

# How Should Unemployment Insurance Vary over the Business Cycle?\*

Serdar Birinci and Kurt Gerrard See†

University of Minnesota, Department of Economics

December 7, 2017

## Abstract

We study optimal unemployment insurance (UI) over the business cycle using a tractable heterogeneous agent job search model that features labor productivity driven business cycles and incomplete asset markets, and find that UI policy should be countercyclical. In this framework, besides providing consumption insurance upon job loss, generous UI payments allow individuals to maintain similar consumption levels even during recessions, when they would otherwise have had to accumulate savings by reducing consumption. Moreover, the presence of borrowing constraints disciplines the unemployed's job search behavior, thus offsetting some of the moral hazard costs introduced by the generous UI payments in downturns. Even when the opportunity cost of employment is set to be high, these channels remain active to preserve the countercyclicality of the optimal UI policy.

**JEL-Codes:** E24, E32, J64, J65

**Keywords:** Unemployment Insurance, Business Cycles, Job Search

---

\*We are grateful to Anmol Bhandari, Kyle Herkenhoff, Loukas Karabarbounis, and Ellen R. McGrattan for their guidance and support. We would also like to thank Naoki Aizawa, Sergio Ocampo Diaz, Jonathan Heathcote, Fatih Karahan, Jeremy Lise, Guido Menzio, Fabrizio Perri, and Mario Silva, as well as seminar participants at the Bank of Canada, the Federal Reserve Bank of San Francisco, the Federal Reserve Bank of St. Louis, and the Federal Reserve Bank of Minneapolis for their useful comments. We thank Adam M. Smith of U.S. Census Bureau for helping us to understand finer details of Survey of Income and Program Participation data. This research was carried out in part using computing resources at the University of Minnesota Supercomputing Institute. We thank Andrew Gustafson for his help in accessing these resources.

†Department of Economics, University of Minnesota, 4-101 Hanson Hall, 1925 Fourth Street South, Minneapolis, MN, 55455. Emails: Serdar Birinci [birin001@umn.edu](mailto:birin001@umn.edu) and Kurt Gerrard See [seex028@umn.edu](mailto:seex028@umn.edu)

# 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, the question of whether UI policy played a quantitatively significant role in slowing the recovery of employment remains at the center of discussion.<sup>1</sup> Alongside this positive debate, an equally important policy question emerges: how then should UI policy vary over the business cycle? Addressing this question will shed light on how UI policy must adjust to economic fluctuations, especially during economic downturns.

Our main contribution to the growing literature on optimal UI over the business cycle is to study the endogenous interaction between precautionary savings and changes in UI policy over recessions and expansions, a mechanism that we show is crucial to correctly measure the welfare benefits and costs of any proposed policy. This is because the level of wealth determines not only the insurance value of any public transfer but also its incentive costs, since the labor market behavior of individuals holding different levels of assets responds in varying degrees to changes in the level of generosity of these programs. Moreover, as wealth holdings and the strength of precautionary saving motives vary over the business cycle, they inevitably influence the cyclical nature of the insurance benefits and incentive costs of UI payments. It is precisely the cyclical nature of the net benefits of UI that will determine how benefit generosity should vary over the business cycle.

We address this question using a heterogeneous agent job search model that incorporates labor productivity driven business cycles and incomplete asset markets. To overcome the computational difficulties encountered in models of this nature, we show that the model's market structure admits a block recursive equilibrium, a subset of recursive equilibria where the endogenous distributions generated by the model are not part of the state space (Menzio and Shi 2010, 2011). This allows us to compute the optimal UI policy in a model with aggregate shocks and saving decisions.

We find that the optimal UI policy is countercyclical. In particular, when the aggregate labor productivity is at its mean, it features a 30 percent replacement rate for 4 quarters. When aggregate labor productivity is depressed by 3.5 percent, however, it offers more generous benefits of a 54 percent replacement rate for 10 quarters, financed by higher labor income taxes. Compared to a UI policy that mimics the policy implemented by the U.S. government during the Great Recession, the optimal policy represents an ex-ante welfare gain of 0.58 percent additional lifetime consumption.

---

<sup>1</sup>For example, Hagedorn et al. (2016) find that a generous UI policy during the recession is partly responsible for the drastic and sustained rise in unemployment that followed. On the other hand, Chodorow-Reich and Karabarbounis (2017) show that the extensions have had limited influence on macroeconomic outcomes.

The countercyclicality of the optimal policy is explained by how the insurance benefits of extra UI payments expand during recessions relative to expansions while relative incentive costs contract. Two important insurance benefit channels expand during recessions: (1) consumption insurance against unemployment risk and (2) consumption insurance against aggregate labor productivity risk. First, generous benefits insure against unemployment risk by alleviating the consumption drop experienced by job losers. This is especially important in recessions when unemployment rises and spells are prolonged. Second, it also insures against aggregate risk since it reduces the burden of having to engage in (costly) precautionary savings during economic downturns. Recessions trigger a strong need to accumulate a buffer stock of savings, which in turn entails a concomitant reduction in consumption. In the absence of public insurance, this makes consumption fluctuate heavily with the business cycle. However, this effect is mitigated when individuals are promised more generous payments for future unemployment spells.<sup>2</sup> Remarkably, this results in sizeable welfare gains not only for job losers but also for those who are employed.

Insurance benefits come with a trade-off: generous UI payments during recessions decrease the job finding rates of the unemployed through a decline in job search effort and an increase in the wages that they seek. This results in longer unemployment durations. However, we show that these costs are relatively lower in recessions for two reasons: (1) the value of job search is low during recessions, and (2) borrowing constraints impose discipline on the unemployed's job search behavior. First, the value of job search during recessions is low because, to begin with, jobs are difficult to find and available jobs offer relatively lower wages. Hence, even if generous benefits were to discourage job search during a recession, the forgone search effort would not have been very productive anyway. Second, a reduction in wealth holdings during recessions induces the unemployed to find a job more quickly as they get closer to becoming borrowing constrained. In this sense, the presence of borrowing constraints is a device to discipline the job search behavior of the unemployed. For both of these reasons, the incentive costs associated with generous benefits are partially offset in recessions.<sup>3</sup>

These channels remain active even under a high level of the opportunity cost of employment calibration. In this case, we find that while the mean replacement rate and duration of the optimal policy reduce to a 19 percent replacement rate for one quarter, the degree of countercyclicality remains roughly similar. As fluctuations in consumption are less pronounced under this calibration, the government implements a low replacement rate for short durations when aggregate labor productivity is at its mean value. Still, insurance benefits expand and incentive costs contract in recessions. Thus, the government finds it optimal to transfer funds from expansions toward recessions. The resulting optimal policy in this case provides ex-ante welfare gains of 0.25 percent lifetime consumption, which is less than half of the welfare gains provided by the

---

<sup>2</sup>This channel is consistent with Engen and Gruber's (2001) empirical finding that UI payments crowd out private savings.

<sup>3</sup>This result is consistent with Kroft and Notowidigdo (2016), who empirically find that the moral hazard cost of UI is procyclical.

optimal policy under the baseline calibration of the opportunity cost of employment.

We quantify various sources of ex-ante welfare gains of the optimal policy and find that most of them are attributable to changes in consumption patterns, whereas the welfare gains from economizing on relatively unproductive search during recessions are negligible. These changes in consumption patterns can potentially increase ex-ante welfare for three reasons: (1) an increase in consumption levels, (2) a decrease in consumption volatility, and (3) a reduction in consumption inequality across individuals. We find large welfare gains due to an increase in the average consumption level along the transition path after the implementation of the optimal UI policy. This is because agents decumulate savings and consume more of their labor income when public insurance is generous, and this effect dominates the increase in labor income taxes. Steady state welfare decomposition reveals that long-run welfare gains are attributable mostly to reduced consumption uncertainty, but at the cost of lower consumption levels. The reduction in the consumption level is due to higher taxes and lower wealth holdings once the economy converges to a new steady state, although this change is not large enough to overturn uncertainty gains. Finally, welfare gains due to a reduction in consumption inequality are small because the optimal policy has two offsetting effects on consumption inequality. On the one hand, the redistribution of labor income from workers to the unemployed creates more equal consumption paths across heterogeneous agents. On the other hand, the optimal policy increases wealth inequality in the stationary distribution. This is because while most of the individuals in the economy under the optimal policy reduce their savings, the response of the agents in the top percentiles of the distribution is very small. The rise in wealth inequality, in turn, increases consumption inequality among heterogeneous agents. We find that these two opposing effects quantitatively cancel each other out and thus result in negligible welfare gains attributable to a decline in consumption inequality.

Next, we analyze the heterogeneous welfare effects of the optimal policy. Unsurprisingly, the unemployed who are eligible for UI benefits gain significantly, with the poor within this group enjoying the largest welfare gains, since each additional dollar of benefit payments is more valuable to them. Workers also enjoy a sizeable welfare gain, albeit to a smaller degree due to two opposing effects. Although they are the primary financiers of the increased government expenditures because of the generous policy, they also experience large consumption smoothing benefits over the business cycle. Similarly, gains are also much larger among poor workers for whom a reduction in precautionary savings diverted toward consumption is most beneficial. Finally, the unemployed who are ineligible for UI gain the least because they will enjoy benefits only if they find a job and become eligible through the loss of that job. They are also adversely affected by lower job finding rates during recessions without the insurance that UI provides.

When solving for the optimal UI policy, we follow a large strand of literature that uses calibrated models

to study the optimal policy for a restricted class of policy instruments.<sup>4</sup> The model simultaneously matches the liquid asset-to-income distribution and salient features of the labor market prior to the Great Recession. The policy instruments in our welfare analysis are restricted to take the form of the UI replacement rate and UI payment duration as functions of current aggregate labor productivity, and a constant labor income tax used to balance the government’s budget for any proposed UI program.

**Related Literature** Our paper contributes to the growing literature on optimal UI over the business cycle. Recent papers in this literature are Landais et al. (2017), Jung and Kuester (2015), Mitman and Rabinovich (2015). However, in these models, risk-averse agents do not have access to asset markets for self-insurance purposes.<sup>5</sup> This assumption has several important implications for the level and cyclicity of the insurance benefits and incentive costs of any proposed UI policy. First, the insurance value of UI payments for job losers is overstated because public insurance is the only way of smoothing consumption upon job loss. Second, since the elasticity of search effort and the wage choice of the unemployed are both decreasing in wealth holdings, a model that abstracts from self-insurance altogether also overestimates the level of the moral hazard costs associated with introducing a more generous UI policy. Third, disregarding asset markets completely eliminates the interaction between self-insurance and public insurance. Importantly, the decline in precautionary saving motives as a response to a generous UI policy contributes to the expansion of insurance benefits of UI in recessions because it also provides consumption insurance against aggregate risk. The novelty of our analysis is to study this endogenous response of the asset distribution to changes in UI policy over the business cycle, which is crucial for the true measurement of the cyclicity of insurance benefits of UI. Among these papers, our model is closest to Mitman and Rabinovich (2015) with two differences: our model 1) allows for self-insurance through incomplete asset markets, and 2) features directed search, making the model still tractable due to block recursivity even under the presence of incomplete asset markets, whereas job search is random in their model. In terms of welfare exercise, Mitman and Rabinovich (2015) are able to solve a Ramsey problem to obtain the optimal UI policy as a function of the entire history of past aggregate shocks, whereas we use our calibrated model to study the optimal policy for a restricted class of policy instruments that only depend on the current period realization of the aggregate shock in order to maintain tractability.

Another strand of literature studies the optimal design of UI policy under the presence of asset markets. However, these papers use models that do not incorporate either unemployment risk (Kroft and Notowidigdo

---

<sup>4</sup>See Hansen and Imrohoroglu (1992), Acemoglu and Shimer (2000), Abdulkadiroglu et al. (2002), Wang and Williamson (2002), Krusell et al. (2010), Koehne and Kuhn (2015), and Eeckhout and Sepahsalari (2015).

<sup>5</sup>In addition to this difference, there are other important modeling differences between our paper and these papers. For example, Jung and Kuester (2015) and Landais et al. (2017) do not consider UI expiration. See Mitman and Rabinovich (2015) for a discussion on the implications of these assumptions.

2016) or aggregate risk (Hansen and Imrohoroğlu 1992, Acemoglu and Shimer 2000, Abdulkadiroğlu et al. 2002, Wang and Williamson 2002, Lentz 2009, Krusell et al. 2010, Koehne and Kuhn 2015, and Eeckhout and Sepahsalari 2015) or both features (Shimer and Werning 2008, Chetty 2008).<sup>6</sup> Absent unemployment risk, assets have no role for precautionary savings purposes, and they are simply used for consumption smoothing until the single spell ends and a permanent job is found.<sup>7</sup> Importantly, we show in our model that saving decisions interact with the changes in UI policy because wealth is a substitute for UI payments for self-insurance purposes. The changes in saving decisions in turn significantly affect the search effort and wage choices of the unemployed as well as the consumption patterns of everyone in the economy. On the other hand, a model in which aggregate risk is absent makes the insurance value of UI time-invariant. In our framework with aggregate risk, the strength of precautionary saving motives significantly varies with the level of unemployment risk over the business cycle. Incorporating this feature is especially important to understand the optimality of time-varying UI policy.<sup>8</sup>

Finally, other papers investigate the impact of changes in UI policy on macroeconomic outcomes.<sup>9</sup> Two recent papers study this question in a framework with search frictions and incomplete markets. First, Nakajima (2012) carefully models UI extensions during the Great Recession and its subsequent recovery using a model with business cycle dynamics and then measures the effect of these extensions on the unemployment rate. He does not, however, study the welfare effects of these changes in UI policy. We extend his model to a general equilibrium model in which the government finances the UI benefits and use the model to study how UI policy must vary over the business cycle. Second, Kekre (2017) studies the macroeconomic and welfare effects of UI extensions during the Great Recession in a model with nominal rigidities and constraints on monetary policy but without business cycle dynamics in the real business cycle tradition. In his model, when the unemployed have a higher marginal propensity to consume than the employed, generous UI policy increases the aggregate demand for consumption both in the current period and in the previous period because individuals endogenously reduce precautionary savings when they expect generous public transfers in the future. As a result, he finds that UI extensions reduced the unemployment rate and provided welfare gains during the Great Recession. Rather than only focusing on discretionary UI policy changes during

---

<sup>6</sup>Although the baseline model in Krusell et al. (2010) incorporates aggregate fluctuations, they study the welfare effects of changes in UI policy in a steady-state experiment. The baseline model in Chetty (2008) has no unemployment risk, but he presents an extension to incorporate it, and he shows that his main results hold under extra assumptions.

<sup>7</sup>Typically, in these models, all agents are initially unemployed, and they decide when to accept a permanent employment offer. These models are often called single-spell models.

<sup>8</sup>Our paper has other important features compared to these papers in the literature. In terms of modeling, previous papers (except for Krusell et al. 2010 and Eeckhout and Sepahsalari 2015) use partial equilibrium models of the labor market. In these models, the changes in aggregate conditions of the economy or in UI policy do not affect firm hiring decisions and offered wages. In terms of welfare analysis, Shimer and Werning (2008) use an optimal contracting approach to study the optimal variation of UI over the unemployment duration. Chetty (2008) and Kroft and Notowidigdo (2016) find a locally optimal UI policy in a welfare exercise that can be used only to calculate the marginal welfare effects of small changes in the UI benefit level, relative to the observed UI benefit level in the data.

<sup>9</sup>See Hagedorn et al. (2016), Mitman and Rabinovich (2014), and Chodorow-Reich and Karabarbounis (2017), among many others.

the Great Recession, we solve for the optimal UI policy over the business cycle and find that it should be countercyclical even when business cycles are completely exogenous and that UI policy has no role on smoothing these fluctuations through its impact on aggregate demand. Complementary to his findings, we also show that the endogenous response of precautionary savings to changes in UI generosity is key to understanding the true welfare benefits and costs of UI benefits.

On the theoretical side, our model is a heterogeneous agent general equilibrium directed search model of the labor market with aggregate labor productivity driven business cycles as in Menzio and Shi (2010, 2011). The market structure enables us to overcome the computational difficulties of solving a model of this type by utilizing the block recursive equilibrium. We extend their framework by incorporating asset markets as in Herkenhoff (2017) to study the optimal UI over the business cycle with endogenous wealth distribution. To the best of our knowledge, our model is the first to study this question in a model with endogenous wage determination, search frictions, incomplete markets, and aggregate fluctuations.

This paper is organized as follows. We present our model in Section 2. Then, Section 3 describes the calibration strategy and model fit. Section 4 explains the calculation of the welfare effects of various UI policies. Section 5 contains the main results. In Section 6, we provide a detailed discussion on our results and conduct robustness checks. Section 7 provides preliminary evidence from the micro-data that support the model's main mechanism. Finally, Section 8 concludes.

## 2 Model

This section first introduces the environment of the model in Section 2.1. We then lay out the problem of the household and firm in Section 2.2 and Section 2.3, respectively. Next, we explain the government's UI policy in Section 2.4. Finally, Section 2.5 defines the equilibrium of the model and characterizes the job search behavior of the unemployed.

### 2.1 Environment

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

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta_t \left[ u(c_t) - \mathbf{1}_U \left[ \nu(s_t) \right] \right]$$

where  $u(\cdot)$  is a strictly increasing and strictly concave utility function over consumption level  $c$  that satisfies Inada conditions,  $\mathbf{1}_U$  is an indicator function that takes the value of one if the agent is unemployed, and  $\nu(\cdot)$  represents the disutility associated with search effort of the unemployed and is a strictly increasing and

strictly convex function of search intensity  $s$ . Moreover,  $\beta_t$  is a stochastic variable that is idiosyncratic - i.i.d. across agents - and describes the cumulative discounting between period 0 and period  $t$ . In particular,  $\beta_{t+1} = \tilde{\beta}\beta_t$ , where  $\tilde{\beta}$  is a five-state, first-order Markov process as in Krusell et al. (2009). The heterogeneity in discount rates allows us to match important features of the empirical asset distribution, as we will discuss in Section 3.1.

In the model, individuals are heterogeneous in terms of their labor market status, asset holdings, labor market earnings, and stochastic discount rate. An agent can be classified into one of the following labor market statuses: a worker  $W$ , an unemployed individual who is eligible for unemployment insurance benefits  $UE$ , or an unemployed individual who is ineligible for unemployment insurance benefits  $UI$ .<sup>10</sup>

The labor market features directed search. Unemployed individuals direct their search effort  $s \in [0, 1]$  toward wage submarkets indexed by  $w$ . Once matched with a firm within submarket  $w$ , the household is paid a fixed wage  $w$  every period until the match exogenously dissolves, as in Menzio and Shi (2010).<sup>11</sup> Unemployed individuals who are eligible for UI benefits receive a fraction of the wage they received during their last employment, whereas the unemployed ineligible do not receive any benefits. In order to finance the unemployment insurance program, the worker and unemployed eligible pay a fraction  $\tau$  of their wages/benefits to the government every period. In addition to labor earnings, all households have access to incomplete asset markets where they can save/borrow at an exogenous interest rate  $r$ .<sup>12</sup> On the other side of the labor market, firms decide the wage submarket in which to post a vacancy. Once matched with a worker, the firm-worker pair operates a constant returns to scale technology that converts one indivisible unit of labor into final consumption goods. All firm-worker pairs are assumed to be identical in terms of their production efficiency; that is, the amount of production only depends on aggregate labor productivity.

The timing of the model is as follows. At the beginning of each time period  $t$ , aggregate labor productivity  $p$  and the idiosyncratic discount rate  $\beta$  for each agent realize. The period labor productivity level  $p$  completely determines 1) the UI replacement rate  $\phi(p) \in [0, 1]$  and the stochastic UI expiration rate  $e(p) \in [0, 1]$ , and 2) the exogenous job separation rate  $\delta(p) \in [0, 1]$ . This implies that  $\delta(p)$  fraction of those who were workers in  $t - 1$  lose their jobs and must spend at least one period being unemployed. Among those who lose their job,  $e(p)$  fraction become ineligible for unemployment benefits. After the realization of the exogenous shocks,

---

<sup>10</sup>Farber et al. (2015) find that UI extensions reduced the labor force exits by 20 to 30 percent during 2008-2011 and 2012-2014 respectively. Notice that even if our model does not incorporate a labor force participation margin, we find that the optimal policy is countercyclical. As a result, given that UI generosity increases labor force participation, the welfare gains from the optimal policy actually constitute a lower bound in our model.

<sup>11</sup>In Section 6.1, we extend our baseline model to endogenize the quit decisions of workers and explore the quantitative implications of this assumption on our main results.

<sup>12</sup>We could endogenize the interest rate by modeling an asset market in which financial intermediaries post asset returns in different locations and individuals look for saving/borrowing opportunities in these different locations depending on their state variables. This is similar to Herkenhoff (2017). In our baseline model, we abstract from this and assume a constant and exogenous interest rate. In Section 6.1, we explore the quantitative implications of this assumption.

there are two stages in each time period  $t$  where agents make endogenous decisions.

First, in the labor market stage, firms decide the wage submarket in which to post a vacancy, while the unemployed choose a wage submarket  $w$  within which to look for a job. Second, the production and consumption stage of time  $t$  open where each firm-worker pair produces  $p$  units of consumption goods, wages are paid to workers, UI benefits are paid to eligible unemployed as a fraction  $\phi(p)$  of their previous wages, and any unemployed receive the monetized value of non market activities  $h$ .<sup>13</sup> The households then make their saving/borrowing decision. 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  $t$ .

It is important to discuss the reasons why this environment is useful in answering our question. Beyond the obvious features of the presence of incomplete markets, a UI program, and equilibrium unemployment, we would like to consider an equilibrium model of the labor market in which firm and household decisions are affected by both aggregate fluctuations and changes in UI policy. This way, we are able to incorporate the moral hazard costs of generous UI policies on the job search intensity and wage choice behavior of the unemployed, as well as changes in the vacancy creation incentives of firms over the business cycle. Moreover, directed search is useful not only because of tractability reasons but also because of its implications for equilibrium efficiency. In particular, under some conditions, the equilibrium is efficient in the directed search model but not in a random search model with Nash bargaining.<sup>14</sup> Hence, in our framework, the government insurance program aims to fix the inefficiencies caused by incomplete asset markets.

## 2.2 Household Problem

A household's individual state vector consists of her current employment status  $l \in \{W, UE, UI\}$ , net asset level  $a \in \mathcal{A} \equiv [\underline{a}, \bar{a}] \subseteq \mathbb{R}$ , the current wage level  $w \in \mathcal{W} \equiv [\underline{w}, \bar{w}] \subseteq \mathbb{R}_+$  if the employment status is  $W$  or the wage level from the previous job if the employment status is  $UE$ , and the current discount rate  $\beta \in \mathcal{B} \equiv [\underline{\beta}, \bar{\beta}] \subset (0, 1)$ .

