Long-term Unemployment Dynamics and Unemployment Insurance Extensions*

W Similan Rujiwattanapong†
University College London and Centre for Macroeconomics

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Abstract

This paper investigates the impact of unemployment insurance (UI) extensions on the incidence of long-term unemployment and on the unemployment duration distribution in the US. Using a search and matching model with endogenous separations, variable job search intensity, on-the-job search and worker heterogeneity, I allow for the maximum UI duration to depend on unemployment rate and for UI benefits to depend on match quality during employment. The model can account for a large fraction of the observed rise in the long-term unemployment and realistic dynamics of the unemployment duration distribution during the Great Recession. I show that eliminating all UI extensions during the Great Recession could potentially lower the unemployment rate by 0.9-3.4 percentage points primarily via the response of job separations. At the same time, it could drastically reduce the long-term unemployment rate by roughly 4 percentage points and the average unemployment duration by up to 27 weeks via the response of job search behaviour of insured unemployed workers. I find that once the worker heterogeneity in UI statuses and benefit levels has been accounted for, unobserved heterogeneity of workers does not account for much of the incidence of long-term unemployment.

JEL Classification. E24, E32, J24, J64, J65.

Keywords. Business cycles, long-term unemployment, unemployment insurance, unemployment duration

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†W Similan Rujiwattanapong: PhD candidate at Department of Economics, University College London, Gordon Street, WC1H 0AX, UK. Email: wongkot.rujiwattanapong.10@ucl.ac.uk.

1 Introduction/Motivation

From the onset of the Great Recession, the US labour market exhibits dynamics never seen before in previous recessions. Underlying the persistently high unemployment is an unprecedented rise in the long-term unemployment (as represented by those whose unemployment duration is greater than 6 months) as seen in Figure 1. The long-term unemployment rate had never been above 2 percent apart from the early 1980s recession where it reached 2.5 percent. During the Great Recession, it went up to 4.4 percent representing 46 percent of the total unemployment population whilst its share was only 26 percent in the early 1980s recession.

This paper investigates the impact of unemployment insurance (UI) extensions on the long-term unemployment and the distribution of unemployment duration over the business cycles using a search and matching model in general equilibrium. While the analysis applies to the cyclical fluctuations in general, the focus of the paper is on the Great Recession, the period during which UI eligible unemployed workers could receive benefits for the maximum of 99 weeks (whereas the standard maximum UI duration is only 26 weeks) as depicted in Figure 2. From the same Figure, it can be seen that the UI duration has been extended during recessionary periods since late 1950s and its generosity, as measured by weeks of maximum UI duration, has been increasing over time (apart from one extension in the early 1980s). In the US, there are primarily two types of UI extensions: (1) automatic UI extensions that are in the federal laws since 1970s and are triggered by the state (insured) unemployment rate, and (2) discretionary UI extensions that are issued specifically during the recessions.[1] Figure 3 shows that both the automatic and total UI extensions have been increasing in their generosity and that discretionary extensions are a feature of every recession since late 1950s.

Based on this countercyclical UI system, I extend the standard search and matching model to incorporate unemployment-dependent UI extensions, variable search intensity, endogenous separations, on-the-job search, and worker's heterogeneity in terms of productivity and benefit level. The job search decision of a worker depends not only on their UI status, benefit level, and individual productivity but also on the aggregate productivity and the unemployment rate which determine when and for how long UI extensions will occur.

Many empirical studies have documented how the labour market outcomes of unemployed workers can differ with respect to their UI status. These differences come in many forms

[1] The automatic extensions are called extended benefits (EB) whilst the ad-hoc extensions are under different names. For example, in 1958, the programme was called Temporary Unemployment Compensation Act (TUC) and in 1961, it was Temporary Unemployment Extended Compensation Act (TEUC). From 1991 onwards, the discretionary extensions have been under the name Emergency Unemployment Compensation (EUC).

including their unemployment duration and unemployment exit rate (Moffitt and Nicholson (1982), Moffitt (1985), Katz and Meyer (1990), Meyer (1990), Card and Levine (2000)), job search intensity (Krueger and Mueller (2010, 2011)) and consumption (Gruber (1997)). Katz and Meyer (1990) find a large fraction of UI recipients expect to be recalled and represent over half of the unemployment duration in the sample. This is related to a recent work by Fujita and Moscarini (2015) who show that the recall rate rises during the recession and that the negative duration dependence in unemployment exit rate only occurs among those who are eventually recalled. I provide further empirical evidence regarding the differences in labour market outcomes of unemployed workers with and without UI by studying their transition rates from unemployment and the stocks of unemployment durations. I find that the differences in the unemployment exit rates between insured and uninsured unemployed workers are more pronounced in 2010, when UI was extended up to 99 weeks, than in 2008 when no extensions was in place. As a result, in 2010, over half of the long-term unemployed workers were represented by the insured unemployed whilst in 2008 they represented only 15 percent of the long-term unemployed.

There is a large literature studying the effects of the recent UI extensions on the unemployment exit rate and total unemployment during the Great Recession. Empirical studies include (but not limited to) Farber and Valletta (2011), Fujita (2011), Valletta and Kuang (2010), Mazumder (2011), Rothstein (2011), Hagedorn, Karahan, Manovskii, and Mitman (2015), Barnichon and Figura (2014), and Hagedorn, Manovskii, and Mitman (2015). Most of these studies focus on the "micro" effect of the UI extensions, namely, the direct impact of increasing maximum UI duration on the probability of exiting unemployment or on the job search decisions of the unemployed. They have found a small but significant impact of UI extensions. A notable exception is Hagedorn, Karahan, Manovskii, and Mitman (2015). They take into account the response of job creation to benefit extensions and find a larger effect on unemployment.

A benefit of using a general equilibrium model is that I can distinguish between the direct impact of UI extensions on the number of insured unemployed workers and the responses of job search behaviour, match formation and match separation. Based on the direct UI effect and the response from job search (which I classify as the "micro" effect), I find that the peak of the unemployment rate would be 0.9-1.7 percentage points smaller if there was no extensions during the Great Recession. This is consistent with estimates from the existing empirical literature that are in the range of 0.1-1.8 percentage points.[2] With respect to the general equilibrium effect where the response of match formation/separation decisions are

[2] Fujita (2011) finds the UI extensions contribute to 0.8-1.8 percentage points increase in the unemployment rate during the Great Recession. Aaronson et al (2010)'s estimates are between 0.5-1.25 percentage points. Valetta and Kuang (2010)'s estimate is 0.4 percentage points. Rothstein (2011)'s estimates are between 0.1-0.5 percentage points.

also considered, I find a larger impact of the UI extensions similar to results from Hagedorn et al (2015). In this paper, however, the additional effect is from the match separation margin.

Quantitative studies on the effects of UI extensions are conducted by Mitman and Rabinovich (2014) on jobless recoveries, Faig, Zhang and Zhang (2012) on the volatility of unemployment and vacancies, and Nakajima (2012) whose focus is on the Great Recession. Nakajima (2012) studies an economy with transition dynamics and finds that the UI extensions can contribute to the rise of 1.4 percentage points in the unemployment rate. The model in this paper is most similar to that in Mitman and Rabinovich (2014). They use an equilibrium search and matching model to study the impact of UI extensions on jobless recoveries. In their model, the discretionary UI extensions are treated as unexpected and assumed to last forever by the agents in the economy (i.e., agents have adaptive expectations) such that the model's simulated UI extensions are exactly the same as the data. In this paper, I assume all the UI extensions are systematic and the agents have rational expectations regarding the timing and the length of these UI extensions which are driven solely by the aggregate productivity (via unemployment rate).[3] As a result, agents in my model would respond less strongly to UI extensions in comparison to theirs, in terms of both the job search intensity and the decision to form or dissolve a match. Additionally, workers in my model have control over their job search intensity whilst in their model workers do not make decisions on how hard to look for a job. Therefore, unemployed workers in my model have heterogeneous job finding rates according to their UI status and benefit level whilst there is a single job finding rate for all unemployed workers in their model. As previously mentioned, I show in the empirical section of the paper that insured and uninsured unemployed workers do have different labour market outcomes and that this gap widened during the Great Recession.

Heterogeneity in the job finding rates is crucial in explaining the unemployment duration structure in the US labour market. As shown in Wiczer (2015), a single job finding rate implies the average unemployment duration and long-term unemployment that are just over half of what can be observed in the data. He offers an alternative explanation on the rise of long-term unemployment using occupational mismatch. His point regarding an inadequacy of a single job finding rate is key to the results in this paper. Not only unemployed workers in my model exit unemployment at different rates according to their UI status but even the insured workers themselves also have different exit rates due to different benefit levels.[4]

This paper also complements the literature on the incidence of the long-term unemployment and worker heterogeneity. Ahn and Hamilton (2016) use a state space model to uncover

[3] I show in the results section how consistent the model's generated UI extensions are with the data.

[4] In Rujiwattanapong (2016), I show that a single job finding rate for insured unemployed workers hardly affects the distribution of unemployment durations. In this paper, I allow for the job finding rates of insured unemployed workers to vary with the benefit level and individual-specific productivity.

the unobserved heterogeneity of workers in terms of unemployment exit rate. Worker heterogeneity is also the focus in Hornstein (2012) in accounting for unemployment dynamics with different durations. Ravn and Sterk (2013) consider this difference in unemployment exit rates together with incomplete markets and price rigidities to study the amplification mechanism on unemployment. Ahn (2016) extends Ahn and Hamilton (2016) to incorporate various observable characteristics of the workers (but not their UI statuses). My paper considers a degree of observed and unobserved worker heterogeneity where the former comes from the unemployment insurance status and the latter is from the worker's productivity which eventually affects the job finding rate.

To show how consistent the unemployment series at different durations from the model are with the empirical data, I estimate the same non-linear state space model in Ahn and Hamilton (2016) using Maximum Likelihood. I find the model's estimates are similar to the empirical values. This has implications on the sources of long-term unemployment. I show that their interpretation of unobserved heterogeneity is related to the UI statuses in my model since the insured unemployed workers have a lower unemployment exit rate. I find that the worker's productivity does not matter much once different UI statuses are taken into account.

The heterogeneity in unemployment exit rates results in the negative duration dependence that is purely compositional. At longer durations, the pool of unemployed workers is more represented by those with lower exit rates. The duration-dependent unemployment exit rate is a featured result in several studies including Clark and Summers (1979), Machin and Manning (1999) and Elsby, Hobijn, and Şahin (2008). Kroft, Lange, Notowidigdo and Katz (2014) analyse the impact of a genuine duration dependence in unemployment exit rate along with the labour force participation margin on the rise of long-term unemployment. They also find little account for the observable characteristics of the workers (but they do not include UI statuses in their analysis). Elsby, Hobijn, Şahin and Valetta (2011) study the flows between non-participation and unemployment at different unemployment durations. Aaronson, Mazumder, and Schechter (2010) analyse the impact of the transition rates between employment, unemployment and non-participation as well as the labour force demographics on the long-term unemployment. While the labour force participation margin is undoubtedly important in accounting for unemployment, the model in this paper abstracts from it. I show in the empirical section that the labour force exit rate varied only little during the Great Recession even when conditioned on the UI status and several observable characteristics of workers. Barnichon and Figura (2014) also find similar results that UI extensions did not affect the labour force participation rate in the past 35 years.

To preview the results, the model can account for a large fraction of the observed rise in the long-term unemployment and realistic dynamics of the unemployment duration distribution during the Great Recession. The main driver of the long-term unemployment is the response of job search behaviour to UI extensions whilst the job separation margin is more important in accounting for the observed rise in total unemployment. In a counterfactual exercise, I show that eliminating all UI extensions during the Great Recession could potentially lower the unemployment rate by 0.9-3.4 percentage points. At the same time, it could drastically reduce the long-term unemployment rate by roughly 4 percentage points and the average unemployment duration by up to 27 weeks. The micro effect of UI extensions is consistent with the existing literature as its effect on the unemployment rate is minimal. I also analyse the impact of Reachback provision, a programme that provides UI eligility to unemployed workers who have already exhausted their benefits prior to the extensions of UI and have found a small impact on unemployment.

