How Should Unemployment Insurance Vary over the Business Cycle?

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Abstract

We study optimal unemployment insurance (UI) 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 UI generosity against existing estimates, and provide an explanation for divergent empirical findings. We show that generating the observed demographic differences between UI recipients and non-recipients is critical in determining the magnitudes of these elasticities. We find that the optimal policy features countercyclical replacement rates with average generosity close to current U.S. policy but adopts longer payment durations reminiscent of European policies.

JEL-Codes: E24, E32, J64, J65

Keywords: Unemployment Insurance, Business Cycles, Job Search

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1 Introduction

The sharp increase in unemployment during the Great Recession was associated with dramatic expansions to the unemployment insurance (UI) program. While intended to provide adequate insurance to the large pool of jobless individuals, whether UI policy played a quantitatively significant role in slowing the recovery of employment remains at the center of discussion. Alongside this positive debate, an equally important policy question emerges: how then should UI policy vary over the business cycle?

Our main contribution to the 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 heterogeneity in UI receipt and wealth dynamics over the cycle. Using micro data, we document that 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 find that the job search behavior of the low-wealth unemployed is mostly inelastic to UI due to the high value they attribute to employment. Furthermore, the composition of UI recipients also changes over the cycle because households who enjoy some degree of self-insurance may forgo benefits during expansions but choose to claim them in recessions. These business cycle movements of the wealth distribution and UI recipient demographics ultimately affect the cyclicality of the insurance benefits and incentive costs of UI payments, which in turn determine the optimal policy.

We build a heterogeneous agent directed job search model with aggregate labor productivity driven business cycles and incomplete markets. Agents are heterogeneous in terms of their idiosyncratic labor productivity, which endogenously affects the unemployeds’ job finding rates, as well as the employeds’ job separation rates and earnings. Unemployed individuals of a given level of productivity direct their job search effort toward a specific wage submarket. Eligibility for UI and the benefit amount depends on a household’s previous earnings. Those who are eligible for UI benefits may elect to claim benefits but incur a utility cost of take-up. These features allow us to generate observed empirical patterns in the micro data that will be 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 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. These moments are important because they determine the strength of 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 on state UI eligibility laws, we find that among the unemployed who are eligible for benefits, recipients have markedly lower wealth holdings than non-recipients. Our model generates a similar pattern because it is precisely households close to the borrowing constraint who elect to take up benefits. Meanwhile, the severity of unemployment can be measured through the magnitudes of the consumption drops upon job loss, the difference in marginal propensities to consume out of transfers between the unemployed and employed, and the distribution of unemployment spell durations over the business cycle. We show that model predictions for these moments are in line with micro evidence.

We then benchmark the model against the empirical literature that estimates the response of individual behavior and aggregate labor market conditions, namely wealth holdings, reemployment wages, and aggregate unemployment, to changes in UI generosity. Importantly, we use these estimates not only to validate model predictions but also to provide an explanation for the wide range of estimates that other studies have arrived at. The model-implied crowding-out of wealth resulting from more generous UI is sizable, as in the empirical findings. On the other hand, the responses of reemployment wages and unemployment in the model align more with studies that have estimated small elasticities. The reason why the model predicts these limited elasticities lies within the labor market response unique to the UI recipient demographic. While generous UI certainly induces households to look for higher wages and reduce search intensity, those who actually take up UI are predominantly low-income and 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 — who now hold lower wealth upon job loss due to the crowding-out effects of UI
extensions – rapidly deplete their savings due to prolonged unemployment spells and subsequently intensify their search for lower-wage jobs that are easier to find. In this sense, the presence of borrowing-constraints self-discipline the job search behavior of the unemployed. We show that in an alternative model where job loss risk is homogenous across employed agents and all eligible unemployed take up benefits, the micro and macro effects of changes in UI generosity approach the upper range of estimates in the data.

Having validated the model against empirical elasticities, we proceed with optimizing UI policy instruments: the levels and cyclicalities of both the UI replacement rate and duration, as well as replacement rate heterogeneity across wages. The optimal UI policy is countercyclical. When aggregate productivity 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 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. Overall, the optimal replacement rates are close to U.S. levels, albeit countercyclical, but payment durations are reminiscent of European UI policies. Finally, replacement rates decline more steeply with wages under the optimal policy than under the U.S. policy.

The countercyclical optimal policy is due to the dampening of incentive costs and increase in insurance benefits during recessions. More generous UI in recessions lowers precautionary savings such that job losers transition into unemployment with less wealth. In a recession, they draw down on this wealth and quickly approach the borrowing constraint, at which point a wealth-effect induces them to intensify efforts to search for lower wages that are easier to find. While the incentive costs are smaller in recessions, generous UI cushions the drop in consumption of eligible unemployed, especially for wealth-poor households who have depleted their savings. 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

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1For example, the UI payment durations in Belgium, France, Spain, Denmark, and Finland are longer than 24 months.
gains – and thus welfare gains – of UI benefits are highest. Overall, relative to U.S. policy, the optimal policy represents ex-ante welfare gains of around 0.3 percent additional lifetime consumption. Ex-post welfare gains are heterogeneous. The highest gains accrue to poor but not 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 are also relieved of the need to build a buffer stock of savings due to more generous public insurance during recessions.

Finally, we analyze the role of heterogeneity in take-up, job separation risk, and UI eligibility on the determination of 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 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 benefit 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, who would have otherwise been excluded from claiming benefits due to insufficient earnings, are now able to access UI.

**Related Literature**  Our paper contributes to the growing literature on optimal UI over the business cycle (Jung and Kuester 2015, Mitman and Rabinovich 2015, Landais et al. 2018, and Pei and Xie 2019). We advance this literature by focusing on the role of both precautionary saving motives and underlying heterogeneity of UI recipients in determining the optimal policy. Wealth holdings not only affect the insurance value of UI but also its incentive costs because job search behavior is a function of wealth. Changes in precautionary savings over the cycle affect the cyclicality of insurance benefits and incentive costs of UI. Additionally, the heterogeneity in take-up, job separation rates, and UI eligibility across the wealth distribution introduces differences in the consumption-smoothing benefits and labor market responses elicited by policy reform. While the insurance benefits are larger for the unemployed who are borrowing-constrained, the incentive costs are smaller for them given that borrowing constraints discipline the search
behavior. 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 Sepahsalar 2018, Braxton et al. 2018, and Kekre 2019). Among these papers, our framework is closer to Eeckhout and Sepahsalar 2018 and Braxton et al. (2018), who also investigate the optimal level of UI payments in a directed job search model with incomplete markets. Relative to these papers, we solve for the optimal cyclicality of UI replacement rates and duration in a model with aggregate shocks, where the strength of precautionary saving motives significantly varies with the level of unemployment risk over the business cycle. Furthermore, relative to papers in this strand of the literature, our model also incorporates endogeneous UI take-up decisions and generates the observed heterogeneity in UI eligibility, take-up, and replacement rates in the micro data. Finally, Nakajima (2012) models UI extensions during the Great Recession and its subsequent recovery using a model with business cycle dynamics. He then 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 government finances UI benefits and use the model to study how UI must vary over the cycle. To overcome the computational difficulties encountered in the model with rich heterogeneity and aggregate shocks, we show that the model’s market structure admits a block recursive equilibrium, 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 provides microeconomic estimates on the effect of changes in UI generosity on wealth holdings

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2 Although the baseline model of Krusell, Mukoyama, and Şahin (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 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 on smoothing these fluctuations through aggregate demand.
(Engen and Gruber 2001), reemployment wages (Card, Chetty, and Weber 2007, Schmieder, von Wachter, and Bender 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, Hagedorn et al. 2019). We use our model not only to validate its mechanisms but also to provide an explanation for the differential magnitudes of 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 UI eligible unemployed will overstate the elasticities of reemployment 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. The appendix provides more details on the model, data, and results.

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 \( t = 0, 1, 2, \ldots \). 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 \( c \) that satisfies Inada conditions; \( \nu(\cdot) \) represents the disutility associated with search effort of the unemployed 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 $\beta$, die with probability $\omega$, and are replaced by new entrants.

The labor market features directed search. An agent can be a worker $W$, unemployed and eligible for unemployment benefits $B$, or unemployed and not eligible for unemployment benefits $NB$. Unemployed individuals direct their search effort $s$ toward submarkets 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 $w$ every period until the match exogenously dissolves at rate $\delta(y, p) \in [0, 1]$, where $p$ is aggregate labor productivity. A fraction $g(w, p) \in [0, 1]$ of job losers who were previously earning wage $w$ 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 UI benefit eligibility stochastically expires at rate $e(p) \in [0, 1]$.