The aggregate state is denoted by  $\mu = (p, \Gamma)$ , where  $p \in \mathcal{P} \subseteq \mathbb{R}_+$  denotes the current aggregate labor productivity and  $\Gamma : \{W, UE, UI\} \times \mathcal{A} \times \mathcal{W} \times \mathcal{B} \rightarrow [0, 1]$  denotes the distribution of agents across employment status, asset level, current/previous wage level, and discount rate. The law of motion for the aggregate states is given by  $\Gamma' = H(\mu, p')$  and  $p' \sim F(p' | p)$ .

<sup>13</sup>The variable  $h$  encompasses both the value of leisure/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.

<sup>14</sup>See Acemoglu and Shimer (1999), Burdett, Shi, and Wright (2001), Shi (2001), and Menzio and Shi (2011) for the efficiency of directed search equilibrium. As discussed by Menzio and Shi (2011), however, the equilibrium of our baseline model does not maximize the joint value of a match (and thus it is not bilaterally efficient) because of the limitations in the contract space. In Section 6.1, we extend our baseline model to a model with endogenous quit decisions and show that the effects of inefficiencies present in the labor market of the baseline model on our main results are negligible.

The recursive problem of the worker is given by

$$V^W(a, w, \beta; \mu) = \max_{c, a'} u(c) + \beta \mathbb{E} \left[ \delta(p') \left[ (1 - e(p')) V^{UE}(a', w, \beta'; \mu') + e(p') V^{UI}(a', \beta'; \mu') \right] \right. \\ \left. + (1 - \delta(p')) V^W(a', w, \beta'; \mu') \right] \Big| \beta, \mu \quad (1)$$

subject to

$$c + a' \leq (1 + r)a + w(1 - \tau) \\ a' \geq -\underline{a} \\ \Gamma' = H(\mu, p') \quad \text{and} \quad p' \sim F(p' | p).$$

Notice in the above problem that the worker may not qualify for UI benefits with probability  $e$  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 the current UI policy in the United States, 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 if they do not meet certain work/earnings requirements.<sup>15</sup>

The unemployed directs her job search effort toward a wage submarket indexed by  $w$  with an associated market tightness given by  $\theta(w; \mu)$ , which is an equilibrium object defined later. Let  $f(\theta(w; \mu))$  be the job finding probability for the unemployed who visits submarket  $w$  when the aggregate state is  $\mu$ . Then, we lay out the recursive problem of eligible unemployed as follows:

$$V^{UE}(a, w, \beta; \mu) = \max_{c, a', s} u(c) - \nu(s) + \beta \mathbb{E} \left[ \max_{\tilde{w}} \left\{ sf(\theta(\tilde{w}; \mu')) V^W(a', \tilde{w}, \beta'; \mu') \right. \right. \\ \left. \left. + (1 - sf(\theta(\tilde{w}; \mu'))) \left[ (1 - e(p')) V^{UE}(a', w, \beta'; \mu') + e(p') V^{UI}(a', \beta'; \mu') \right] \right\} \right] \Big| \beta, \mu \quad (2)$$

subject to

$$c + a' \leq (1 + r)a + h + \phi(p)w(1 - \tau) \\ a' \geq -\underline{a} \\ \Gamma' = H(\mu, p') \quad \text{and} \quad p' \sim F(p' | p).$$

where the eligible unemployed receives a fraction  $\phi$  of her previous wage as UI benefits and pays  $\tau$  fraction as labor income tax. As described earlier, she may lose her eligibility with probability  $e$  if she is unable to

---

<sup>15</sup>The unemployed must meet requirements for wages earned or time worked during an established period of time referred to as the base period. In most states of the United States, this is usually the first four out of the last five completed calendar quarters prior to the time that a UI application is filed.

find a job during the labor market stage of the current period. When choosing the wage submarket to search for jobs, the unemployed individual faces the trade-off between the level of surplus from a possible match (i.e., the wage level) and the probability of finding a job because of the lower number of vacancies posted for high-paying jobs.

Finally, the recursive problem of the ineligible unemployed is given by

$$V^{UI}(a, \beta; \mu) = \max_{c, a', s} u(c) - \nu(s) + \beta \mathbb{E} \left[ \max_{\tilde{w}} \left\{ sf(\theta(\tilde{w}; \mu')) V^W(a', \tilde{w}, \beta'; \mu') \right. \right. \quad (3)$$

$$\left. \left. + (1 - sf(\theta(\tilde{w}; \mu'))) V^{UI}(a', \beta'; \mu') \right\} \middle| \beta, \mu \right]$$

subject to

$$c + a' \leq (1 + r)a + h$$

$$a' \geq -\underline{a}$$

$$\Gamma' = H(\mu, p') \quad \text{and} \quad p' \sim F(p' | p).$$

Notice that in the above problem, the unemployed ineligible is unable to regain eligibility for UI benefits if job search fails. This captures the fact that according to current UI policy in the United States, 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.

### 2.3 Firm Problem

Firms post vacancies offering fixed wage contracts in certain wage submarkets. The labor market tightness of submarket  $w$  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  $\theta(w; \mu) = \frac{v(w; \mu)}{S(w; \mu)}$ . Let  $M(v, u)$  be a constant returns to scale matching function that determines the number of matches in a submarket with  $S$  level of aggregate search effort and  $v$  vacancies. We can then define  $q(w; \mu) = \frac{M(v(w; \mu), S(w; \mu))}{v(w; \mu)}$  to be the vacancy filling rate and  $f(w; \mu) = \frac{M(v(w; \mu), S(w; \mu))}{S(w; \mu)}$  to be the job finding rate in submarket  $w$  when aggregate state is  $\mu$ . The constant returns to scale assumption on the matching function guarantees that the equilibrium object  $\theta$  suffices to determine job finding and vacancy filling rates since  $q(\theta) = \frac{M(v, S)}{v} = M\left(1, \frac{1}{\theta}\right)$  while  $f(\theta) = \frac{M(v, S)}{S} = M(\theta, 1)$ .

First, consider a firm that is matched with a worker in submarket  $w$  when the aggregate state is  $\mu$ . The pair operates under a linear production technology and produces  $p$  units of output, and there is no capital in the economy. The worker is paid a fixed wage of  $w$  and with some probability  $\delta(p)$ , the match dissolves.

Hence, the value of a matched firm is given by

$$J(w; \mu) = p - w + \frac{1}{1+r} \mathbb{E} \left[ (1 - \delta(p')) J(w; \mu') \mid \mu \right] \quad (4)$$

subject to

$$\Gamma' = H(\mu, p') \quad \text{and} \quad p' \sim F(p' \mid p).$$

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

$$V(w; \mu) = -\kappa + q(\theta(w; \mu)) J(w; \mu), \quad (5)$$

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

When firms decide the submarket in which to post vacancies to maximize profits, they face the trade-off between the probability of filling a vacancy and the level of surplus from a possible match. This is because if a firm posts a vacancy in a low (high) wage submarket, then the level of the surplus from the match in that submarket will be higher (lower) for the firm, but the probability of filling the vacancy will be lower (higher) as less (more) unemployed individuals visit that submarket to search for a job.

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  $V(w; \mu) = 0$  for any submarket  $w$  such that  $\theta(w; \mu) > 0$ . Then, we impose the free entry condition to Equation (5) and obtain the equilibrium market tightness:

$$\theta(w; \mu) = \begin{cases} q^{-1} \left( \frac{\kappa}{J(w; \mu)} \right) & \text{if } w \in \mathcal{W}(\mu) \\ 0 & \text{otherwise.} \end{cases} \quad (6)$$

The equilibrium market tightness contains all the relevant information needed by households to evaluate the job finding probabilities at each submarket.

## 2.4 Government Policy

The UI policy is characterized by  $\{\phi(p), e(p), \tau\}$ , where  $\phi(p)$  is the replacement rate and  $e(p)$  is the expiration rate, both of which may vary with current aggregate labor productivity  $p$ .<sup>16</sup> A labor income tax  $\tau$  is levied on the labor earnings of the worker and on the UI benefits of the eligible unemployed in order to

---

<sup>16</sup>We restrict the UI policy to depend on the aggregate state of the economy  $\mu$  only through the current aggregate labor productivity  $p$  and not through the distribution of individuals across states  $\Gamma$ . This restriction allows our model to retain the block recursivity, which we will explain in Section 2.5.

finance the UI program.<sup>17</sup> The benefit expiration rate  $e(\cdot)$  is stochastic, as in Fredriksson and Holmlund (2001), Albrecht and Vroman (2005), Faig and Zhang (2012), and 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 government balances the following budget constraint in expectation:<sup>18</sup>

$$\sum_{t=0}^{\infty} \sum_i \left( \frac{1}{1+r} \right)^t \times \left[ \mathbf{1}_{\{l_{it}=W\}} \times w_{it} + \mathbf{1}_{\{l_{it}=UE\}} \times w_{it} \phi(p_t) \right] \times \tau = \sum_{t=0}^{\infty} \sum_i \left( \frac{1}{1+r} \right)^t \times w_{it} \phi(p_t) \times \mathbf{1}_{\{l_{it}=UE\}}, \quad (7)$$

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

## 2.5 Equilibrium

**Definition of the Recursive Equilibrium:** Given a UI policy  $\left\{ \tau, \phi(p), e(p) \right\}_{p \in \mathcal{P}}$ , a recursive equilibrium for this economy is a list of household policy functions for assets  $\left\{ g_a^l(a, w, \beta; \mu) \right\}_{l=\{W, UE\}}$  and  $g_a^{UI}(a, \beta; \mu)$ , wage choices  $g_w^{UE}(a, w, \beta; \mu)$  and  $g_w^{UI}(a, \beta; \mu)$ , search effort  $g_s^{UE}(a, w, \beta; \mu)$  and  $g_s^{UI}(a, \beta; \mu)$ , a labor market tightness function  $\theta(w; \mu)$ , and an aggregate law of motion  $\mu' = (p', \Gamma')$  such that

1. Given government policy, shock processes, and the aggregate law of motion, the household's policy functions solve their respective dynamic programming problems (1), (2), and (3).
2. The labor market tightness is consistent with the free entry condition (6).
3. The government budget constraint (7) is satisfied.
4. The law of motion of the aggregate state is consistent with household policy functions.

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

---

<sup>17</sup>We focus on the optimality of government policies that can be conditioned on the employment status of the individuals so that the government policies provide insurance against unemployment risk. Also, if the government finds it optimal to make transfers (by reducing taxes) during recessions, it can obviously do this by increasing the UI replacement rate and duration. For these reasons, we consider time-invariant income tax schedules in our analysis.

<sup>18</sup>This assumption is motivated by the fact that according to the current UI system in the United States, 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.

**Definition of the Block Recursive Equilibrium (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  $\Gamma$ .

Now, we prove that our model admits block recursivity.

**Proposition 1:** *If i) utility function  $u(\cdot)$  is strictly increasing, strictly concave, and satisfies Inada conditions;  $v(\cdot)$  is strictly increasing and strictly convex, ii) choice sets  $\mathcal{W}$  and  $\mathcal{A}$ , and sets of exogenous processes  $\mathcal{P}$  and  $\mathcal{B}$  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 Block Recursive Equilibrium for this economy. If, in addition,  $M = \min\{v, S\}$ , then the Block Recursive Equilibrium is the only recursive equilibrium.*

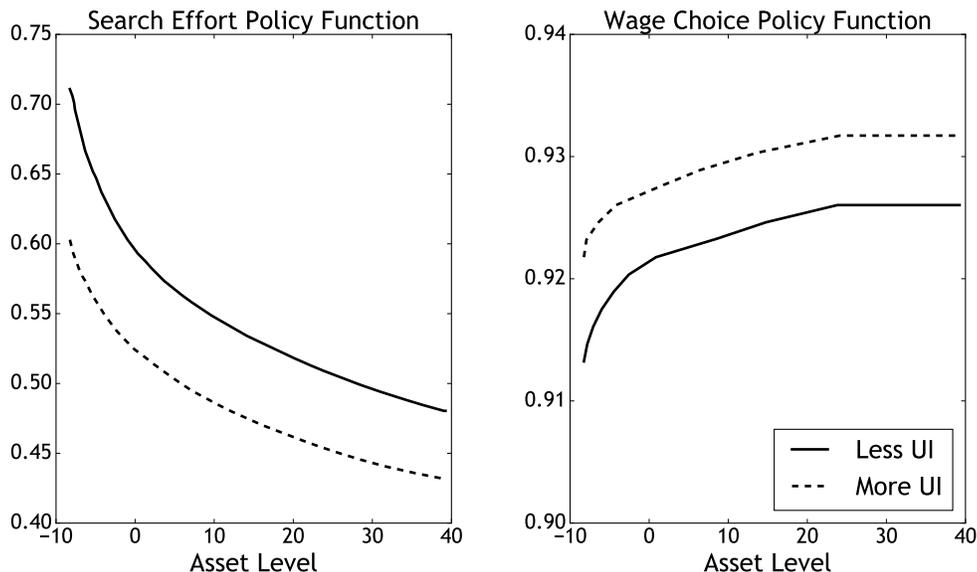
**Proof:** See Appendix B.

Proposition 1 is very useful because it allows us to solve the model 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 financial market. These decisions, in turn, are functions of individual states whose distribution is determined by  $\Gamma$ . Hence, the evolution of aggregate variables after a change in 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 of the economy, 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 distribution 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 United States, the assumption that UI policy depends on aggregate productivity is not too restrictive because of the strong correlation between the unemployment rate and aggregate labor productivity in the model.

**Job search decision rules** We now characterize the job search behavior of the unemployed. This will supplement our discussions of the main results of the paper in Section 5.

Figure 1: Search Effort and Wage Choice Policy Functions of the Eligible Unemployed



*Note:* These figures plot the search effort and wage choice policy functions of the eligible unemployed holding different levels of wealth for average levels of labor productivity, discount rate, and previous wage under a less generous and a more generous UI policy.

Figure 1 plots the labor market behavior of the eligible unemployed holding various levels of wealth under a less generous UI policy and a generous UI policy. It shows that the search intensity is decreasing in wealth, whereas the wage choice is increasing in wealth for any UI policy.<sup>19</sup>

Moreover, similar to Krusell et al. (2010), the marginal effect of an increase in assets on wage choice and search effort is relatively higher for the borrowing-constrained unemployed.<sup>20</sup> While this result is unsurprising and intuitive, it highlights the importance of accounting for wealth heterogeneity across agents, since the aggregate search effort and wage levels in the economy now crucially depend on the underlying wealth distribution. An economy where agents are relatively wealthy is likely to exhibit lower levels of aggregate search and higher wages, whereas the opposite is true when wealth levels are low. Since business cycles induce changes in precautionary savings and thus variation in aggregate search effort and wage choices, the optimal design of UI policy over the business cycle must account for this channel. For instance, in a recession where many individuals deplete their existing wealth, this channel exerts an upward pressure on search effort and downward pressure on wage choices as agents seek to find jobs more quickly. This effect dampens the moral hazard costs induced by introducing a more generous UI policy during recessions, since poorer agents tend to ramp up job-finding efforts themselves.

<sup>19</sup>Notice that there is little dispersion across wage choices of the unemployed holding different levels of wealth. Hornstein et al. (2011) show that frictional wage dispersion - measured by the mean-min wage ratio - is very small in a directed search model. When calibrated to match the empirical asset distribution and salient features of the labor market prior to the Great Recession in the United States, our model generates a mean-min wage ratio of 1.034, in line with their conclusion (less than 1.05).

<sup>20</sup>These patterns are also present for the ineligible unemployed.

Next, a comparison of the two policy functions across UI policies highlights two important points. First, generous UI payments entail incentive costs because they lead the eligible unemployed to decrease their search effort and increase their wage choices.<sup>21</sup> The combined effect of lower search effort and a shift toward higher-paying jobs, which are more difficult to find, results in a lower aggregate job finding rate and prolonged unemployment spells. Second, the unemployed holding different levels of wealth respond in varying degrees to changes in UI policy. Similar to Chetty (2008), wealthier agents are less responsive to changes in UI policy because the insurance value of a marginal increase in benefits is less important to them. This implies that a model that abstracts from self-insurance altogether overestimates the level of the moral hazard costs of introducing a more generous UI policy. The assumption that agents have no access to asset markets effectively raises the aggregate elasticity of search effort and wage choice to changes in UI policy, since the most responsive agents are precisely those with the least available self-insurance. As a result, it is crucial for the model to match the observed asset distribution in the data in order to generate the true magnitude of moral hazard costs in the model.

### 3 Calibration

We calibrate the stochastic steady state of our model to match salient features of the labor market and asset distribution of the U.S. economy prior to the Great Recession. In doing so, we feed into the model a constant replacement rate and expiration rate, which we call the *acyclical/flat* policy.

The model period is taken to be a week. We use the following separable functional form for the period utility function:

$$u(c_t) - \mathbf{1}_U[\nu(s_t)] = \frac{c_t^{1-\sigma}}{1-\sigma} - \mathbf{1}_U \left[ \alpha \frac{s_t^{1+\chi}}{1+\chi} \right],$$

which is also used by Chetty (2008) and Nakajima (2012). We restrict the values of discount rates to be symmetric around an average value  $\bar{\beta}$  with a difference of  $\eta$  between two adjacent values. Moreover, we allow  $\beta$  to take five different values. In our simulations of the model, we set 40 percent of the population to the middle discount rate value and 10 percent to each extreme point in any time period. The expected duration of being in the extreme discount rate value is set to be 50 years, where transitions can only occur between adjacent values.

The labor market matching function is  $M(v, S) = \frac{uS}{[u^\gamma + S^\gamma]^{1/\gamma}}$  as in den Haan et al. (2000). This CES functional form of the matching function implies that both the job finding rate  $f(\theta) = \theta(1 + \theta^\gamma)^{-1/\gamma}$  and the vacancy filling rate  $q(\theta) = (1 + \theta^\gamma)^{-1/\gamma}$  are between 0 and 1.

---

<sup>21</sup>This result is also established in the previous literature. See Shavell and Weiss (1979), Hopenhayn and Nicolini (1997), and Acemoglu and Shimer (1999), among many others.

Following Shimer (2005), we use a process for the job destruction rate that depends only on labor productivity,  $\delta_t = \bar{\delta} \times \exp(\omega(p_t - 1))$ , where  $\bar{\delta}$  is the average weekly exogenous job destruction rate in the data. 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). Moreover, the probability of this idiosyncratic event is correlated with the aggregate state of the economy. As a result, this specification allows the model to capture the cyclicity of employment-to-unemployment (E-U) transitions.<sup>22</sup> We then calibrate  $\omega$  so that the volatility of quarterly E-U transitions in the model matches its data counterpart, which we calculate using E-U transition rates measured by Fujita and Ramey (2009) for the time period 1976:I-2005:IV.<sup>23</sup>

The logarithm of the aggregate labor productivity  $p_t$  follows an AR(1) process:

$$\ln p_{t+1} = \rho \ln p_t + \sigma_\epsilon \epsilon_{t+1}.$$

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) for the time period 1951:I-2007:IV, we estimate the above process at a weekly frequency and find that  $\rho = 0.9720$  and  $\sigma_\epsilon = 0.0025$ .

Next, we calibrate the replacement rate and expiration rate of the acyclical/flat policy by matching the long-run empirical averages of U.S. government policy. First, we discuss the calibration of the replacement rate. Chodorow-Reich and Karabarbounis (2016) measure the mean of pretax benefits per recipient as 21.5 percent of pretax marginal product.<sup>24</sup> Under a mean take-up rate of UI benefits among the eligible unemployed of 65 percent, this implies setting the mean of pretax benefits per recipient to 14 percent, since we do not model UI take-up decisions given the complexity of our framework.<sup>25</sup> Second, we take the UI benefit duration as 26 weeks (2 quarters), which is the standard benefit duration without extensions. Under the stochastic steady state calibration of our model, these two numbers require us to set  $\phi_t = 0.14$  and

---

<sup>22</sup>Empirically, Elsby et al. (2009), Fujita and Ramey (2006, 2009), Yashiv (2007), and Fujita (2011a) show that the separation rate into unemployment is countercyclical.

<sup>23</sup>The model-implied Beveridge curve, which plots the relationship between unemployment and vacancies, exhibits a negative slope as in the data. This is because when labor productivity declines, firms cut back on vacancies, which translates to lower job finding rates and higher unemployment. Moreover, the rise in separation shocks further amplifies the increase in unemployment. As a result, unemployment and vacancies move in the opposite direction.

<sup>24</sup>This value is consistent with a replacement rate level that accounts for the difference between wage and total compensation, the difference between compensation and the marginal product, and the gap in productivity and compensation between those receiving UI and the economywide average. In our model, wages are not exactly equal to marginal product because of frictions, but the difference between the two is small.

<sup>25</sup>Estimates in the literature for the fraction of all eligibles who receive UI range from 50 to 77 percent using Current Population Survey (CPS) data for different samples. Fuller, Ravikumar, and Zhang (2013) find that during the Great Recession, only about 50 percent of those eligible collected their benefits. Vroman (1991) uses CPS supplements from 1989 and 1990 and finds 53 percent. Blank and Card (1991) estimate the take-up rate as 71 percent for the period 1977–1987. Auray, Fuller, and Lkhagvasuren (2013) estimate the average take-up rate as 77 percent from 1989 to 2012 using detailed state-level eligibility criteria. Meanwhile, Anderson and Meyer (1997) use administrative data between the late 1970s and early 1980s and find that the take-up rate is 54 percent for a subsample that represents mainly separations from mass layoffs. In our baseline calibration, we set the take-up rate as 65 percent, which is around the mean of the above estimates in the literature.

$e_t = 1/26 \forall t$  as the acyclical/flat policy.<sup>26</sup> Then, a labor income tax rate of  $\tau = 0.36$  percent balances the government budget in equilibrium when the unemployment rate is 4.8 percent.

Having specified functional forms, the law of motion of the productivity process, and UI policy, we now calibrate several parameters outside of our model. We choose a coefficient of relative risk aversion  $\sigma = 2$  and set  $r = 0.095$  percent, which generates an annual return on assets of around 5 percent. Hagedorn and Manovskii (2008) estimate the combined capital and labor costs of vacancy creation as 58 percent of weekly labor productivity. Following their estimate, we set the cost of vacancy creation as  $\kappa = 0.58$ .

We measure the average weekly job separation rate  $\bar{\delta}$  using data from the Survey of Income and Program Participation (SIPP) for the time period between 2005 and 2007. The SIPP comprises individual level longitudinal data in which each respondent provides information on monthly income and government transfers as well as weekly labor force status. We restrict our sample to individuals between the ages of 24 and 65 who do not own a business or derive income from self-employment. We classify the individual as employed (E) if he/she reports having a job and either working or not on layoff, but absent without pay. 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. We then calculate the average E-U transition rate in the data where we account for seasonality by removing weekly fixed effects and obtain  $\bar{\delta} = 0.0022$ .