The main contribution of this paper is to quantify the impact of UI extensions on the incidence of long-term unemployment and on the unemployment duration distribution in a general equilibrium model, taking into account the responses of job search, match formation and job separation under rational expectation regarding the maximum UI duration. The framework is useful for policy experiments to study the mechanisms through which the UI extensions affect the aggregate labour market.

The paper is organised as follows. Section 2 discusses some motivating data on UI extensions and long-term unemployment during the Great Recession. Section 3 describes the model. Section 4 discusses the calibration exercise. Section 5 analyses the results under the baseline model and counterfactual experiments, and it also discusses welfare implications. Section 6 measures how consistent the model's results are with the empirical data. Section 7 concludes.

2 Empirical Evidence

I first examine the empirical evidence that (1) workers currently receiving UI benefits tend to find a job at a slower rate than those without UI and that (2) this gap between insured and uninsured workers' job finding rates was more pronounced during the Great Recession. These findings are important for explaining the surge in the long-term unemployment. I study the transition rates from unemployment to employment, unemployment and out-of-labour-force (OLF) (namely UE, UU and UOLF rates respectively) as well as the distributions of unemployment duration between 2006 and 2014 according to the UI statuses and several other observable characteristics of unemployed workers including age, education, gender, industry, occupation, reasons for unemployment and recall expectation. They are constructed from the CPS Basic Monthly Data and CPS Displaced Worker, Employee Tenure, and Occupational

Mobility Supplement. I consider workers whose age is 16 years or older. Since the workers' UI history is only surveyed when the supplement takes place (every two years), I obtain the transition rates by merging the January supplement data with the basic monthly data for the following February. Transition rates are calculated as a fraction of unemployed workers conditioned on their UI status (i.e., whether they are currently receiving UI benefits or not) and possibly other characteristics moving into either employment, unemployment or OLF in the following month.

I focus on the changes in the transition rates in January 2008, when UI extensions were not in place, relative to January 2010, conveniently when the UI duration was just extended to 99 weeks in most states. Tables 2, 3 and 4 summarise respectively the UE, UU and UOLF rates in 2008 and 2010. I subsequently show that as a result of the increase in UE rate and the drop in UU rate, the share of long-term unemployed workers who were receiving UI benefits became larger in 2010 and 2012. The shares during 2006-2014 are summarised in Table 5. I contrast them with the shares of newly unemployed workers (with duration less than 5 weeks) who were receiving UI benefits in Table 6.

Job findings Table 2 shows that the job finding rate of current UI recipients is generally smaller than that of non-UI recipients and this gap became larger during the Great Recession. In January 2008, when there was no UI extensions, unemployed workers with and without UI found a job at rate 21 percent and 28 percent respectively, whilst in January 2010, when the maximum UI duration was 99 weeks, the job finding rate of insured unemployed workers fell dramatically to 7 percent, 11 percentage points smaller than that of the uninsured unemployed. The UE rate by UI status for 2006-2014 periods is plotted in Figure 4.

These findings are still consistent when I control for other observable characteristics of the workers. Insured workers had a lower job finding rate than uninsured workers in most subgroups in 2008 and in all subgroups in 2010.[5] The job finding rates from 2008 to 2010 for current UI recipients in most subgroups fell by a larger maginitude than for non-UI recipients.

To stay unemployed or to exit the labour force? Accompanying the drop in job findings during the Great Recession are an increase in the UU rate and a small change in the UOLF rate. This is the case regardless of the workers' UI statuses. Table 3 shows that from 2008 to 2010 the UU rate increased by 16 percentage points for workers with UI and by 12 percentage points for workers without UI. At the same time, Table 4 shows that the fall in the UOLF rate was only 2(3) percentage points for the (un)insured unemployed. This finding suggests that

[5]Current UI recipients in the following subgroups find a job at a faster rate than non-UI recipients: professional/business services, those on temporary layoff, those who are expecting a recall. However, workers in professional/business services have a much lower job finding rate in 2010 (at 4.3 percent) than in 2008 (at 46 percent). It is not surprising that insured workers knowing or expecting to be back at work have a job finding rate similar to uninsured workers in the same subgroups.

UI extensions do not significantly affect the labour force exit rate.[6] The same results apply when I condition on other observable characteristics of workers. I plot the UU and UOLF rates by UI status during 2006-2014 in Figures 5 and 6 respectively.

Distribution of unemployment duration I now shift the focus to the stocks of unemployment by durations. Figure 7 shows that the unemployment duration distribution shifted towards longer duration bins in 2010 and 2012. This is expected since the average job finding rate fell substantially during these periods, but what is interesting is that the shares of insured unemployed workers in longer duration bins also increased dramatically as depicted in Figure 8.

In fact, the share of long-term unemployed workers who were current UI recipients rose substantially from 15 percent to 51 percent between 2008 and 2010 as shown in Figure 9. This large increase in the share of current UI recipients during the Great Recession is a prominent feature in all subgroups considered as shown in Table 5.[7] In Figure 9, I contrast this with the shares of insured workers amongst the newly unemployed that did not increase as much.

In summary, insured unemployed workers tend to find a job at a slower rate than those without UI and this gap was more pronounced when the maximum UI duration was extended during the Great Recession. These results largely apply when I condition on several other observable characteristics of the workers. Accompanying the drop in the job finding rate was a substantial rise in the UU rate whilst the UOLF rate remained rather stable. Following the change in these transition rates, the long-term unemployment rose dramatically during the Great Recession and were mainly represented by insured unemployed workers.

3 Model

I present in this section a random search and matching model à la Pissarides (2000) with endogenous separations, variable job search intensity and on-the-job search. On top of this, I allow for the maximum UI duration to depend on the unemployment rate. Workers may differ in terms of UI status, benefit level and labour productivity. Only the last attribute is permanent. These differences not only affect how hard workers search for jobs but also how likely worker-firm matches are formed and dissolved. Workers with higher outside options, e.g. those with higher (potential) UI benefits, tend to exit unemployment more slowly and are more likely to quit.

[6] For simplicity, the model I present in the following section will therefore not feature the labour force participation margin.

[7] In most subgroups, there is at least a 30 percentage point increase in the share of current UI recipients from 2008 to 2010. This finding does not apply to two subgroups: workers with less than high school degree and workers with low-skilled occupations.

I begin this section by specifying technology and preferences of workers and firms as well as the UI duration policy and UI eligibility. I then discuss wage determination, and finally present the equilibrium conditions.

3.1 Technology and Preferences

Time is discrete and runs forever. There are two types of agents in the economy: a continuum of workers of measure one and a large measure of firms. Workers have either high or low productivity (type H or L). A match consists of one worker and one firm whose output depends on the aggregate productivity (z), its match-specific productivity (m), and type-i worker's productivity (η_i). Specifically,

$$y_{it}(m) \quad = \quad z_t \times m \times \eta_i \quad ; i \in \{H, L\}$$

The price of output $y_{it}(m)$ is normalised to one. The aggregate productivity z has the following AR(1) representation

$$\ln z_t \quad = \quad \rho_z \ln z_{t-1} + \varepsilon_t$$

where the only exogenous shock in the model ε_t is normally and independently distributed with mean zero and standard deviation σ_z. The match-specific productivity m is drawn at the start of every new worker-firm match from a distribution $F(m)$. At the rate $1-\lambda$, a given match keeps its match quality m to the next period, otherwise it has to redraw a new m from the same distribution $F(m)$ for its production next period. η_i is type-i worker's productivity where $\eta_L < \eta_H$ and η_H is normalised to 1. A worker's productivity is permanent.

With respect to preferences, both workers and firms are infinitely-lived and risk-neutral. They discount future flows by the same factor $\beta \in (0,1)$. Workers are either employed (e), insured unemployed (UI) or uninsured unemployed (UU). They exert job search effort s at the cost of $\nu_e(s)$ when employed, and at the cost $\nu_u(s)$ when unemployed regardless of their UI status. These search cost functions $\nu_e(.)$ and $\nu_u(.)$ are strictly increasing and convex. During unemployment, workers' job search intensity may vary depending on their UI status, benefit level and productivity, whilst during employment, it depends on their match quality and productivity. For employment status $j \in \{e,u\}$, a worker's period utility flow is $c_i - \nu_j(s)$ where c_i is type-i worker's consumption:

$$c_{it} \quad = \quad \begin{cases} w_{it}(m,\tilde{m}) & \text{if employed at match quality } m \\ h + b_i(\tilde{m}) & \text{if insured unemployed} \\ h & \text{if uninsured unemployed} \end{cases}$$

where $w_i(m, \tilde{m})$ is the wage of type-i worker that depends on m, the current match quality, and $\tilde{m}$, the match quality in her most recent employment. h can be interpreted as home production or leisure flow during unemployment. $b_i(\tilde{m})$ is the UI benefit of type-i worker with match quality $\tilde{m}$ in her most recent employment. I describe the UI system in the next subsection.

On the firm side, they are either matched with a worker or unmatched. Matched firms sell output, pay negotiated wage to their workers and pay lump-sum tax τ to finance the UI payment. A match is exogenously separated at rate δ and an endogenous separation can occur when either the value of a worker or firm is negative. When firms are unmatched with a worker, they post a vacancy at cost κ and cannot direct their posting to a specific type of workers.

3.1.1 UI Duration Policy and UI Eligibility

UI Duration The maximum UI duration is captured by the variable $\phi(u_t)$. Namely, insured unemployed workers exhaust their UI benefits at the rate

$$\phi(u_t) \equiv \phi_L \mathbb{1}\{u_t \geq \bar{u}\} + \phi_H \mathbb{1}\{u_t < \bar{u}\}$$

where $\phi_L < \phi_H$ implying the rate is a decreasing function of the unemployment rate u_t in the economy.[8] Since the inverse of $\phi(u_t)$ is the expected duration of receiving UI benefits, a fall in the rate implies an unemployment insurance extension. This UI duration policy is set to mimic the rules for the UI extensions in the US where these extensions are dependent on the state unemployment rate (above which the extensions are triggered). During normal times when $u_t < \bar{u}$, the UI exhaustion rate is ϕ_H which is set to imply a standard UI duration of 26 weeks. When the unemployment rate is high and above $\bar{u}$ (often in recessions), insured unemployed workers exhaust the benefits at a slower rate ϕ_L. I can capture the observed increase in the duration of UI extensions in the US by lowering in the value that ϕ_L takes.

UI Eligibility Upon losing a job, employed workers become uninsured at the rate $1-\psi$. This is to reflect how some unemployed workers do not take up their UI benefits. On top of this, insured unemployed workers lose UI eligibility after an unproductive meeting with a firm at rate ξ to reflect how UI recipients' job search are being monitored.

[8]This stochastic UI exhaustion is first used in Fredericksson and Holmlund (2001). Mitman and Rabinovich (2014), Faig, Zhang and Zhang (2012), and Rujiwattanapong (2016) treat this rate to be state-dependent.

UI payment is financed each period by lump-sum tax payment (τ) from matched firms:

$$\tau(1-u) \quad = \quad \sum_{i\in\{H,L\}} \sum_{\tilde{m}} u_i^{UI}(\tilde{m}) b_i(\tilde{m})$$

where $u_i^{UI}(\tilde{m})$ is the number of type-i insured unemployed workers whose UI benefit is $b_i(\tilde{m})$.

3.1.2 Search and Matching

Workers and unmatched firms meet via a meeting function $M(s,v)$ where s is the aggregate search intensity and v is the number of job vacancies. The meeting function $M(.,.)$ has constant returns to scale, and is strictly increasing and concave in its arguments. Market tightness can be defined as $\theta \equiv v/s$. The conditional job finding probability per unit of search is $\frac{M}{s} = M(1,\theta)$; therefore, the conditional job finding probability of type-i worker with employment status j is $s_i^j M(1,\theta) \equiv p_i^j(\theta)$.[9] Analogously, the probability that a firm meets a worker is $\frac{M}{v} \equiv q(\theta)$.

