time  $T$  under the baseline/existing UI policy  $E$  according to the historical patterns of the UI program in the U.S. Similarly, let  $\{c_t^R(z), s_t^R(z), d_t^R(z)\}_{t=T}^{\infty}$  denote the path of allocations of the same individual under a proposed UI policy reform  $R$  from time  $T$  onward.

$\pi_1(z)$  is the percentage additional lifetime consumption that must be endowed at all future dates and states to *an* agent with individual state  $z$  under the stochastic steady-state distribution for an economy where policy  $E$  is implemented so that *the individual's* welfare will be the same as that under an economy where policy  $R$  is instead implemented forever. Formally, for all  $z \in \mathcal{Z}$ ,  $\pi_1(z)$  satisfies the following equation:<sup>38</sup>

$$\begin{aligned} E_T \sum_{t=T}^{\infty} \beta^{t-T} U(c_t^E(z)(1 + \pi_1(z)), s_t^E(z), d_t^E(z)) \\ = E_T \sum_{t=T}^{\infty} \beta^{t-T} U(c_t^R(z), s_t^R(z), d_t^R(z)), \end{aligned} \quad (\text{A.2})$$

where  $T$  is the time period when the UI policy changes from  $E$  to  $R$ .<sup>39</sup> Once we obtain  $\pi_1(z)$  for all  $z \in \mathcal{Z}$  by solving this equation, we can obtain an aggregate welfare measure by integrating over the stationary distribution  $\Gamma_{ss}^E$  in the baseline economy with policy  $E$ :

$$\bar{\pi}_1 = \int_{z \in \mathcal{Z}} \Gamma_{ss}^E(z) \times \pi_1(z). \quad (\text{A.3})$$

---

<sup>38</sup>Given the functional form of the utility function, there are no closed-form solutions for  $\pi_1(z)$ ,  $\bar{\pi}_1$ , or  $\bar{\pi}_2$ .

<sup>39</sup>In this calculation, the policy change occurs when the aggregate labor productivity is at its mean level at time  $T$  (i.e.,  $p_T = \bar{p}$ ) but is allowed to vary over time according to its AR(1) process from time  $T$  onward.



$\bar{\pi}_2$  is the percentage additional lifetime consumption that must be endowed at all future dates and states to *all* agents under the stationary distribution of the economy where policy  $E$  is implemented so that the *average* welfare will be equal to that of an economy that is populated with the same agents but where policy  $R$  is implemented. Formally,  $\bar{\pi}_2$  satisfies the following equation:

$$\begin{aligned} & \int_{z \in \mathcal{Z}} \Gamma_{ss}^E(z) E_T \sum_{t=T}^{\infty} \beta^{t-T} U(c_t^E(z)(1 + \bar{\pi}_2), s_t^E(z), d_t^E(z)) \\ &= \int_{z \in \mathcal{Z}} \Gamma_{ss}^E(z) E_T \sum_{t=T}^{\infty} \beta^{t-T} U(c_t^R(z), s_t^R(z), d_t^R(z)). \end{aligned} \quad (\text{A.4})$$

The government chooses the UI policy instruments in order to maximize the ex-ante lifetime utility of an individual who is born (under the veil of ignorance) into the stationary equilibrium under policy  $E$ , which is subject to the government budget constraint. In other words, the government's objective is to maximize ex-ante lifetime utility  $\int_{z \in \mathcal{Z}} \Gamma_{ss}^E(z) E_T \sum_{t=T}^{\infty} \beta^{t-T} U(c_t^R(z), s_t^R(z), d_t^R(z))$  subject to Equation (6) by choosing policy  $R$ . The policy reform implemented at time  $T$  is unanticipated and permanent. Moreover, our welfare measures incorporate the effects of the transition path from the stationary distribution of the economy under policy  $E$  to that under policy  $R$ .

We search over policy parameters, together with the implied tax rate  $\tau$  that balances the government's budget in expectation, to obtain our optimal UI policy. Hence, the optimal policy will be a policy  $R$  with some  $m_0^b$ ,  $m_w^b$ ,  $m_p^b$ ,  $m_0^e$ ,  $m_p^e$ , and  $\tau$  that maximizes the ex-ante welfare.

The welfare gains of the optimal policy are similar under these two measures. In particular, we find that the welfare gains are 0.29 percent under the first measure and 0.32 percent under the second measure; i.e.,  $\bar{\pi}_1 = 0.29$  percent and  $\bar{\pi}_2 = 0.32$  percent. With the exception of Table 7 in the main text, all welfare gains are presented in terms of  $\bar{\pi}_2$ .