This leaves us eight parameters to be calibrated: i) the average value of discount rates  $\bar{\beta}$ , ii) the difference between two adjacent discount rates  $\eta$ , iii) the borrowing limit  $\underline{a}$ , iv) the level parameter of the search cost function  $\alpha$ , v) the curvature parameter of the search cost function  $\chi$ , vi) the matching function parameter  $\gamma$ , vii) the separation rate parameter  $\omega$ , and viii) the monetized value of non-market activity  $h$ . We jointly calibrate these parameters to match the following eight data moments, respectively: i) the median value of liquid asset holdings relative to weekly after-tax labor income distribution, ii) fraction of the population with non-positive liquid wealth, iii) the median value of the credit limit to labor income ratio, iv) the average unemployment rate, v) the response of the average unemployment duration to changes in the replacement rate, vi) the standard deviation of the unemployment rate, vii) the standard deviation of the job separation rate, and viii) the level of the opportunity cost of employment.

The first two moments related to the asset-to-income distribution is calculated from SIPP 2004 data and details are given in Section 3.1. Kaplan and Violante (2014) calculate the median value of the credit limit to quarterly labor income ratio for households aged 22 to 59 as 74 percent using Survey of Consumer Finances (SCF) data. We choose the borrowing limit parameter  $\underline{a}$  so that the median value of the ratio of

---

<sup>26</sup>In Section 6.1, we also calculate the welfare gains from the optimal policy under 40 percent of the replacement rate (i.e.,  $\phi = 0.4 \forall t$ ), which is the unadjusted replacement rate value calculated by the Department of Labor. We show that the optimal UI policy still yields significant welfare gains relative to the benchmark policy under this alternative high calibration of the replacement rate.

$a$  to after-tax quarterly labor income in the model is 0.74.

The average unemployment rate and its standard deviation are calculated from U.S. data. In our baseline calibration, we choose the curvature parameter of the search cost function  $\chi$  so that a 10 percentage point increase in the replacement rate generates an increase of 0.5 week in average unemployment duration among the UI eligible, which is within the range of available empirical estimates.<sup>27</sup> Hence, this parameter is important because it controls the magnitude of the incentive costs associated with the increase in UI payments.

Finally, Chodorow-Reich and Karabarbounis (2016) use a complete markets model and estimate the level of the opportunity cost of employment as 47 percent of the marginal product of employment under separable preferences. We choose the monetized value of non-market activity  $h$  so that the opportunity cost of employment generated by our model is 0.47. Given the incomplete markets model we have, to make the calibration comparable, we only simulate agents from the top 1 percent of the stationary asset-to-income distribution when calculating the opportunity cost of employment using our model. This is because the behavior of the very rich agents in the incomplete markets model converges to the behavior of agents in the complete markets model. Section 3.2 explains how we calculate the opportunity cost of employment in our model. Later in Section 6.2, we target 0.955 as an alternative level of the opportunity cost of employment, which is the value calibrated by Hagedorn and Manovskii (2008), and discuss its implications for our main results.

Table 1 summarizes these calibrated parameters and compares the model’s match to these data moments.

### 3.1 Asset distribution

In addition to monthly data on income and government transfers as well as weekly data on employment status, the SIPP also contains data on respondents’ asset holdings. In each SIPP panel, respondents provide information on various types of asset holdings during two or three waves within the panel, usually one year or, equivalently, three waves apart. We use Wave 6 of the 2004 panel of SIPP, which covers interview months October 2005 - January 2006 and is the wave closest to the Great Recession that provides wealth holding information. We restrict our sample to individuals ages 24-65 and to those who neither own a business nor derive income from self-employment.

We use individual net liquid asset holdings as our primary measure of wealth because of its immediate availability as a means to smooth consumption in the event of job loss. The net liquid asset holdings of an individual are calculated by adding transaction accounts (checking, saving, money market, call accounts) and

---

<sup>27</sup>See Nakajima (2012) for the summary of empirical estimates. We evaluate the welfare gains from the optimal policy under different values of  $\chi$  that match other levels of the available estimates in the literature. We find that the welfare gains from the optimal policy remain similar for different values of  $\chi$ . These results are available upon request.

Table 1: Internally calibrated parameters

Parameter	Explanation	Value	Target	Model	Data
$\bar{\beta}$	Average discount rate	0.9986	Median asset-to-income ratio	6.17	6.22
$\eta$	Deviation from $\bar{\beta}$	0.0005	Frac. of population with non-positive wealth	0.27	0.27
$\underline{a}$	Borrowing limit	-8.25	Median credit-limit-to-income ratio	0.74	0.74
$\alpha$	Level of search cost	5.02	Average unemployment rate	0.048	0.048
$\chi$	Curvature of search cost	1.49	Response of average unemployment duration to changes in replacement rate	0.5	0.5
$\gamma$	Matching function parameter	0.217	Std. dev. of unemployment rate	0.10	0.12
$\omega$	Separation rate parameter	-14.3	Std. dev. of separation rate	0.18	0.16
$h$	Value of nonmarket activity	0.342	Level of opportunity cost of employment	0.47	0.47

*Note:* The average unemployment rate is calculated using monthly data between January 2005 and December 2007 provided by FRED - Federal Reserve Economic Data from the Federal Reserve Bank of St. Louis. The average standard deviation of the unemployment rate is reported in logs as quarterly deviations from an HP-filtered trend with a smoothing parameter of 1600, using quarterly data between 1951:I-2007:IV provided by FRED. The same procedure is applied to obtain the volatility of separation rates using data from Fujita and Ramey (2009) from 1976:I-2005:IV. The rest of the data moments are discussed in the main text.

tradable assets (mutual funds, stocks, bonds), and then deducting unsecured debt. We follow Koehne and Khun (2015) and include net vehicle equity when calculating net liquid asset holdings. The reason is that income can decrease substantially upon unemployment, and some unemployed could resort to liquidating other forms of assets (i.e., the sale of vehicles) to smooth consumption upon job loss.

To normalize wealth and better capture the level of self-insurance, we compute respondents' asset-to-income ratio by dividing net liquid assets by weekly after-tax labor income.<sup>28</sup> We determine after-tax income using the statutory income tax codes. Table 2 shows the computed quantiles of the asset distribution in the data and model. The calibrated model comes close to matching the empirical asset distribution. In particular, our model reasonably captures the left tail of the distribution and at the same time exactly matches the fraction of the population holding non-positive liquid wealth. Matching the left tail of the distribution matters for our analysis because agents in this region of the distribution are the most affected by changes in UI policy. Job losers with low wealth have little to no capacity to self-insure or smooth consumption using their own liquid assets and are thus very sensitive to changes in unemployment insurance generosity.

<sup>28</sup>We use weekly employment status information to obtain weekly labor earnings from monthly labor earnings data. We simply divide the monthly labor earnings by the number of weeks with a job for that month to obtain weekly labor earnings. Appendix A provides more details on the calculation of the asset holdings and after-tax labor income.

Table 2: Percentiles of the distribution of liquid asset holdings relative to weekly after-tax labor income

	Quantiles					Fraction of population with non-positive wealth
	10th	25th	50th	75th	90th	
Data	-8.59	0.00	6.22	20.23	56.57	0.27
Model	-3.84	-0.85	6.17	33.32	42.46	0.27

*Note:* This table shows the liquid asset to after-tax labor income distribution in both the data and the model. The empirical distribution is calculated by the authors using the SIPP 2004 Panel. The main text provides the details of the calculation.

### 3.2 Opportunity cost of employment

In order to calculate the opportunity cost of employment across individual and aggregate states, we first derive surpluses obtained from moving from eligible unemployment to employment, and from ineligible unemployment to employment separately. Let  $S^{UE}(a, w^{UE}, \beta; p)$  be the surplus derived by an unemployed eligible with state  $(a, w^{UE}, \beta; p)$  who transitions into employment in a job that pays her optimal wage choice  $\tilde{w}(a, w^{UE}, \beta; p)$ . Similarly, let  $S^{UI}(a, \beta; p)$  be the surplus associated with moving from ineligible unemployment with state  $(a, \beta; p)$  to a job that pays the optimal wage choice  $\tilde{w}(a, \beta; p)$ . We can then write

$$S^{UE}(a, w^{UE}, \beta; p) = V^W(a, \tilde{w}(a, w^{UE}, \beta; p), \beta; p) - V^{UE}(a, w^{UE}, \beta; p) \quad (8)$$

and

$$S^{UI}(a, \beta; p) = V^W(a, \tilde{w}(a, \beta; p), \beta; p) - V^{UI}(a, \beta; p). \quad (9)$$

Now consider the same individual who loses the aforementioned job that pays  $\tilde{w}(a, w^{UE}, \beta; p)$ . We can define the next period surplus of an eligible unemployed as

$$\begin{aligned} S(a'^W, \tilde{w}(a, w^{UE}, \beta; p), \beta'; p') &= V^W(a'^W, \tilde{w}(a'^W, \tilde{w}(a, w^{UE}, \beta; p), \beta'; p'), \beta'; p') \\ &\quad - V^{UE}(a'^W, \tilde{w}(a, w^{UE}, \beta; p), \beta'; p'), \end{aligned} \quad (10)$$

where the right-hand side is the difference in the value of again finding a job that pays optimal wage choice  $\tilde{w}(a'^W, \tilde{w}(a, w^{UE}, \beta; p), \beta'; p')$  and remaining as unemployed eligible. Similarly, the next period surplus for the ineligible unemployed is given by

$$S^{UI}(a'^W, \beta'; p') = V^W(a'^W, \tilde{w}(a'^W, \beta'; p'), \beta'; p') - V^{UI}(a'^W, \beta'; p') \quad (11)$$

Evaluating  $V^W$ ,  $V^{UE}$ , and  $V^{UI}$  at  $a'^W$  in Equations (10) and (11) restricts the continuation surpluses to only that part associated with entering next period in the employed state. Next, substituting (1), (2), and (3) into (8) and (9), we obtain

$$\begin{aligned} \frac{S^{UE}(a, w^{UE}, \beta; p)}{\lambda^W} &= \tilde{w}(a, w^{UE}, \beta; p) \times (1 - \tau) - \underbrace{(z_{flow}^{UE} + z_a^{UE} + z_w^{UE} + z_{elg}^{UE})}_{z^{UE}} \\ &+ \beta \mathbb{E} \left[ \frac{\lambda'^W}{\lambda^W} \times \frac{(1 - \delta(p') - sf(\theta(\tilde{w}(a'^{UE}, w^{UE}, \beta'; p'); p')))}{\lambda'^W} S^{UE}(a'^W, \tilde{w}(a, w^{UE}, \beta; p), \beta'; p') \right] \end{aligned} \quad (12)$$

and

$$\begin{aligned} \frac{S^{UI}(a, \beta; p)}{\lambda^W} &= \tilde{w}(a, \beta; p) \times (1 - \tau) - \underbrace{(z_{flow}^{UI} + z_a^{UI} + z_w^{UI} + z_{elg}^{UI})}_{z^{UI}} \\ &+ \beta \mathbb{E} \left[ \frac{\lambda'^W}{\lambda^W} \times \frac{(1 - \delta(p') - sf(\theta(\tilde{w}(a'^{UI}, \beta'; p'); p')))}{\lambda'^W} S^{UI}(a'^W, \beta'; p') \right], \end{aligned} \quad (13)$$

where  $\lambda^W$  is the the marginal utility of consumption for the worker. The opportunity cost of employment  $z^l$  for each unemployed type  $l = \{UE, UI\}$  consists of four components:  $z_{flow}^l$  is simply the flow utility difference between a worker and an unemployed type  $l$ ,  $z_a^l$  is the change in value due to differential asset accumulation between the employed and the unemployed type  $l$ ,  $z_w^l$  measures the change in value due to wage differences that result from the possibility of losing a job the next period and finding another job with a different wage as opposed to keeping the same job, and finally,  $z_{elg}^l$  represents the difference in value due to changes in the likelihood of ineligibility. Appendix B provides derivations of these terms in detail.<sup>29</sup> This calculation yields the opportunity cost of employment  $z^{UE}(a, w^{UE}, \beta; p)$  and  $z^{UI}(a, \beta; p)$  for each state. As discussed above, we then simulate agents from the top 1 percent of the stationary asset-to-income distribution and calculate a weighted average of the opportunity cost of employment among this group. We then choose the monetized value of non-market activity  $h$  so that the average opportunity cost of employment for the richest agents in our model is 0.47.

The derivations above show that the opportunity cost of employment in our model is beyond the flow utility difference between the employed and unemployed. Importantly, our calculation takes into account the dynamic effects of one period of additional employment on the opportunity cost of employment. Intuitively, one period of additional employment causes a relative decline in the budget, since the employed typically

<sup>29</sup>Our calculation extends the opportunity cost of employment derivation in Chodorow-Reich and Karabarbounis (2016). In addition to the asset differential  $z_a$  in the incomplete markets version of their model, we account for the wage differential  $z_w^l$  and ineligibility probability differential  $z_{elg}^l$  in our opportunity cost of employment formula for each unemployment type  $l$ . In addition,  $z_a$  varies for each unemployment type  $l$  in our setup.

accumulate more assets. However, entering next period with higher levels of wealth creates an offsetting gain in the continuation value. Moreover, higher wealth holdings encourage the unemployed to search for higher wages and thus increase the possibility of higher labor income. Finally, one extra period of employment decreases the probability of ineligibility because the worker must separate from his job first before being subject to eligibility risk, as opposed to an unemployed eligible who constantly faces the risk of losing benefits. As a result, these dynamic benefits of employment measured respectively by  $z_a^l$ ,  $z_w^l$ , and  $z_{elg}^l$  jointly dampen the flow opportunity cost of employment  $z_{flow}^l$ .<sup>30</sup>

### 3.3 Testable implications

In this section, we discuss our model’s implications for several important untargeted moments of the data. First, we measure the economy wide size and cyclical of marginal propensity to consume (MPC) as well as the average consumption drop upon job loss predicted by the model. These are then compared to available empirical estimates in the literature. It is important for the model to generate a reasonable level and cyclical of MPCs and average consumption drop in order to properly measure the insurance benefits of any proposed UI policy. For example, if the consumption drop were very low, then the insurance benefit of UI would be understated. Second, we present how the model compares to the data on labor market transitions, survival probabilities into unemployment, and the aggregate impact of UI extensions on the unemployment rate. Generating transition rates and unemployment survival functions, that are in line with the data is crucial to understanding the individual labor market response (incentive costs) of the unemployed to changes in UI policy, and generating a reasonable response of the unemployment rate ensures that the aggregate effects of UI are well accounted for. The following sections present the results of these exercises.

#### Marginal propensity to consume

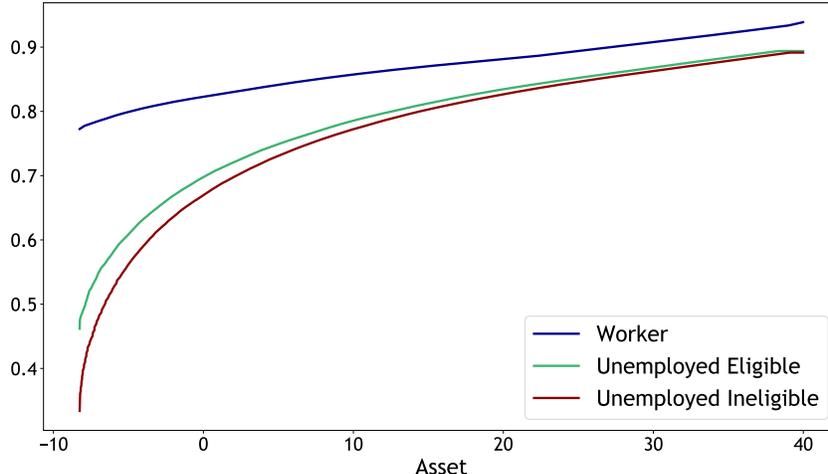
Figure 2 qualitatively demonstrates the consumption choices of agents across different asset holdings and employment states. The unemployed not only consume less than workers but also exhibit higher marginal propensities to consume. The differences in MPCs between workers and the unemployed is most evident for agents holding little wealth, but this differential eventually diminishes as wealth increases.

In order to quantitatively understand how MPCs differ across heterogeneous agents in the economy, Table 3 presents the average quarterly MPC of different asset-to-income and employment groups based on the stationary distribution of the economy. We compute the MPC of an agent by calculating the fraction of

---

<sup>30</sup>In our model,  $z_a^l + z_w^l + z_{elg}^l$  is small for the richest agents, and thus  $z^l$  approaches  $z_{flow}^l$  in the calibration. This is because the dynamic benefits of one period of extra employment have little value for this group of agents. While disregarding these benefits does not affect the calibration of value of non-market activity  $h$ ,  $z_a^l + z_w^l + z_{elg}^l$  is relatively large for poorer agents. Thus, it is crucial to account for these dynamic benefits when calculating the opportunity cost of employment across different agents in the economy so that the insurance benefits and the incentive costs of any proposed UI policy are correctly measured.

Figure 2: Consumption Policy Function



*Note:* This figure plots the consumption choices of agents with different employment statuses and asset holdings. The wages of workers and the unemployed eligible are set to be the economy’s mean wage. Productivity and discount rates are also set to their means.

Table 3: Heterogeneous MPCs

Employment	Asset-to-Income Groups				
	$a_1$	$a_2$	$a_3$	$a_4$	$a_5$
Worker	0.13	0.11	0.07	0.05	0.04
Unemployed Eligible	0.34	0.18	0.12	0.07	0.04
Unemployed Ineligible	0.64	0.20	0.12	0.06	0.04

*Note:* This table shows the average quarterly MPCs of various type-groups, where columns represent agents with varying asset-to-income ratios and rows represent agents of differing employment statuses. Individual MPCs are calculated by computing the fraction consumed out of an unexpected \$500 transfer. Asset-to-income groups are  $a_1 < p(10)$ ,  $a_2 \in [p(10), p(25))$ ,  $a_3 \in [p(25), p(50))$ ,  $a_4 \in [p(50), p(75))$ , and  $a_5 \geq p(75)$ , where percentiles are from the stationary asset-to-income distribution.

an unexpected transfer, scaled such that it is equivalent to \$500, that an agent spends on consumption. As in Kaplan and Violante (2014), we implement a \$500 rebate in order to ensure consistency with available empirical estimates that study the impact of tax rebates on consumption. Noticeably, the poor unemployed ineligible exhibit the highest MPC given the absence of both public and private insurance. Across employment states, the unemployed have significantly higher MPCs than workers, especially for agents in the lower end of the wealth distribution. Meanwhile, for any given employment status, the MPC is decreasing in wealth holdings.

The empirical literature documents two aggregate MPC data moments that we can use to validate our model. To do so, we calculate two untargeted average quarterly MPC moments in our model using the stationary distribution of agents across states and compare it to these available empirical estimates. Results are summarized in Table 4.

Table 4: Model Fit of Average MPCs

	Model	Data
Economy wide MPC	0.08	0.12 – 0.30
MPC difference of borrowing-constrained individuals between 2008 and 2011	0.08	0.08

*Note:* This table shows the average quarterly economy wide MPC, and the average semiannual MPC of borrowing-constrained individuals between 2008 and 2011 implied by the model’s simulations. Individual MPCs are calculated by computing the fraction consumed out of an unexpected \$500 transfer. These model-generated average values are then compared to available empirical estimates in the literature.

First, we find that the average quarterly economy wide MPC is 8 percent in our model. On the empirical side, Parker et al. (2013) measure that households, under different specifications, spend between 12 and 30 percent of unexpected tax rebates in the quarter that they are received. Thus, the fraction of borrowing-constrained individuals who have large MPCs as shown in Table 3 is too small to generate a sizeable response in the aggregate in our model.<sup>31</sup> Second, Gross et al. (2016) measure the cyclicity of the MPC by exploiting the unexpected changes in credit card borrowing limits of previously bankrupt individuals and find that the MPC is countercyclical over the Great Recession. In particular, they show that the average semiannual MPC difference of borrowing-constrained individuals between 2008 and 2011 is 8 percent. Using the Great Recession simulation of our model, we calculate the same moment and find that it is also 8 percent.<sup>32</sup> Hence, while the economy wide average MPC in our model is lower than its empirical counterpart, our model replicates the observed variation in the average MPC over the business cycle. This implies that our model successfully generates cyclical variation in the insurance value of UI, which is crucial when studying the optimal design of UI policy over the business cycle.