3.1.3 Timing

1. Given (u_t, z_t), production takes place and UI duration policy $\phi(u_t)$ is set
2. Workers choose job search effort
3. Current matches draw a new m at rate λ
4. Workers and unmatched firms meet
5. Aggregate productivity z_{t+1} next period is realised
6. Matches/meetings dissolve
7. u^{UI} lose UI eligibility at rate $\phi(u_t)$ if not meeting a firm, or at rate $\phi(u_t) + \big(1-\phi(u_t)\big)\xi$ if a meeting has occurred
8. Unemployment u_{t+1} for next period is realised

3.1.4 Workers' Value Functions

I first define the set of state variables as $\omega \equiv \{z, u, u_i, u_i^{UI}(\tilde{m}), u_i^{UU}, e_i(m);\ \forall m, \tilde{m}$ and $i \in \{H,L\}\}$ where u_i is the number of type-i unemployed workers, $u_i^{UI}(\tilde{m})$ is the number of type-i insured unemployed workers whose match quality in their most recent employment was $\tilde{m}$, u_i^{UU} is the number of type-i uninsured unemployed workers and $e_i(m)$ is the number of type-i employed workers with current match quality m.

[9]The conditional job finding probability is essentially the probability that a worker meets a firm. The true job finding rate dependes on whether such a meeting leads to a successful match formation.

Employed workers The value of a type-i employed worker with last period's employment status and associated benefit level $j \in \{e(\tilde{m}), UI(\tilde{m}), UU\}$ is

$$
\begin{aligned}
W_i^j(m;\omega) \;=\; \max_{s_i^e(m;\omega)} \;& w_i^j(m;\omega) - \nu_e(s_i^e(m;\omega)) + \beta E_{\omega'|\omega}\Bigg[\\
& \underbrace{(1-\delta)(1-\lambda)}_{\text{Pr(stay matched, keep } m)} \Bigg[\underbrace{(1-p_i^e(m;\omega)(1-F(m)))}_{\text{Pr(stay with current firm)}} W_i^{e(m)+}(m;\omega') \\
& + \underbrace{p_i^e(m;\omega)(1-F(m))}_{\text{Pr(move to new firm)}} E_{m'|m'>m}[W_i^{e(m)+}(m';\omega')] \Bigg] \\
& + \underbrace{(1-\delta)\lambda}_{\text{Pr(stay matched, new } m)} E_{m'} \Bigg[\underbrace{(1-p_i^e(m;\omega)(1-F(m')))}_{\text{Pr(stay with current firm)}} W_i^{e(m)+}(m';\omega') \\
& + \underbrace{p_i^e(m;\omega)(1-F(m'))}_{\text{Pr(move to new firm)}} E_{m''|m''>m'}[W_i^{e(m)+}(m'';\omega')] \Bigg] \\
& + \underbrace{\delta}_{\text{Pr(match exogenously separated)}} \Big((1-\psi)U_i^{UI}(m,\omega') + \psi U_i^{UU}(\omega') \Big) \Bigg] \qquad (1)
\end{aligned}
$$

where $W_i^{e(m)+}(m';\omega') \equiv \max\{W_i^{e(m)}(m';\omega'), (1-\psi)U_i^{UI}(m,\omega') + \psi U_i^{UU}(\omega')\}$ showing that employed workers can always become unemployed (and get unemployment insurance at rate $1-\psi$).[10] $U_i^{UI}(m)$ and U_i^{UU} are respectively the value of the insured unemployed with benefit $b_i(m)$ and the value of the uninsured unemployed. The expressions for optimal search intensity of employed workers can be found in Appendix A.

Unemployed worker The difference between insured and uninsured workers stems from the period utility flow during unemployment. Amongst insured unemployed workers, their period utility flow can differ according to $\tilde{m}$, their match quality in the most recent employment, since the UI benefits are attached to this variable. Therefore, the values of type-i uninsured unemployed workers and insured unemployed workers with benefit $b_i(\tilde{m})$ are respectively

$$
\begin{aligned}
U_i^{UU}(\omega) \;=\; \max_{s_i^{UU}(\omega)} \;& h - \nu_u(s_i^{UU}(\omega)) + \beta E_{m'\omega'|\omega}\Big[\ldots \\
& p_i^{UU}(\omega)\max\{W_i^{UU}(m';\omega'), U_i^{UU}(\omega')\} + (1-p_i^{UU}(\omega))U_i^{UU}(\omega')\Big] \qquad (2)
\end{aligned}
$$

[10] Similar to the argument made in Krause and Lubik (2010), the current wage affects neither the decision of the employed worker to quit nor their job search effort due to the timing of the model and the bargaining structure. As a result, the bargaining set is still convex and Nash bargaining is still applicable for the determination of wage. Shimer (2006) discusses the implications of having a non-convex payoff set.

and

$$
\begin{aligned}
U_i^{UI}(\tilde{m},\omega) &= \max_{s_i^{UI}(\tilde{m},\omega)} \quad b_i(\tilde{m}) + h - \nu_u(s_i^{UI}(\tilde{m},\omega)) \\
&\quad +\beta E_{m'\omega'|\omega}\Bigg[p_i^{UI}(\tilde{m},\omega)\max\Big\{W_i^{UI(\tilde{m})}(m';\omega'),\ldots \\
&\quad \underbrace{(1-\phi_u)(1-\xi)}_{\text{Pr(keep UI | meeting a firm)}}U_i^{UI}(\tilde{m},\omega') + \underbrace{(\phi_u+(1-\phi_u)\xi)}_{\text{Pr(lose UI | meeting a firm)}}U_i^{UU}(\omega')\Big\} \\
&\quad +(1-p_i^{UI}(\tilde{m},\omega))\Big((1-\phi_u)U_i^{UI}(\tilde{m},\omega') + \phi_u U_i^{UU}(\omega')\Big)\Bigg] \qquad (3)
\end{aligned}
$$

The expressions for optimal search intensity of insured and uninsured unemployed workers are shown in Appendix A.

3.1.5 Firms

Matched firms Similar to the setup of employed workers, the value of a matched firm with type-i worker whose work history is $j \in \{e(\tilde{m}), UI(\tilde{m}), UU\}$ is

$$
\begin{aligned}
J_i^j(m;\omega) &= y_i(m;\omega) - w_i^j(m;\omega) - \tau(\omega) + \beta E_{\omega'|\omega}\Bigg[\ldots \\
&\quad (1-\delta)(1-\lambda)\Big[(1-p_i^e(m;\omega)(1-F(m)))J_i^{e(m)+}(m;\omega')\Big] \\
&\quad +(1-\delta)\lambda E_{m'}\Big[(1-p_i^e(m;\omega)(1-F(m')))J_i^{e(m)+}(m';\omega')\Big]\Bigg] \qquad (4)
\end{aligned}
$$

where $J_i^{e(m)+}(m';\omega') \equiv \max\{J_i^{e(m)}(m';\omega'),0\}$. Note that I have already imposed the free entry condition which implies the value of an unmatched firm is zero, i.e. $V(\omega) = 0, \forall\omega$.

Unmatched firms Since unmatched firms cannot direct their search to a particular type of worker, the distribution of workers' search intensity over employment status, UI status, benefit level, productivity type and match quality of on-the-job searchers (as denoted by ζ's in the following equation) enters the unmatched firm's problem and, therefore, becomes a part of the state variables. The value of an unmatched firm is

$$
\begin{aligned}
V(\omega) &= -\kappa + \beta q(\omega)E_{\omega'|\omega}\Bigg[\sum_{i\in\{H,L\}}\Big(\sum_m \zeta_i^e(m;\omega)(1-F(m))E_{m'|m'>m}[J_i^{e(m)+}(m';\omega')] \\
&\quad +\sum_m \zeta_i^{UI}(m,\omega)E_{m'}[J_i^{UI(m)+}(m';\omega')] + \zeta_i^{UU}(\omega)E_{m'}[J_i^{UU+}(m';\omega')]\Big)\Bigg] \qquad (5)
\end{aligned}
$$

$$
\begin{aligned}
\text{where}\quad \zeta_i^e(m) &= \frac{(1-\lambda)s_i^e(m)e_i(m)+\lambda f(m)\sum_m s_i^e(m)e_i(m)}{s} \\
\zeta_i^{UI}(m) &= \frac{s_i^{UI}(m)u_i^{UI}(m)}{s}; \quad \zeta_i^{UU} = \frac{s_i^{UU}u_i^{UU}}{s} \\
s &= \sum_{i\in\{H,L\}} \Big(\sum_m \big(s_i^e(m)e_i(m) + s_i^{UI}(m)u_i^{UI}(m) \big) + s_i^{UU}u_i^{UU} \Big)
\end{aligned}
$$

3.2 Wage and Surplus

Wages are negotiated bilaterally using a generalised Nash bargaining rule. For $i \in \{H,L\}$, type-i workers with previous employment status $j \in \{e(\tilde{m}), UI(\tilde{m}), UU\}$ and match quality m receive

$$
w_i^j(m;\omega) = \text{argmax} \left(WS_i^j(m;\omega) \right)^{\mu} \left(J_i^j(m;\omega) \right)^{(1-\mu)} \tag{6}
$$

where μ is the worker's bargaining power. WS_i^j is the surplus of type-i employed workers with history j and it is the difference between the value of working and the corresponding outside option. We can define the total match surplus $S_i^j \equiv WS_i^j + J_i^j$. As a result, $WS_i^j = \mu S_i^j$ and $J_i^j = (1-\mu)S_i^j$. The surpluses of employed workers are as follows

$$
\begin{aligned}
WS_i^{e(\tilde{m})}(m;\omega) &\equiv W_i^{e(\tilde{m})}(m;\omega) - (1-\psi)U_i^{UI}(\tilde{m},\omega) - \psi U_i^{UU}(\omega) \\
WS_i^{UI(\tilde{m})}(m;\omega) &\equiv W_i^{UI(\tilde{m})}(m;\omega) - (1-\phi(u))(1-\xi)U_i^{UI}(\tilde{m},\omega) \\
&\quad -(\phi(u)+(1-\phi(u))\xi)U_i^{UU}(\omega) \\
WS_i^{UU}(m;\omega) &\equiv W_i^{UU}(m;\omega) - U_i^{UU}(\omega)
\end{aligned}
$$

The expressions for total match surpluses can be found in Appendix A.

3.3 Recursive Competitive Equilibrium

A recursive competitive equilibrium is characterised by value functions, $W_i^{e(\tilde{m})}(m;\omega)$, $W_i^{UI(\tilde{m})}(m;\omega)$, $W_i^{UU}(m;\omega)$, $U_i^{UI}(\tilde{m},\omega)$, $U_i^{UU}(\omega)$, $J_i^{e(\tilde{m})}(m;\omega)$, $J_i^{UI(\tilde{m})}(m;\omega)$, $J_i^{UU}(m;\omega)$, and $V(\omega)$; market tightness $\theta(\omega)$; search policy $s_i^e(m;\omega)$, $s_i^{UI}(m,\omega)$ and $s_i^{UU}(\omega)$; and wage functions $w_i^{e(\tilde{m})}(m;\omega)$, $w_i^{UI(\tilde{m})}(m;\omega)$, and $w_i^{UU}(m;\omega)$, such that, given the initial distribution of workers over productivity level, employment status, UI status, benefit level and match productivity, the government's policy $\tau(\omega)$ and $\phi(\omega)$, and the law of motion for z:

1. The value functions and the market tightness satisfy the Bellman equations for workers and firms, and the free entry condition, namely, equations (1), (2), (3), (4) and (5)

2. The search decisions satisfy the FOCs for optimal search intensity, which are equations (7), (8) and (9)

3. The wage functions satisfy the FOCs for the generalised Nash bargaining rule (equation (6))
4. The government's budget constraint is satisfied each period
5. The distribution of workers evolves according to the transition equations (10), (12) and (13), which can be found in Appendix B, consistent with the maximising behaviour of agents

3.4 Solving the Model

In order to compute the market tightness (and, in effect, total match surpluses and search effort) in the model, the agents in the economy need to keep track of the distribution of workers over the productivity level, employment status, UI status, benefit level and match quality $\{e_i(m), u_i^{UI}(\tilde{m}), u_i^{UU}; i \in \{H,L\}, \forall m, \tilde{m}\}$ as they enter the vacancy creation condition (equation 5). In order to predict next period's unemployment rate they need to know the inflow into and outflow from unemployment which are based on this distribution. I use the Krusell & Smith (1998) algorithm to predict the laws of motion for both the insured and total unemployment rates as a function of current unemployment rate (u) and aggregate productivity (z). As the distributions of employed workers by match quality and insured unemployed workers by benefit level do not vary much over time, I use the stochastic steady state distributions (also separating between high and low unemployment periods for the distribution of the insured unemployed), and adjust for the employment rate that can be inferred from the state variables. I report the performance of this approximation in Appendix C as well as the computational algorithm in Appendix D.