In order to finance the UI program, workers and benefit recipients pay a fraction $\tau$ of their wages or benefits to the government every period. In addition to labor earnings, all households have access to incomplete asset markets where they can save or borrow at an exogenous interest rate $r$. 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 indivisible unit of labor into final consumption goods, the amount of which is determined jointly by the idiosyncratic labor productivity of the worker $y$ and aggregate labor 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 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 subma-

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3The U.S. UI policy is such that benefit duration is determined by the level of aggregate unemployment. Ideally, the UI policy instruments in the model should depend on the unemployment rate. However, as we explain in Section 2.5, this would make the model intractable. Hence, we instead define policy instruments to be a function of aggregate labor productivity in the model – a good approximation to the existing U.S. policy since aggregate unemployment is primarily driven by aggregate labor productivity in our model.

4In Section 6, we explore the quantitative and welfare implications of allowing interest rates to vary over the business cycle.
ket $w$ within which to look for a job. The unemployed can only direct their search toward submarkets appropriate for their own labor productivity $y$. Second, the production and consumption stage opens, 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 unemployed receive the monetized value of non-market activities $h$.\footnote{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 $h$ is a utility value instead of a monetary value.} Households then make their saving 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 $t$.

\subsection{2.2 Household Problem}

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

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

$$V^W(a, w, y; \mu) = \max_{c, a' \geq a_l} u(c) + \beta (1 - \omega) \mathbb{E} \left[ (1 - \delta(y', p')) V^W(a', w, y'; \mu') + \delta(y', p') \left[ (1 - g(w, p')) V^{UE}(a', w, y'; \mu') + g(w, p') V^{UI}(a', y'; \mu') \right] \right]$$

subject to

$$c + a' \leq (1 + r) a + w (1 - \tau)$$

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

$$V^W(a, w, y; \mu) = \max_{c, a' \geq a_l} u(c) + \beta (1 - \omega) \mathbb{E} \left[ (1 - \delta(y', p')) V^W(a', w, y'; \mu') + \delta(y', p') \left[ (1 - g(w, p')) V^{UE}(a', w, y'; \mu') + g(w, p') V^{UI}(a', y'; \mu') \right] \right]$$

subject to

$$c + a' \leq (1 + r) a + w (1 - \tau)$$

$$\Gamma' = H(\mu, p'), \quad p' \sim F(p' | p), \quad y' \sim Q(y' | y).$$
Notice in the above problem that the worker may not qualify for UI benefits with probability $g$ after losing her job due to 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 transitioning into unemployment qualify for UI benefits. In particular, individuals do not qualify for benefits if they voluntarily quit their job or they do not meet certain work/earnings requirements, both of which we will discuss in Section 3 in detail. Notice also that we keep track of previous wages $w$ for only 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 benefits.

The unemployed direct their search efforts toward a wage submarket $w$ based on their labor productivity $y$, with an associated market tightness given by $\theta(w, y; \mu)$, which is an equilibrium object 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

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

subject to

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

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 eligibility with probability $e$.\footnote{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.}
The choice of wage submarket 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 eligibility for UI benefits if 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 offering fixed wage contracts in different submarkets. The labor market tightness of submarket \((w, y)\) is defined as the ratio of vacancies \(v\) posted in the submarket to the aggregate search effort \(S\) exerted by all the unemployed searching for a job within that submarket. It 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

\[
J(w, y; \mu) = py - w + \frac{1}{1 + r} \left(1 - \omega\right) \mathbb{E} \left[ \left(1 - \delta (y', p')\right) J(w, y'; \mu') \right]_{y, \mu} \\
\text{subject to} \\
\Gamma' = H(\mu, p'), \quad p' \sim F(p'|p), \quad y' \sim Q(y'|y).
\]

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

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

(4)

where $\kappa$ is a fixed cost of posting a vacancy that is financed by 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 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 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 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:

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

(5)

Equilibrium market tightness contains all relevant information for households 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 replacement rates and 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 cyclicality of UI replacement rates,
UI duration, and eligible fraction of job losers.\textsuperscript{7}

The government balances the following budget constraint in expectation:\textsuperscript{8}

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

where the left-hand side is the present discounted value of tax revenues collected from the labor income of workers and the eligible unemployed who take up benefits, and the right-hand side is the present discounted value of UI payments to the eligible unemployed who take up benefits.

\textbf{2.5 Equilibrium}

\textbf{Definition of the Recursive Equilibrium:}

Given UI policy $\{b(w, p), e(p), g(w, p), \tau\}_{p \in P}$, a recursive equilibrium for this economy is a list of household policy functions for asset, wage, search effort, and UI take-up decisions, 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 budget constraint (6) is satisfied.
4. The law of motion of the aggregate state is consistent with 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

\textsuperscript{7}We restrict 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 recursitivity, which we explain below.

\textsuperscript{8}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 they are allowed to run budget deficits during some periods. Nevertheless, we explore the implications of this assumption on our main results in Section 6.
address this issue, we exploit the structure of the model and use the notion of block recursive equilibrium (BRE) developed by Menzio and Shi (2010, 2011).

**Definition of the BRE:** 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 the 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 \( \nu(\cdot) \) is strictly increasing and strictly convex; ii) choice sets \( W \) and \( A \) and sets of exogenous processes \( \mathcal{P} \) and \( \mathcal{Y} \) are bounded; iii) matching function \( M \) exhibits constant returns to scale; and iv) UI policy is restricted to be 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 nonemployment duration with respect to changes in UI duration. Several papers estimate this elasticity using cross-state or over-time differences in UI duration. The magnitudes of the estimated elasticities range from an average change of 0.08 month (Card and Levine 2000) to 0.3 month (Johnston and Mas 2018) in response to a one-month change in 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 account the effect of this policy change on equilibrium wages and market tightness, we choose $\chi$ to generate the same change of time in nonemployment for UI recipients as in the data.

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

**Aggregate and idiosyncratic labor productivity** The logarithm of the 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 the quarterly data constructed by the Bureau of Labor Statistics (BLS) between 1951 and 2007. Estimation of 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 possessing the same productivity level. We use the standard deviation of the error term $\sigma^y$ to match earnings dispersion, specifically, the ratio of the 90th to 10th percentiles of the labor earnings distribution among

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9Examples of these studies include Moffitt (1985), Katz and Meyer (1990), Card and Levine (2000), Valletta (2014), and Johnston and Mas (2018).

10Notice that when agents change the wage submarkets in which they look for a job in response to a change in UI policy, they face different market tightness in the new wage submarket. For this reason, although changes in UI policy do not affect the menu of market tightness across wage submarkets, once households change their wage choices in response to changes in UI policy, they in turn face different labor market tightness.
the employed individuals in the Survey of Income and Program Participation (SIPP) data. Appendix B provides details about our sample with SIPP data.

**Labor market**  Following Shimer (2005), we use a process for the job destruction rate that depends on aggregate labor productivity $p$ and modify it to incorporate heterogeneity across idiosyncratic labor productivity levels $y$: $\delta(y, p) = \bar{\delta} \times \exp\left(\eta_p^\delta (p - \bar{p})\right) \times \exp\left(\eta_y^\delta (y - \bar{y})\right)$, where i) $\bar{\delta}$ is the average job destruction rate over time, $\bar{p}$ and $\bar{y}$ are mean aggregate and idiosyncratic labor productivities, respectively; ii) $\eta_p^\delta$ captures the volatility of job destruction rate over time; and iii) $\eta_y^\delta$ captures the variation of the job destruction rate across income groups.\(^{11}\) We jointly choose these parameters to match i) the average monthly job separation rate, ii) the standard deviation of the job separation rate, and iii) the heterogeneity of the job separation rate across the earnings distribution in the data. The first two moments are obtained from the monthly transition rates between 1976 and 2005 calculated by Fujita and Ramey (2006). For the last moment, we use the SIPP between 1996 and 2007 to calculate the ratio of the job separation rate of workers below the first quintile to that above the fifth quintile of the labor earnings distribution.

The labor market matching function is specified to be

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

where $\lambda(y, p) = \bar{\lambda} \times \exp\left(\eta_p^\lambda (p - \bar{p})\right) \times \exp\left(\eta_y^\lambda (y - \bar{y})\right).\(^{12}\) 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).\(^{13}\) We jointly choose $\bar{\lambda}$, $\eta_p^\lambda$, and $\eta_y^\lambda$ to match i) the average monthly

\(^{11}\)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).