### Average consumption drop upon job loss

First, we compare the model-implied value of the average drop in consumption upon experiencing a job loss to the available empirical estimates in the literature. To do so, we estimate the following distributed-lag regression using the simulation data:

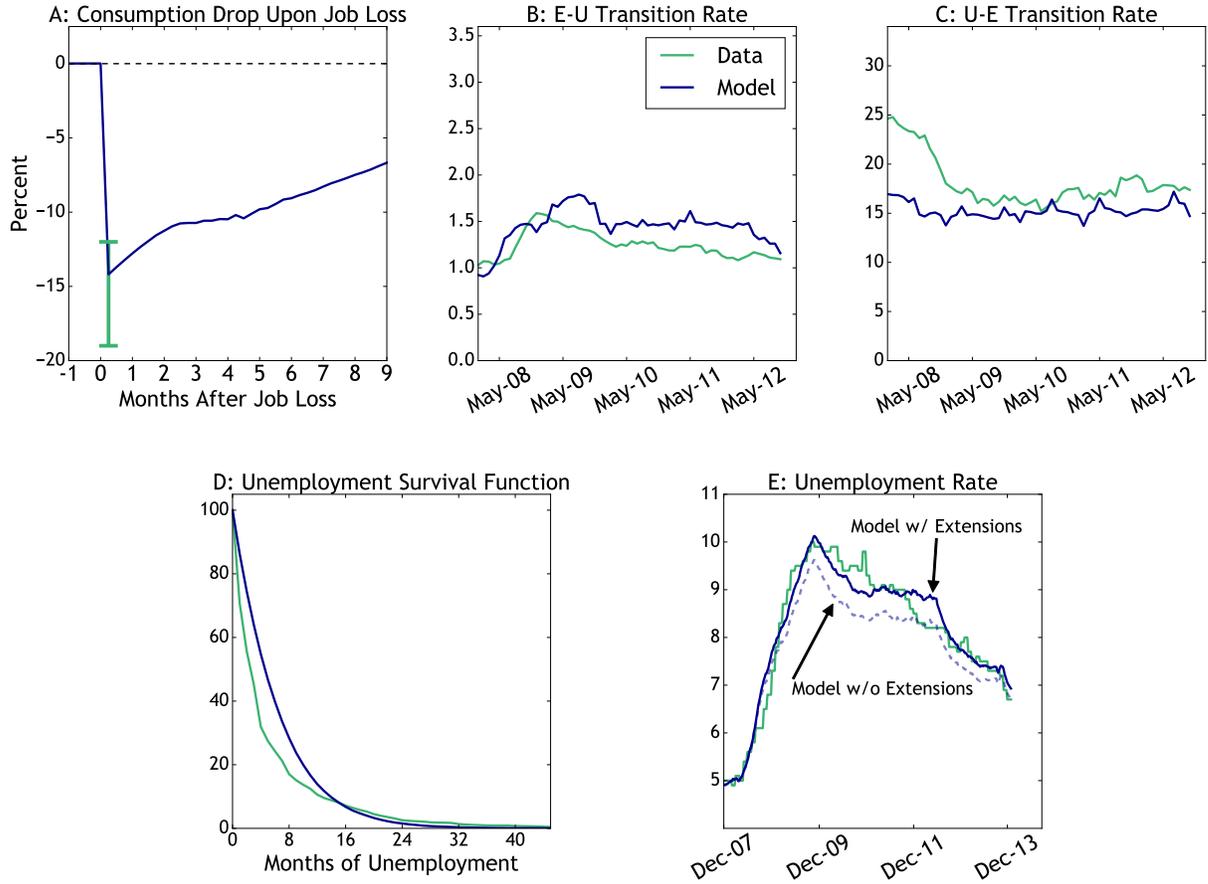
$$\log(c_{it}) = \alpha_i + \gamma_t + \beta a_{it} + \sum_{k=-4}^{36} \delta_k D_{it}^k + \epsilon_{it}, \quad (14)$$

where the outcome variable  $\log(c_{it})$  is the logarithm of consumption of individual  $i$  in week  $t$ ,  $\alpha_i$  are coefficients on individual fixed effects,  $\gamma_t$  are coefficients on week fixed effects,  $a_{it}$  is the net asset level of individual  $i$  in week  $t$ , and the error  $\epsilon_{it}$  represents random factors. The indicator variables  $D_{it}^k$  identify all individuals

<sup>31</sup>Notice that since our model generates a lower average MPC than its empirical counterpart, the households spend a relatively lower fraction of UI receipt on consumption. However, even if this is the case, we still find that the optimal policy is countercyclical. Thus, welfare gains provided by the optimal policy can be considered as a lower bound.

<sup>32</sup>Section 5.1 explains the details on how we simulate the Great Recession using the model.

Figure 3: Model Fit



*Note:* This figure shows our model's implications for several important untargeted moments of the data. The main text discusses the details of this comparison.

$k$  weeks prior to or after a job loss, where  $k = 0$  is the week of job loss. For instance,  $D_{it}^k = 1$  for individual  $i$  who experiences job loss at time  $t - k$ , and zero otherwise.

Our treatment group consists of individuals who experience at least one job loss during the simulation period. Thus, the control group consists of individuals who never lost their jobs. Thus,  $D_{it}^k = 0$  for all weeks  $t$  for individuals who belong to the control group.<sup>33</sup> Thus, the coefficients  $\{\delta_k\}_{k \in \{-4, \dots, 36\}}$  measure the effect of job loss on consumption  $k$  weeks prior-to or after the incident relative to individuals who do not experience any job loss. Panel A of Figure 3 plots the estimated values for  $\{\delta_k\}_{k \in \{-4, \dots, 36\}}$ . It shows that in the week of job loss, consumption drops 14 percent on average and then slowly recovers over time.

Several papers in the literature estimated the average consumption drop upon job loss from various data sources. Gruber (1997) finds a decline in food expenditure of 6.8 percent using the Panel Study of Income

<sup>33</sup>Notice that since the job loss event is exogenous in our model, simulated groups should not exhibit any selection bias.

Dynamics (PSID) for the period up to 1987. Saporta-Eksten (2014) uses cross-sectional variation in the PSID and estimates an 8 percent decline in consumption expenditure in the year during which a job loss occurs.<sup>34</sup> Stephens (2004) estimates the average decline in food expenditure upon job loss in the Health and Retirement Survey (HRS) and the PSID and finds that the decline is between 12 percent (PSID) and 15 percent (HRS) when an individual experiences a job loss between interviews. Browning and Crossley (2001) report a 14 percent decline using Canadian Out of Employment Panel (COEP) survey data. Chodorow-Reich and Karabarbounis (2016) conduct an analysis of the effects of job loss on consumption in both the PSID and the Consumer Expenditure Survey (CE) and find that the decline in total food expenditure is between 14 percent (PSID) and 21 percent (CE). Finally, Aguiar and Hurst (2005) report a 19 percent decline in food expenditure among the unemployed using scanner data.

In summary, our model generates an estimate for the average decline in consumption upon job loss that is in line with available empirical estimates in the literature.<sup>35</sup>

### **Labor market transitions**

Next, we focus on the employment-to-unemployment (E-U) and unemployment-to-employment (U-E) transition rates implied by the model during the Great Recession and how they compare with the data. This way, we are able to evaluate the model's implications for the cyclical patterns of labor market transition rates. Since the timing of SIPP panels misses the rise in the E-U rate and the decline in the U-E rate during the first months of the Great Recession, the transition rates in Panel B and C of Figure 3 are taken from Current Population Survey (CPS) data as calculated by Kroft et al. (2016).<sup>36</sup> First, Panel B shows that the model is able to generate the initial rise in the E-U rate due to the rise in exogenous job separations in the model. It is also able to match the observed slow decline throughout the recovery, although the model-implied E-U rate decreases relatively earlier due to the recovery of aggregate labor productivity and the resulting decline in job separation shocks. Second, Panel C reveals that the model generates a smaller decline in job finding rates at the start of the Great Recession relative to the drastic decline in the data, but the levels of the model and the data become similar afterward. This is because in the model, when labor productivity decreases and firms do not post vacancies in submarkets offering high wages, the unemployed optimally direct their

---

<sup>34</sup>However, this estimate does not condition on the fraction of the year spent as unemployed. When we assume an average unemployment duration of 17 weeks, this would imply a decline in consumption of around 24 percent.

<sup>35</sup>Notice that the magnitude of the average consumption drop upon job loss in our model is largely controlled by the value of non-market activity  $h$ , which is calibrated to match the level of the opportunity cost of employment. Hence, the result that our model generates a similar magnitude of the average consumption drop upon job loss to the data lends support to our baseline calibration of the level of the value of non-market activity  $h$ .

<sup>36</sup>Kroft et al. (2016) report that CPS transition rates are not consistent with the stock levels of unemployment, employment, and non-participation. Then, they describe a procedure to adjust these rates so that the transition rates become consistent with observed changes in stocks between months. The data also account for seasonality by residualizing out month fixed effects and are smoothed by taking three-month moving averages.

search effort toward submarkets offering lower wages where job-finding rates are relatively higher. As a result, the magnitude of the drop in the average job finding rate of the model during economic downturns is relatively smaller than its data counterpart. This, however, does not mean that the model underestimates the costs of recessions. While not as drastic as the Great Recession, the drop in the job finding rate is still sizeable and is accompanied by a significant decline in offered wages. Furthermore, even if the model generates a smaller drop in job finding rates in response to changes in aggregate productivity, it generates the observed elasticity of average unemployment duration with respect to changes in UI generosity, as this is one of the data moments in our calibration. This is also evident in Figure 8, where we show the impact of a countercyclical UI policy on the job finding rate.

### **Unemployment survival function**

In the model, the likelihood of exiting from an unemployment spell depends on the aggregate labor productivity as well as the unemployed agent's choice of search intensity and wage submarket. A useful summary of how long individuals spend unemployed is given by the unemployment survival function, which shows the probability that an agent will remain unemployed beyond a given unemployment duration.

First, we use the SIPP 2008 panel to measure the survival function in the data. We restrict our sample to working-aged individuals age 24 to 65 who do not own a business or derive income from self-employment. 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 we do not model the non-participation margin. Panel D of Figure 3 shows that the unemployment survival function generated by the model under the baseline calibration is close to its data counterpart. While survival data exhibit sharp drops during early months, the model survival function decays in a smooth fashion given the probabilistic nature of eligibility and job-finding rates in the model.

### **Impact of UI extensions on aggregate unemployment**

In order to understand the model's predictions about the aggregate effect of benefit 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. Panel E of Figure 3 shows that during the depth of the recession, the model-implied unemployment rate would have been 0.6 percentage points lower in the absence of benefit extensions.

The body of work that studies the impact of UI on macroeconomic aggregates has found mixed results. Rothstein (2011) exploits variation in UI benefits across states with similar economic conditions, the behavior of UI ineligible as a control group, and several other strategies to address endogeneity problems in measuring the impact of UI on labor market conditions. Using CPS data, he finds that UI extensions raised the unemployment rate in early 2011 by only about 0.1 to 0.5 percentage points. Consistent with this finding, Chodorow-Reich and Karabarbounis (2017) implement a novel empirical strategy by using exogenous variation coming from measurement error in real-time state unemployment rates and find that benefit extensions increased the unemployment rate by at most 0.3 percentage points. Coglianesi (2015) uses a similar strategy and also finds small effects. Meanwhile, Farber and Valletta (2015) use variation in individuals' time-to-exhaustion and find that extended benefits account for an increase of around 0.4 percentage points in the 9 percent unemployment rate in 2010. Valletta and Kuang (2010) find that in the absence of extended benefits, the unemployment rate would have been about 0.4 percentage points lower at the end of 2009, while Marinescu (2017) also finds small effects due to the reduced congestion resulting in a higher job-finding rate of any given job application.

On the other hand, Hagedorn et al. (2016) highlight that benefit extensions lead to higher equilibrium wages and thus lower vacancies. They also emphasize the role of firm expectations on future UI policies when making vacancy or hiring decisions. Accounting for this additional channel, they find that UI generosity increased the unemployment rate by 2.0 to 2.7 percentage points. This result is consistent with the findings of Johnston and Mas (2016), who find large effects of reductions in UI duration on unemployment. Fujita (2011b) also finds that extensions led to a substantial 1.2 percentage points increase in male workers' unemployment rate.

## 4 Welfare Calculation

We measure the welfare effects of any proposed UI policy by answering the following question: how much additional lifetime consumption must be endowed to all agents in an economy where some benchmark policy is being implemented so that average welfare will be equal to an economy where the proposed policy is implemented? In effect, we are evaluating whether an alternate UI policy will be welfare improving when compared to a benchmark policy, a natural choice being the actual UI policy implemented during the recession. Henceforth, we will refer to the UI policy implemented by the U.S. government during the Great Recession as the *benchmark policy*.<sup>37</sup>

---

<sup>37</sup>During the Great Recession, the U.S. government increased the duration of UI payments to as much as 99 weeks in some states but kept replacement rates almost constant. We set a duration of UI payments that increases from 26 weeks (2 quarters) to up to 90 weeks (7 quarters) over the decline in aggregate productivity  $p$ , while the replacement rate of UI payments is kept

Let  $b$  denote the benchmark policy and  $n$  denote the new/proposed policy. We can compute the additional percent lifetime consumption  $\bar{\pi}$  that makes the average welfare equal across these two economies using the following equation:

$$\int_i \left[ E_0 \sum_{t=0}^{\infty} \beta_i^t U(c_{it}^b (1 + \bar{\pi}), s_{it}^b) \right] d\Gamma_{ss}(i) = \int_i \left[ E_0 \sum_{t=0}^{\infty} \beta_i^t U(c_{it}^n, s_{it}^n) \right] d\Gamma_{ss}(i) \quad (15)$$

where  $c_{it}^j$  and  $s_{it}^j$  denote the consumption and search effort levels of agent  $i$  at time  $t$  under UI policy  $j \in \{b, n\}$ , and  $\Gamma_{ss}$  is the stationary distribution of the economy.

One can interpret the welfare exercise in Equation (15) as follows. Consider two countries populated by people with the same type-distribution. The only difference between both countries is that the government of the first country changes UI policy to policy  $b$ , while the second changes UI policy to policy  $n$ . The question is how much additional lifetime consumption  $\bar{\pi}$  should the first government compensate an individual who is behind the veil of ignorance (i.e., does not know her initial type in the stationary distribution) in order to make her indifferent between being part of one of these two countries? Thus, the best UI policy  $n$  that the second government can implement is the one that makes the first government pay the highest compensation  $\bar{\pi}_{max}$  to weakly attract this prospective citizen. This policy will be the optimal UI policy.

We restrict the class of candidate UI policies to be linear in current productivity level  $p$  such that  $\phi(p) = q_\phi + m_\phi p$  and  $e(p) = q_e + m_e p$ . Under this restriction of UI policy instruments, we search over five UI policy parameters ( $q_\phi, m_\phi, q_e, m_e, \tau$ ) to solve for the optimal UI policy.

In order to obtain ex-ante welfare gains/losses  $\bar{\pi}$  for each policy  $n$ , we begin from the stationary distribution of our calibrated economy  $\Gamma_{ss}$  where (1) aggregate labor productivity is constant at its mean level and (2) the unemployment benefit policy is fixed at a 14 percent replacement rate and 26 weeks expiration, which we call the *acyclical/flat* UI policy  $f$ . In each economy, an unanticipated but permanent policy change toward benchmark policy  $b$  and proposed policy  $n$ , respectively, is implemented. Given any guess of  $\bar{\pi}$ , we can now compute for both sides of Equation (15) by integrating over the stationary distribution. We then solve for the  $\bar{\pi}$  that equates both sides of Equation (15) and select the UI policy that yields the highest welfare gain  $\bar{\pi}_{max}$  as the optimal UI policy.<sup>38</sup>

---

fixed at its long-run average of 14 percent for all levels of  $p$ . This policy closely mimics the UI policy in the United States during the Great Recession and its recovery, assuming the United States as a single state.

<sup>38</sup>Given the functional form of the utility function, there is no closed-form solution for  $\bar{\pi}$ .

## 5 Main Results

We find that  $m_\phi = -6.44$ ,  $q_\phi = 6.75$ ,  $m_e = 0.34$ ,  $q_e = -0.32$ , and  $\tau = 1.06$  percent, implying that the optimal UI policy should be countercyclical in both replacement rate and duration. These values imply that the optimal policy offers a 30 percent replacement rate for 4 quarters when aggregate labor productivity is at its mean value, and a 54 percent replacement rate for 10 quarters when aggregate labor productivity is depressed by 3.5 percent. This means that the optimal policy offers a more generous replacement rate for a longer duration compared to the U.S. government's UI policy during the Great Recession, which provided 14 percent of the replacement rate for around 7 quarters of payments for the same drop in labor productivity. Compared to this benchmark policy, the optimal policy increases welfare by 0.58 percent additional lifetime consumption for all agents. Meanwhile, compared to an acyclical policy that offers 14 percent of the replacement rate for 2 quarters for all levels of aggregate labor productivity, the optimal policy yields a welfare gain equivalent to 0.74 percent additional lifetime consumption.<sup>39</sup>

These welfare gains from the optimal UI policy are much larger when compared to welfare gains of eliminating the business cycle obtained by Lucas (1987), who finds that the welfare of an infinitely lived representative agent increases by only 0.008 percent in consumption equivalents for logarithmic preferences if cycles are removed. A more relevant comparison to our model is Krusell et al. (2009), who extend this analysis in an incomplete asset markets model with heterogeneous households and study the welfare effects of eliminating both aggregate risk and its impact on idiosyncratic risk when there is a correlation between these two shocks. They find that the welfare gains of eliminating the cycle and its effect on idiosyncratic risk are as much as 1 percent in consumption equivalents for the same period utility function. Importantly, they show that the effect of business cycles on idiosyncratic risk has great quantitative consequences. Specifically, if one does not correctly integrate out the effect of cycles on idiosyncratic risk, then the welfare gains of eliminating cycles are only slightly larger than those calculated by Lucas (1987). Similar to Krusell et al. (2009), our model features aggregate shocks and incomplete asset markets in which aggregate risk significantly affects the magnitude of idiosyncratic risk, as job finding and job separation rates are functions of aggregate labor productivity. Both models are also similar in that households are heterogeneous in terms of their employment status, discount rates, and wealth holdings. These similarities suggest that welfare results in their study are a useful benchmark against our model. In our model, optimal UI smooths aggregate shocks by introducing cyclicity into the generosity of benefits and also attenuates idiosyncratic unemployment risk by providing higher benefit levels on average. Nonetheless, as the optimal UI policy in our framework can only partially

---

<sup>39</sup>To obtain this number, we repeat the welfare calculation procedure in Section 4 where we set the benchmark policy  $b$  as the acyclical/flat policy  $f$ . In this case, the first country continues to implement UI policy  $f$ , while the second country changes it to the optimal UI policy.

smooth the effect of cycles on consumption, welfare gains are much lower than the upper bound provided by Krusell et al. (2009).

The following discussions elucidate on the sources and distribution of welfare gains brought about by the countercyclical policy. First, we simulate the Great Recession using our model and compare how consumption patterns and labor market aggregates differ between the optimal policy and an acyclical policy. This will provide useful insight about the insurance benefits and incentive costs of the countercyclical optimal policy, especially when a recession triggers more generous benefits. We then proceed to quantitatively decompose ex-ante welfare gains of the optimal policy attributable either to changes in consumption patterns resulting from altered saving and wage choices, or to changes in the search intensity exerted by the unemployed. Finally, we look at ex-post welfare outcomes among heterogeneous agents in order to understand how welfare gains are distributed across agents with different employment statuses and wealth holdings.

## 5.1 Great Recession Exercise

We now use the Great Recession as an interesting test case that allows us to understand the insurance benefits and incentive costs associated with the countercyclical optimal policy. In order to discipline this exercise, we take as given the U.S. government’s UI extension policy during the Great Recession and then pick the realizations of aggregate labor productivity to match the unemployment rate from December 2007 to December 2013 – the period that spans the beginning of the recession until the time when the Emergency Unemployment Compensation Act of 2008 (EUC08) was no longer renewed. Matching the realized unemployment rate by imposing that government policy mimics benefit extensions during the Great Recession is important, since using the model’s aggregate labor productivity alone to match the unemployment rate disregards the fact that more generous UI policies implemented during the recession and recovery may have contributed to the heightened level of unemployment. Thus, in this exercise, the drop in labor productivity triggers lower job finding rates, higher separation rates, and longer benefit durations, all of which contribute to the rise in unemployment. Figure 4A shows the realizations of the labor productivity process that we obtain from this procedure, while Figure 4B compares the unemployment rate generated by the model to its counterpart in the data.<sup>40</sup>

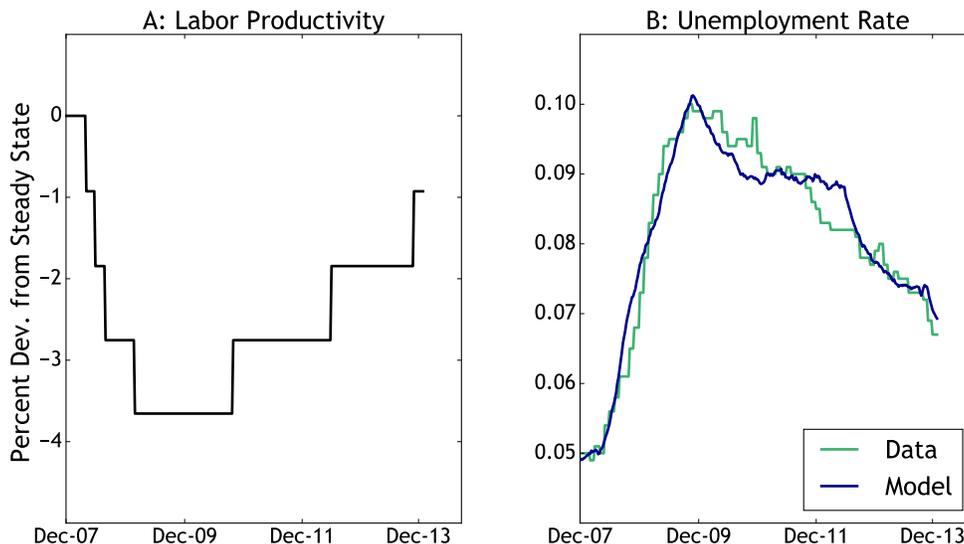
In this exercise, we consider two economies that both experience the Great Recession between December 2007 and December 2013 but differ in the UI policy that is implemented. In both economies, the simulation begins under the stationary distribution.<sup>41</sup> At  $t = 0$ , we introduce a recession to both economies by feeding

---

<sup>40</sup>We acknowledge that labor productivity in the data during the Great Recession did not decline in a similar way. However, given that labor productivity in our model is the only source of aggregate fluctuations, we place more emphasis on matching the observed unemployment rate and less on the manner by which we do it. While we call the decline in  $p$  “labor productivity shock”, it can stand in for other forms of shocks such as TFP, aggregate demand, or financial shocks.

<sup>41</sup>We select the number of agents to simulate  $N$  to be large enough such that  $\bar{\pi}$  does not change with further increases in

Figure 4: Labor Productivity and Unemployment Rate



*Note:* Panel A shows the labor productivity series that we use in our model to generate the observed time series of the unemployment rate in the data during the Great Recession. Panel B compares the paths of the unemployment rate in the data and the model.

the labor productivity series into Figure 4A. It must be noted, however, that agents use the AR(1) process to take expectations on labor productivity. One economy introduces the optimal policy  $o$ , and the other maintains the less generous acyclical policy  $f$ . In both cases, the policy change is unanticipated by agents. This is a reasonable assumption, as UI extensions during deep recessions (such as the EUC08) are typically beyond the scope of pre-existing triggers that households are aware of. This policy change is permanent and will thus apply the same UI policy to future fluctuations of the same magnitude.

In the following sections, we separately analyze the consumption-smoothing benefits and incentive costs of the optimal policy if it had been implemented during the Great Recession and compare them to that of the acyclical policy.<sup>42</sup> We place emphasis on how the cyclicity of these benefits and costs rationalizes a countercyclical optimal policy.