4 Calibration

Before I calibrate the model to match the US economy, I specify the functional forms for the search cost functions, the distribution function of the match-specific productivity and the meeting function between workers and firms. I obtain a subset of the parameters using the simulated method of moments. The rest of the parameters are taken from the empirical data and the literature. Table 8 summarises the pre-specified parameters while table 10 describes the calibrated ones.

Functional forms I assume the search cost function takes the following power function

$$v_j(s) = a_j s^{1+d_j} \; ; \; j \in \{e,u\}$$

where a_j and d_j are strictly positive scalars. I distinguish the search cost only between employment (e) and unemployment (u) to control for the relation between job-to-job transition rate and the job finding rate. Workers of type-H and type-L face the same cost of search and so do unemployed workers with and without UI.

With respect to the distribution of match quality, a worker-firm match draws a new m from the following Beta distribution

$$F(m) = \underline{m} + \text{betacdf}(m - \underline{m}, \beta_1, \beta_2)$$

where β_1 and β_2 are strictly positive scalars, and $\underline{m} > 0$ is the lowest productivity level.

The meeting function between unmatched firms and workers is similar to that in den Haan, Ramey and Watson (2000) with the introduction of search intensity

$$M(s,v) = \frac{sv}{\left(s^l + v^l\right)^{\frac{1}{l}}}; l > 0$$

Discretisation I discretise the aggregate productivity (z) using Rouwenhurst (1995)'s method to approximate an AR(1) process with a finite-state Markov chain. I use 51 nodes to solve the model and 5,100 nodes by linear interpolation in the simulations. Similarly, I use 51 equidistant nodes to approximate the Beta distribution of the match-specific productivity $F(m)$ when solving the model and 5,100 nodes by linear interpolation in the simulations. I define $f(m)$ to be $F'(m)/\sum_m F'(m)$ where $F'(m)$ is the probability density function of $F(m)$. Finally, I use 101 equidistant nodes to approximate the unemployment rate between 0.02 to 0.2.

Simulation I apply the calibrated model to the U.S. economy by feeding in the productivity shocks that match the deviations of output (GDP per capita) from HP trend as well as the observed maximum UI durations during each recession. It is useful to note that the timing of each UI extension and how long it lasts are not predetermined. They are purely the result of the model's simulated unemployment rate which can be used to measure how well the model can replicate the US labour market.

Additionally, from May 2007, the Emergency Unemployment Compensation law has included the "Reachback Provision" providing UI eligility to unemployed workers who have already exhausted their benefits prior to the extensions of UI. I also simulate the model accordingly and study the impact of this programme in the results section.

4.1 Pre-specified Parameters

The pre-specified parameters in the model are summarised in Tables 8 and 9. The model is monthly and I use the value 0.9967 for the discount factor β, implying an annual interest rate of 4% which is the U.S. average. I follow Fujita and Ramey (2012) in pinning down the vacancy creation cost κ to be 0.0392 using survey evidence on vacancy durations and hours spent on vacancy posting.[11] I assign μ, the worker's bargaining power, to be 0.5 following den Haan, Ramey and Watson (2000).

ϕ_H and ϕ_L are respectively the UI exhaustion rates during normal periods and recessions. I set ϕ_H to be 1/6 which implies the standard maximum UI duration of 26 weeks given the monthly frequency. With regards to the UI extensions during recessions, I can sort them into four main UI duration groups:

1. 39 weeks (9 months) for January 1948 - December 1971
2. 52 weeks (1 year) for January 1972 - December 1974 and July 1982 - September 1991
3. 68 weeks (16 months) for January 1975 - June 1982 and October 1991 - July 2008
4. 90 weeks (21 months) for August 2008 - June 2014

The above durations are obtained by averaging the observed maximum UI durations over the respective periods when UI were extended. The value ϕ_L changes and implies the maximum UI duraitons according to the above UI duration regimes. Note that these are the maximum UI durations used only when the unemployment rate is above the threshold $\bar{u}$. For example, in the simulation, the UI extension in the Great Recession is not triggered until April 2009. I set $\bar{u}$ to be 6.5 percent which has been historically used as a criterion in most of the UI extensions.

To determine the utility flow of type-i unemployed workers, h and, if insured, $b_i(m)$, I use the results in Gruber (1997). In particular, the drop in consumption for the newly unemployed workers is 10 percent when receiving UI and 24 percent when not receiving UI given the replacement rate of 50 percent.[12] To find the implied h and $b_i(m)$ given a set of parameters, I first guess the mean wages for the (type-i) unemployed with different match qualities $\{w^0(m), w_i^0(m); \forall m\}$ and set h such that the average ratio of h to $w^0(m)$ is 0.76 (where I use the steady state distribution of unemployed workers by match qualities to

[11] Fujita and Ramey (2012) find the vacancy cost to be 17% of a 40-hour-work week. Normalising the mean productivity to unity, this gives the value of 0.17 per week or 0.0392 per month. The actual mean productivity may be higher than (but not greatly different from) unity due to truncation from below of the match-specific quality.

[12] Aguiar and Hurst (2005) report the drop in food consumption of workers upon becoming unemployed to be 5 percent and the drop in food expenditure to be 19 percent. However, in their study, unemployed workers are not distinguished by their UI status which makes it impossible separately identify h and $b_i(m)$'s under the present calibration strategy.

compute the weighted average). For $b_i(m)$, it is set such that the ratio of $h+b_i(m)$ over $w_i^0(m)$ is 0.9 for each match quality m. I then solve and simulate the model to check if the guess is close to its counterpart from the simulation. If it is not, I replace the guessed wages with the simulated ones and repeat until they are close enough.

The slope of the search cost function for the unemployed a_u is normalised such that the search effort of the uninsured unemployed s^{UU} is unity when the economy is in the steady state, similar to Nagypál (2005). The power parameters in the search cost functions for both employed and unemployed workers (d_e and d_u) are set to unity in line with Christensen, Lentz and Mortensen (2005) and Yashiv (2000) implying a quadratic search cost function.

4.2 Calibrated Parameters

I use the simulated method of moments to assign values to the remaining twelve parameters $\{l, \delta, \lambda, \psi, \xi, a_e, \underline{m}, \beta_1, \beta_2, \rho_z, \sigma_z, \eta_L\}$ by matching main statistics in the U.S. labour market as well as the labour productivity process during 1948-2007.[13] The twelve moments I try to match are the following:

- First and second moments of unemployment rate, job finding rate, job separation rate, and average unemployment duration
- First moment of job-to-job transition rate and insured unemployment rate
- Second moment and autocorrelation of labour productivity[14]

The model's generated moments are reported in Table 7 along with their empirical counterparts. Table 11 shows other related moments not targeted in the calibration. The values of calibrated parameters are in Table 10.

In terms of the targeted moments, the baseline model matches the twelve targeted moments quite well overall. However, the insured unemployment rate is slightly higher and the job finding rate is more volatile than in the data. With regards to related moments that are not targeted, it can match the dynamics of unemployment grouped in four duration bins quite well in terms of the first and second moments. However, the model could further improve on the volatility of vacancies and the correlation between unemployment and vacancies.[15]

[13]The calibrated parameters are to minimise the sum of squared residuals of percentage changes between the model-generated moments and their empirical counterparts.

[14]The transition rates are author's own calculations based on the CPS data. For output, I use the quarterly real GDP series provided by the Bureau of Economic Analysis (BEA), and I use the BLS quarterly series for non-farm output per job to represent the labour productivity.

[15]The main reason why vacancies are not as volatile as they are in the data is due to the endogenous separation margin. In recessions, unemployment increases at a faster rate from endogenous match separations which makes vacancy posting less costly, and this counteracts with the effect of negative aggregate shocks.

5 Results

In this section, I first discuss the model's performance in generating realistic dynamics of the US labour market with the focus on the long-term unemployment and the unemployment duration structure. The results are based on the aggregate productivity series that matches the deviations of output from its HP trend as depicted in Figure 10.[16] Next, I study the mechanisms of the model in generating such dynamics, particularly how the three following channels respond to UI extensions: job search behaviour, match formation and match separation. Then I conduct policy experiments to measure the impact of UI extensions (via these channels) and the Reachback Provision programme on the labour market during the Great Recession. Lastly, I study the duration dependence in the unemployment exit rate.

5.1 Performance

UI Extensions I show in Figure 11 that the model is successful in generating realistic UI extensions both in terms of when they are triggered and how long each extension lasts. This is due to how well the model can replicate the unemployment rate in the US (of which UI extensions are a function) as shown in Figure 12. The model produces 95 percent of the observed unemployment rate between October 2009 and June 2014 as shown in Table 12.[17]

Long-term Unemployment The model can account for a large fraction of the observed rise in long-term unemployment in the Great Recession as depicted in Figure 13. Specifically, between October 2009 and June 2014, it generates 87 percent of the observed long-term unemployment rate (reported in Table 12). Despite this success, the model tends to overshoot the long-term unemployment and does not produce enough persistence in some of the previous recessions. The main reason for this comes from the sudden change in optimal job search behaviour of insured unemployed workers when the maximum UI duration returns to the standard duration, the mechanism that I will discuss in the next subsection.

Distribution of Unemployment Duration Figure 14 shows that the model can produce a substantial rise in the average unemployment duration in the Great Recession.[18] However, the model's series drops quickly as the economy recovers whilst it is more persistent in the data. The model also does very well in producing a realistic shift in the distribution of unemployment duration towards longer duration bins as previously discussed in the empirical

[16] We can see that the drop in aggregate productivity during the Great Recession is neither of larger magnitude nor does it exhibit more persistence than in previous recessions.

[17] This number is calculated by averaging the absolute percentage deviations of the model's unemployment series from the empirical counterpart. I choose October 2009 as the starting period as it was when the US unemployment rate reached its peak at 9.98 percent during the Great Recession.

[18] To be specific, the model can generate 77 percent of the empirical average unemployment duration series as reported in Table 12.

section. In Figure 15 I plot the distributions in December 2007 and June 2010, where UI was only extended in the latter case.[19] With respect to the entire 1948-2014 period, I show in Figure 16 the shares of unemployment by four duration bins (less than 1 month, 2-3 months, 4-6 months and longer than 6 months). These figures provide an evidence that the model is suitable for studying the dynamics of the entire distribution of unemployment durations and not just for the long-term unemployment dynamics.

Job Findings In the left panel of Figure 17, I compare the model's job finding rate with the empirical series. Despite a clear negative trend that the model does not take into account, it produces a fall in the job finding rate during the Great Recession similar in magnitude to that in the data. When I further condition on the UI status of workers as displayed in the left panel of Figure 18, we can see that (1) the job finding rate of the insured unemployed workers are on average lower than that of the uninsured, and (2) the job finding rate of the insured falls more dramatically than that of the uninsured. Both features are consistent with findings from the empirical section.

5.2 Mechanisms

Job Search Behaviour The endogenous UI extensions affect the optimal search behaviour of workers in the following ways: (1) only the search intensity of insured unemployed workers varies with the maximum UI duration and (2) the higher the UI benefits the lower the search effort is being exerted, and such behaviour is more noticeable when the extended UI duration is longer.

I show in Figure 19 that the conditional job finding rate of the insured unemployed workers drops whenever UI is extended (implied by $u \geq \bar{u}$) whilst the rates for the employed and uninsured unemployed are largely constant. Further, amongst the insured unemployed, their job search effort decreases in the amount of benefit they receive as shown in the left panel of Figure 20. With regards to the worker heterogeneity, higher productivity workers exert more search effort as their value during employment is relatively higher than the lower productivity type (right panel of Figure 20). Mapping this to the simulation of the US economy in Figure 18, the job finding rates between the two productivity types during 1948-2014 are quite similar. However, when I separate the job finding rates by UI statuses instead, they are very different. Specifically, the unemployment exit rate of the insured unemployed is smaller and exhibits higher volatility which is consistent with the empirical evidence. This suggests that once we condition on the UI status, the workers' productivity types contribute little to the rise of the long-term unemployment.