\(^{12}\)Based on this functional form of the matching function, the job finding rate and the vacancy filling rate 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.

\(^{13}\)Time-varying matching efficiency can be interpreted as changes in the aggregate recruiting intensity over the business cycle, as recently documented by Mongey and Violante (2019). In our work, we do not model the firm’s recruiting decisions, but the above specification captures
job finding rate, ii) the standard deviation of job finding rate, and iii) the heterogeneity of job finding rate across the earnings distribution in the data. For the last moment, we use the SIPP between 1996 and 2007 to calculate the ratio of the job finding rate of the unemployed below the first quintile to that above the fifth quintile of the previous employment earnings distribution.

Shimer (2005) shows that standard search and matching model fails to generate the observed volatility of the unemployment rate. In our model, changes in aggregate labor productivity generate exogeneous variations in the job separation rates and matching function efficiency. We calibrate the parameters 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 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 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. Hence, the magnitude of $h$ controls the magnitude of budgetary loss upon job separation. For this reason, we use $h$ to match the average consumption drop upon job loss in the data. Several papers in the literature estimated the average consumption drop upon job loss from various data sources. 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 with nonpositive net liquid wealth in the SIPP. We discuss the calculation of this moment in Section 4.1. The borrowing limit $a_t$ is set to match a median value of the credit limit to quarterly labor income ratio of 74 percent in the Survey of Consumer Finances. Finally, we set $r = 0.33$ percent, which generates an annual return on assets of around 4 percent.

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the cyclical variation in aggregate matching efficiency through $\eta^\lambda$ in reduced form.

14See, for example, Browning and Crossley (2001), Aguiar and Hurst (2005), Saporta-Eksten (2014), and Chodorow-Reich and Karabarbounis (2016).
UI policy Motivated by the current design of UI policy, we assume the following functional forms for the UI policy instruments:

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

\[
b(w, p) = m_0^b + m_w^b w + m_p^b p
\]

\[
g(w, p) = m_0^g + m_w^g w + m_p^g p.
\]

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

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-recession 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 \( m_e^p \) 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 during recessions.

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 benefits; and iii) 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 decision of benefit-eligible unemployed individuals. While the SIPP provides information on respondents’ earnings, employment status, and amount of UI receipt, it does not collect information on respondents’ UI eligibility status. To overcome this, we construct a program that combines SIPP
data with state-level UI laws between 1996 and 2006 to predict a respondent’s eligibility. State laws impose a variety of eligibility 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. 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 SIPP data on employment status, earnings, reason for job separation, and state of residence to predict the eligibility status of unemployed individuals. This allows us to compute the fraction of eligible unemployed (FEU) \( \frac{\text{Eligible Unemployed}}{\text{Unemployed}} \). Together with information on self-reported UI 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 benefit amount formulas to arrive at individual-specific replacement rates. The predicted replacement rate for an eligible unemployed is measured as the ratio of her predicted UI weekly benefit amount and her average weekly wages during the months in her base period where she earned positive wages. 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 generosity of the UI replacement rate offered by the government and not 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.

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15 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/).

16 The formula for wage and employment requirements vary 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.

17 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 the self-reported UI receipt as the basis for the replacement rate. Results remain similar when we consider these individuals as ineligible.
Table 1: Internally calibrated parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Explanation</th>
<th>Value</th>
<th>Target</th>
<th>Model</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Preferences and borrowing limit</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\beta$</td>
<td>Discount factor</td>
<td>0.9928</td>
<td>Frac. non-pos. net liq. wealth</td>
<td>0.27</td>
<td>0.26</td>
</tr>
<tr>
<td>$\chi$</td>
<td>Curvature of utility cost of job search</td>
<td>1.52</td>
<td>Elasticity of nonemp. duration with respect to UI duration</td>
<td>0.15</td>
<td>0.16</td>
</tr>
<tr>
<td>$\phi$</td>
<td>Take-up utility cost</td>
<td>1.41</td>
<td>UI take-up rate among eligible</td>
<td>0.57</td>
<td>0.55</td>
</tr>
<tr>
<td>$a_l$</td>
<td>Borrowing limit</td>
<td>−2.09</td>
<td>Median credit limit/income</td>
<td>0.73</td>
<td>0.74</td>
</tr>
<tr>
<td><strong>Labor market</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\bar{\delta}$</td>
<td>Ave. job sep. rate</td>
<td>0.021</td>
<td>Ave. monthly job sep. rate</td>
<td>0.02</td>
<td>0.02</td>
</tr>
<tr>
<td>$\eta^\delta_p$</td>
<td>Cyc. job sep. rate</td>
<td>−6.4</td>
<td>Standard dev. of job sep. rate</td>
<td>0.058</td>
<td>0.058</td>
</tr>
<tr>
<td>$\eta^\delta_y$</td>
<td>Heterogeneity of job sep. rate</td>
<td>−0.94</td>
<td>Ave. job sep. rate ratio of low- (&lt; p20) vs high-income (&gt; p80) workers</td>
<td>3.24</td>
<td>3.28</td>
</tr>
<tr>
<td>$\bar{\lambda}$</td>
<td>Ave. of matching efficiency</td>
<td>1.01</td>
<td>Ave. monthly job finding rate</td>
<td>0.34</td>
<td>0.34</td>
</tr>
<tr>
<td>$\eta^\lambda_p$</td>
<td>Cyc. of matching efficiency</td>
<td>5.4</td>
<td>Standard dev. of job finding rate</td>
<td>0.078</td>
<td>0.077</td>
</tr>
<tr>
<td>$\eta^\lambda_y$</td>
<td>Heterogeneity of matching efficiency</td>
<td>−0.94</td>
<td>Ave. job finding rate ratio of low- (&lt; p20) vs high-previous-employment earnings (&gt; p80) unemployed</td>
<td>0.85</td>
<td>0.96</td>
</tr>
<tr>
<td>$\sigma^y$</td>
<td>Dispersion of id. labor prod.</td>
<td>0.077</td>
<td>Ave. ratio of 90th to 10th percentile of labor earnings dist.</td>
<td>4.50</td>
<td>6.30</td>
</tr>
<tr>
<td>$h$</td>
<td>Value of nonmarket activity</td>
<td>0.04</td>
<td>Ave. consumption drop upon job loss</td>
<td>0.13</td>
<td>0.14</td>
</tr>
<tr>
<td><strong>UI policy</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$m^b_0$</td>
<td>UI rep. rate level</td>
<td>0.75</td>
<td>Ave. UI rep. rate</td>
<td>0.52</td>
<td>0.52</td>
</tr>
<tr>
<td>$m^b_w$</td>
<td>Heterogeneity of UI replacement rate</td>
<td>−0.24</td>
<td>Ave. ratio of rep. rate of low- (&lt; p20) vs high-income (&gt; p80) workers</td>
<td>1.91</td>
<td>1.89</td>
</tr>
<tr>
<td>$m^g_0$</td>
<td>Fraction of job losers who are eligible for UI</td>
<td>0.42</td>
<td>Ave. frac. of unemployed eligible for UI</td>
<td>0.58</td>
<td>0.58</td>
</tr>
<tr>
<td>$m^g_w$</td>
<td>Heterogeneity of UI eligibility risk</td>
<td>−0.14</td>
<td>Ave. ratio of frac. of unemp. eligible for UI of low- (&lt; p20) vs high-income (&gt; p80) workers</td>
<td>0.74</td>
<td>0.53</td>
</tr>
</tbody>
</table>

*Note:* This table provides a list of model parameters that are calibrated using our model. Please refer to main text for a detailed discussion.
This analysis allows us to calibrate the parameters of UI replacement rate $m_b^b$, $m_w^b$, $m_p^b$ and UI eligibility rate $m_0^g$, $m_w^g$, $m_p^g$ as well as the utility cost of UI take up $\phi$. We jointly choose $m_0^b$, $m_w^b$, and $m_p^b$ to match i) the average replacement rate of 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 benefit-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 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 replacement rates across previous average weekly wages in the data and the model resulting from our calibration. The linearity of UI replacement rate in previous wages approximates well to the replacement rates in the data.\(^{18}\)

Next, we discipline the parameters of the UI eligibility rate. We use level parameter $m_0^g$ to match an average FEU of 58 percent; the slope parameter with respect to 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 variation of eligibility rules over time.\(^{19}\) Based on state UI laws over 1996-2019, 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 is 55 percent in the data. We use the disutility of UI take-up parameter $\phi$ to match the same value in the model. Under this joint calibration of model parameters, the income tax rate $\tau$ that satisfies Equation (6) in equilibrium is 0.765 percent.\(^{20}\)

\(^{18}\)The realized average replacement rate, which is obtained by setting the replacement rate of eligible unemployed who do not claim benefits to 0, is 0.27 in the data and 0.33 in the model.