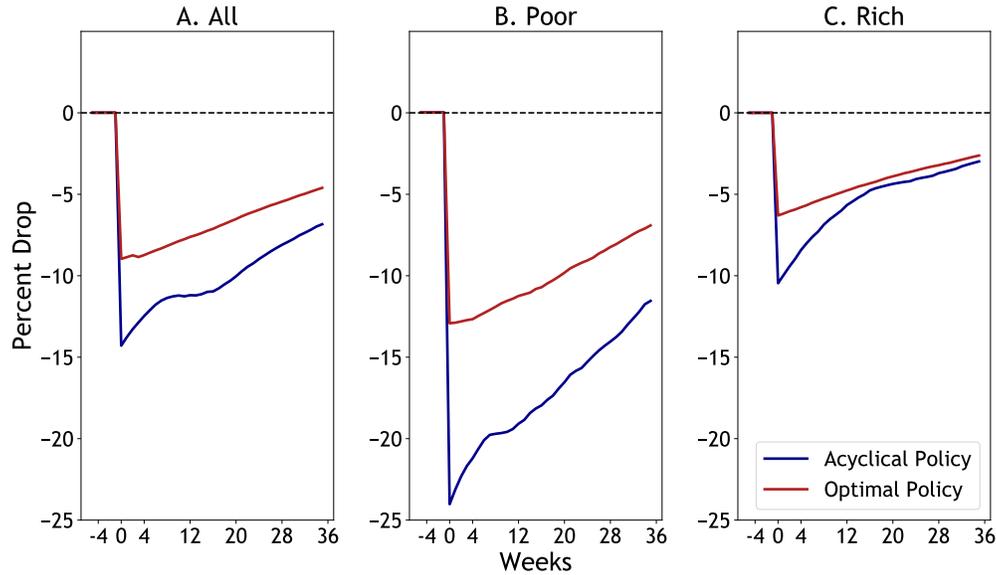
### 5.1.1 Insurance Benefits

**Consumption Smoothing Upon Job Loss** We first show the effect of the optimal UI policy on the consumption drop experienced upon job loss. We ask what would happen to the consumption profile of agents who experience a job loss in the economy that introduces the optimal policy and the economy that remains under the acyclical policy. The comparison of consumption profiles across these two economies will

<sup>42</sup>*N.* We find that  $N = 120,000$  is sufficient for this goal.

<sup>42</sup>Comparing the optimal and acyclical policies makes the illustration of the idea clear, as the acyclical policy offers the same replacement rate and duration across different realizations of the aggregate state. The intuition provided by the exercise also holds qualitatively when comparing the optimal policy with the benchmark policy.

Figure 5: Average Consumption Drop Upon Job Loss



*Note:* Panel A plots the path of the average consumption drop upon job loss between 4 weeks prior to job loss and 36 weeks after the job loss. Two different consumption profiles are obtained from a distribution-lag regression in Equation (14) using model-generated data under the acyclical policy and the optimal policy. Panels B and C repeat this exercise for poor and rich agents experiencing job loss. “Poor” refers to agents who enter unemployment with an asset-to-income ratio below the 75th percentile of the stationary asset-to-income distribution, while “Rich” refers to those above the threshold.

reveal the welfare benefits of the generous optimal policy coming from smoothing consumption between E-U transitions. Using model-generated data, we run the same distributed-lag regression in Equation (14) for each economy.

Figure 5 compares the consumption drop upon job loss between an acyclical policy and the generous optimal policy. On average, the consumption drop upon job loss is 15 percent under the acyclical policy, and 9 percent under the optimal policy, implying that the decline is 6 percentage points less under the optimal policy. This simply demonstrates the role of UI in dampening large fluctuations in consumption when job loss occurs, an insurance benefit on which the literature has traditionally focused. Moreover, this lower drop in consumption upon job loss is enjoyed by a larger number of agents in a recession due to the higher incidence of unemployment and longer spells during which wealth is depleted. As a result, the insurance value of UI payments in smoothing consumption upon job loss is larger in recessions.

Note that the reduction in the consumption drop is the net effect of two opposing forces: a more generous UI policy (1) directly increases consumption upon job loss due to higher benefits but also (2) indirectly crowds out precautionary savings. The first channel raises public insurance and thus decreases the consumption drop, while the second channel decreases self-insurance and thus increases the consumption drop as individuals enter unemployment with less wealth. In addition, notice that the recovery of consumption is slightly faster under the acyclical policy given how agents are forced to find jobs more quickly compared to an economy

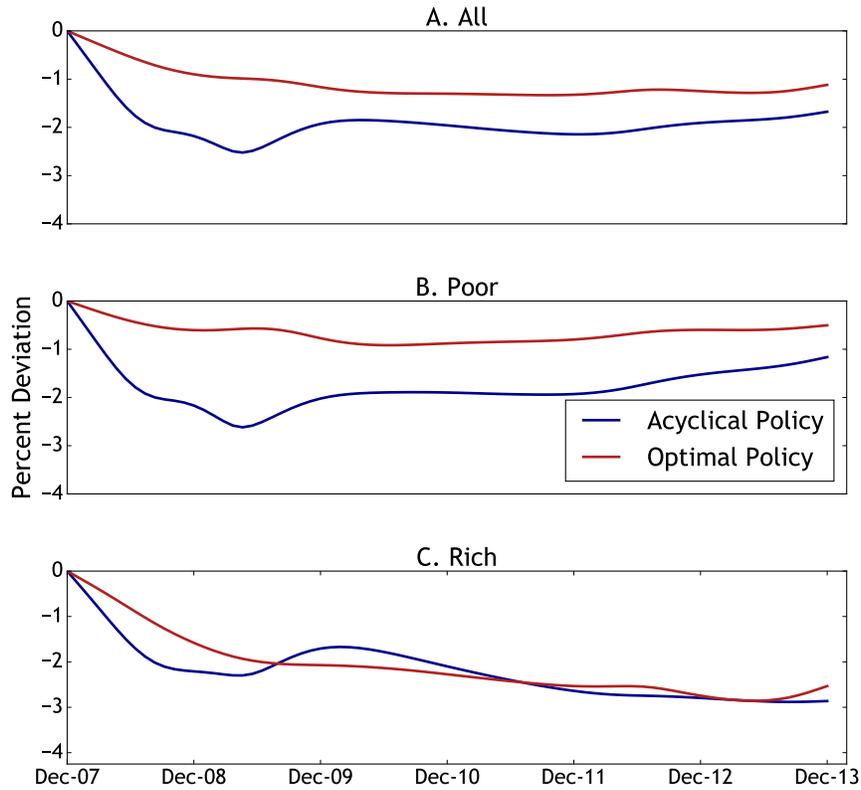
where the optimal policy is implemented.

It is also insightful to understand the effect of the optimal policy on the consumption drop upon job loss among rich and poor households. In Figure 5, we group individuals based on their asset-to-income ratio at the moment of job loss when the acyclical policy is implemented and then plot their consumption profiles. The first group consists of those who enter unemployment with an asset-to-income ratio below the 75th percentile of the stationary asset-to-income distribution, while the second group consists of those above that threshold. Using the same grouping (and the same job destruction shocks), we calculate the consumption drop that individuals would have experienced had the optimal policy been implemented instead. Panels B and C of Figure 5 demonstrate substantial heterogeneity in the consumption-smoothing benefits agents derive from the optimal policy. Among the poor, the consumption drop is reduced by around 12 percent, while for the rich, it is only around 4 percent. This result highlights the need to carefully calibrate the model's wealth distribution to match the data in order to correctly evaluate the true magnitude of any proposed policy's insurance benefits.

In summary, the optimal policy provides substantial insurance against E-U transitions, the magnitude of which varies significantly across the wealth distribution. More importantly, these benefits are larger during recessions simply because more agents experience job loss and remain unemployed for longer durations during which wealth declines.

**Consumption Smoothing over the Business Cycle** Although the insurance benefits of UI are traditionally seen to accrue mostly to job losers, we show in this section that in the presence of aggregate shocks and incomplete asset markets, UI also provides consumption-smoothing benefits even to those who do not lose their jobs. Under this framework, UI policy plays an important role in smoothing consumption over the business cycle. In order to demonstrate this channel, consider for the moment a worker in an economy that does not have a UI program. When a recession occurs, the worker anticipates that there is a higher risk of losing her job and that the unemployment spell is likely to be prolonged given the persistence of negative shocks. In the absence of government insurance, the worker self-insures by cutting back on consumption in order to build a buffer stock of savings that she could use to attenuate the impact of potential job loss. This means that consumption fluctuates heavily with aggregate fluctuations even if job loss does not actually occur. This reaction is simply a manifestation of the inefficiencies resulting from over-saving in an incomplete markets model, relative to its first best. The government then uses its UI program to reduce the excessive precautionary saving behavior of workers by promising higher public insurance during times when the unemployment risk is large in order to bring the economy closer to the efficient allocation. When UI is generous during recessions, individuals are relieved of the burden to reduce consumption in order to build

Figure 6: Average Consumption over the Business Cycle

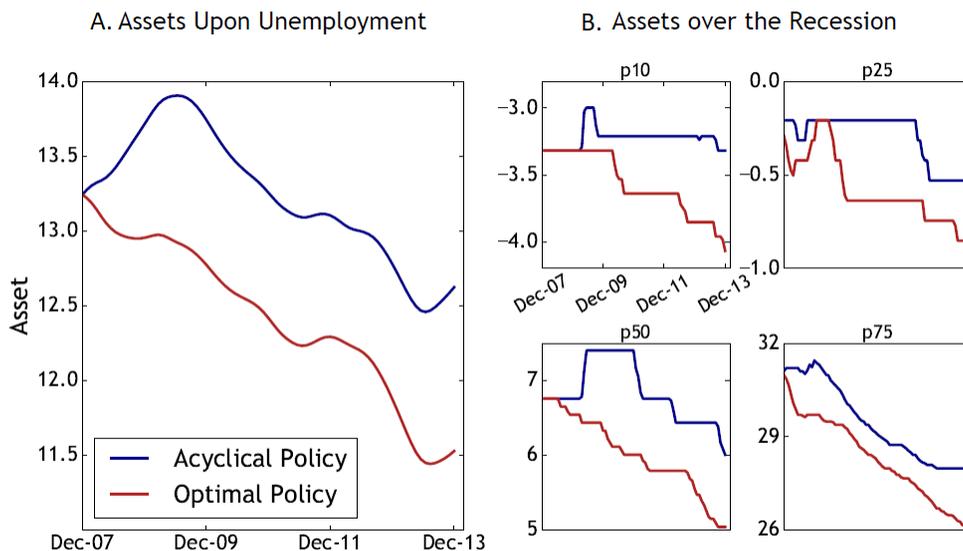


*Note:* Panel A plots the percent deviation of average consumption’s trend during the Great Recession from its steady-state level at the start of this period under the acyclical and optimal UI policies. Panels B and C repeat this exercise for poor and rich agents. “Poor” refers to agents who enter unemployment with an asset-to-income ratio below the 75th percentile of the stationary asset-to-income distribution, while “Rich” refers to those above the threshold.

savings, since UI makes the prospect of losing one’s job less painful. This further contributes to the expansion of insurance benefits during recessions because it is precisely during this time when excessive precautionary saving behavior is triggered. While this channel is also present in previous models with incomplete markets, the literature on the optimal design of UI over the business cycle has not quantified the effect, possibly because of computational difficulties, which we are able to overcome.

Panel A of Figure 6 demonstrates this channel by comparing the average consumption of the economy during the Great Recession under the optimal and acyclical UI policies. It reveals that average consumption is much smoother under the optimal policy. The large drop in consumption at the onset of the recession when UI is acyclical is caused precisely by agents diverting consumption toward savings. This is corroborated by Panel A of Figure 7 which plots the average wealth of job losers during the first week of entering unemployment. At the start of the recession when labor productivity starts declining, it is clear that workers in the economy under the acyclical policy engage in precautionary savings due to the higher risk of losing a job and staying

Figure 7: Average Assets upon Job Loss over the Business Cycle

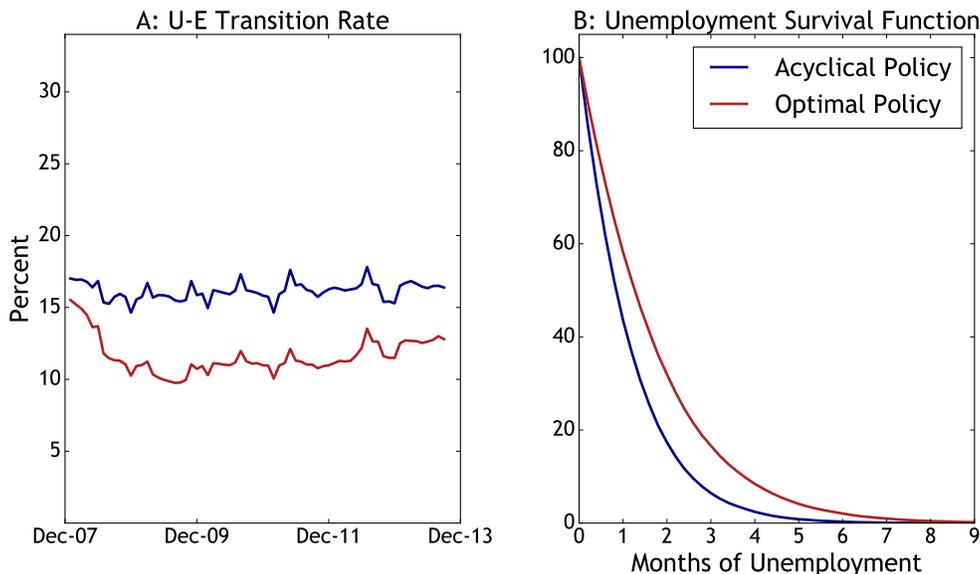


*Note:* Panel A plots the trend of average asset holdings of the unemployed during the first week of entering unemployment over the Great Recession under the acyclical and optimal UI policies. Panel B shows the evolution of various percentiles of the asset distribution over the Great Recession under these two policies.

unemployed for longer durations. Thus, we see that average asset holdings upon entering unemployment rise during this period and only begin to decline during the recovery. In the case of the optimal policy, however, the need for precautionary saving is offset by the generous UI payments, implying that agents enter their unemployment spell with less self-insurance compared to their counterparts under the acyclical policy. The same idea is also apparent in Panel B of Figure 7, which plots the evolution of various percentiles of the asset distribution when a recession hits both economies. It shows that the level of precautionary savings under the generous optimal policy is markedly muted. Furthermore, similar to the consumption-smoothing benefits upon job loss, consumption smoothing through this channel is also cyclical. It is stronger during recessions precisely because it is during this time when precautionary saving motives are strong and thus significant cuts in consumption occur.

Next, we analyze the consumption-smoothing benefits of the optimal policy over the business cycle for agents with varying wealth levels. To do this, we again group agents based on their asset-to-income level at the start of the Great Recession. The first group consists of agents whose asset-to-income level at the start of this period is below the 75th percentile of the stationary asset-to-income distribution, while the second group comprises of those above this threshold. Panels B and C of Figure 6 then plot the average consumption paths of these two groups over the Great Recession. Comparing average consumption paths under the acyclical and optimal policies shows intuitively that the consumption-smoothing benefits of the optimal policy over the business cycle are largely different for poor and rich agents. While the optimal policy

Figure 8: Incentive Costs of the Optimal Policy



*Note:* Panel A shows the average job finding rates during the Great Recession under the acyclical and optimal UI policies. Panel B plots the unemployment survival function under these two policies, which shows the probability that an unemployment spell will last beyond  $t$  months.

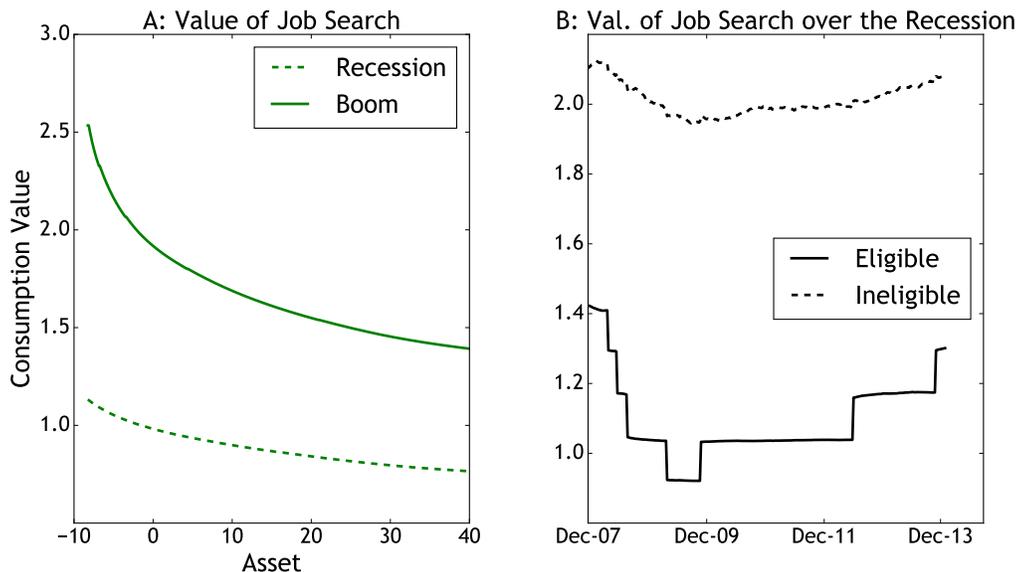
improves consumption smoothing for the poor, it does not for the rich, as they are already well insured.

### 5.1.2 Incentive Costs

While the optimal policy provides consumption-smoothing benefits to a large fraction of agents in the economy, it also induces certain moral hazard costs. This section discusses the magnitude of these costs associated with introducing the optimal UI policy vis-à-vis the acyclical UI policy. First, we look at how these costs manifest through lower job-finding probabilities and thus longer durations in unemployment. Second, we discuss how the magnitude of these moral hazard costs varies over the business cycle.

When a more generous UI policy is implemented, the unemployed eligible reduce their search effort and ask for higher wages because of an increase in the opportunity cost of employment. To provide a useful summary of the combined effects of both margins, in Figure 8, we look at how job finding rates and survival in unemployment change between the two economies. Panel A demonstrates that job finding rates during the recession shift downward when the optimal policy is introduced. Meanwhile, Panel B plots the Kaplan-Meier estimates of the unemployment survival function under both policies, as described in Section 3.3. The lower job finding rates result in the outward shift of the unemployment survival function under the optimal policy when compared to that of the less generous acyclical policy. This simply means that the likelihood that a duration will last beyond  $t$  months is always higher in the economy under the optimal policy. For instance, the probability that an unemployment spell will last beyond one month is around 40 percent under

Figure 9: Value of Job Search



*Note:* Panel A shows the consumption value of job search across different levels of asset holdings in recessions and booms. Panel B plots the average consumption value of job search during the Great Recession for unemployed eligible and ineligible.

the acyclical policy, whereas it goes up to 60 percent under the optimal policy.

It is now evident that the optimal UI policy induces nontrivial costs through lower job-finding rates and thus longer unemployment durations. However, what is key to determining the optimal policy over the business cycle is the cyclical nature of the size of these moral hazard costs, that is, how they expand and contract over the business cycle.

First, the value of job search is cyclical. A forgone unit of search during a recession is less costly than a forgone unit of search during a boom because jobs are difficult to find during a recession and conditional on finding a job, wages are likely to be lower as well. This means that while an extra dollar of benefits received during a recession induces the unemployed to search less, this reduction in search effort is not as costly compared to when the same dollar is received in an expansion during which firms are posting a lot more vacancies at higher wages. The cyclical nature of the value of search effort is evident in Panel A of Figure 9 which shows that the consumption value of a unit of search effort is markedly lower during a recession compared to a boom. The same message is conveyed in Panel B, which shows that the average value of job search drops during the Great Recession and rises during the recovery for both eligible and ineligible unemployed, although the change is larger for the eligible unemployed, as they are the direct recipient of UI payments.

Second, wealth effects that discipline job search are more likely to manifest during recessions. For any given UI policy, recessions generally lead to prolonged unemployment spells during which agents draw down

their assets to supplement consumption. Getting closer to their borrowing constraints, the unemployed have a higher incentive to ramp up their job finding efforts through a combination of higher search intensity and lower wage choices, as they seek to find work more quickly. This is evident in the household decision rules in Figure 1, which shows that for every unit of the decline in asset holdings at the time of unemployment, there is a disproportionate increase in search effort and decline in wage choices as the unemployed get closer to becoming borrowing constrained. Simply put, the presence of borrowing constraints acts like a self-disciplining device for job search efforts of the unemployed during recessions. As a result, the moral hazard costs are dampened by the fact that agents are more ill-prepared in terms of their own private savings during recessions.

In summary, while a generous UI policy decreases the job finding rate and increases the average unemployment spell duration, these moral hazard costs are partially offset in recessions because the consumption value of job search is low during recessions, and the decline in asset holdings in recessions incentivizes the unemployed to ramp up their job search. This result is consistent with Kroft and Notowidigdo (2016), who empirically find that the moral hazard cost of UI is procyclical.

## 5.2 Welfare Decomposition

The Great Recession exercise in the previous section demonstrates the qualitative effects of the optimal policy on individual decision rules as well as the aggregate outcomes. We now proceed to quantitatively decompose the welfare contribution of the aforementioned changes. The ex-ante welfare gains of the optimal policy can be decomposed into either its effects on consumption coming from changes in savings and wage choices or its effects on the search intensity exerted by the unemployed. In order to isolate the welfare gains attributable to changes in consumption from those attributable to search effort, we shut down endogenous search decisions in the model.<sup>43</sup> This version of the model is then recalibrated and used to evaluate the welfare gains coming from the countercyclical optimal policy. When policy has no effects on search intensity, welfare increases by 0.56 percent of additional lifetime consumption for all agents relative to the benchmark policy. Thus, the welfare gains of the optimal policy attributable to changes in search effort are negligible.<sup>44</sup> As a result, we conclude that the welfare gains come largely from changes in consumption patterns.

Having isolated the welfare gains attributable to search, we then want to understand how the optimal

---

<sup>43</sup>We do this by assuming that the unemployed searches for a job full-time, (i.e.,  $s = 1$ ), without incurring a disutility from search effort, (i.e.,  $\alpha = 0$ ).

<sup>44</sup>The result that changes in UI policy have small effects on the job search intensity of the unemployed is consistent with previous empirical evidence in the literature. For example, Ashenfelter et al. (2005) find that low job search effort is not a significant source of UI overpayments using evidence from randomized trials in four U.S. sites. Recently, Hagedorn et al. (2016) carefully analyze the effect of changes in UI policies on both the search intensity of unemployed workers (the micro effect), and the aggregate job finding rate per unit of search effort through vacancy posting decisions of the firms (the macro effect). They also find a small micro effect.

policy changes consumption patterns in the model without endogenous search effort. Our first step is to disentangle welfare gains along the transition from the long-run (steady state) gains. To do this, we make a slight but important modification in Equation (15). In particular, we change  $\Gamma_{ss}$  to  $\Gamma_b$  (where  $b$  denotes the benchmark policy) on the left-hand side, and  $\Gamma_{ss}$  to  $\Gamma_n$  on the right-hand side, where  $n$  is set to be the optimal UI policy. This implies that the first economy has implemented the benchmark policy, while the second economy has implemented the optimal policy for a very long time so that these two economies are in their respective steady states. We then ask an unborn agent who does not know her type within the respective stationary distributions which economy she prefers to live in. The ex-ante steady state welfare gains/losses from the optimal policy  $\pi_{ss}$  are then given by the percentage of additional lifetime consumption that the first government should compensate this agent in order to make her indifferent between being part of one of these two economies. We find that  $\pi_{ss} = 0.18$ , which is smaller than the welfare gain with a transition of 0.56. This result suggests sizeable welfare gains along the transition from the economy under the acyclical policy to the economy under the optimal policy. We know from our earlier analysis that the optimal policy reduces the precautionary saving motives, as agents substitute away from self-insurance to public insurance for consumption-smoothing purposes. As a result, agents decumulate savings and consume more of their labor income along the transition path. This increase in consumption is enough to overcome any rise in taxes brought about by the policy change, thus providing large welfare gains along the transition.