[19] I choose June 2010 because it is when the model's long-term unemployment rate reaches its peak. Additionally, the model generates a hump in the distribution in 2010 similar to the empirical distribution owing to the endogenous separation margin.

It is useful to note that the job finding rates in Figure 18 are driven not only by the job search behaviour but also by the decision between a worker and a firm to form a match once they meet. Such decisions as well as match separation decisions are also affected by the endogenous UI extensions as I discuss next.

Match Formation/Dissolution From the model section, we learn that the worker's surplus from being employed and the value of producing firms ($WS_i^j(m;\omega)$ and $J_i^j(m;\omega)$; $j \in \{e(\tilde{m}), UI(\tilde{m}), UU\}$) are simply a constant fraction of the total match surplus ($\mu S_i^j(m;\omega)$ and $(1-\mu)S_i^j(m;\omega)$ respectively). This means both workers and firms always agree when a match should be formed (when the total surplus is positive) and when it should be dissolved (when the total surplus is negative). The match surplus when the worker is currently employed ($S_i^{e(\tilde{m})}(m;\omega)$) determines the endogenous match separations whereas the match surplus when the worker is currently unemployed ($S_i^{UI(\tilde{m})}(m;\omega)$ or $S_i^{UU}(m;\omega)$) determines how many matches will be formed, given that unemployed workers and firm have met.

Figure 21 shows that total match surpluses for employed and insured unemployed workers ($S_i^{e(\tilde{m})}(m;\omega)$ and $S_i^{UI(\tilde{m})}(m;\omega)$) decrease in unemployment and that they decrease at a faster rate when UI is extended ($u \geq \bar{u}$).[20] Similar to the optimal job search policy, The longer the extended duration, the more drastic is the drop in the surplus. Further, I show that $S_i^{UI(\tilde{m})}(m;\omega)$ increases in m and decreases in $\tilde{m}$ in Figures 22. m increases the surplus because a higher match quality in the production raises the firm's profit, the worker's wage and also the worker's potential UI benefit after being employed at m; on the other hand, a higher $\tilde{m}$ implies a higher outside option of the insured unemployed $(h + b_i(\tilde{m}))$ which means it is less likely for a match to be formed. A similar argument applies to $S_i^{e(\tilde{m})}(m;\omega)$ but instead on the job separation margin where $(h + b_i(\tilde{m}))$ is the outside option of the employed worker if she quits and is eligible for UI.

From the model's simulation, Figure 23 shows that the success rate of worker-firm meetings is procyclical and always close to one. The reasons are (1) for insured workers, those likely to have an unproductive meeting are those with currently high UI benefits and it is unlikely for them to meet a firm in the first place, and (2) for uninsured workers, the surplus from working is very high due to their lower outside option which means the meetings are likely to lead to viable matches. With respect to job separation, we can see from the right panel of Figure 17 that the separation rate is countercyclical which is a result of $S_i^{e(\tilde{m})}(m;\omega)$ becoming negative during recessions.

What Drives the Long-term Unemployment? In this exercise, I study the contribution of the three UI channels (job search behaviour, match formation and job separation) on the

[20]It can be seen that the match surplus for the uninsured unemployed workers is higher when the UI extension is longer. This is because it is actually better for the uninsured unemployed to regain employment and potentially qualify for UI benefits.

long-term unemployment during the Great Recession. By fixing one channel at a time I study the evolution of the long-term unemployment given the same path of aggregate shock (z) as in the baseline model (Figure 10).[21]

I find that the long-term unemployment is largely unaffected by the response of match formation and dissolution but it would fall drastically (over 3 percentage points) when the job search behaviour is fixed as shown in Figure 24. Despite a small impact on the long-term unemployment, the job separation margin has a sizeable contribution to the average unemployment duration and is more important than the job search response in accounting for the total unemployment as displayed in 25.

5.3 Policy Experiment

To quantify the effects of UI extensions on the aggregate labour market during the Great Recession, I conduct a counterfactual experiment by eliminating all UI extensions, i.e. the maximum UI duration is 26 weeks instead of 90 weeks. I then study how unemployment, long-term unemployment and average unemployment duration respond under this scenario. Just like the previous decomposition exercise, I use the same path of aggregate productivity (z) as in the baseline model (Figure 10). The benefit of using a general equilibrium model is that I can isolate the effects of UI extensions according to the factors that respond to the maximum UI duration. I will study three scenarios:

1. The direct impact of changing the maximum UI duration from 90 weeks to 26 weeks
    - Only the number of insured unemployed workers is affected by this change
2. The direct impact of UI extensions + the response of job search intensity
    - I allow the optimal search intensity to adjust to when there is no UI extensions. Specifically, workers exert job search effort as if the unemployment rate was at its historical mean at 5.83 percent (below $\bar{u}$)
3. The direct impact of UI extensions + the responses of job search intensity and match surpluses:
    - I allow both the optimal search intensity and the decisions on match formation and match dissolution to correspond to when there is no UI extensions (setting the unemployment rate at 5.83 percent in the policy functions)

As most of the literature studying the effects of UI extensions mainly focus on the "micro" effect, the first two scenarios are most comparable whilst the last scenario can be considered

[21] Specifically, I set the unemployment rate used in the respective policy functions to be at the pre-Great Recession level which is less than $\bar{u}$ implying that UI is not extended.

as the "general equilibrium" effect where firms and workers take into account the effect of UI extensions on match separations.[22] Table 13 summarises the results from this experiment.

Long-term unemployment Figure 26 shows the evolution of the maximum UI durations under the counterfactual experiment where in the Great Recession it is 26 instead of 90 weeks. The response of long-term unemployment to the change in maximum UI duratiom is shown in Figure 27. It can be seen that UI extension has a huge impact on long-term unemployment even when the behaviour of workers and firms do not react to this change. This is however not surprising since with the standard UI duration (of 26 weeks) all long-term unemployed workers are uninsured by definition, and we also know that uninsured unemployed workers have a much higher unemployment exit rate than do insured unemployed workers. As a result, by removing all UI extensions during the Great Recession, the peak of the long-term unemployment rate falls drastically from 4.9 percent in the baseline model to 1.2 percent in the first scenario where workers and firms do not react to the cut in maximum UI duration (as shown in Table 13). It falls to 0.6 percent when job search behaviour responds to the change in UI duration and just slightly further to 0.5 percent when both job search and job separations respond to this change.

Unemployment Figure 28 shows the responses of unemployment rate (top panel). Comparing to the long-term unemployment, the unemployment rate is much less affected by the cut in UI duration. The direct impact of removing UI extensions is a slight fall of less than one percentage point in the unemployment rate (measured at its peak) as can be seen in Table 13. When job search behaviour responds to the extension removal, the peak of the unemployment rate falls by 1.7 percentage points. It is only within the general equilibrium context, where the decisions on match separations also react to the UI duration cut, that the peak of the unemployment rate substantially falls by 3.4 percentage points to 6.8 percent.

The reason that under the first two scenarios the impact on the unemployment rate is more subdued is because they are relevant for only a subgroup of unemployment population whilst in the last scenario the job separation margin applies to all employed workers and determines the inflow of (insured) unemployed workers. Using the same argument, we can explain why under the first two scenarios the UI extensions have a large impact on the long-term unemployment.

This result is consistent with the existing literature that studies the impact of UI extensions on the unemployment rate in the Great Recession. Most of the studies focus on the micro effect where the worker-firm relationships are not taken into account, and find that the unemployment rate would have been 0.1 to 1.8 percentage points lower had there been no

[22]It is clear from the previous decomposition exercise that the response of match formation to UI extensions is negligible.

UI extensions. My "micro effect" of around 0.9-1.7 percentage points is within the range of the empirical estimates (0.1-1.8 percentage points) albeit on the higher side. Moreover, the larger "general equilibrium" effect of UI extensions in this model is similar to findings in Hagedorn et al (2015) but they focus the impact on vacancy creation whilst mine comes from match separations. Lastly, the unemployment rate is much less persistent when there is no UI extensions, i.e. there would be no jobless recoveries. This result is consistent with the findings in Mitman and Rabinovich (2014).

Average unemployment duration In contrast to the response of the unemployment rate, eliminating UI extensions significantly affects the average unemployment duration during the Great Recession as depicted in the bottom panel of Figure 28. The direct effect of eliminating (64 weeks of) UI extensions alone accounts for a 24-week drop in the average duration of unemployment (measured at the peak of the series) as shown in Table 13. When job search behaviour adjusts to the UI duration cut, the duration drops by 2 weeks further. The additional impact from the general equilibrium effect is minimal.

To summarise, I find a large impact of UI extensions on the long-term unemployment and the average unemployment duration which mainly comes from the direct effect of changing maximum UI duration and to a smaller extent from the response of job search behaviour (where I label these two channels the micro effect) with a small role from the job separation margins. However, the story is the opposite for the unemployment rate. The micro effect of UI extensions is small relative to the general equilibrium effect when match formation/dissolution decisions respond to the change in the maximum UI duration. Overall, the impact of UI extensions on the unemployment rate is consistent with results from the existing literature.

5.4 Reachback Provision Programme

From May 2007, the Emergency Unemployment Compensation law has included the "Reachback Provision" providing UI eligility to unemployed workers who have already exhausted their benefits prior to the extensions of UI. This programme can potentially affect the long-term unemployment since the programme is targeted directly at this group of workers. As the programme is already incorporated when I simulate the model and present the results, I will in this exercise remove the programme and leave everything else the same including the paths of aggregate productivity and UI extensions in the baseline model. The results from this exercise are summaried in Table 14. Figure 29 shows how the long-term unemployment, unemployment and average unemployment duration are impacted by the removal of the programme.

I find that the programme does not have a significant impact on the aggregate labour market. The (long-term) unemployment rate is only (0.2) 0.3 percentage points smaller than in the baseline model when measured at its peak. The small impact of the programme is due to the fact that the subgroup of workers who are affected by the programme represents just 3.5 percent of the unemployment population. However, from the CPS data, the true effect of this programme could be non-trivial since unemployed workers who already exhausted UI represented a substantial 44 percent of the long-term unemployment population in January 2008. The model produces a much smaller number for this group of workers because once the insured unemployed exhaust their benefits, they adopt the job search behaviour of the uninsured which implies a much higher unemployment exit rate than the insured.

5.5 Welfare Implication

I show in this exercise who would benefit/suffer the most from UI extensions. I extend the model in Section 3 by further distinguishing between unemployed workers with shorter and longer unemployment durations (less than 4 months vs. 4 months or more) to study the impact of UI extensions on job search intensity of insured unemployed workers who are closer to exhaust their UI (the group whose duration is 4 months or more). Since the state of the economy also determines the magnitude of the effects of UI extensions, I consider two scenarios: (1) extending UI during a recession and (2) extending UI during a non-recessionary period... *(to be completed)*

5.6 Hazard Rate of Exiting Unemployment

Due to the heterogeneity in job finding rates amongst unemployed workers, the model generates the negative duration dependence in unemployment exit rate that comes purely from the changing composition in the stocks of unemployment. At longer unemployment durations, the stocks of unemployment are more represented by those with lower exit rates, and they are the insured unemployed workers with higher UI benefits in this case. Moreover, the strength of the duration dependence is positively correlated with the state of the economy as pointed out in Wiczer (2015).

In Figure 30, I plot the hazard rates of exiting unemployment by duration for December 2007 (maximum 26 weeks of UI) and June 2010 (maximum 90 weeks of UI) to show how the recession and UI extensions affect this hazard rate. The negative duration dependence is more severe with UI extensions and persists as long as the maximum UI duration itself. In the same figure, I also plot the empirical estimate by Kroft et al (2014) over 2002-2007 period and the model's counterpart. Empirical results based on Kroft et al (2014) and Wiczer (2015) suggest that the hazard rate is rather stable after 6 months of being unemployed. In the model, however, since the uninsured unemployed workers exit unemployment at a faster rate than do the insured, the hazard rate rises upon the exhaustion of UI benefits.

The heterogeneous worker productivity could potentially help explain the negative duration dependence after the UI exhaustion since type-H workers exit unemployment at a faster rate. However, despite this heterogeneity, the exit rates of both types (H and L) when uninsured are quite similar and much higher than when they are insured leaving the average exit rate after UI exhaustion rather stable. In order to fit the empirical results better, other heterogeneity amongst uninsured unemployed workers could be introduced such as different values of home production, or even a larger degree of heterogeneity in productivity.