\(^{19}\)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.

\(^{20}\)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 expenditure to account for other forms of government spending and transfers, which implies higher levels of income taxes. Then, we check the implications of this assumption for our main results.
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, 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, reemployment wages of UI recipients, and aggregate unemployment with respect to changes in the UI generosity and 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 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 allows us to capture UI recipient demographics. We emphasize the importance of these channels in generating observed empirical elasticities and provide an explanation for the differential magnitudes of elasticities found in various microeconomic studies.

4.1 Baseline economy

Wealth holdings of UI take-up vs non-take-up  Previously, we document 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 benefit-eligible job losers. We consider a job loser as having taken up benefits if he/she reported receiving benefits during any month within the unemployment spell. We then calculate the net liquid asset to monthly labor income distribution of each group. Details of this calculation are in Appendix B.
Table 2: Asset-to-income distribution, take-up vs. non-take-up

<table>
<thead>
<tr>
<th>Percentile</th>
<th>Take-up</th>
<th>Non-take-up</th>
<th>Take-up</th>
<th>Non-take-up</th>
</tr>
</thead>
<tbody>
<tr>
<td>10th</td>
<td>−2.34</td>
<td>−1.89</td>
<td>−2.33</td>
<td>−2.14</td>
</tr>
<tr>
<td>25th</td>
<td>−0.34</td>
<td>−0.19</td>
<td>−1.37</td>
<td>−0.46</td>
</tr>
<tr>
<td>50th</td>
<td>0.42</td>
<td>0.41</td>
<td>−0.29</td>
<td>1.02</td>
</tr>
<tr>
<td>75th</td>
<td>1.73</td>
<td>2.61</td>
<td>0.72</td>
<td>3.09</td>
</tr>
<tr>
<td>90th</td>
<td>7.80</td>
<td>14.31</td>
<td>1.90</td>
<td>5.09</td>
</tr>
<tr>
<td>Mean</td>
<td>2.15</td>
<td>5.43</td>
<td>−0.06</td>
<td>1.94</td>
</tr>
</tbody>
</table>

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

The first two columns of Table 2 compare the net liquid wealth to monthly labor income distribution between benefit-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 decided not to receive benefits despite being eligible.\(^{21}\) 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 net liquid wealth to monthly labor income distribution in the model to that in the data. The wealth distribution is a moment of interest, as it directly influences the insurance benefits of UI. 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

\(^{21}\)Mean values of these distributions are statistically different from each other at the 5 percent significance level.
agents in this region of the distribution are more likely to be UI recipients.  

**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 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 consumption of individual \( i \) in period \( t \), \( \iota_i \) and \( \xi_t \) are individual and time fixed effects, and \( \epsilon_{it} \) represents 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 job loss occurs. For instance, \( D_{it}^2 = 1 \) for individual \( i \) who experiences 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 group consists of those with no job loss during the sample period.

Figure 1 plots the estimated values for \( \{\psi_k\}_{k \in \{-6, \ldots, 6\}} \), which measure the effect of job loss on consumption \( k \) periods prior to or after the incident relative to the control group. This is compared with estimates found by Saporta-Eksten

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22 In the absence of an exogenous stochastic discount factor as in Krusell and Smith (1998) or an exogenous income process calibrated to match 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.

23 The regression is run on yearly data, which is constructed by aggregating monthly data.
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.

(2014), who implements the same regression using Panel Study of Income Dynamics (PSID) data from 1999 to 2009. Given that low-income households face higher unemployment risk, the model is able to generate the lower consumption of job losers even prior to 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 job loss and two years prior. However, the consumption profile after 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 of temporary government transfers have on the consumption behavior of unemployed and employed households. In the model, we compute an agent’s MPC by calculating the fraction of an unexpected and temporary transfer – scaled to be equivalent to $500 – spent on consumption. As in Kaplan and Violante (2014), this is implemented as a tax rebate in order to ensure consistency with available empirical estimates.

Table 4 shows that the aggregate quarterly MPC in the model is 12 percent, which is comparable to estimates found by Parker et al. (2013), who find that households spend between 12 and 30 percent of unexpected tax rebates in the
Table 4: MPCs

<table>
<thead>
<tr>
<th></th>
<th>Model</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aggregate quarterly MPC</td>
<td>0.12</td>
<td>0.12 – 0.30</td>
</tr>
<tr>
<td>Annual MPC difference between the unemployed and employed</td>
<td>0.29</td>
<td>0.25</td>
</tr>
</tbody>
</table>

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

quarter that they are received. Furthermore, the model predicts that the difference in 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 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 unemployment and thus the insurance benefits of UI. We compare the distributions of completed unemployment spell durations between periods of nonrecession and recession using the SIPP 2004 Panel, which covers October 2003 through December 2007, and the 2008 Panel, which covers 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 between October 2003 and November 2013. Figure A.2 in Appendix B shows the resulting series in this experiment and compares the unemployment rate generated by the model with that in the data for this time period.

Figure 2 shows that both in 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 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.
Figure 2: Distribution of unemployment spell duration

![Figure 2: Distribution of unemployment spell duration](image)

Note: This figure plots the distributions of completed unemployment spell durations before and after the Great Recession in 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.

4.2 Micro and Macro Effects of Changes in UI Policy

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

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 UI benefit generosity 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:

\[ WEALTH_i = \epsilon_i + \zeta_1 X_i + \zeta_2 RR_i + \zeta_3 \varphi_j + \zeta_4 \xi_t + \epsilon_{ijt}, \] (8)
Table 5: Micro and macro elasticities with respect to UI generosity

<table>
<thead>
<tr>
<th></th>
<th>Model</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assets</td>
<td>−0.16</td>
<td>−0.18</td>
</tr>
<tr>
<td>Reemployment wages</td>
<td>0.07</td>
<td>−0.13 - 0.25</td>
</tr>
<tr>
<td>Aggregate unemployment</td>
<td>0.10</td>
<td>0.10 - 2.15</td>
</tr>
</tbody>
</table>

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

where $\text{WEALTH}_i$ is the asset-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 UI replacement rate of the individual, and $\nu_i$, $\varphi_j$, and $\xi_t$ are individual-state-year-specific dummies. They find that a 5 percentage point increase in the replacement rate decreases the asset-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 asset-to-income ratio by 0.16 percentage points.

**Reemployment wages** While the model is calibrated to match the response of nonemployment duration to changes in UI generosity, we do not directly target moments on reemployment outcomes. Here, we compare the elasticity of reemployment wages with respect to benefit extensions in the model with available empirical estimates. This moment is informative about the extent to which increases in benefit generosity allow workers to match with higher-paying jobs which are, however, 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 reemployment wage effect of UI is not statistically different from zero. Schmieder, von Wachter, and Bender
(2016) find that workers with longer potential UI spells have lower wages: a six-month (one-month) increase in 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 reemployment wages. They reconcile these mixed results by showing that while increases in UI duration lead the unemployed to look for higher wages (selectivity margin), it also causes longer unemployment spells and duration dependence due to lower search effort, leading to a reduction in subsequent wages (search margin).

To benchmark the model against these findings, we compare average reemployment wages between the baseline economy and one where the maximum UI duration is extended by a month, taking into account the effect of this policy change on equilibrium market tightness. We find that this leads to only a 0.07 percent increase in reemployment 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 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 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 spells generate negative pressure on reemployment wages due to the wealth channel.