Next, we decompose the steady state welfare gains of the optimal policy. In particular, under a utilitarian equally weighted social welfare function as in Equation (15), the optimal policy can increase steady state welfare for three reasons: (1) an increase in the average consumption of the economy (the level effect), (2) a decline in the volatility of individual consumption paths (the volatility effect), and (3) a decline in inequality across individual consumption paths (the egalitarian effect). Following Floden (2001), the welfare gain from the optimal policy under the steady state comparison can be decomposed approximately into (1), (2), and (3):

$$\pi_{ss} = (1 + \pi_{lev})(1 + \pi_{vol})(1 + \pi_{egal}) - 1. \quad (16)$$

Comparing the average consumption level of economies under the optimal and benchmark UI policies, we find that average consumption is 0.18 percent *lower* in the steady state of the optimal policy, (i.e.,  $\pi_{lev} = -0.18$ ). This is because once the economy converges to a new steady state with lower wealth holdings and higher taxes, consumption levels decrease. On the other hand, we find that the optimal policy significantly reduces the volatility of average consumption and that there are sizeable welfare gains because of this channel. On average, we find that  $\pi_{vol} = 0.35$ , which implies that uncertainty gains overcome any reduction in long-run consumption levels. This is again due to the endogenous response of saving decisions to changes in

UI policy over the business cycle. Recall from our Great Recession exercise in the previous section that the government uses its UI program to reduce the excessive precautionary saving behavior of workers by implementing a generous UI during times when unemployment risk is large in order to bring the economy closer to the efficient allocation. Therefore, the impact of fluctuations in aggregate labor productivity on the consumption path of individuals is lower under the optimal policy relative to that under the benchmark policy. This smoother consumption profile over the business cycle provides significant welfare gains. Finally, we find that  $\pi_{egal} = 0.01$ , implying that there are negligible welfare gains from the optimal policy due to equalizing the consumption paths across heterogeneous agents. However, this result masks the two opposing effects of the optimal policy on the inequality across individual consumption paths. On the one hand, generous UI payments to the unemployed and higher income tax rates create more equal consumption paths across heterogeneous agents and thus increase  $\pi_{egal}$ . On the other hand, the steady state asset distribution under the optimal policy is more unequal than its counterpart under the benchmark policy. This is because while most of the individuals in the economy under the optimal policy save less, the response of the agents in the top percentiles of the distribution is very small. As a result, the Gini coefficient of the asset distribution increases from 0.68 under the benchmark policy to 0.91 under the optimal policy. This rise in the inequality of the steady-state wealth distribution in fact reduces  $\pi_{egal}$ , as it makes individual consumption paths across heterogeneous agents more unequal. We find that these two opposing effects quantitatively cancel each other out, and thus on average  $\pi_{egal}$  is small.<sup>45</sup>

### 5.3 Heterogeneous Welfare Effects

While the previous section decomposes the average ex-ante welfare gains into various mechanisms at work in our model, it is also insightful in understanding which type of agents stand to gain or lose from the optimal policy compared to the benchmark policy. In order to measure the ex-post heterogeneous welfare gains/losses from the optimal UI policy, we group agents by their employment status and asset level based on the stationary distribution. We then calculate  $\bar{\pi}$  from Equation (15) for each group by only integrating over agents that belong to each group.

Table 5 shows the heterogeneous welfare impacts of the optimal policy on various type-groups, where columns represent agents holding various levels of assets (set to be the different ranges in the asset distribution) and rows represent agents of differing employment statuses.

It is clear that the unemployed eligible stand to gain the most from the optimal policy. This result

---

<sup>45</sup>The welfare decomposition exercise presented here can be modified to incorporate the effects of transition on  $\pi_{lev}$ ,  $\pi_{unc}$ , and  $\pi_{egal}$ . The reason why we decompose the welfare gains across two different steady states is to isolate the long-run effects of the optimal policy as the policy change is permanent. However, we also did this exercise with transition and find that the level gains in consumption from the optimal policy are large because of the decline in savings along the transition.

Table 5: Heterogeneous Welfare Impacts of Optimal Policy

Employment	Asset Groups				
	$a_1$	$a_2$	$a_3$	$a_4$	$a_5$
Worker	0.73	0.67	0.58	0.53	0.52
Unemployed Eligible	1.89	1.55	1.28	0.96	0.84
Unemployed Ineligible	0.61	0.58	0.55	0.50	0.51

*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 numbers are in percent lifetime equivalent consumption terms. Asset groups are  $a_1 < p(10)$ ,  $a_2 \in [p(10), p(25))$ ,  $a_3 \in [p(25), p(50))$ ,  $a_4 \in [p(50), p(75))$ , and  $a_5 \geq p(75)$ , where percentiles are from the stationary asset distribution. Gains are calculated relative to the benchmark policy.

is unsurprising, since the unemployed eligible are the direct beneficiaries of more generous payments and durations, and thus enjoy the largest consumption-smoothing gains. Intuitively, among the unemployed eligible, poorer individuals also enjoy larger welfare gains compared to their richer counterparts, given how each additional dollar of benefit payment is more valuable to them.

Consistent with our earlier discussion, the unemployment eligible are not the sole beneficiaries of the optimal UI policy. Workers also enjoy a sizeable welfare gain, albeit to a smaller degree, because of two opposing effects. On the one hand, workers maintain smoother consumption over the business cycle given the weaker need to engage in precautionary savings afforded to them by optimal UI benefits; on the other hand, they are the primary financers of the optimal UI policy and would thus face higher taxes and lower consumption levels. Nonetheless, the ability to maintain smoother consumption during economic fluctuations dominates the financing effect. Note that if we had not accounted for this benefit, then we would expect workers to experience welfare losses, as they would be paying taxes without enjoying the benefit of being able to smooth consumption over fluctuations in aggregate labor productivity. Unsurprisingly, welfare gains are also much larger among poor workers for whom savings (and the corresponding forgone consumption) is most costly.

Meanwhile, the unemployed ineligible only receive the generous UI payments in the event that they find a job, lose it, and become eligible, which is a small probability. While they do not contribute to financing the optimal UI policy, they incur costs because of lower job-finding rates resulting from the generous UI payments. Having to spend longer weeks without benefits and being forced to exert more effort in finding a job results in this group experiencing the lowest gains from the optimal policy.

## 6 Robustness

### 6.1 Welfare under different specifications

In this section, we compute the welfare gains or losses from the optimal policy relative to the benchmark policy under different specifications of the baseline model. In these exercises, whenever a change in parametrization is necessary, the model is recalibrated to match the moments found in Section 3 and tax rates are adjusted under each UI policy so that the government budget constraint holds in equilibrium. The nature of the first three exercises in this section requires us to simulate a recession in order to compute the welfare gains. To preserve consistency within this section, we report the welfare gains of the remaining specifications under a scenario in which a recession occurs initially as well. The results are summarized in Table 6.

First, in order to quantify how welfare gains change depending on the timing of the policy change, we evaluate the welfare gains from the optimal policy when the policy change is introduced at the onset of a recession. This exercise follows the Great Recession simulation discussed in Section 5.1 where an unanticipated UI policy change is implemented. The only difference here is that for the first economy, the benchmark policy  $b$  is introduced at  $t = 0$ , whereas in the alternate economy, the optimal UI policy is implemented.

We modify the welfare criterion in Section 4 slightly, as we now require a simulation-based welfare calculation. Additional details regarding the computational procedure are provided in Appendix C. We compute for  $\bar{\pi}$  in Equation (15) modified to account for the recession that occurs right at the same time the policy change is made and find that the optimal policy increases ex-ante welfare by 1.25 percent additional lifetime consumption relative to the benchmark policy. The welfare gains of the optimal policy are unsurprisingly much higher when the policy is implemented right before a sharp drop in aggregate labor productivity, since there is a frontloading of gains coming from large net insurance benefits provided during the recession. At the onset of a recession, stronger precautionary motives cause larger drops in consumption, and a larger pool of unemployed individuals experiences the consumption drop upon job loss. This is in contrast to welfare gains of 0.58 when we do not take a stance on the realizations of aggregate productivity.<sup>46</sup>

The second exercise we perform considers how welfare gains change if the policy were temporary. While we study permanent changes in the UI benefit schedule, our framework is also useful to assess the welfare effects of discretionary fiscal policies such as the one implemented during the Great Recession. We now assume that the optimal policy is only implemented during the period of the Great Recession, and it unexpectedly

---

<sup>46</sup>Furthermore, when the government implements the optimal policy right before a boom, we find that it increases ex-ante welfare by 0.23 percent additional lifetime consumption relative to the benchmark policy. Given that the optimal policy raises welfare more when implemented right before a recession compared to that of a boom provides strong evidence about the countercyclicality of insurance benefits net of incentive costs.

Table 6: Welfare Gains under Different Specifications

Exercise	Welfare gains (%) from the optimal policy
Great Recession simulation	1.25
Temporary policy change	0.83
Procyclical interest rates	0.64
Endogenous quit decisions	1.10
Replacement rate $\phi = 0.4$	0.77
UI eligibility requirements	0.94
Permanent discount factor	1.24

*Note:* This table shows welfare gains from the optimal policy under different specifications of the baseline model. Welfare numbers are in percent lifetime equivalent consumption terms. Gains are calculated relative to the benchmark policy under a labor productivity series that generates the observed unemployment rate time path during the Great Recession.

reverts back to the acyclical policy  $f$  at the end of this period. This is to closely pattern the simulation of the model to the events that occurred during the Great Recession where the EUC08 was completely terminated in December 2013 and UI policy returned to what it had been prerecession. We find that the welfare gains from the optimal policy become 0.83 percent additional lifetime consumption relative to the benchmark policy. The difference between this value and welfare gains when the policy change is permanent (1.25 percent) reveals that around 35 percent of the total welfare gains are attributable to the expectation of generous UI payments during future economic downturns.

Third, we test the quantitative effects of assuming a time-invariant interest rate  $r$  on the welfare gains from the optimal policy. In this exercise, we consider an interest rate that varies with the state of the economy such that it is procyclical and closely mimics its data counterpart during the Great Recession.<sup>47</sup> Under this exercise, we find that the optimal policy yields a welfare gain equivalent to 0.64 percent additional lifetime consumption relative to the benchmark policy. The reason for the reduction in welfare gains from 1.25 percent to 0.64 percent is that the decline in the real interest rate reduces precautionary saving motives during recessions, making agents' consumption profiles relatively smoother over the business cycle even under a less generous benchmark policy. This reduces the welfare gains from the optimal policy. While the welfare gains under a recession are reduced to half their original value, the countercyclical optimal policy still provides substantial gains. Moreover, given that interest rate fluctuates drastically with the state of the economy in this exercise, this result places an upper bound on the likely effects of endogenizing interest rates.

<sup>47</sup>The weekly real interest rate reduces from its baseline value of 0.00095 to  $-0.0003$  at the depth of the Great Recession. This way, we are able to measure the quantitative effects of significant changes in the real interest rate.

Fourth, we address the feature of the baseline model where a matched worker receives the same wage throughout her tenure within a firm. These fixed-wage contracts introduce “job lock” since an unemployed individual who is desperate for work may land a low-paying job during a recession but be unable to switch to a higher-paying job unless the match exogenously dissolves. This feature of the model may be a source of inefficiency that the optimal policy is trying to correct, since generous benefits during recessions can nudge agents toward looking for higher-paying jobs. Hence, generous benefits during recessions not only may be providing consumption insurance but also may serve as a means of convincing the unemployed to look for jobs that will be paying higher even after the recession ends. In order to understand whether the optimal UI policy is also correcting inefficiencies introduced by the fixed-wage contract assumption of the baseline model, we solve for the welfare gains of the optimal policy in an extended model that allows for endogenous quits.<sup>48</sup> In this extended model, workers can choose to quit their jobs in order to begin searching for a new job. Under this setup, the artificial job lock problem is eliminated, as workers who place a higher value on the option of becoming unemployed and looking for a higher-paying job can actually leave their employer. The model details and a modified computational algorithm can be found in Appendices D and E.2, respectively. The welfare gains under the model with endogenous quits is given by 1.10 percent when the optimal policy is implemented at the onset of the Great Recession. Introducing endogenous quit decisions into the model has a small effect because the option of quitting is not widely used by workers, given that the value of becoming unemployed ineligible is very low. As a result, inefficiencies created by fixed wage contracts in the baseline model have a small quantitative impact on the welfare gains from the optimal policy.

The fifth robustness exercise considers the calibration of the replacement rate of the benchmark UI policy. Recall that our benchmark replacement rate of 14 percent takes into account the effect of partial take-up among those eligible for benefits and adjusts for differences between wages and total compensation. To understand the effects of this adjustment, we calculate the welfare gains from the optimal policy when the benchmark policy replacement rate is set to 40 percent, (i.e.,  $\phi(p) = 0.4 \quad \forall p$ ), the (unadjusted) value calculated by the Department of Labor. The goal of this exercise is to understand whether the countercyclical optimal policy would still be welfare improving when compared to a new benchmark policy that has a significantly higher but time-invariant level replacement rate. We find that the optimal policy increases welfare by 0.77 percent relative to the new benchmark. This result implies that there are still sizeable welfare gains when the government transfers funds from booms to recessions, as the insurance value of UI payments expands and incentive costs contract during recessions. This also emphasizes that welfare gains are not mostly driven by more generous benefits levels but by the introduction of cyclical generosity.

---

<sup>48</sup>Without the fixed-wage contract assumption, solving for the optimal policy will be computationally burdensome, as firms would now need to keep track of household decisions.

The sixth exercise considers eligibility rules for workers at the moment of job loss. According to the UI program in the United States, workers have to satisfy some monetary and nonmonetary requirements to be eligible for UI benefits.<sup>49</sup> Under these requirements, on average, around 75 percent of the workers are in fact eligible for UI benefits upon job loss.<sup>50</sup> When studying the optimal design of UI program, it will be interesting to consider the welfare implications of treating these eligibility requirements as another policy instrument. In our baseline setup, eligibility requirements upon job loss are controlled by the UI expiration rate  $e$ . Thus, an extension of UI duration also implies a relaxation of UI eligibility requirements for workers in our baseline model. In order to understand the effects of this relationship, we change the problem of the worker in Equation (1) such that the probability of being eligible upon job loss is fixed at 75 percent rather than controlled by changes in  $e$ . We then evaluate the welfare gains from the optimal policy, and find that it yields 0.94 percent additional lifetime consumption relative to the benchmark policy. Since a lower fraction of workers are now eligible for UI benefits upon job loss relative to the baseline model, the welfare gains from the optimal policy are slightly reduced under this exercise.

Finally, we explore the implications of time-varying discount factors  $\beta_t$ . The stochasticity of discount factors introduces another idiosyncratic shock to households, and so one might be concerned about the presence of an unintended role of UI payments as providing insurance against the discount factor risk. In order to quantify this effect, we set discount factors to be permanent and use an equally weighted social welfare function in computing the welfare gains. We find that the optimal policy yields 1.24 percent additional lifetime consumption relative to the benchmark policy, implying that the effect of time-varying discount factors on welfare gains of the optimal policy is negligible. This result is expected given that discount factors are calibrated to be highly persistent in our baseline calibration.

## 6.2 High Level of Opportunity Cost of Employment

We now explore the features of the optimal policy under a high level of opportunity cost of employment calibration. In particular, we recalibrate our baseline economy so that the model matches the same labor market and asset-to-income distribution moments as in our baseline calibration, but the level of opportunity cost of employment is set to be 0.955, as calibrated by Hagedorn and Manovskii (2008). Next, we evaluate the welfare gains/losses of the same set of linear policies and obtain the optimal policy for this case under the welfare criterion in Section 4.

We find that the optimal policy is still countercyclical even under a high level of opportunity cost of

---

<sup>49</sup>For example, in terms of monetary requirements, workers must receive enough wages during the base period to establish a claim. In terms of nonmonetary requirements, the reason for the workers' job loss must be through no fault of their own, and they must be actively looking for work while unemployed.

<sup>50</sup>See Chodorow-Reich and Karabarbounis (2016).

employment. Specifically, it features a 19 percent replacement rate for one quarter when aggregate labor productivity is at its mean value, and a 59 percent replacement rate for 4 quarters when aggregate labor productivity is depressed by 3.5 percent. Compared to the U.S. government's UI policy during the Great Recession (the benchmark policy), this optimal policy increases welfare by 0.25 percent additional lifetime consumption for all agents. Relative to the optimal policy under the baseline calibration of opportunity cost of employment, the optimal policy in this case offers a lower replacement rate for a much shorter duration when labor productivity is at its mean, while the cyclical nature of the optimal policy remains roughly the same. This result is intuitive because when the value of unemployment is close to the value of employment because of a high opportunity cost of employment, the consumption drop upon job loss becomes less pronounced. Thus, the government implements a low replacement rate for short durations under the mean level of aggregate labor productivity. Moreover, consumption still fluctuates because of changes in the saving behavior of agents as a response to fluctuations in aggregate labor productivity. Hence, the government still finds it optimal to transfer funds from expansions to recessions. However, the magnitude of these fluctuations in consumption is relatively smaller, as the precautionary saving motives are not as strong under a high level of opportunity cost of employment. For this reason, the welfare gains from the optimal policy in this case are less than half of the welfare gains provided by the optimal policy under the baseline calibration of opportunity cost of employment.

This exercise is also useful to compare our result to the findings of the previous literature. As we discussed in Section 1, Mitman and Rabinovich (2015) also study the optimal cyclical nature of UI replacement rate and duration in an equilibrium search model in which agents are not allowed to save/borrow. In their baseline calibration, the summation of UI benefits  $b$  and the value of nonmarket activity  $h$  is equal to 0.984, implying that the flow opportunity cost of employment is high. In this setup, they find that the optimal UI policy is procyclical. Then, in Section 5.4 of their paper, they discuss the implications of relaxing the no saving/borrowing assumption on their results. In this discussion, they also acknowledge that when agents are allowed to save/borrow, fluctuations in agents' wealth holdings over the business cycle may create a force that has a potential to reverse the cyclical nature of their optimal UI policy. In our model, we allow agents to save/borrow through incomplete asset markets and indeed show that this channel is strong enough to rationalize the countercyclical nature of the optimal policy even under a high level of opportunity cost of employment.

## 7 Evidence on the mechanism: a first pass

In this section, we empirically test the interaction between UI generosity and savings decisions in order to check whether our main mechanism is also observed in the micro data. This exercise builds on Engen and Gruber (2001), who find that UI benefits tend to crowd out individual savings.<sup>51</sup> We focus on the Great Recession period to understand the impact of drastic changes in UI policy on the saving decisions of individuals. Using the SIPP panel 2008 core data, we obtain household employment, labor income, and state of residence information. Wealth data are once again obtained from the topical data of the same panel, which is typically released on a yearly basis as opposed to the monthly frequency of the core data. State-level UI duration data during the Great Recession consist of maximum potential duration by adding up standard weeks, Extended Benefits (EB), and EUC tiers 1-4 (when applicable).<sup>52</sup> Meanwhile, the state-level replacement rate is defined as either (1) the weighted average of the ratio of the weekly benefit amount and average claimants' wage or (2) the ratio of the weighted average of the weekly benefit amount and the weighted average of claimants' wage.<sup>53</sup> To obtain the expected benefit receipt of a worker, we compute the average weekly wage of the respondent for one quarter prior to the wealth observation and multiply it by the replacement rate offered by her state of residence during that time.

Our sample includes workers ages 24 to 65 who report not owning any business in part or in full and has worked for at least one quarter prior to the first observation and are always working in between observations. This more or less guarantees eligibility for UI if the observed worker is displaced in the future. Moreover, focusing only on employed individuals between observations eliminates other reasons for changes in asset holdings, such as experiencing unemployment. We organize the data into person-time information (where  $t = \{2009, 2010\}$ ) and run the following regression:

$$a_{it} = \gamma_{ben}benefit_{it} + \gamma_{dur}dur_{st} + \beta X_{it} + \alpha_i + \alpha_s + \alpha_t + \epsilon_{ist}$$

where  $a_{it}$  is the asset-to-income ratio of individual  $i$  at time  $t$ ,  $benefit_{it}$  is the expected weekly benefit receipt of individual  $i$  at time  $t$ ,  $dur_{st}$  is the maximum potential duration of UI in state  $s$  during time  $t$ ,  $X_{it}$  is a set of controls which include education, marital status, and age, and  $\alpha_{j \in \{i,s,t\}}$  are individual, time, and state fixed effects.<sup>54</sup> The coefficients of interest are the impact of the unemployment benefit level and duration on the asset-to-income ratio given by  $\gamma_{ben}$  and  $\gamma_{dur}$ . Note that a selection problem arises if there is a systematic

---

<sup>51</sup>While Engen and Gruber (2001) study the effect of the UI replacement rate on saving decisions, we also include time- and state-varying UI duration in order to account for the effect of expected length of UI receipts on wealth for the period of the Great Recession.

<sup>52</sup>We thank A. Yusuf Mercan for kindly sharing this dataset with us.

<sup>53</sup>See [https://oui.doleta.gov/unemploy/ui\\_replacement\\_rates.asp](https://oui.doleta.gov/unemploy/ui_replacement_rates.asp) for more details.

<sup>54</sup>Notice that  $benefit_{it}$  is affected by the replacement rate offered by the state  $s$  that individual  $i$  resides in during time  $t$ .