6 On the Sources of Long-term Unemployment

In this section I first show how consistent the model's unemployment series are with the empirical data by estimating a non-linear state space model in Ahn & Hamilton (2016) using the model's generated data. Then I study the implications on the sources of long-term unemployment. They explore the roles of worker's unobserved heterogeneity on unemployment dynamics. Their interpretation is that there are two types of workers: type-H workers have an ex-ante higher rate of exiting unemployment than do type-L workers. They also allow for genuine duration dependence that could be positive (motivational effect) and negative (scarring effect). The measurements or observables in their model are unemployment series by 5 duration bins $\{u_t^1, u_t^{2.3}, u_t^{4.6}, u_t^{7.12}, u_t^{13+}\}$ which are, respectively, unemployed workers with duration less than 1 month, 2-3 months, 4-6 months, 7-12 months, and more than 12 months. The latent or hidden states are also time varying. They are the number of newly unemployed workers for each type and a factor governing the unemployment continuation probability for each type. I summarise their state space model in Appendix E.

I obtain 50 different series of $\{u_t^1, u_t^{2.3}, u_t^{4.6}, u_t^{7.12}, u_t^{13+}\}$ using the Monte Carlo simulations from the baseline model. For each set of the simulated unemployment series, I use Maximum Likelihood to obtain a set of (twelve) estimates from the state space model as described in Appendix E. The extended Kalman fiter is used to construct the likelihood function since some latent variables enter the equations for unemployment series non-linearly. Table 15 reports these estimates and their standard errors.

Overall, the model's estimates are consistent with the empirical ones in Ahn and Hamilton (2016). Based on these estimated parameters, I construct the series for (1) the probability that newly unemployed workers of each type stay unemployed the following month, (2) the number of newly unemployed workers of each type, and (3) the share of unemployment by each type. Comparisons between these series and their empirical counterparts from Ahn and Hamilton (2016) are shown in Figures 31, 32 and 33 respectively.

The probabilities that the newly unemployed workers stay unemployed in the following month from the model's estimates (Figure 31) exhibit more volatility over the business cycles especially for type-L workers. Nonetheless, during the Great Recession, the model's data implies the rise of this probability for type-L workers and a small drop for type-H workers similar to its empirical counterpart. Going back to the model's results, we can see from the left panel of Figure 18 that they complement well with the results from this estimation where the insured unemployed workers (the type with "lower" exit rate) has a much more volatile unemployment exit rate than the uninsured (the type with "higher" exit rate).

With respect to the number of newly unemployed during the Great Recession (Figure 32), the model's estimates also imply a spike of the inflow of type-L workers (and a much smaller rise for type-H) with similar magnitude to the empirical counterpart. However, since the UI status of newly unemployed workers in the model is governed solely by the poisson rate ψ, the series for the newly unemployed workers who are insured and uninsured are perfectly correlated and therefore do not complement the results in Figure 32. The series only differ as the workers remain unemployed which is related to Figure 33, showing the shares of total unemployment by unobserved types. The model's implied share has very similar dynamics to the data throughout the observed periods. However, the share of type-L workers does not show a clear negative trend like in Ahn and Hamilton (2016), but this is expected since the model does not account for any low frequency changes or a trend e.g. in the unemployment rate or the job finding rate. Figure 34 shows the model's shares of total unemployment by UI status and worker's productivity. It can be seen that the rise in the share of type-L workers from the estimation (Figure 33) has more similar dynamics to the share of the insured unemployed workers in the model (rather than the share of the low productivity workers which exhibits smaller fluctuations).

Figure 35 shows the implied unemployment continuation probabilities from the true duration dependence component which are similar to the empirical estimates. This probability is rather constant in the first 6 months of duration, and then increases during 6-12 months of unemployment implying a scarring effect. After 12 months of unemployment, it is more likely that a worker exits unemployment the longer she stays unemployed . These estimates are somewhat consistent with the model's hazard rate of exiting unemployment (Figure 30) discussed in the previous subsection. As the UI benefits run out, workers search harder for jobs and exit unemployment more quickly. The change in the job search behaviour (and therefore the hazard rate) depends on the maximum UI duration but we can observe that in the 1976-2014 periods (upon which the observations are based) the maximum UI duration during recessions is at least 12 months which is consistent with a fall in the probability of remaining unemployed after 12 months.

In summary, the model's unemployment series are consistent with the empirical data as estimated using a state space model. I can relate Ahn and Hamilton (2016)'s interpretation of worker unobserved heterogeneity to the UI statuses of unemployed workers in my model since the insured unemployed have lower unemployment exit rate than do the uninsured. They have similar dynamics in terms of the unemployment exit rate as well as the shares of total unemployment. Moreover, some feature of the genuine duration dependence in the job finding rate can also be related to the UI exhaustion in the model.

7 Conclusion

The long-term unemployment dynamics has an important implication on the recovery of the aggregate labour market. This paper quantifies the impact of countercyclical UI extensions on the long-term unemployment and the unemployment duration distribution.

I develop a general equilibrium search and matching model where the maximum UI duration depends on the unemployment rate and the UI benefits depend on the match quality during employment. Unemployed workers' job search behaviour differs according to their UI status, benefit level and productivity, and is affected by the maximum UI duration.

The main result is that UI extensions have a significant impact on the long-term unemployment and the average unemployment duration but the impact on the unemployment rate is more limited. By studying the mechanisms through which the UI extensions affect the labour market, the response of job search behaviour plays a crucial role on the long-term unemployment dynamics whereas the response of job separation decisions is more important in accounting for the total unemployment.

The model is also used to assess the impact of UI extensions during the Great Recession distinguishing between the micro effect (the direct impact on the number of insured workers and the response of job search) and the general equilibrium effect (micro effect plus the response of job separation decisions). The micro effect on unemployment is small and consistent with existing studies whilst the general equilibrium effect is somewhat larger. This is because the micro effect is relevant for a subgroup of unemployment population but the job separation margin applies to all employed workers determining the inflow of (insured) unemployed workers.

The result that the model produces little persistence in the long-term unemployment outside the extended UI periods could be altered by using an empirical fact that the majority of long-term unemployed workers outside recessionary periods are those who have already exhausted UI. A distinction between uninsured workers who never receive UI and those who have exhausted UI could help create the persistence needed to match the data. Specifically, the unemployment exit rate of the formerly-insured unemployed workers can be smaller than the rest of the uninsured unemployment population. This could come from selection whereby workers with high non-UI outside options are more likely to stay unemployed (e.g. heterogeneous values of home production, leisure, or a larger degree of individual productivity). Persistence or habits in job search behaviour during unemployment could potentially help explain not only the persistence of long-term unemployment but also its trend. The introduction of savings in the model could be useful in studying the interaction between private and public insurance as well as in the welfare analyses. These extensions would provide a more complete framework to study the impact of UI extensions.

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A Expressions for Optimal Search Intensity and Match Surplus

Given the worker's value functions when employed, insured unemployed and uninsured unemployed, we can take the first derivative to find the optimal search effort. The first order conditions for type-i workers are as follows

$$\begin{aligned}
\nu_e'(s_i^e(m;\omega)) &= -\beta(1-\delta)M(\theta(\omega))E_{\omega'|\omega}\Big[\ldots \\
&(1-\lambda)(1-F(m))\Big(WS_i^{e(m)+}(m;\omega') - E_{m'|m'>m}[WS_i^{e(m)+}(m';\omega')]\Big) \\
&+ \lambda E_{m'}\Big[(1-F(m'))(WS_i^{e(m)+}(m';\omega') - E_{m''|m''>m'}[WS_i^{e(m)+}(m'';\omega')])\Big]\Big] \quad (7)
\end{aligned}$$

$$\nu_u'(s_i^{UI}(m,\omega)) = \beta M(\theta(\omega))E_{m'\omega'|\omega}\Big[\max\{WS_i^{UI(m)}(m';\omega'),0\} - \xi(1-\phi(u))US_i(m,\omega')\Big] \quad (8)$$

$$\nu_u'(s_i^{UU}(\omega)) = \beta M(\theta(\omega))E_{m'\omega'|\omega}\Big[\max\{WS_i^{UU}(m';\omega'),0\}\Big] \quad (9)$$

Total match surpluses and unemployed worker's surplus are as follows

$$\begin{aligned}
S_i^{e(\tilde{m})}(m;\omega) &= y_i(m,\omega) - \nu_e(s_i^e(m;\omega)) - \tau(\omega) - (1-\psi)(b_i(\tilde{m}) + h - \nu_u(s_i^{UI(\tilde{m})}(\omega))) \\
&-\psi(h - \nu_u(s_i^{UU}(\omega))) + \beta E_{\omega'|\omega}\Big[\ldots \\
&(1-\delta)(1-\lambda)\Big((1-p_i^e(m;\omega)(1-F(m)))S_i^{e(m)+}(m;\omega')\ldots \\
&+p_i^e(m;\omega)(1-F(m))E_{m'|m'>m}[\mu S_i^{e(m)+}(m';\omega')]\Big) \\
&+(1-\delta)\lambda E_{m'}\Big[(1-p_i^e(m;\omega)(1-F(m')))S_i^{e(m)+}(m';\omega')\ldots \\
&+p_i^e(m;\omega)(1-F(m'))E_{m''|m''>m'}[\mu S_i^{e(m)+}(m'';\omega')]\Big] \\
&-(1-\psi)p_i^{UI(\tilde{m})}(\omega)E_{m'}[\mu S_i^{UI(\tilde{m})+}(m';\omega')] \\
&-\psi p_i^{UU}(\omega)E_{m'}[\mu S_i^{UU+}(m';\omega')] \\
&+(1-\psi)\Big(US_i(m,\omega') - US_i(\tilde{m},\omega')\ldots \\
&+(\phi(u) + p_i^{UI(\tilde{m})}(\omega)\xi(1-\phi(u)))US_i(\tilde{m},\omega')\Big)\Big]
\end{aligned}$$

$$
\begin{aligned}
S_i^{UI(\tilde{m})}(m;\omega) &= y_i(m,\omega) - \nu_e(s_i^e(m;\omega)) - \tau \\
&-(1-\phi)(1-\xi)(b(\tilde{m}) + h - \nu_u(s_i^{UI(\tilde{m})}(\omega))) \\
&-(1-(1-\phi)(1-\xi))(h - \nu_u(s_i^{UU}(\omega))) + \beta E_{\omega'|\omega}\Big[\ldots \\
&(1-\delta)(1-\lambda)\Big((1-p_i^e(m;\omega)(1-F(m)))S_i^{e(m)+}(m;\omega')\ldots \\
&+p_i^e(m;\omega)(1-F(m))E_{m'|m'>m}[\mu S_i^{e(m)+}(m';\omega')]\Big) \\
&+(1-\delta)\lambda E_{m'}\Big[(1-p_i^e(m;\omega)(1-F(m')))S_i^{e(m)+}(m';\omega')\ldots \\
&+p_i^e(m;\omega)(1-F(m'))E_{m''|m''>m'}[\mu S_i^{e(m)+}(m'';\omega')]\Big] \\
&-(1-\phi)(1-\xi)p_i^{UI(\tilde{m})}(\omega)E_{m'}[\mu S_i^{UI(\tilde{m})+}(m';\omega')] \\
&-\Big(1-(1-\phi)(1-\xi)\Big)p_i^{UU}(\omega)E_{m'}[\mu S_i^{UU+}(m';\omega')] \\
&+(1-\psi)US_i(m,\omega') \\
&-\Big((1-\phi)^2(1-\xi)(1-\xi p_i^{UI(\tilde{m})}(\omega))\Big)US_i(\tilde{m},\omega')\Big]
\end{aligned}
$$

$$
\begin{aligned}
S_i^{UU}(m;\omega) &= y_i(m,\omega) - \nu_e(s_i^e(m;\omega)) - \tau - (h - \nu_u(s_i^{UU}(\omega))) + \beta E_{\omega'|\omega}\Big[\ldots \\
&(1-\delta)(1-\lambda)\Big((1-p_i^e(m;\omega)(1-F(m)))S_i^{e(m)+}(m;\omega')\ldots \\
&+p_i^e(m;\omega)(1-F(m))E_{m'|m'>m}[\mu S_i^{e(m)+}(m';\omega')]\Big) \\
&+(1-\delta)\lambda E_{m'}\Big[(1-p_i^e(m;\omega)(1-F(m')))S_i^{e(m)+}(m';\omega')\ldots \\
&+p_i^e(m;\omega)(1-F(m'))E_{m''|m''>m'}[\mu S_i^{e(m)+}(m'';\omega')]\Big] \\
&-p_i^{UU}(\omega)E_{m'}[\mu S_i^{UU+}(m';\omega')] \\
&+(1-\psi)US_i(m,\omega')\Big]
\end{aligned}
$$

$$
\begin{aligned}
US_i(m,\omega) &= b(m) - \nu_u(s_i^{UI(m)}(\omega)) + \nu_u(s_i^{UU}(\omega)) \\
&+\beta E_{\omega'|\omega}\Big[p_i^{UI(m)}(\omega)E_{m'}[\mu S_i^{UI(m)+}(m';\omega')]\ldots \\
&-p_i^{UU}(\omega)E_{m'}[\mu S_i^{UU+}(m';\omega')] \\
&+(1-\phi)\Big(1-\xi p_i^{UI(m)}(\omega)\Big)US_i(m,\omega')\Big]
\end{aligned}
$$