**Aggregate unemployment**  Finally, we compare the effect of UI benefit extensions during the Great Recession on the unemployment rate in 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 limited macroeconomic effects of UI benefit extensions. 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. On the other hand, 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 Great Recession period with and without UI benefit 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 between December 2007 and 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 points lower in the absence of benefit extensions, implying that benefit extensions during the Great Recession played a limited role in exacerbating 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 benefit generosity and 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 reemployment wages and the aggregate unemployment rate with respect to UI generosity. To do so, we sequentially explore the implications of accounting for household heterogeneity in unemployment risk and 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 benefit duration is halved, i.e., $\hat{e}(p) = 2e(p) \forall p$. Table 6 presents the percentage point changes (as the alternative policy value minus the baseline policy value) of the unemployment rate in our baseline model and in 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 benefit generosity because primarily wealth-poor households take up UI, as seen in Table 2. These households are inelastic to
Table 6: Effect of UI duration on unemployment rate in different models

<table>
<thead>
<tr>
<th>Baseline</th>
<th>( \phi = 0 )</th>
<th>( \phi = 0 )</th>
<th>( \phi = 0 )</th>
<th>( \phi = 0 )</th>
<th>( \phi = 0 )</th>
<th>( \phi = 0 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \eta_y^\delta = 0 )</td>
<td>( \eta_y^\delta = 0 )</td>
<td>( \eta_y^\delta = 0 )</td>
<td>( \eta_y^\delta = 0 )</td>
<td>( \eta_y^\delta = 0 )</td>
<td>( \eta_y^\delta = 0 )</td>
<td></td>
</tr>
<tr>
<td>( g = 0.5 )</td>
<td>( g = 0.5 )</td>
<td>( g = 0.5 )</td>
<td>( g = 0.5 )</td>
<td>( g = 0.5 )</td>
<td>( g = 0.5 )</td>
<td></td>
</tr>
<tr>
<td>( b = 0.52 )</td>
<td>( b = 0.26 )</td>
<td>( b = 0.98 )</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| Change in 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 benefit duration is cut by half; i.e., \( \hat{\epsilon}(p) = 2\epsilon(p) \forall p \). 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 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.

changes in UI policy because jobs are most valuable to them because they are close to the borrowing limit and have almost no access to self-insurance. 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 UI receipt. Finally, the richest unemployed exhibit negligible responses 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 search effort and wage choices of the unemployed across the quintiles of the asset-to-income distribution following the change in UI duration in the baseline model.\(^{24}\) The result emphasizes that the heterogeneity in elasticities across the asset-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 decision by setting the utility cost

\(^{24}\)Here, we use the percentiles of the asset-to-income distribution of the model under the baseline UI policy when defining the quintiles of the distribution in this exercise.
Figure 3: Search and wage choices of unemployed across asset-to-income quintiles

Note: This figure compares the stochastic steady-state average search effort and wage choice of the unemployed across asset-to-income quintiles under our baseline policy and under a policy where the potential benefit 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 \( \phi = 0 \), \( \eta^\delta_y = 0 \), \( g = 0.5 \), and \( b = 0.52 \)). Values in the figure are percent changes of average search effort and wage choices of the unemployed relative to their values under the baseline policy.

of take-up to zero; i.e., \( \phi = 0 \). Here, effective UI coverage expands 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 of reemployment 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 UI extensions are pronounced.

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

We then impose that UI eligibility upon job loss is independent of past earn-
ings, i.e., $m_{w}^{g} = 0$, and set $g(w, p) = 0.5$ for all agents. Here, households with severely low income who used to be excluded from UI by earnings requirements now enjoy a higher probability of receiving benefits. The inclusion of poorer and inelastic households into the pool of unemployed dampens the overall response of unemployment to a change in benefit generosity.

Finally, we reduce the heterogeneity further 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 benefit amount is larger for higher earners, their labor market behaviors also become more elastic to changes in benefit 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 UI policy. This leads to a much larger response of the aggregate unemployment rate when UI policy changes. Hence, this exercise shows that abstracting from these important dimensions of heterogeneity in the model results in a larger unemployment response due to overestimation of labor market responses of the unemployed with 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 unemployed, the response is markedly weaker but still much higher than 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 UI 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 $m^b_0$, $m^b_w$, $m^b_p$, $m^e_0$, $m^e_p$ and the implied tax rate $\tau$ to maximize the ex-ante lifetime utility of an individual who is born (under the veil of ignorance) into the economy under the baseline policy subject to the government budget constraint.\(^{25}\) 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 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 replacement rate and benefit duration and features a higher replacement rate for low-wage earners than high-wage earners.\(^{26}\) It prescribes that the replacement rate rises from 43 percent 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 80th percentile receives only 27 percent, 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, lower than the baseline tax rate of $\tau = 0.76$ percent. This is explained by the lower average replacement rates and that despite a rise in potential duration, benefit recipients typically find jobs before the extensions are utilized. Overall,

\(^{25}\)We focus on the optimal level and cyclicality of the UI replacement rate and duration, but we keep the UI eligibility parameters $(m^0_0, m^0_w, m^0_p)$ 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 UI duration when testing policy reforms.

\(^{26}\)We find that $m^b_0 = 1.5$, $m^b_p = -0.78$, $m^b_w = -0.28$, $m^e_0 = 451.47$, and $m^e_p = -426.87$. 

the optimal replacement rates are close to U.S. levels, albeit countercyclical, while the optimal durations are reminiscent of UI policy in many European countries. For example, Belgium, France, Spain, Denmark, and Finland prescribe up to an 80 percent replacement rate with potential UI duration longer than 24 months.

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. Each economy begins with its respective stationary distribution when the shock is realized. Aggregate productivity then returns to its mean after 60 months. Figure 5.1 shows that under the optimal policy, the recession triggers both a rise in replacement rates and extensions in UI duration. 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 substantially longer UI duration. As discussed in Section 4.3, this is because of the small responses of wage choice and search effort of the UI-recipient demographic. Furthermore, the optimal policy also crowds out self-insurance. Not only do agents enter unemployment spells with less wealth, they also deccumulate this wealth to supplement UI during longer spells during recessions. As they approach the borrowing constraint, the unemployed are induced to find jobs more quickly by decreasing their wage choice and increasing their search effort. In this sense, the presence of borrowing constraints is a device to discipline the job search behavior of the unemployed.

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 an asset-to-income ratio 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. While incidences of long-term unemployment are low, these households have the highest marginal utility of consumption. Note that

27 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 the baseline policy.
28 The percent change in the fraction of households who exhaust benefits under the optimal policy is small, as the policy provides much longer UI durations in all states of the economy.
Figure 4: Impulse response functions under the baseline and optimal policies

Note: This figure compares the response of an economy under the optimal policy in place with an economy under the baseline policy to a drop in aggregate labor productivity 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.
despite longer UI durations under the optimal policy, the average UI take-up duration is very similar under the baseline and 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 during recessions when unemployment spells are prolonged. Thus, while the unemployed below the 20th percentile of the asset-to-income distribution exhibit almost no change in UI claims during recessions, those above the 20th percentile drastically increase 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 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 ex-post welfare gains/losses of subgroups under the optimal policy. To do so, we first compute welfare gains for each individual state. We then group agents by their employment status and assets based on the stationary distribution under the baseline policy. Finally, for each group, we integrate individual welfare gains over agents who belong to the group. This gives us the average ex-post welfare gains/losses of the group.\(^{29}\) Table 7 summarizes the results.

The highest welfare gains are enjoyed by the unemployed eligible for UI benefits. This is unsurprising because conditional on their take-up decisions, they are the direct recipients of UI. 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 the response of take-up rates in Figure 5.1. 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

\(^{29}\)Appendix C provides formal expressions for this calculation.
Table 7: Heterogeneous welfare gains

<table>
<thead>
<tr>
<th>Employment</th>
<th>Asset groups</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$a_1$</td>
</tr>
<tr>
<td>Worker</td>
<td>0.28</td>
</tr>
<tr>
<td>Eligible unemployed</td>
<td>0.40</td>
</tr>
<tr>
<td>Ineligible unemployed</td>
<td>0.38</td>
</tr>
</tbody>
</table>

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

UI is not deemed valuable enough to claim. However, when a recession occurs, their take-up rate increases drastically. 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 and wealth whose future labor market outcomes are characterized by 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 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 weaken the need for precautionary savings. Furthermore, they also face larger unemployment risk during recessions and thus benefit from 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 critical features of the model.

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30While 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
Table 8: Welfare gains from optimal policy in alternative models

<table>
<thead>
<tr>
<th>Baseline</th>
<th>$\phi = 0$</th>
<th>$\phi = 0$</th>
<th>$\phi = 0$</th>
<th>$\phi = 0$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$\eta_g^i = 0$</td>
<td>$\eta_g^i = 0$</td>
<td>$g = 0.5$</td>
<td>$g = 0.5$</td>
</tr>
<tr>
<td>Welfare</td>
<td>0.32</td>
<td>0.15</td>
<td>-0.05</td>
<td>-0.01</td>
</tr>
</tbody>
</table>

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 separations rates, and iii) heterogeneous UI eligibility. Welfare gains are in percent lifetime equivalent consumption terms.