Table 7: Regression Results

	Benefit Calculation 1		Benefit Calculation 2	
	(1)	(2)	(1)	(2)
benefit	-.0135*** (.0010)	-.0135*** (.0010)	-.0153*** (.0012)	-.0153*** (.0012)
dur	-.0122 (.0164)	-.0123 (.0164)	-.0119 (.0164)	-.0119 (.0164)
moving		-.0924 (.2255)		-.0933 (.2254)
individual fixed effects	Yes	Yes	Yes	Yes
state fixed effects	Yes	Yes	Yes	Yes
time fixed effects	Yes	Yes	Yes	Yes
observations	33,012	33,012	33,012	33,012

*Note:* The dependent variable is the asset-to-income ratio of individuals. “Benefit Calculation 1” uses a replacement ratio calculated as the weighted average of the following ratio: weekly benefit amount (WBA) / weekly wage. “Benefit Calculation 2” uses a replacement rate ratio calculated as the ratio of the weighted average of WBA and the weighted average of the weekly wage. \*, \*\*, \*\*\* denote statistical significance at the 10%, 5%, and 1% level, respectively.

movement of a certain type of worker to states with high levels of UI generosity. In order to control for this, we also expand the original regression to control for individuals moving from one state to another.

Given that isolating the causal effect of benefit generosity on self-insurance is beyond the scope of this exercise because of endogeneity, our intention is simply to provide correlational evidence on this relationship. Table 7 shows that expected benefit receipt has a negative and statistically significant impact on self-insurance. While the length of UI duration has a negative coefficient, it is not statistically significant. For example,  $\gamma_{ben} = -.0135$  implies that a \$100 increase in the expected benefit amount received each week should unemployment occur results in a decrease in the asset-to-income ratio that is equivalent to 1.35 weeks’ worth of insurance. Alternatively, this would also imply a reduction in savings by around \$1124 for a worker earning the median weekly wage of \$833. This relationship is consistent with the crowding-out effect of UI on precautionary savings documented by Engen and Gruber (2001). This result lends evidentiary support to the idea that the insurance benefits of a generous UI policy during recessions are partially attributable to the relief UI benefits provide workers who no longer need to experience sudden drops in consumption in order to build a buffer stock of savings. Results in the second and fourth columns also indicate that the issue of selection caused by state-to-state moves is not consequential. Finally, comparing the first two columns with the last two reveals that the relationship is robust to the manner by which replacement rates are calculated.

Motivated by the above empirical evidence, we revisit our welfare analysis in the model to understand if the replacement rate is a more important instrument in providing welfare gains relative to the UI duration. We find that a UI policy that consists of an optimal replacement rate but a UI duration of the benchmark policy, together with the tax rate that balances the government's budget constraint for this hybrid policy, yields an average welfare gain that is equivalent to 0.46 percent additional lifetime consumption relative to the benchmark policy. This implies that around 80 percent of the welfare gains from the optimal policy are attributable to the optimality of the UI replacement rate, and the remaining 20 percent of the gains come from the optimality of UI duration. This is consistent with the above empirical result that the changes in replacement rates significantly affect the self-insurance decisions of individuals.

## 8 Conclusion

We study optimal UI over the business cycle using a tractable heterogeneous agent job search model that features labor productivity driven business cycles and incomplete asset markets. We find that the optimal UI policy is countercyclical. In particular, when aggregate labor productivity is at its mean, it features a 30 percent replacement rate for 4 quarters, but when aggregate labor productivity is depressed by 3.5 percent, it offers more generous benefits of a 54 percent replacement rate for a duration of 10 quarters financed by higher labor income taxes. Compared to a UI policy that mimics the policy implemented during the Great Recession by the United States government, the optimal policy represents an average welfare increase of 0.58 percent additional lifetime consumption. We show that incorporating the response of individual saving behavior to changes in UI policy is quantitatively important in measuring the welfare benefits and costs of UI policy.

Insurance benefits are larger in recessions relative to expansions, while incentive costs exhibit the opposite pattern. Insurance benefits expand during recessions because (1) consumption insurance upon job loss is provided for a larger pool of unemployed and long jobless spells, and (2) it attenuates the need to engage in precautionary savings by cutting back on consumption at the onset of a recession. Meanwhile, incentive costs are also relatively smaller in recessions because (1) jobs are difficult to find and forgone search is not as worthwhile, and (2) borrowing constraints impose discipline on individual job search behavior because of a wealth effect. As a result, the optimal policy is countercyclical.

A quantitative decomposition of ex-ante welfare gains reveals that in the long run, the optimal policy provides a substantial reduction in consumption uncertainty at the cost of lower consumption levels. Along the transition, however, large consumption level gains are enjoyed by agents as they decumulate savings in response to more generous public insurance during recessions. Meanwhile, gains from reduced inequality and

lower search effort are present but limited. In addition, ex-post welfare gains are shown to be heterogeneous across different types of agents. The unemployed eligible gain the most, but the employed remarkably enjoy large gains as well because of the reduced precautionary motives during recessions. Unsurprisingly, gains are largest for the poor across all employment types.

Our contribution to the existing literature lies in carefully accounting for the welfare effects of endogenous interaction between savings and UI policy over the business cycle. The natural extension of our analysis is to analyze how other sources of private insurance (such as family labor supply) react to changes in UI policy and how this interaction would affect the optimal policy. Another avenue for future research is to incorporate capital accumulation in order to account for the effect of government programs on aggregate capital stock. However, given the complexity of our current model, we leave these extensions to future work.

## References

- [1] Abdulkadiroğlu, A., Kuruşçu, B., & Şahin, A. (2002). Unemployment insurance and the role of self-insurance. *Review of Economic Dynamics*, 5(3), 681-703.
- [2] Acemoglu, D., & Shimer, R. (1999). Efficient unemployment insurance. *Journal of Political Economy*, 107(5), 893-928.
- [3] Acemoglu, D., & Shimer, R. (2000). Productivity gains from unemployment insurance. *European Economic Review*, 44, 1195-1224.
- [4] Aguiar, M., & Hurst, E. (2005). Consumption versus expenditure. *Journal of Political Economy*, 113(5), 919-948.
- [5] Albrecht, J., & Vroman, S. (2005). Equilibrium search with time-varying unemployment benefits. *The Economic Journal*, 115(505), 631-648.
- [6] Anderson, P. M., & Meyer, B. D. (1997). Unemployment insurance takeup rates and the after-tax value of benefits. *Quarterly Journal of Economics*, 112(3), 913-937.
- [7] Ashenfelter, O., Ashmore, D., & Deschênes, O. (2005). Do unemployment insurance recipients actively seek work? Evidence from randomized trials in four US states. *Journal of Econometrics*, 125(1), 53-75.
- [8] Auray, S., Fuller, D., & Lkhagvasuren, D. (2013). Unemployment insurance take-up rates in an equilibrium search model. Working Paper 13001, Concordia University.
- [9] Blank, R. M., & Card, D. E. (1991). Recent trends in insured and uninsured unemployment: is there an explanation?. *Quarterly Journal of Economics*, 106(4), 1157-1189.
- [10] Browning, M., & Crossley, T. F. (2001). Unemployment insurance benefit levels and consumption changes. *Journal of Public Economics*, 80(1), 1-23.
- [11] Burdett, K., Shi, S., & Wright, R. (2001). Pricing and matching with frictions. *Journal of Political Economy*, 109(5), 1060-1085.
- [12] Chetty, R. (2008). Moral hazard versus liquidity and optimal unemployment insurance. *Journal of Political Economy*, 116(2), 173-234.
- [13] Chodorow-Reich, G., & Karabarbounis, L. (2016). The cyclicity of the opportunity cost of employment. *Journal of Political Economy*, 124(6), 1563-1618.

- [14] Chodorow-Reich, G., & Karabarbounis, L. (2017). The limited macroeconomic effects of unemployment benefit extensions. Working Paper 386166, Harvard University.
- [15] Coglianesi, J. (2015). Do unemployment insurance extensions reduce employment?. Working Paper, Harvard University.
- [16] den Haan, W. J., Ramey, G., & Watson, J. (2000). Job destruction and propagation of shocks. *American Economic Review*, 90(3), 482-498.
- [17] Eeckhout, J., & Sepahsalari, A. (2015). Unemployment risk and the distribution of assets. Working Paper, University College London.
- [18] Elsby, M. W., Michaels, R., & Solon, G. (2009). The ins and outs of cyclical unemployment. *American Economic Journal: Macroeconomics*, 1(1), 84-110.
- [19] Engen, E. M., & Gruber, J. (2001). Unemployment insurance and precautionary saving. *Journal of Monetary Economics*, 47(3), 545-579.
- [20] Faig, M., & Zhang, M. & (2012). Labor market cycles, unemployment insurance eligibility, and moral hazard. *Review of Economic Dynamics*, 15(1), 41-56.
- [21] Farber, H. S., Rothstein, J., & Valletta, R. G. (2015). The effect of extended unemployment insurance benefits: Evidence from the 2012–2013 phase-out. *American Economic Review P&P*, 105(5), 171-176.
- [22] Farber, H. S., & Valletta, R. G. (2015). Do extended unemployment benefits lengthen unemployment spells? Evidence from recent cycles in the US labor market. *Journal of Human Resources*, 50(4), 873-909.
- [23] Floden, M. (2001). The effectiveness of government debt and transfers as insurance. *Journal of Monetary Economics*, 48(1), 81-108.
- [24] Fredriksson, P., & Holmlund, B. (2001). Optimal unemployment insurance in search equilibrium. *Journal of Labor Economics*, 19(2), 370-399.
- [25] Fujita, S. (2011a). Dynamics of worker flows and vacancies: evidence from the sign restriction approach. *Journal of Applied Econometrics*, 26(1), 89-121.
- [26] Fujita, S. (2011b). Effects of extended unemployment insurance benefits: evidence from the monthly CPS. Federal Reserve Bank of Philadelphia Working Paper 10-35/R.
- [27] Fujita, S., & Ramey, G. (2006). The cyclical nature of job loss and hiring. Federal Reserve Bank of Philadelphia Working Paper 06-17.

- [28] Fujita, S., & Ramey, G. (2009). The cyclicalty of separation and job finding rates. *International Economic Review*, 50(2), 415-430.
- [29] Fuller, D. L., Ravikumar, B., & Zhang, Y. (2013). Unemployment benefits: how much money goes unclaimed? Federal Reserve Bank of St. Louis Economic Synopses No. 2013-18.
- [30] Gross, T., Notowidigdo, M.J., & Wang, J. (2016). The marginal propensity to consume over the business cycle. Working Paper, Northwestern University.
- [31] Gruber, J. (1997). The Consumption Smoothing Benefits of Unemployment Insurance. *The American Economic Review*, 87(1), 192-205.
- [32] Hagedorn, M., Karahan, F., Manovskii, I., & Mitman, K. (2016). Unemployment benefits and unemployment in the Great Recession: The role of macro effects. NBER Working Paper No. 19499.
- [33] Hagedorn, M., & Manovskii, I. (2008). The cyclical behavior of equilibrium unemployment and vacancies revisited. *American Economic Review*, 98(4), 1692-1706.
- [34] Hansen, G. D., & Imrohoroğlu, A. (1992). The role of unemployment insurance in an economy with liquidity constraints and moral hazard. *Journal of Political Economy*, 100(1), 118-142.
- [35] Herkenhoff, K., (2017). The impact of consumer credit access on unemployment. Working Paper, University of Minnesota.
- [36] Hopenhayn, H. A., & Nicolini, J. P. (1997). Optimal unemployment insurance. *Journal of Political Economy*, 105(2), 412-438.
- [37] Hornstein, A., Krusell, P., & Violante, G. L. (2011). Frictional wage dispersion in search models: A quantitative assessment. *American Economic Review*, 101(7), 2873-2898.
- [38] Johnston, A. C., & Mas, A. (2016). Potential unemployment insurance duration and labor supply: The individual and market-level response to a benefit cut. NBER Working Paper No. 22411.
- [39] Jung, P., & Kuester, K. (2015). Optimal labor-market policy in recessions. *American Economic Journal: Macroeconomics*, 7(2), 124-156.
- [40] Kaplan, G., & Violante, G. L. (2014). A model of the consumption response to fiscal stimulus payments. *Econometrica*, 82(4), 1199-1239.
- [41] Karahan, F., & Rhee, S. (2013). Geographical reallocation and unemployment during the great recession: The role of the housing bust.. New York Fed Staff Reports No. 605.

- [42] Kekre, R. (2017). Unemployment insurance in macroeconomic stabilization. Working Paper, University of Chicago.
- [43] Koehne, S., & Kuhn, M. (2015). Should unemployment insurance be asset tested?. *Review of Economic Dynamics*, 18(3), 575-592.
- [44] Kroft, K., Lange, F., Notowidigdo, M. J., & Katz, L. F. (2016). Long-term unemployment and the Great Recession: the role of composition, duration dependence, and nonparticipation. *Journal of Labor Economics*, 34(S1), S7-S54.
- [45] Kroft, K., & Notowidigdo, M. J. (2016). Should unemployment insurance vary with the unemployment rate? Theory and evidence. *Review of Economic Studies*, 83(3), 1092-1124.
- [46] Krusell, P., Mukoyama, T., & Şahin, A. (2010). Labour-market matching with precautionary savings and aggregate fluctuations. *Review of Economic Studies*, 77(4), 1477-1507.
- [47] Krusell, P., Mukoyama, T., Şahin, A., & Smith Jr., A. A. (2009). Revisiting the welfare effects of eliminating business cycles. *Review of Economic Dynamics*, 12(3), 393-404.
- [48] Landais, C., Michailat, P., & Saez, E. (2017). A macroeconomic approach to optimal unemployment insurance: Applications. *American Economic Journal: Economic Policy*, forthcoming.
- [49] Lentz, R. (2009). Optimal unemployment insurance in an estimated job search model with savings. *Review of Economic Dynamics*, 12(1), 37-57.
- [50] Lise, J., & Robin, J.-M. (2017). The macrodynamics of sorting between workers and firms. *American Economic Review*, 107(4), 1104-1135.
- [51] Lucas, Jr., R. E. (1987). *Models of business cycles*. Basil Blackwell, New York.
- [52] Marinescu, I. (2017). The general equilibrium impacts of unemployment insurance: Evidence from a large online job board. *Journal of Public Economics*, 150, 14-29.
- [53] Menzio, G., & Shi, S. (2010). Block recursive equilibria for stochastic models of search on the job. *Journal of Economic Theory*, 145(4), 1453-1494.
- [54] Menzio, G., & Shi, S. (2011). Efficient search on the job and the business cycle. *Journal of Political Economy*, 119(3), 468-510.
- [55] Mitman, K., & Rabinovich, S. (2014). Do unemployment benefits explain the emergence of jobless recoveries? Working Paper, Stockholm University.

- [56] Mitman, K., & Rabinovich, S. (2015). Optimal unemployment insurance in an equilibrium business-cycle model. *Journal of Monetary Economics*, 71, 99-118.
- [57] Nakajima, M. (2012). A quantitative analysis of unemployment benefit extensions. *Journal of Monetary Economics*, 59(7), 686-702.
- [58] Parker, J.A., Souleles, N.S., Johnson, D.S, & McClelland, R. (2013). Consumer spending and the economic stimulus payments of 2008. *American Economic Review*, 103(6), 2530-2553.
- [59] Rothstein, J. (2011). Unemployment insurance and job search in the Great Recession. *Brookings Papers on Economic Activity*, 143-214.
- [60] Rothstein, J., and Valletta, R.G. (2017). Scraping by: Income and program participation after the loss of extended unemployment benefits. NBER Working Paper No. 23528.
- [61] Saporta-Eksten, I. (2014). Job loss, consumption, and unemployment insurance. Working Paper, Stanford University.
- [62] Shavell, S., & Weiss, L. (1979). The optimal payment of unemployment insurance benefits over time. *Journal of Political Economy*, 87(6), 1347-1362.
- [63] Shi, S. (2001). Frictional assignment. I. Efficiency. *Journal of Economic Theory*, 98(2), 232-260.
- [64] Shimer, R. (2005). The cyclical behavior of equilibrium unemployment and vacancies. *American Economic Review*, 95(1), 25-49.
- [65] Shimer, R., & Werning, I. (2008). Liquidity and insurance for the unemployed. *American Economic Review*, 98(5), 1922-1942.
- [66] Stephens Jr., M. (2004). Job loss expectations, realizations, and household consumption behavior. *Review of Economics and Statistics*, 86(1), 253-269.
- [67] Valletta, R., & Kuang, K. (2010). Extended unemployment and UI benefits. Federal Reserve Bank of San Francisco Economic Letter No. 2010-12.
- [68] Vroman, W. (1991). The decline in unemployment insurance claims activity in the 1980s. Unemployment Insurance Occasional Paper 91-2, Washington, DC: U.S. Department of Labor-ETA.
- [69] Wang, C., & Williamson, S. D. (2002). Moral hazard, optimal unemployment insurance, and experience rating. *Journal of Monetary Economics*, 49(7), 1337-1371.

- [70] Yashiv, E. (2007). US labor market dynamics revisited. *Scandinavian Journal of Economics*, 109(4), 779-806.

# Appendix

## A. Data

### A.1. SIPP Data

We use the U.S. Census Bureau's Survey of Income and Program Participation (SIPP) to document the liquid asset holdings of individuals. The SIPP is a longitudinal survey that follows individuals for a duration of up to five years, with interviews being 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, labor force 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. Most 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. We use the 2004 panel of the SIPP, which contains 12 waves covering information between January 2004 and December 2007. This particular panel allows us to observe data on asset holdings at Waves 3 and 6. Since it is the closest date to the Great Recession, we calculate the asset distribution using Wave 6.

### A.2. Asset Distribution

We focus on the 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, amount in non-interest-earning checking accounts, equity in stocks and mutual funds, and face value of U.S. savings bonds. Moreover, for married individuals, the survey asks about the amount 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 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 liquid asset holdings for each individual.<sup>55</sup>

The SIPP also provides information about the monthly gross job earnings for each individual. We use this information to determine the monthly gross labor income of the individual. If the individual is unemployed during the interview month, we use her gross labor income associated with the last employment from earlier waves. Next, using the weekly employment status of the individual for that month, we calculate the weekly gross labor income of the individual by dividing monthly gross labor income by the number of weeks with a job during the interview month.

We then calculate annual income and payroll tax rates using the statutory U.S. income tax codes in the following steps. First, we calculate the annual income of each individual. Annual income includes labor income, capital income, and all kinds of government transfers including UI received in the fiscal year. Next, we apply the year-specific federal income tax schedule to the annual income net of year-specific personal exemptions and deductions to obtain the total annual income tax for each respondent. After that, we calculate the total annual payroll tax (Social Security and Medicare tax) for each individual. We obtain the total annual payroll tax for each individual by applying the year-specific Social Security and Medicare tax schedule to the total annual labor income of the individual for the time period.<sup>56</sup> Then, our measure for the tax rate is

$$\tau = \frac{\text{Share of labor income} \times \text{Annual income tax} + \text{Annual payroll tax}}{\text{Annual labor income}},$$

where the share of labor income is the ratio of annual labor income to annual income. We then apply the tax rate  $\tau$  for each individual in our sample and obtain weekly after-tax labor income. Last, dividing the liquid asset holdings measure to weekly after-tax labor income gives us the asset-to-income ratio for each

---

<sup>55</sup>Net financial asset holdings are calculated as follows by using the following variables in 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 own name (joint account), TALSbv is the face value of U.S. savings bonds, TIMIA (TIMJA) is amount of bonds/securities in own name (joint account), TIAITA (TIAJTA) is the amount in interest earning account in own name (joint account), ESMIV (ESMJV) value of stocks/funds in own name (joint account), and EALIDAB (EALJDAB) amount owed for store bills/credit cards in own 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 +THHVEHCL /number of persons within the household age 16 and above.

<sup>56</sup>We also consider the fact that there is a maximum taxable annual labor income for Social Security tax, while Medicare tax does not have such a limit. As a result, we get total annual tax as the sum of total annual income and payroll taxes.

individual.

## B. Proofs

### B.1. Opportunity cost of employment

In this section, we show the derivations of Equations (12) and (13) in the main text.

First, substituting (1) and (2) into (8), we have

$$\begin{aligned}
S^{UE}(a, w^{UE}, \beta; p) &= V^W(a, \tilde{w}(a, w^{UE}, \beta; p), \beta; p) - V^{UE}(a, w^{UE}, \beta; p) \\
&= u(c^W) - u(c^{UE}) + \nu(s) \\
&\quad + \beta \mathbb{E}[\delta(p') [(1 - e(p')) V^{UE}(a'^W, \tilde{w}(a, w^{UE}, \beta; p), \beta'; p') + e(p') V^{UI}(a'^W, \beta'; p')]] \\
&\quad + \beta \mathbb{E}[(1 - \delta(p')) V^W(a'^W, \tilde{w}(a, w^{UE}, \beta; p), \beta'; p')] \\
&\quad - \beta \mathbb{E}\left[ sf(\theta(\tilde{w}(a'^{UE}, w^{UE}, \beta'; p'); p')) V^W(a'^{UE}, \tilde{w}(a'^{UE}, w^{UE}, \beta'; p'), \beta'; p') \right] \\
&\quad - \beta \mathbb{E}[(1 - sf(\theta(\tilde{w}(a'^{UE}, w^{UE}, \beta'; p'); p')))(1 - e(p')) V^{UE}(a'^{UE}, w^{UE}, \beta'; p')] \\
&\quad - \beta \mathbb{E}[(1 - sf(\theta(\tilde{w}(a'^{UE}, w^{UE}, \beta'; p'); p')) e(p') V^{UI}(a'^{UE}, \beta'; p')]
\end{aligned}$$

In order to obtain (12), we add and subtract terms, rearrange them, then use (10), and divide both sides by  $\lambda^W$ . This yields

$$\begin{aligned}
\frac{S^{UE}(a, w^{UE}, \beta; p)}{\lambda^W} &= \frac{u(c^W) - u(c^{UE}) + \nu(s)}{\lambda^W} \\
&\quad + \frac{\beta}{\lambda^W} \mathbb{E}\left[ sf(\theta(\tilde{w}(a'^{UE}, w^{UE}, \beta'; p'); p')) \right. \\
&\quad \times (V^W(a'^W, \tilde{w}(a, w^{UE}, \beta; p), \beta'; p') - V^W(a'^{UE}, \tilde{w}(a'^{UE}, w^{UE}, \beta'; p'), \beta'; p')) \left. \right] \\
&\quad + \frac{\beta}{\lambda^W} \mathbb{E}\left[ (1 - sf(\theta(\tilde{w}(a'^{UE}, w^{UE}, \beta'; p'); p')) - \delta(p') e(p')) \right. \\
&\quad \times (V^{UE}(a'^W, \tilde{w}(a, w^{UE}, \beta; p), \beta'; p') - V^{UE}(a'^{UE}, w^{UE}, \beta'; p')) \left. \right] \\
&\quad + \frac{\beta}{\lambda^W} \mathbb{E}\left[ (1 - \delta(p') - sf(\theta(\tilde{w}(a'^{UE}, w^{UE}, \beta'; p'); p'))) \right. \\
&\quad \times (V^W(a'^W, \tilde{w}(a, w^{UE}, \beta; p), \beta'; p') - V^W(a'^W, \tilde{w}(a'^W, \tilde{w}(a, w^{UE}, \beta; p), \beta'; p'), \beta'; p')) \left. \right] \\
&\quad + \frac{\beta}{\lambda^W} \mathbb{E}\left[ (1 - sf(\theta(\tilde{w}(a'^{UE}, w^{UE}, \beta'; p'); p')) - \delta(p')) e(p') \right. \\
&\quad \times (V^{UE}(a'^{UE}, w^{UE}, \beta'; p') - V^{UI}(a'^{UE}, \beta'; p')) \left. \right] \\
&\quad + \beta \mathbb{E}\left[ \frac{\lambda'^W}{\lambda^W} \frac{(1 - \delta(p') - sf(\theta(\tilde{w}(a'^{UE}, w^{UE}, \beta'; p'); p')) S(a'^W, \tilde{w}(a, w^{UE}, \beta; p), \beta'; p'))}{\lambda'^W} \right]
\end{aligned}$$

where the summation of the second and third terms on the right-hand side is  $-z_a^{UE}$ , the fourth term is  $-z_w^{UE}$ , and the fifth term is  $-z_{elg}^{UE}$ . Given the form of the utility function, we cannot isolate  $z_{flow}^{UE}$  from the first term on the right-hand side. However, since we know that the flow value of employment is  $\tilde{w}(a, w^{UE}, \beta; p) \times (1 - \tau)$ , we can numerically calculate  $z_{flow}^{UE}$  using the above equation as follows:

$$z_{flow}^{UE} = \frac{S^{UE}(a, w^{UE}, \beta; p)}{\lambda^W} - \tilde{w}(a, w^{UE}, \beta; p) \times (1 - \tau) + z_a^{UE} + z_w^{UE} + z_{elg}^{UE} - \beta \mathbb{E} \left[ \frac{\lambda'^W (1 - \delta(p') - sf(\theta(\tilde{w}(a'^{UE}, w^{UE}, \beta'; p'); p'))) S(a'^W, \tilde{w}(a, w^{UE}, \beta; p), \beta'; p')}{\lambda'^W} \right].$$

This gives us the opportunity cost of employment for the eligible unemployed  $z^{UE} = z_{flow}^{UE} + z_a^{UE} + z_w^{UE} + z_{elg}^{UE}$  for each state  $(a, w^{UE}, \beta; p)$ .