B Transitions

Employment The mass of type-i employed agents in t with match quality m, $e_{i,t}(m)$, evolves as follows

$$\begin{aligned} e_{i,t+1}(m) &= (1-\delta)(1-\lambda)(1-p^e_{i,t}(m)+p^e_{i,t}(m)F(m))e_{i,t}(m)\mathbb{1}\{S^{e(m)}_{i,t+1}(m)>0\} \\ &+(1-\delta)(1-\lambda)f(m)\int_{m'<m} p^e_{i,t}(m')e_{i,t}(m')\mathbb{1}\{S^{e(m')}_{i,t+1}(m)>0\}dm' \\ &+(1-\delta)\lambda f(m)\int_{m'}(1-p^e_{i,t}(m')+p^e_{i,t}(m')F(m))e_{i,t}(m')\mathbb{1}\{S^{e(m')}_{i,t+1}(m)>0\}dm' \\ &+(1-\delta)\lambda F(m)f(m)\int_{m'} p^e_{i,t}(m')e_{i,t}(m')\mathbb{1}\{S^{e(m')}_{i,t+1}(m)>0\}dm' \\ &+f(m)\int_{\tilde{m}} u^{UI}_{i,t}(\tilde{m})p^{UI}_{i,t}(\tilde{m})\mathbb{1}\{S^{UI(\tilde{m})}_{i,t+1}(m)>0\}d\tilde{m} \\ &+f(m)u^{UU}_{i,t}p^{UU}_{i,t}\mathbb{1}\{S^{UU}_{i,t+1}(m)>0\} \end{aligned} \tag{10}$$

where $\mathbb{1}\{\cdot\}$ is an indicator function. The total employment is the sum of all employed workers over productviity types and match qualities $e_t = \sum_{i=H,L}\int e_{i,t}(m)\ dm$ and the aggregate output can be computed as $y_t = z_t \sum_{i=H,L}\int m \cdot e_{i,t}(m)\ dm$.

Job Destructions The job destruction rate of type-i employed workers with match quality m at the beginning of period t and m' at the end of period t, and the average job destruction rate are respectively

$$\begin{aligned} \rho_{x,it}(m,m') &= \begin{cases} \delta & \text{if } S^{e(m)}_{i,t+1}(m')>0, \\ 1 & \text{otherwise} \end{cases} \\ \rho_{x,it} &= \Bigg(\delta \int\int_{\{(m,m'):S^{e(m)}_{i,t+1}(m')>0\}} e^{post}_{i,t}(m,m')dm\,dm' \\ &\quad + \int\int_{\{(m,m'):S^{e(m)}_{i,t+1}(m')\leq 0\}} e^{post}_{i,t}(m,m')dm\,dm'\Bigg)/e_t \end{aligned} \tag{11}$$

$$\begin{aligned} \text{where } e^{post}_{i,t}(m,m') &= (1-\lambda)(1-p^e_{i,t}(m')+p^e_{i,t}(m')F(m'))e_{i,t}(m') \\ &+(1-\lambda)f(m')p^e_{i,t}(m)e_{i,t}(m)\mathbb{1}\{m<m'\} \\ &+\lambda f(m')(1-p^e_{i,t}(m)+p^e_{i,t}(m)F(m'))e_{i,t}(m) \\ &+\lambda F(m')f(m')p^e_{i,t}(m)e_{i,t}(m) \end{aligned}$$

denotes employed workers with match productivity m at the beginning of period t and m' at the end of the period t.

Job Findings The job finding rate for a type-i unemployed worker of status $j = \{UI(\tilde{m}), UU\}$ and the average job finding rate are respectively

$$\begin{aligned}
\rho^{j}_{f,it} &= \int \rho^{j}_{f,it}(m) f(m) dm \\
\rho_{f,t} &= \frac{\int_{\tilde{m}} u^{UI}_{i,t}(\tilde{m}) \rho^{UI(\tilde{m})}_{f,it} d\tilde{m} + u^{UU}_{i,t} \rho^{UU}_{f,it}}{\int_{\tilde{m}} u^{UI}_{t}(\tilde{m}) d\tilde{m} + u^{UU}_{t}} \\
\text{where } \rho^{j}_{f,it}(m) &= \begin{cases} p^{j}_{i,t} & \text{if } S^{j}_{i,t+1}(m) > 0, \\ 0 & \text{otherwise} \end{cases}
\end{aligned}$$

Job-to-job Transitions The match-specific and the average job-to-job transition rates are respectively

$$\begin{aligned}
\rho^{ee}_{i,t}(m) &= (1-\delta)\Big((1-\lambda) p^{e}_{i,t}(m)(1-F(m)) E_{m'>m}[\mathbf{1}\{S^{e}_{i,t+1}(m,m') > 0\}] \\
&\quad + \lambda \int_{m'} p^{e}_{i,t}(m) f(m')(1-F(m')) E_{m''>m'}[\mathbf{1}\{S^{e}_{i,t+1}(m,m'') > 0\}] dm'\Big) \\
\rho^{ee}_{i,t} &= \frac{\int_{m} \rho^{ee}_{i,t}(m) e_{i,t}(m) dm}{e_t}
\end{aligned}$$

Unemployment The mass of type-i unemployed workers with and without UI benefits as well as the total unemployment evolve respectively as follows

$$\begin{aligned}
u^{UI}_{i,t+1}(\tilde{m}) &= \underbrace{(1-\phi_t)(1-p^{UI}_{i,t}(\tilde{m})) u^{UI}_{i,t}(\tilde{m})}_{\text{unmatched, not losing UI}} + \underbrace{\chi^{UI}_{i,t}(\tilde{m})(1-\phi_t)(1-\xi) p^{UI}_{i,t}(\tilde{m}) u^{UI}_{i,t}(\tilde{m})}_{\text{bad match, not losing UI}} \\
&\quad \underbrace{+ (1-\psi) \int_{m'} \rho_{x,it}(\tilde{m}, m') e_{i,t}(\tilde{m}, m') dm'}_{\text{destroyed match, not losing UI}} \qquad (12) \\
u^{UU}_{i,t+1} &= \int_{\tilde{m}} \Big(\underbrace{\phi_t (1-p^{UI}_{i,t}(\tilde{m})) u^{UI}_{i,t}(\tilde{m})}_{\text{unmatched, losing UI}} + \underbrace{\chi^{UI}_{i,t}(\tilde{m}) \Big(\phi_t + (1-\phi_t)\xi\Big) p^{UI}_{i,t}(\tilde{m}) u^{UI}_{i,t}(\tilde{m})}_{\text{bad match, losing UI}} \Big) d\tilde{m} \\
&\quad + (1-\rho^{UU}_{f,it}) u^{UU}_{i,t} + \underbrace{\psi \rho_{x,it} e_{i,t}}_{\text{destroyed match, losing UI}} \qquad (13) \\
u_{t+1} &= \sum_{i=H,L} \left(\int_{\tilde{m}} u^{UI}_{i,t+1}(\tilde{m}) d\tilde{m} + u^{UU}_{i,t+1} \right) \qquad (14)
\end{aligned}$$

where $\chi^{UI}_{i,t}(\tilde{m}) \equiv \int \mathbf{1}\{S^{UI}_{i,t+1}(\tilde{m}, m) \leq 0\} f(m) dm$ denotes the rate the newly formed matches with $u^{UI}_{i}(\tilde{m})$ are not viable.

C Performance of the Approximation Method

Below I report the average percentage deviations (in absolute value) of the 1st, 2nd, 3rd and 4th moments of the approximated distribution of employed workers over match quality from the distributions obtained from the simulation. The method described in the Model section delivers distributions that are less than 1% different in terms of the 1st, 2nd and 4th moments from the actual distributions found in the simulation. However it generates the 3rd moment that is more than 3% different from its counterpart since the skewness is more sensitive to the cut-offs in the distributions coming from endogenous destructions.

Table 1: **Performance of the Approximation Method**

	Percentage deviations (%)	
	Mean	SE
1st moment	0.5650	0.3953
2nd moment	0.4670	0.4499
3rd moment	3.6819	3.4767
4th moment	0.2009	0.2936

D Computational Algorithm

(to be completed)

E Ahn and Hamilton (2016)'s State Space Model

To summarise briefly, Ahn and Hamilton (2016)'s state space model contains the latent variables which are the number of each type entering unemployment in each time period ($w_{H,t}$,$w_{L,t}$) and the time-varying factors governing their outflow rates ($x_{H,t}$,$x_{L,t}$). These four variables follow a random walk process. For example,

$$w_{H,t} \quad = \quad w_{H,t-1} + \varepsilon^{w}_{H,t}$$

The errors are independently and normally distributed with mean zero and standard deviation $\{\sigma^w_H, \sigma^w_L, \sigma^x_H, \sigma^x_L\}$ respectively. They assume the true duration dependence of unemployment exit rate is time invariant and summarised by $\{\delta_1, \delta_2, \delta_3\}$. The measurements or observables in their model are unemployment series by 5 duration bins $\{u^1_t, u^{2.3}_t, u^{4.6}_t, u^{7.12}_t, u^{13+}_t\}$.

They are, respectively, unemployed workers with duration less than 1 month, 2-3 months, 4-6 months, 7-12 months, and more than 12 months. All five unemployment series can contain measurement errors $\{r_t^1, r_t^{2.3}, r_t^{4.6}, r_t^{7.12}, r_t^{13+}\}$ which are independently and normally distributed with mean zero and standard deviation $\{R1, R2.3, R4.6, R7.12, R13+\}$. The evolution of these series are as follows

$$\begin{aligned}
u_t^1 &= \sum_{i=H,L} w_{it} + r_t^1 \\
u_t^{2.3} &= \sum_{i=H,L} [w_{i,t-1}P_{it}(1) + w_{i,t-2}P_{it}(2)] + r_t^{2.3} \\
u_t^{4.6} &= \sum_{i=H,L}\sum_{k=3}^{5} [w_{i,t-k}P_{it}(k)] + r_t^{4.6} \\
u_t^{7.12} &= \sum_{i=H,L}\sum_{k=6}^{11} [w_{i,t-k}P_{it}(k)] + r_t^{7.12} \\
u_t^{13+} &= \sum_{i=H,L}\sum_{k=12}^{47} [w_{i,t-k}P_{it}(k)] + r_t^{13+}
\end{aligned}$$

$$\begin{aligned}
\text{where } P_{it}(j) &= p_{i,t-j+1}(1) \times p_{i,t-j+2}(2) \times \ldots \times p_{i,t}(j) \\
p_{it}(\tau) &= \exp[-\exp(x_{it} + d_\tau)] \\
d_\tau &= \begin{cases} \delta_1(\tau - 1) & \text{for } \tau < 6 \\ \delta_1[(6-1)-1] + \delta_2[\tau - (6-1)] & \text{for } 6 \le \tau < 12 \\ \delta_1[(6-1)-1] + \delta_2[(12-1)-(6-1)] + \delta_3[\tau - (12-1)] & \text{for } 12 \le \tau \end{cases}
\end{aligned}$$

The parameters to be estimated are the standard deviations of the errors $\{\sigma_H^w, \sigma_L^w, \sigma_H^x, \sigma_L^x,$ $R1, R2.3, R4.6, R7.12, R13+\}$ and the parameters for true duration dependence $\{\delta_1, \delta_2, \delta_3\}$. I obtain 50 different series of $\{u_t^1, u_t^{2.3}, u_t^{4.6}, u_t^{7.12}, u_t^{13+}\}$ by using the Monte Carlo simulations. For each set of the simulated unemployment series, I obtain a set of twelve estimates from the same non-linear state space model using Maximum Likelihood. The extended Kalman fiter is used to construct the likelihood function since $\{x_{H,t}, x_{L,t}\}$ enter the equations for unemployment series non-linearly. Table 15 reports these estimates and their standard errors.