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 0.32 percent additional lifetime consumption. The second and third columns show that when we introduce full take-up or uniform job separation rates, welfare gains of the optimal policy are reduced significantly. As we discussed in Section 4.3, when the model abstracts from these features, the pool of UI recipients becomes relatively wealthier. This makes the aggregate incentive costs of changes in UI generosity over the business cycle larger, as the labor market behavior of the unemployed with some positive level of self-insurance is more elastic to UI. As a result, 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 earners who are inelastic now qualify for UI. Overall, these exercises reveal that modeling the heterogeneity of UI recipients as 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 function such that the government’s period-by-period surplus/deficits are minimized. Third, we consider the effects of introducing a higher level of government expenditure 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 tool for redistribution. Detailed explanations on how we implement these exercises can be found in Appendix D.

7 Conclusion

We study optimal UI over the business cycle using a tractable heterogeneous agent job search model with aggregate risk and incomplete markets and find that optimal UI policy is countercyclical for both the replacement rate and duration. We argue that accounting for the observed demographic differences between UI recipients and non-recipients is key to this result. UI recipients – who start their unemployment spell already with little wealth – drive down their wealth quickly and approach their borrowing limits. The resulting wealth effect induces them to intensify efforts to search for easier to find jobs. Overall, 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 left and long-term unemployment risk is higher. This is supported by a smaller drop in consumption of the unemployed and a marked increase in take-up rates during recessions under the optimal policy.

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 heterogeneity in UI receipt and wealth dynamics over the cycle. We show that abstracting from such heterogeneity and wealth dynamics results in drastically different aggregate implications of policy reform. Beyond the insurance benefit and incentive cost trade off, the optimal policy may have implications for the occupational choices of UI recipients. Given that optimal UI benefits offer more generous replacement rates for longer durations, UI recipients may be willing to start their own businesses. This is because of the weakened need for precautionary saving, allowing diversion of funds to finance a new business. We leave these analysis to future work.

References


Appendix for Online Publication

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 BRE of the model. 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

\[
V^NB(a, y; \mu) = \max_{c, a' \geq a} \left[ u(c) - \nu(s) + \beta \mathbb{E} \left[ \max_{\tilde{w}} \left\{ sf(\tilde{w}, y'; \mu') V^W(a', \tilde{w}, y'; \mu') \right\} \right] \right] \\
+ \left( 1 - sf(\tilde{w}, y'; \mu') \right) V^{UI}(a', y'; \mu') \mid y, \mu \]

subject to

\[
c + a' \leq (1 + r) a + h \\
\Gamma' = H(\mu, p'), \quad p' \sim F(p' \mid p), \quad y' \sim Q(y' \mid y).
\]

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

A.2 BRE

**Proposition:** If i) utility function \( u(\cdot) \) is strictly increasing, strictly concave, and satisfies Inada conditions and \( \nu(\cdot) \) is strictly increasing and strictly convex; ii) choice sets \( W \) and \( A \) and sets of exogenous processes \( P \) and \( Y \) are bounded; iii) matching function \( M \) exhibits constant returns to scale; and iv) UI policy is restricted to be only a function of 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 government finances the time-varying UI benefits and show that the model still admits block recursivity.

Existence: We prove the existence of the 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 UI policy instruments are restricted to be a function of aggregate labor productivity, we show that the household 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 labor market tightness constitute a BRE.

Let \( J (W, \mathcal{Y}, \mathcal{P}) \) be the set of bounded and continuous functions \( J \) such that \( J : W \times \mathcal{Y} \times \mathcal{P} \rightarrow \mathbb{R} \) and let \( T_J \) be an operator associated with Equation (3) such that \( T_J : J \rightarrow J \). Then, using Blackwell’s sufficiency conditions for contraction and the assumptions of the boundedness of sets of exogenous processes \( \mathcal{Y} \) and \( \mathcal{P} \) and choice set \( W \), we can show that \( T_J \) is a contraction and has a unique fixed point \( J^* \in J \). 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 posted by the firms in equilibrium \( W \) for each labor productivity level in the set \( \mathcal{Y} \) is determined by aggregate labor productivity as well. Plugging \( J^* \) into Equation (5) yields

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

Hence, we show that equilibrium market tightness does not depend on the distribution of agents across states as well.\(^{31}\)

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

\(^{31}\)Notice that, the constant-returns-to-scale property of the matching function \( M \) is crucial here so that we can write the job finding rate and vacancy filling rate as functions of \( \theta \) only. The free entry condition (5) is also important to pin down market tightness.
value function $R : \{0,1\} \times \{0,1\} \times \mathcal{A} \times \mathcal{W} \times \mathcal{Y} \times \Omega \rightarrow \mathbb{R}$ such that

\[
R (l = 1, n = 0, a, w, y; \mu) = V^W (a, w, y; \mu)
\]
\[
R (l = 0, n = 1, a, w, y; \mu) = V^B (a, w, y; \mu)
\]
\[
R (l = 0, n = 0, a, w, y; \mu) = V^{NB} (a, y; \mu).
\]

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

\[
(T_R R) (l, n, a, w, y; p) = l \left[ \max_{c, a' \geq a} u (c) + \beta \mathbb{E} \left[ \delta (p') \left[ (1 - g (p')) R (l = 0, n = 1, a', w, y'; p') + g (p') R (l = 0, n = 0, a', w, y'; p') \right] + (1 - \delta (p')) R (l = 1, n = 0, a', w, y'; p') \right] \right] + (1 - l) n \left[ \max_{c, a', s, d} u (c) - \nu (s) - \phi d \right. \\
+ \beta \mathbb{E} \left[ \max_{\tilde{w}} \left\{ sf (\theta (\tilde{w}, y'; p')) R (l = 1, n = 0, a', \tilde{w}, y'; p') + (1 - sf (\theta (\tilde{w}, y'; p'))) \left[ (1 - e (p')) R (l = 0, n = 1, a', w, y'; p') + e (p') R (l = 0, n = 0, a', w, y'; p') \right] \right\} \right] \right] + (1 - l) (1 - n) \left[ \max_{c, a', s} u (c) - \nu (s) \right. \\
+ \beta \mathbb{E} \left[ \max_{\tilde{w}} \left\{ sf (\theta (\tilde{w}, y'; p')) R (l = 1, n = 0, a', \tilde{w}, y'; p') + (1 - sf (\theta (\tilde{w}, y'; p'))) \left[ (1 - e (p')) R (l = 0, n = 1, a', w, y'; p') \right. \right. \\
\left. + e (p') R (l = 0, n = 0, a', w, y'; p') \right) \right\} \right] \right] \\
\left. \right] \right] \\
\text{subject to} \\
c + a' \leq (1 + r) a + lw (1 - \tau) \\
+ (1 - l) n [ b (y, p) d (1 - \tau) + h ] + (1 - l) (1 - n) h \\
p' \sim F (p' \mid p), \quad y' \sim Q (y' \mid y),
\]

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

3
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., \( T_R : \mathcal{R} \to \mathcal{R} \)). Then, using Blackwell’s sufficiency conditions for a contraction and the assumptions of boundedness of sets of exogenous processes \( \mathcal{P} \) and \( \mathcal{Y} \), and choice sets \( \mathcal{W} \) and \( \mathcal{A} \), we can show that \( T_R \) is a contraction and 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 \( p \) only.

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

**Wage policy function:** Under the assumptions on \( u(\cdot) \) and \( \nu(\cdot) \) together with the assumptions of boundedness of sets of exogenous processes \( \mathcal{P} \) and \( \mathcal{Y} \), and 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\(^{32}\):

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

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

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

\(^{32}\)The following results can be obtained under an \( N \) state Markov process assumption for \( p \) and no restrictions on the job destruction rate.
Thus, the job finding rate \( f(\cdot) \) is linear and decreasing in \( w \). Then, rewriting the objective function for the wage choice of eligible unemployed, we have

\[
\max_{\tilde{w}} \left( \begin{array}{c} s f (\theta (\tilde{w}, y; p)) V^W (a', \tilde{w}, y; p) + (1 - s f (\theta (\tilde{w}, y; p))) \\ \times \left[ (1 - e(p)) V^B (a', w, y; p) + e(p) V^{NB} (a', y; p) \right] \right).
\]

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 objective function above 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

\[
\max_{\tilde{w}} \left( \begin{array}{c} s f (\theta (\tilde{w}, y; p)) V^W (a', \tilde{w}, y; p) + (1 - s f (\theta (\tilde{w}, y; p))) V^{NB} (a', y; p) \end{array} \right)
\]

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 choice sets \( A \), \( W \) and exogenous processes \( Y \), \( P \), 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 asset policy functions are unique for \( l = \{W, NB, B\} \).