Second, substituting (1) and (3) into (9), we have

$$\begin{aligned} S^{UI}(a, \beta; p) &= V^W(a, \tilde{w}(a, \beta; p), \beta; p) - V^{UI}(a, \beta; p) \\ &= u(c^W) - u(c^{UI}) + \nu(s) \\ &\quad + \beta \mathbb{E} [\delta(p') [(1 - e(p')) V^{UE}(a'^W, \tilde{w}(a, \beta; p), \beta'; p') + e(p') V^{UI}(a'^W, \beta'; p')]] \\ &\quad + \beta \mathbb{E} [(1 - \delta(p')) V^W(a'^W, \tilde{w}(a, \beta; p), \beta'; p')] \\ &\quad - \beta \mathbb{E} [sf(\theta(\tilde{w}(a'^{UI}, \beta'; p'); p')) V^W(a'^{UI}, \tilde{w}(a'^{UI}, \beta'; p'), \beta'; p')] \\ &\quad - \beta \mathbb{E} [(1 - sf(\theta(\tilde{w}(a'^{UI}, \beta'; p'); p')))] V^{UI}(a'^{UI}, \beta'; p') \end{aligned}$$

Similarly, in order to obtain (13), we again add and subtract terms, rearrange them, then use (11), and divide both sides by  $\lambda^W$ . This yields

$$\begin{aligned} \frac{S^{UI}(a, \beta; p)}{\lambda^W} &= \frac{u(c^W) - u(c^{UI}) + \nu(s)}{\lambda^W} \\ &\quad + \frac{\beta}{\lambda^W} \mathbb{E} [sf(\theta(\tilde{w}(a'^{UI}, \beta'; p'); p')) [V^W(a'^W, \tilde{w}(a, \beta; p), \beta'; p') - V^W(a'^{UI}, \tilde{w}(a'^{UI}, \beta'; p'), \beta'; p')]] \\ &\quad + \frac{\beta}{\lambda^W} \mathbb{E} [(1 - sf(\theta(\tilde{w}(a'^{UI}, \beta'; p'); p')))] [V^{UI}(a'^W, \beta'; p') - V^{UI}(a'^{UI}, \beta'; p')] \\ &\quad + \frac{\beta}{\lambda^W} \mathbb{E} [(1 - \delta(p') - sf(\theta(\tilde{w}(a'^{UI}, \beta'; p'); p')))] \\ &\quad \times [V^W(a'^W, \tilde{w}(a, \beta; p), \beta'; p') - V^W(a'^W, \tilde{w}(a'^W, \beta'; p'), \beta'; p')] \\ &\quad + \frac{\beta}{\lambda^W} \mathbb{E} [\delta(p') (1 - e(p')) [V^{UE}(a'^W, \tilde{w}(a, \beta; p), \beta'; p') - V^{UI}(a'^W, \beta'; p')]] \\ &\quad + \beta \mathbb{E} \left[ \frac{\lambda'^W (1 - \delta(p') - sf(\theta(\tilde{w}(a'^{UI}, \beta'; p'); p'))) S^{UI}(a'^W, \beta'; p')}{\lambda'^W} \right], \end{aligned}$$

where the summation of the second and third terms on the right-hand side is  $-z_a^{UI}$ , the fourth term is  $-z_w^{UI}$ , and the fifth term is  $-z_{elg}^{UI}$ . Similarly, we numerically calculate  $z_{flow}^{UI}$  as follows:

$$z_{flow}^{UI} = \frac{S^{UI}(a, \beta; p)}{\lambda^W} - \tilde{w}(a, \beta; p) \times (1 - \tau) + z_a^{UI} + z_w^{UI} + z_{elg}^{UI} - \beta \mathbb{E} \left[ \frac{\lambda'^W (1 - \delta(p') - sf(\theta(\tilde{w}(a'^{UI}, \beta'; p'); p'))) S^{UI}(a'^W, \beta'; p')}{\lambda'^W} \right].$$

This gives us the opportunity cost of employment for the eligible unemployed  $z^{UI} = z_{flow}^{UI} + z_a^{UI} + z_w^{UI} + z_{elg}^{UI}$  for each state  $(a, \beta; p)$ .<sup>57</sup>

## B.2. Block Recursive Equilibrium

**Proposition 1:** *If i) utility function  $u(\cdot)$  is strictly increasing, strictly concave, and satisfies Inada conditions;  $v(\cdot)$  is strictly increasing and strictly convex, ii) choice sets  $\mathcal{W}$  and  $\mathcal{A}$ , and sets of exogenous processes  $\mathcal{P}$  and  $\mathcal{B}$  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 Block Recursive Equilibrium for this economy. If, in addition,  $M = \min\{v, S\}$ , then the Block Recursive Equilibrium is the only recursive equilibrium.*

**Proof:** The proof presented here follows from Karahan and Rhee (2013) and Herkenhoff (2017), which are extensions of Menzio and Shi (2010, 2011). We extend the former's proof to a model in which government finances the time-varying UI benefits and show that the model still admits block recursivity. We then use the model to study how UI policy must vary over the business cycle. In doing so, the additional assumption we make here is to restrict the class of UI policies to be a function of current aggregate labor productivity.

Existence:

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

Let  $\mathcal{J}(\mathcal{W}, \mathcal{P})$  be the set of bounded and continuous functions  $J$  such that  $J : \mathcal{W} \times \mathcal{P} \rightarrow \mathbb{R}$  and let  $T_J$  be an operator associated with (4) such that  $T_J : \mathcal{J} \rightarrow \mathcal{J}$ . Then, using Blackwell's sufficiency conditions for

---

<sup>57</sup>In this numerical calculation, we calculate the opportunity cost under fixed wages and disregard  $z_w^{UE}$  and  $z_w^{UI}$ .

a contraction and the assumptions of the boundedness of sets of exogenous processes  $\mathcal{P}$  and  $\mathcal{B}$ , and choice sets  $\mathcal{W}$  and  $\mathcal{A}$ , we can show that  $T_J$  is a contraction and has a unique fixed point  $J^* \in \mathcal{J}$ . Thus, the firm value function satisfying (4) depends on the aggregate state of the economy  $\mu$  only through the aggregate labor productivity  $p$ . This means that the set of wages posted by the firms in equilibrium  $\mathcal{W}$  is determined by the aggregate labor productivity  $p$  as well. Then, plugging  $J^*$  into (6) yields

$$\theta^*(w; p) = \begin{cases} q^{-1} \left( \frac{\kappa}{J^*(w;p)} \right) & \text{if } w \in \mathcal{W}(p) \\ 0 & \text{otherwise} \end{cases}$$

Notice that, as explained in the main text, 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 a function of  $\theta$  only.<sup>58</sup> Hence, we show that equilibrium market tightness does not depend on the distribution of agents across states as well.

Next, using this result and the assumption that the UI policy only depends on  $p$ , we show that the household value functions do not depend on the aggregate distribution of agents across states. To do so, we first 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 value function  $R : \{0, 1\} \times \{0, 1\} \times \mathcal{A} \times \mathcal{W} \times \mathcal{B} \times \Omega \rightarrow \mathbb{R}$  such that

$$\begin{aligned} R(l = 1, d = 0, a, w, \beta; \mu) &= V^W(a, w, \beta; \mu) \\ R(l = 0, d = 1, a, w, \beta; \mu) &= V^{UE}(a, w, \beta; \mu) \\ R(l = 0, d = 0, a, w, \beta; \mu) &= V^{UI}(a, \beta; \mu) \end{aligned}$$

Then, we define the set of functions  $\mathcal{R} : \{0, 1\} \times \{0, 1\} \times \mathcal{A} \times \mathcal{W} \times \mathcal{B} \times \mathcal{P} \rightarrow \mathbb{R}$  and let  $T_R$  be an operator such that

---

<sup>58</sup>The free entry condition (6) is also important to pin down market tightness.

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

subject to

$$\begin{aligned}
c + a' &\leq (1 + r)a + lw(1 - \tau) + (1 - l)d[\phi(p)w(1 - \tau) + h] + (1 - l)(1 - d)h \\
a' &\geq -\underline{a} \\
p' &\sim F(p' | p)
\end{aligned}$$

where we use the result from above that market tightness does depend on  $\Gamma$ .

Assuming the utility function is bounded and continuous,  $\mathcal{R}$  is the set of continuous and bounded functions. Then, we can show that the operator  $T_R$  maps a function from  $\mathcal{R}$  into  $\mathcal{R}$  (i.e.,  $T_R : \mathcal{R} \rightarrow \mathcal{R}$ ). Then, using Blackwell's sufficiency conditions for a contraction and the assumptions of boundedness of sets of exogenous processes  $\mathcal{P}$  and  $\mathcal{B}$ , 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  $\left\{ g_a^l(a, w, \beta; p) \right\}_{l=\{W, UE\}}$ , and  $g_a^{UI}(a, \beta; p)$ , wage choice  $g_w^{UE}(a, w, \beta; p)$  and  $g_w^{UI}(a, \beta; p)$ , and search effort  $g_s^{UE}(a, w, \beta; p)$  and  $g_s^{UI}(a, \beta; p)$ .

**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  $\mathcal{B}$ , and choice sets  $\mathcal{W}$  and  $\mathcal{A}$ , value functions  $V^l$  are strictly concave in  $w$  for  $l = \{W, UE\}$  and  $V^{UI}$  is constant in  $w$ . For simplicity, assume that  $p$  is non-stochastic and

$\delta(p) = \delta$ . We then obtain the equilibrium value of a matched firm using Equation (4) as follows:<sup>59</sup>

$$J^*(w; p) = \frac{p - w}{r + \delta} (1 + r)$$

Then, we can write the equilibrium labor market tightness as

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

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

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

This implies that 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

$$\max_{\tilde{w}} sf(\theta(\tilde{w}; p)) V^W(a', \tilde{w}, \beta'; p) + (1 - sf(\theta(\tilde{w}; p))) [(1 - e(p)) V^{UE}(a', w, \beta'; p) + e(p) V^{UI}(a', \beta'; p)].$$

Using the result that  $V^l$  is strictly concave in  $w$  for  $l = \{W, UE\}$  and  $V^{UI}$  is constant in  $w$ , and that  $f(\cdot)$  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  $g_w^{UE}(a, w, \beta; p)$  is unique.

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

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

and using the same reasoning implies that the wage policy function  $g_w^{UI}(a, \beta; p)$  is also unique.

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

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

---

<sup>59</sup>The following results can be obtained under  $N$  state Markov process assumption for  $p$  and no restrictions on the job destruction rate.

functions  $g_s^{UE}(a, w, \beta; p)$  and  $g_s^{UI}(a, \beta; p)$  are unique.

### C. Welfare Calculation for Great Recession Simulation

First, we focus on individual  $i$ . Let  $t = 0$  be December 2007 and let  $T$  be December 2013. For ease of exposition, we discuss the calculation of welfare in two separate parts: let period (A) include any time  $t \in [0, \dots, T]$  during the Great Recession and recovery and (B) represent the terminal time period post-December 2013  $t > T$ .

Let  $c_i^j(\mathbf{x}_t, p_t)$  and  $s_i^j(\mathbf{x}_t, p_t)$  denote the consumption and search effort policy functions of individual  $i$  with individual state  $\mathbf{x}_t$  at time  $t$  when aggregate productivity is  $p_t$  and UI policy is  $j \in \{b, f, n\}$ , where  $b$  denotes the benchmark policy,  $f$  denotes the flat policy, and  $n$  denotes the new/alternative policy.<sup>60</sup> To evaluate the welfare gains from the optimal policy in this exercise, we set policy  $n$  to be the optimal policy.

First consider welfare in period (A). Under the benchmark policy  $b$ , the utility of individual  $i$  during period (A) when endowed with additional  $\bar{\pi}$  percent of consumption for her lifetime is given by

$$\sum_{t=0}^T (\beta_{i,t})^t U(c_i^b(\mathbf{x}_t, p_t)(1 + \bar{\pi}), s_i^b(\mathbf{x}_t, p_t)),$$

where  $U(c_i^b(\mathbf{x}_t, p_t)(1 + \bar{\pi}), s_i^b) = \frac{[c_i^b(\mathbf{x}_t, p_t)(1 + \bar{\pi})]^{1-\sigma}}{1-\sigma} - \mathbf{1}_U \left[ \alpha \frac{s_i^b(\mathbf{x}_t, p_t)^{1+\chi}}{1+\chi} \right]$ . Note that in the above expression,  $\{p_t\}_{t=0}^T$  represents the labor productivity that is fed into the model during the recession, while  $\{\beta_{i,t}\}_{t=0}^T$  represents the realized values of discount factor  $\beta$ . Agents, however, take expectations on aggregate labor productivity using the AR(1) process.

Now consider period (B). The continuation value of the individual post-December 2013 is given by

$$\mathbb{E}_{T+1} \sum_{t=T+1}^{\infty} (\beta_{i,t})^t U(c_i^j(\mathbf{x}_t, p_t)(1 + \bar{\pi}), s_i^j(\mathbf{x}_t, p_t)),$$

which recursively can be written as  $(\beta_{i,T+1})^{T+1} V_{\bar{\pi}}^{l_i, j}(a_{T+1}, w_{T+1}, \beta_{T+1}, p_{T+1})$  where  $V_{\bar{\pi}}^{l_i, j}$  denotes the value of individual  $i$  with labor force status  $l_i \in \{W, UE, UI\}$  under the policy  $j$  when consumption is multiplied by  $1 + \bar{\pi}$  every period from  $t = T + 1$  onward. Computationally, we can find  $V_{\bar{\pi}}^{l_i}$  once we have obtained the policy functions associated with the underlying value function  $V^{l_i}$ . We do this recursively by policy function iteration with the difference being that consumption is multiplied by  $(1 + \bar{\pi})$  at every iteration. Under the original exercise where the policy is permanent, we set  $j = b$ , while under the exercise when the policy is discretionary/temporary, the government reverts back to the flat policy postrecession and thus  $j = f$ .

---

<sup>60</sup>Notice here that we are using the result that policy functions of the agents in our economy depend on the aggregate state of economy only through  $p$  as a result of block recursivity.

Hence, the welfare of agent  $i$  who is endowed with an additional  $\bar{\pi}$  percent of lifetime consumption over periods (A) and (B) under the baseline policy  $b$  can be written as

$$\sum_{t=0}^T \left[ (\beta_{i,t})^t U(c_i^b(\mathbf{x}_t, p_t)(1 + \bar{\pi}), s_i^b(\mathbf{x}_t, p_t)) \right] + (\beta_{i,T+1})^{T+1} V_{\bar{\pi}}^{l_i,j}(a_{T+1}, w_{T+1}, \beta_{T+1}, p_{T+1}).$$

Now, aggregating across individuals at each point in time, we can write the left-hand side of Equation (15) as

$$\sum_{t=0}^T \left[ \int_i (\beta_{i,t})^t U(c_i^b(\mathbf{x}_t, p_t)(1 + \bar{\pi}), s_i^b(\mathbf{x}_t, p_t)) d\Gamma_t^b(i) \right] + \int_i (\beta_{i,T+1})^{T+1} V_{\bar{\pi}}^{l_i,j}(a_{T+1}, w_{T+1}, \beta_{T+1}, p_{T+1}) d\Gamma_{T+1}^b(i), \quad (\text{A.1})$$

where  $\Gamma_t^b$  is the distribution of the economy at time  $t$  under policy  $b$ .

Similarly, the right-hand-side of equation (15) is computed by solving

$$\sum_{t=0}^T \left[ \int_i (\beta_{i,t})^t U(c_i^n(\mathbf{x}_t, p_t), s_i^n(\mathbf{x}_t, p_t)) d\Gamma_t^n(i) \right] + \int_i (\beta_{i,T+1})^{T+1} V^{l_i,j}(a_{T+1}, w_{T+1}, \beta_{T+1}, p_{T+1}) d\Gamma_{T+1}^n(i), \quad (\text{A.2})$$

where  $\Gamma_t^n$  is the corresponding distribution under policy  $n$  and the superscript  $j$  of the value function in (B) depends on whether the policy is permanent ( $j = n$ ) or temporary ( $j = f$ ).

Under a temporary policy, we emphasize that even if the policy reverts to the flat policy  $f$  after December 2013, the terminal value will be different for policy  $b$  and  $n$  because the distribution of each economy at  $t = T + 1$  is going to be different from each other (i.e.,  $\Gamma_{T+1}^b \neq \Gamma_{T+1}^n$ ).

Then, we simply use a zero-finder to find  $\bar{\pi}$  that makes equations (A.1) and (A.2) the same.<sup>61</sup>

## D. Model with Endogenous Quits

In this section, we present the extended model that incorporates the endogenous quit decisions of workers.

### Worker's Problem

Under the model with quits, workers matched with a firm can decide to leave employment. After the separation shock realizes, a firm-worker pair that is not dissolved exogenously may endogenously be separated

---

<sup>61</sup>Note that there is no closed-form solution for  $\bar{\pi}$  given the functional form of the utility function.

if the worker chooses to quit. The worker's problem is now given by

$$V^W(a, w, \beta; \mu) = \max_{c, a'} u(c) + \beta \mathbb{E} \left[ \delta(p') [(1 - e(p')) V^{UE}(a', w, \beta'; \mu') + e(p') V^{UI}(a', \beta'; \mu')] \right. \\ \left. + (1 - \delta(p')) \max_{d \in \{0,1\}} \left\{ dV^{UI}(a', \beta'; \mu') + (1 - d)V^W(a', w, \beta'; \mu') \right\} \right] \quad (\text{A.3})$$

subject to

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

$$a' \geq -\underline{a}$$

$$\Gamma' = H(\mu, p') \quad \text{and} \quad p' \sim F(p' | p).$$

### Firm's Problem

The value of a matched firm is modified to account for the possibility of a quit. Even if a match is not dissolved by the exogenous shock  $\delta$ , it can be dissolved if the worker's decision to quit is  $g_d = 1$ :

$$J(a, w, \beta; \mu) = p - w + \frac{1}{1 + r} \mathbb{E} \left[ (1 - \delta(p')) (1 - g_d(a', w, \beta', \mu')) J(a', w, \beta'; \mu') \mid \beta, \mu \right] \quad (\text{A.4})$$

subject to

$$\Gamma' = H(\mu, p') \quad \text{and} \quad p' \sim F(p' | p),$$

where  $a' = g_a(a, w, \beta, \mu)$ .

So, the value of posting a vacancy is given by

$$V(a, w, \beta; \mu) = -\kappa + q(\theta(a, w, \beta; \mu)) J(a, w, \beta; \mu) \quad (\text{A.5})$$

and market tightness can be obtained by solving

$$\theta(a, w, \beta; \mu) = \begin{cases} q^{-1} \left( \frac{\kappa}{J(a, w, \beta; \mu)} \right) & \text{if } w \in \mathcal{W}(\mu) \\ 0 & \text{otherwise.} \end{cases} \quad (\text{A.6})$$

Notice that the value of a firm  $J$  depends on individual states  $\mathbf{x} = (a, w, \beta, b)$  because heterogeneous workers will have different quit thresholds. This would then imply that market tightness  $\theta$  is also a function of these states.

## Unemployed's Problem

The unemployed's problem remains unchanged, except that market tightness is now a function of other individual states  $\mathbf{x} = (a, w, \beta, b)$  for reasons stated in the firm's problem.

## E. Computational Algorithm

### E.1 Solving the Baseline Model

The model is solved using the following steps:

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

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

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

3. Given the function  $\theta$ , we can then solve for the household value functions  $V^W$ ,  $V^{UE}$ , and  $V^{UI}$  using standard value function iteration. In order to decrease 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.

### E.2 Extended Model with Endogenous Quits

Solving the model will require modifying the baseline algorithm above as follows:

1. Guess a market tightness function  $\theta_0(a', w, \beta', p')$ .
2. Taking  $\theta_0$  as given, solve for the household's problem.
3. Using the household's policy function  $g_d^W(\theta_0)$  and  $g_a^W(\theta_0)$ , solve for the firm's problem.
4. After obtaining  $J_0(a, w, \beta, p)$ , use Equation A.6 to back out the implied market tightness  $\theta_1(a', w, \beta', p')$ .
5. If convergence criterion  $\|\theta_1 - \theta_0\| \leq \epsilon_\theta$  is not satisfied, use  $\theta_1$  as a guess and repeat the steps outlined above.