To measure the ex-post heterogeneous welfare gains across employment and asset groups, as shown in Table 7, for each group  $k$ , we compute for

$$\bar{\pi}_{1,k} = \int_{z \in \mathcal{Z}_k} \Gamma_{ss,k}^E(z) \times \pi_1(z), \quad (\text{A.5})$$

Table A.3: Decomposition of welfare gains by policy parameter

| Optimal policy features introduced   | Welfare gains (%) | Optimal policy features introduced    | Welfare gains (%) |
|--------------------------------------|-------------------|---------------------------------------|-------------------|
| Rep. rate-wage het.                  | 0.06              | Duration level                        | 0.03              |
| + Rep. rate level                    | 0.10              | + Duration cyclical-ity               | 0.09              |
| + Rep. rate cyclical-ity             | 0.13              | + Rep. rate-wage het.                 | 0.17              |
| + Duration level                     | 0.24              | + Rep. rate level                     | 0.27              |
| + Duration cyclical-ity (optimal UI) | 0.32              | + Rep. rate cyclical-ity (optimal UI) | 0.32              |

*Note:* This table shows welfare gains from a UI policy that sequentially introduces features of the optimal UI policy, one by one. The first two columns show the results of starting from the baseline UI policy and sequentially changing the wage-replacement-rate schedule, the level and cyclical-ity of the replacement rate, and the level and cyclical-ity of the UI duration required to reach the optimal UI policy. The last two columns provide the results of a similar exercise but this time from changing the policy instruments starting from the UI duration level. For each step, we adjust the tax rate  $\tau$  so that Equation (6) holds. The welfare gains are calculated relative to the baseline UI policy, and they are in percentage additional lifetime consumption units.

where  $\mathcal{Z}_k$  is the set of individual states in group  $k$ , and  $\Gamma_{ss,k}^E(z)$  is the measure of type- $z$  agents in group  $k$  under the baseline policy’s stationary distribution.

**Joint optimization** A key feature of the optimal-policy exercise in this paper is the joint determination of the levels and cyclical-ities of both the replacement rates and the duration, as well as the rate at which the replacement rates vary with wages. The interaction of these different policy parameters is critical for realizing the welfare gains that result from the optimal policy. For example, the introduction of a countercyclical replacement rate would not result in substantial welfare gains if households were unable to claim these benefits for a long enough duration during economic downturns.

To quantify this claim, we compute the welfare gains that result from introducing individual features of the optimal policy, one by one. The first two columns of Table A.3 show the results of starting from the baseline UI policy and sequentially changing the wage-replacement-rate schedule, the level and cyclical-ity of the replacement rate, and the level of and cyclical-ity of the UI duration to reach the optimal UI policy.<sup>40</sup> For each step, we adjust tax rate  $\tau$  so that Equ-

<sup>40</sup>For the step where we introduce adjustments to the level of the replacement rates, for each wage, we set the level of the replacement rate to the one prescribed by the optimal policy when

Table A.4: Robustness

|   |      |
|---|------|
| Baseline model  | 0.32 |
| Time-varying interest rates                                     | 0.31 |
| Time-varying tax rates  | 0.25 |
| High level of government expenditure                            | 0.41 |
| High level of government expenditure under progressive taxation | 0.18 |

*Note:* This table shows the welfare gains of the optimal policy relative to the baseline policy when we change the assumptions in our model one at a time. Welfare gains are in percent additional lifetime consumption units.

tion (6) holds. Noticeably, introducing changes to the replacement-rate policy alone results in a welfare gain of only 0.13 percent, compared with 0.32 percent for the optimal policy. The last two columns provide the results of a similar exercise but this time changing policy instruments starting from the UI duration level. This demonstrates that putting in place the optimal UI duration policy without altering the replacement-rate schedule results in welfare gains that are just over a quarter of what the optimal policy yields.

## D. Robustness

In this section, we provide details on the implementation of our robustness exercises and show the welfare gains from the optimal policy when we change some of the assumptions of our model, one at a time. Even though the optimal policy in our baseline model may not be optimal anymore once we change the model, these exercises are still useful for exploring the effects of such assumptions on the optimal policy. The results are summarized in Table A.4.

**Time-varying interest rates** In our model, we assume a constant and exogenous interest rate  $r$ . Alternatively, in an equilibrium model of asset markets, an increase in aggregate savings during recessions would reduce interest rates and offset the need to engage in precautionary savings. As a result, given that in our model the interest rate is constant over time, this may lead to the excessive labor productivity is at its mean.

cyclicality of the precautionary-savings motives in our model, when compared to an equilibrium model of asset markets.

To understand the implications of this issue on the welfare gains from the optimal policy, we consider procyclical interest rates and let the path of interest rates vary with aggregate labor productivity such that  $r(p) = m_0^r + m_p^r p$ . Then, we calibrate  $m_0^r$  and  $m_p^r$  to match the average and the standard deviation of the (detrended) effective federal-funds rate from the data. Next, we recalibrate the parameters of the model under the baseline UI policy and then evaluate the welfare gains from the optimal policy. In this case, we find that the optimal policy yields a welfare gain that is equivalent to 0.31 percent of additional lifetime consumption relative to that of the baseline UI policy. Hence, the constant-interest-rate assumption has very limited effects on the welfare gains from the optimal policy.