**Search effort policy function:** Using the same reasoning, objective functions for the search effort choices of 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, value functions, and labor market tightness independent of \( \Gamma \), it 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 wealth distribution of the
economy is determined by household decision rules in the labor market and fi-
nancial 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 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 it would break the block recursivity of the model. This is because
agents would need to calculate next period’s unemployment rate to know the
replacement rate and UI duration next period. However, this requires calculating
the flows in and out of unemployment, the latter of which depends on the distrib-
ution of agents across states $\Gamma$. Although the changes in UI policy are triggered
by the changes in the unemployment rate according to the current UI program
in the U.S., the assumption that UI policy depends on aggregate productivity is
not restrictive, because of the strong correlation between the unemployment rate
and 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 standard value function iteration. In order to de-
crease computation time, we implement Howard’s improvement algorithm (policy-function iteration).

4. Once household policy functions are obtained, we are able to simulate 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 Section 3 and 4 of the main text.

B.1 SIPP Data

We use the SIPP data to discipline labor market transitions, the asset-to-income distribution, and 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 interview of the first rotation group. This way, all four rotation groups, and thus all respondents, will have been interviewed at the end of each wave.

In each interview, respondents are asked questions about their income, employment status, and government transfer receipts 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 labor force status. Importantly, the SIPP also contains data on the asset holdings of the respondent.
In each SIPP panel, respondents provide information on various types of asset holdings at 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 calculation of empirical moments from the SIPP data. We restrict our sample to individuals ages 25-65 and to those who neither own a business nor derive income from self-employment.

**Labor market transitions**  Using SIPP 1996, 2001, and 2004 panels (covering data from 1996 to 2007), we calculate monthly job finding rate and job separation rates. First, we classify an individual as employed (E) if he/she reports having a job and is either working or not on layoff, but is absent without pay in the first week of the month. We classify the individual as unemployed (U) if he/she reports either having no job and actively looking for work or having a job but currently 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 job finding rates and job separation rates across the income distribution, we use monthly labor earnings data.\(^{33}\)

**Heterogeneity in job separation rates** To measure the heterogeneity in job separation rates across the income distribution, we use monthly data from SIPP between 1996 and 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 monthly fixed effects. The average ratio of the job separation rate of low-income workers and high-income workers over time is 3.28, implying that workers in the first quintile of earnings distribution are more than three times more likely to separate from their employers than those in

\(^{33}\)Variables TPMSUM1 and TPMSUM2 provide monthly gross labor earnings from up to two jobs. We sum these two variables to obtain monthly labor income.
the fifth quintile of the earnings distribution. We use $\eta^6_y$ to match this value for the same moment in the model.

**Heterogeneity in job finding rates** Calculating the calibration target pertaining to heterogeneity in the job finding rates follows a similar procedure. In particular, for each unemployment spell, we record the previous employment income as the unemployed’s labor earnings from the month prior to job loss. Then, for each month, we calculate the distribution of previous employment income for these job losers. Next, for each month, we separately calculate the job finding rate of 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 monthly fixed effects. The average ratio of the job finding rate of low-income unemployed to high-income unemployed over time is 0.96, implying that the bottom and the top income quintiles have similar job finding rates. We use $\eta^6_y$ to match this value for the same moment in the model.

**Asset-to-income distribution** We use the SIPP 2004 panel, which contains 12 waves covering information between January 2004 and December 2007. We use the topical module in wave 6 to obtain information on the asset holdings.

We focus on the net liquid asset holdings of individuals. The SIPP contains individual level data on financial liquid assets such as interest-earning financial assets in banking and other 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 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

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

35 A similar result has been documented in Lise and Robin (2017) and Krusell et al (2017). Lise and Robin (2017) use CPS to calculate the levels and cyclicalities of 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 labor market transition rates of individuals across quintiles of the asset distribution. They find that the ratio of the job finding rate of unemployed individuals from the first quintile of the asset distribution to that from the fifth quintile of the asset distribution is 0.83.
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 asset accounts net of revolving debt gives us the net financial asset holdings of the individual. 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 net financial asset holdings of the individual gives us the measure of net liquid asset holdings for each individual.36

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

**Unemployment spell duration** Here, we provide additional details on the construction of the completed unemployment spell duration distribution 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 employment status of the respondents are dropped. Finally, we define spells to be uninterrupted months of unemployment and thus do not consider time spent out of the labor force, since

---

36Net financial asset holdings of individuals are calculated as follows 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 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, net equity in vehicles of the household is given by THHVEHCL. We divide this value among the members of the household above age 16. Thus, we get the net liquid asset holdings of the individual as follows:

Net liquid assets = Net financial assets + \( \frac{THHVEHCL}{\text{Num. of persons in household > age 16}} \).
Table A.1: Externally calibrated parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Explanation</th>
<th>Value</th>
<th>Parameter</th>
<th>Explanation</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\omega$</td>
<td>Probability of death</td>
<td>0.0021</td>
<td>$\gamma$</td>
<td>Matching function</td>
<td>0.5</td>
</tr>
<tr>
<td>$\sigma$</td>
<td>Risk aversion</td>
<td>2</td>
<td>$m^e_0$</td>
<td>Level of UI expiration rate</td>
<td>507.17</td>
</tr>
<tr>
<td>$r$</td>
<td>Interest rate</td>
<td>0.0033</td>
<td>$m^e_p$</td>
<td>Cyclicality of UI expiration rate</td>
<td>−500.67</td>
</tr>
<tr>
<td>$\kappa$</td>
<td>Vacancy posting cost</td>
<td>0.58</td>
<td>$e_{cap}$</td>
<td>Maximum UI expiration rate during non-recessions</td>
<td>4/26</td>
</tr>
<tr>
<td>$\rho^\nu$</td>
<td>Persistence of idiosyncratic labor productivity</td>
<td>0.9867</td>
<td>$m^b_p$</td>
<td>Cyclicality of UI replacement rate</td>
<td>0</td>
</tr>
<tr>
<td>$\rho^p$</td>
<td>Persistence of aggregate labor productivity</td>
<td>0.9183</td>
<td>$m^g_p$</td>
<td>Cyclicality of fraction of job losers who are eligible for UI</td>
<td>0</td>
</tr>
<tr>
<td>$\sigma^p$</td>
<td>Dispersion of aggregate labor productivity</td>
<td>0.0042</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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

we do not model the non-participation margin. For each panel, we then report the duration distribution of completed unemployment spells.

B.2 Calibration and Validation

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

Table A.2 compares aggregate labor market properties in the data and the model. In our calibration, 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: Aggregate labor market properties

<table>
<thead>
<tr>
<th></th>
<th>Data</th>
<th>Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>$X_t$</td>
<td>$UR_t$</td>
<td>$JFR_t$</td>
</tr>
<tr>
<td>$\sigma_X$</td>
<td>0.096</td>
<td>0.106</td>
</tr>
<tr>
<td>$\sigma_X/\sigma_p$</td>
<td>10.70</td>
<td>12.32</td>
</tr>
<tr>
<td>$\text{cor}(X_t, X_{t-1})$</td>
<td>0.93</td>
<td>0.93</td>
</tr>
<tr>
<td>$\text{cor}(UR_t, X_t)$</td>
<td>1</td>
<td>-0.82</td>
</tr>
</tbody>
</table>

Note: This table compares aggregate labor market properties in the data and the model. We obtain the monthly times series for the unemployment rate between 1975-2005 from the BLS. 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 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.

Table A.2. The rest of the table reveals that the model moments are reasonably close to their empirical counterparts, with the exception that the volatility of market tightness is much smaller in the model than the data.

Next, Figure A.1 compares UI replacement rates in the model and the data as a function of previous employment wages relative to 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 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 ii) the aggregate unemployment rates with and without UI extensions during the Great Recession 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 distance between the unemployment rate of the model and 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
Figure A.1: UI replacement rates in the model vs data

Note: This figure compares UI replacement rates in the model and the data across the average weekly wage relative to the mean wage. We calculate the replacement rates of UI eligible unemployed across average weekly wages by creating a program that combines information from SIPP data and eligibility rules on state level UI laws. This allows us to predict whether or not a respondent is eligible for unemployment benefits based on 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 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 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 ii) the unemployment rates with and without UI extensions during the Great Recession in Section 4.2.
relative to the existing policy. The first measure, $\pi_1(z)$, is computed separately for each individual state $z$ possible in the economy; i.e., $z \in Z \equiv \{W, B, NB\} \times A \times W \times Y$. This measure enables us to assess the heterogeneous welfare gains or losses that proposed reform to UI policy may have on different types or subgroups of agents. We can also aggregate it 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 better comparison with the existing literature.

We now formally define these two measures. Let $\left\{ c^E_t(z), s^E_t(z), d^E_t(z) \right\}_{t=T}^\infty$ denote the path allocations of an individual with 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 $\left\{ c^R_t(z), s^R_t(z), d^R_t(z) \right\}_{t=T}^\infty$ 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 percent 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 the 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 $z \in Z$, $\pi_1(z)$ satisfies the following equation:

$$
E_T \sum_{t=T}^\infty \beta^{t-T} U \left( c^E_t(z) (1 + \pi_1(z)) , s^E_t(z) , d^E_t(z) \right) \tag{A.2}
= E_T \sum_{t=T}^\infty \beta^{t-T} U \left( c^R_t(z) , s^R_t(z) , d^R_t(z) \right),
$$

where $T$ is the time period when UI policy changes from $E$ to $R$. Once we obtain $\pi_1(z)$ for all $z \in Z$ by solving this equation, we can obtain an aggregate welfare measure by integrating over the stationary distribution $\Gamma^E_{ss}$ in the baseline.

---

37Given the functional form of the utility function, there are no closed-form solutions for $\pi_1(z)$, $\bar{\pi}_1$, or $\bar{\pi}_2$.

38In 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.
economy with policy $E$:

$$\bar{\pi}_1 = \int_{z \in \mathbb{Z}} \Gamma_{ss}^E (z) \times \pi_1 (z).$$

(A.3)

$\bar{\pi}_2$ is the percent 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 populated with the same agents but where policy $R$ is implemented. Formally, $\bar{\pi}_2$ satisfies the following equation:

$$\int_{z \in \mathbb{Z}} \Gamma_{ss}^E (z) E_T \sum_{t=1}^{\infty} \beta^{t-T} U \left( c^E_t (z) (1 + \bar{\pi}_2), s^E_t (z), d^E_t (z) \right)$$

$$= \int_{z \in \mathbb{Z}} \Gamma_{ss}^R (z) E_T \sum_{t=1}^{\infty} \beta^{t-T} U \left( c^R_t (z), s^R_t (z), d^R_t (z) \right).$$

(A.4)

The government chooses the UI policy instruments in order to maximize the ex-ante lifetime utility of an individual born (under the veil of ignorance) into the stationary equilibrium under policy $E$ subject to the government budget constraint. In other words, the government’s objective is to maximize ex-ante lifetime utility $\int_{z \in \mathbb{Z}} \Gamma_{ss}^E (z) E_T \sum_{t=1}^{\infty} \beta^{t-T} U \left( c^E_t (z) (1 + \bar{\pi}_2), s^E_t (z), d^E_t (z) \right)$ 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 budget in expectation, to obtain our optimal UI policy. Hence, the optimal policy will be a policy $R$ with some $m^b_0, m^b_{uw}, m^b_p, m^e_0, m^e_p$, and $\tau$ that maximizes the ex-ante welfare.

Welfare gains of the optimal policy are similar under these two measures. In particular, we find that 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. Except in 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
Table A.3: Decomposition of welfare gains by policy parameter

<table>
<thead>
<tr>
<th>Optimal policy features introduced</th>
<th>Welfare gains (%)</th>
<th>Optimal policy features introduced</th>
<th>Welfare gains (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rep. rate-wage het.</td>
<td>0.06</td>
<td>Duration level</td>
<td>0.03</td>
</tr>
<tr>
<td>+ Rep. rate level</td>
<td>0.10</td>
<td>+ Duration cyclicality</td>
<td>0.09</td>
</tr>
<tr>
<td>+ Rep. rate cyclicality</td>
<td>0.13</td>
<td>+ Rep. rate-wage het.</td>
<td>0.17</td>
</tr>
<tr>
<td>+ Duration level</td>
<td>0.24</td>
<td>+ Rep. rate level</td>
<td>0.27</td>
</tr>
<tr>
<td>+ Duration cyclicality</td>
<td>0.32</td>
<td>(optimal UI)</td>
<td>0.32</td>
</tr>
</tbody>
</table>

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 result of starting from the baseline UI policy and sequentially changing the wage-replacement rate schedule, level of the replacement rate, cyclicality of the replacement rate, level of the UI duration, and cyclicality of the UI duration to reach the optimal UI policy. The last two columns provide the results of a similar exercise but this time changing the policy instruments starting from the UI duration level. For each step, we adjust the tax rate $\tau$ so that Equation (6) holds. Welfare gains are calculated relative to the baseline UI policy, and they are in percent additional lifetime consumption units.

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

To quantify this claim, we compute the welfare gains from introducing individual features of the optimal policy one by one. The first two columns of Table A.3 show the result of starting from the baseline UI policy and sequentially changing the wage-replacement rate schedule, level of the replacement rate,
Table A.4: Robustness

<table>
<thead>
<tr>
<th>Assumption</th>
<th>Welfare Gain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline model</td>
<td>0.32</td>
</tr>
<tr>
<td>Time varying interest rates</td>
<td>0.31</td>
</tr>
<tr>
<td>Time varying tax rates</td>
<td>0.25</td>
</tr>
<tr>
<td>High level of government expenditure</td>
<td>0.41</td>
</tr>
<tr>
<td>High level of government expenditure under progressive taxation</td>
<td>0.18</td>
</tr>
</tbody>
</table>

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

cyclicality of the replacement rate, level of the UI duration, and cyclicality of the UI duration to reach the optimal UI policy.\textsuperscript{39} For each step, we adjust tax rate \( \tau \) so that Equation (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 starting to change policy instruments starting from the UI duration level. It 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 of 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 in exploring the effects of such assumptions on the optimal policy. Results are summarized in Table A.4.

\textsuperscript{39}For the step where we introduce adjustments to the level of replacement rates, for each wage, we set the level of replacement rate to the one prescribed by the optimal policy when labor productivity is at its mean.
**Time varying interest rates** In our model, we assume a constant and exogenous interest rate $r$. Alternatively, in an equilibrium model of asset market, 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 the interest rate is constant over time in our model, this may lead to excessive cyclicality of precautionary saving 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 $r(p) = m^r_0 + m^r_p p$. Then, we calibrate $m^r_0$ and $m^r_p$ to match an 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 of the optimal policy. In this case, we find that the optimal policy yields a welfare gain equivalent to 0.31 percent of additional lifetime consumption relative to 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 budget and income taxation. In our model, we assume that the present discounted value of government debt is zero, implying that the government budget holds in expectation. Alternatively, we could have assumed that the government finances its expenses every period. However, this makes the task of solving for the optimal policy infeasible. 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 employment and wage distributions of agents, 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 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 bud-
get in the long run, we now assume countercyclical income taxes such that 
\[ \tau(p) = m^\tau_0 + m^\tau_p p. \]

The intention of this is that when the UI budget deficit of the government increases during recessions, we allow tax rates also to increase so that the government can increase its tax revenues. Thus, this assumption makes our model closer to a model where the government budget holds in every period, without needing to keep track of the distribution of agents across states. In doing so, we choose \( (m^\tau_0, m^\tau_p) \) such that i) the government budget balances in expectation (i.e., Equation (6) holds) and ii) the sum of squared values of period government debt/surplus is minimized; i.e., \( (m^\tau_0, m^\tau_p) \) minimizes

\[
\sum_{t=0}^{\infty} \left[ \sum_{i} \left( 1_{l_{it}=W} \times w_{it} + 1_{l_{it}=B \text{ and } d_{it}=1} \times b_{it} w_{it} \right) \times \left( m^\tau_0 + m^\tau_p p_t \right) \right]^2 - 1_{l_{it}=B \text{ and } d_{it}=1} \times b_{it} w_{it}.
\]

Namely, under the baseline UI policy, the parameters of the tax function are such that the government 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 \( m^\tau_p \) so that both policies are financed under the same cyclicity of the tax function and choose \( m^\tau_0 \) to satisfy Equation (6). In this case, we find that the welfare gains from the optimal policy relative to the baseline policy is 0.25 percent. As a result, this exercise suggests that allowing the government 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 have for our results. We now investigate the impact of level of income taxation on the welfare gains from the optimal policy. In order to do so, we now assume that government has additional (thrown away) expenses of around 19 percent of period output, which is motivated by the fact that the total government expenditure to GDP
ratio 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 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 after-tax labor income of the individual 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 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 redistribution.