**Time varying tax rates** The next three exercises are related to our assumptions on balancing the government's budget and on income taxation. In our model, we assume that the present discounted value of government debt is zero, implying that the government's budget holds in expectation. Alternatively, we could have assumed that the government finances its expenses every period. However, this makes it infeasible to solve for the optimal policy. This is because for any proposed UI policy reform, in order to calculate the tax rate for any time period, one would need to keep track of the agents' employment and wage distributions, which is an infinite dimensional object. For this reason, to preserve the block-recursivity feature of our model, we maintain the assumption that the government's budget holds in the long run. Nevertheless, we believe that this is a reasonable assumption, given that many U.S. states borrow from a federal UI trust fund when they meet certain federal requirements and, thus, they are allowed to run budget deficits, especially during recessions.

Here, instead of using constant income taxes to balance the government's budget in the long run, we now assume countercyclical income taxes such that  $\tau(p) = m_0^\tau + m_p^\tau p$ . The intention of this is that when the government's UI budget deficit increases during recessions, we allow tax rates to also increase so the government can increase its tax revenues. Thus, this assumption makes our

model closer to a model where the government's budget holds in every period, without needing to keep track of the distribution of agents across states. In doing so, we choose  $(m_0^\tau, m_p^\tau)$  such that i) the government's budget balances in expectation (i.e., Equation (6) holds) and ii) the sum of squared values of period government debt/surpluses is minimized; i.e.,  $(m_0^\tau, m_p^\tau)$  minimizes

$$\sum_{t=0}^{\infty} \left[ \sum_i \left( \mathbf{1}_{\{l_{it}=W\}} \times w_{it} + \mathbf{1}_{\{l_{it}=B \text{ and } d_{it}=1\}} \times b_{it}w_{it} \right) \times \left( m_0^\tau + m_p^\tau p_t \right) - \mathbf{1}_{\{l_{it}=B \text{ and } d_{it}=1\}} \times b_{it}w_{it} \right]^2.$$

Namely, under the baseline UI policy, the parameters of the tax function are such that the government's budget exhibits much smaller deficits/surpluses for each period and at the same time holds in the long run. Next, for the optimal policy, we fix  $m_p^\tau$  so that both policies are financed under the same cyclicity of the tax function and we choose  $m_0^\tau$  to satisfy Equation (6). In this case, we find that the welfare gains from the optimal policy relative to the baseline policy amount to 0.25 percent. As a result, this exercise suggests that allowing the government's budget to exhibit a surplus/deficit for each period does not have a quantitatively significant impact on the welfare gains from the optimal policy.

**High level of government expenditure** In our model, the income tax required to finance the UI program is less than 1 percent. Although this tax level is reasonable, given the absence of any other type of government spending in our model, one concern may be what a higher income tax would imply for our results. We now investigate the impact of the level of income taxation on the welfare gains from the optimal policy. In order to do so, we now assume that the government has additional (thrown away) expenses of around 19 percent of period output, which is motivated by the fact that the ratio of total government expenditures to GDP is around 19 percent, on average, in the U.S. In this model, under the baseline UI policy, we recalibrate the parameters of the model and find that the resulting income tax rate is now around 21 percent. Then, we find that the optimal policy yields a welfare gain that is equivalent to 0.41 percent of

additional lifetime consumption relative to the baseline UI policy. Hence, in this case, the optimal policy provides slightly higher welfare gains.

**High level of government expenditure and progressive taxation** Finally, in the model with a high level of government expenditure (and thus a high level of income taxation), we now introduce progressive income taxation. Following Heathcote et al. (2014), the individual's after-tax labor income is given by  $\tilde{x} = \Phi x^{1-\Upsilon}$ , where  $x = w$  for a worker and  $x = bw$  for a UI recipient,  $\Phi$  determines the level of taxation, and  $\Upsilon \geq 0$  determines the rate of progressivity that is built into the tax system. This implies that the government's tax revenue from an individual with labor income  $x$  is  $T(x) = x - \Phi x^{1-\Upsilon}$ . Then, under the baseline UI policy, we recalibrate the parameters of the model, where we set  $\Upsilon = 0.151$ , as in Heathcote et al. (2014), and search for  $\Phi$  to satisfy Equation (6). In this case, we find  $\Phi = 0.81$ . Next, we evaluate the welfare gains of the optimal policy and find that it yields 0.18 percent of additional lifetime consumption relative to the baseline UI policy, implying that the welfare gains reduce by around half. This result is intuitive because progressive income taxation diminishes the efficacy of UI as tool for income redistribution.