Figure 1: Unemployment and Long-term Unemployment (those unemployed > 6 months) in the U.S. (Source: CPS)

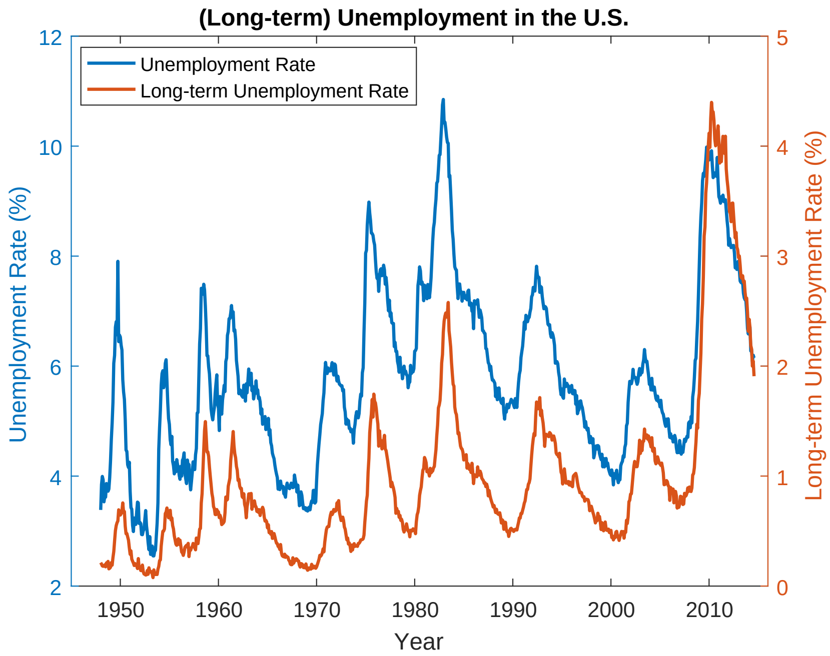


Figure 2: Maximum Unemployment Insurance Duration (weeks) in the U.S. (Source: ETA. Shaded areas denote the recessions)

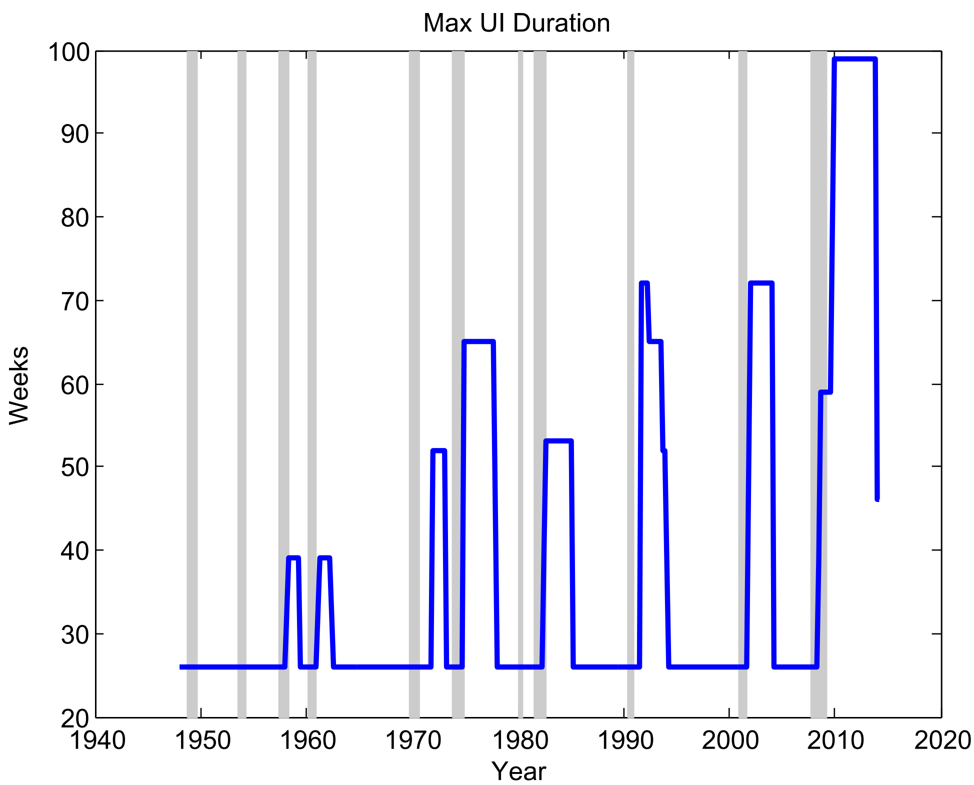


Figure 3: Maximum Unemployment Insurance Duration (weeks) in the U.S. with Automatic Extensions (Source: ETA. Shaded areas denote the recessions. Dashed green line denotes the automatic extensions)

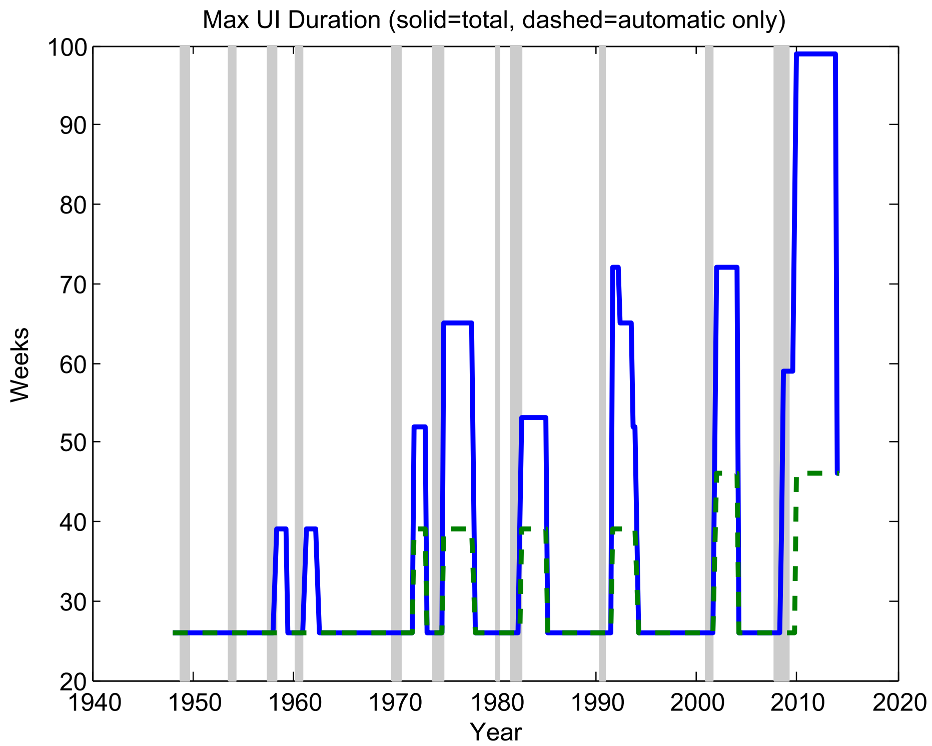


Figure 4: Unemployment-to-Employment Transition Rate (%) by UI status (Source: CPS)

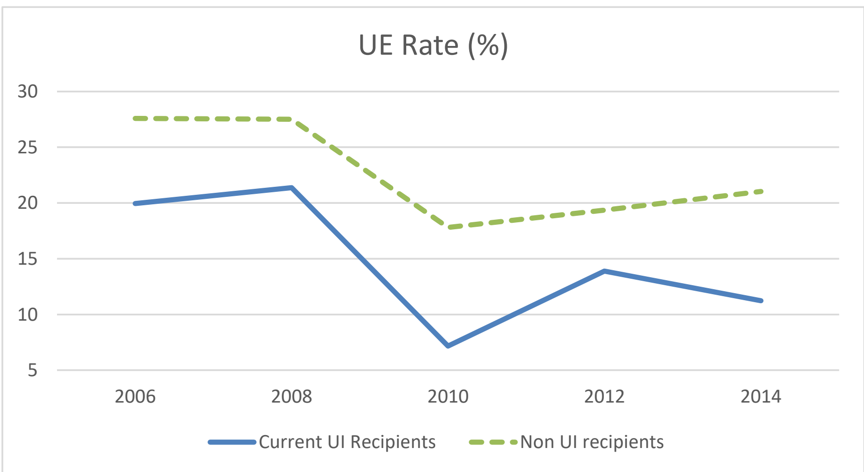


Figure 5: Unemployment-to-Unemployment Transition Rate (%) by UI status (Source: CPS)

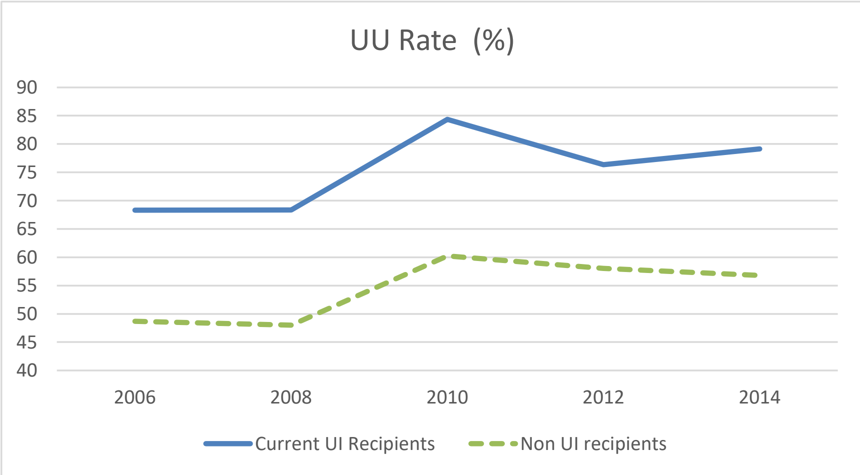


Figure 6: Unemployment-to-Out-of-Labour-Force Transition Rate (%) by UI status (Source: CPS)

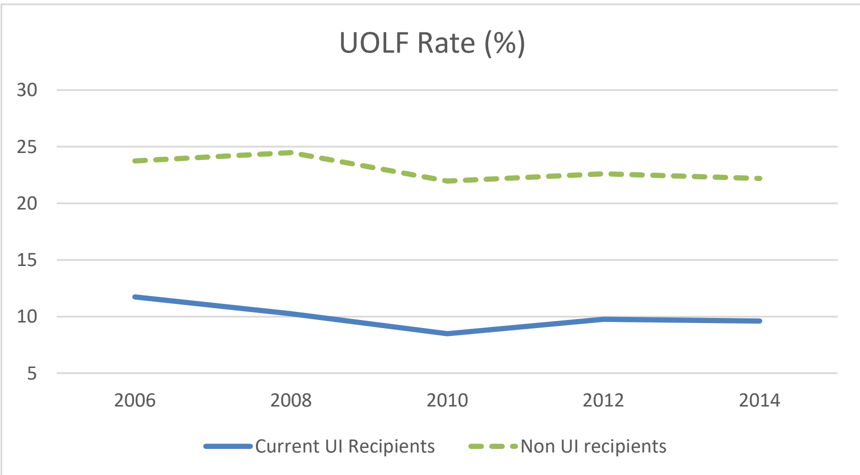


Figure 7: Distributions of unemployment durations and fractions represented by current UI recipients (Source: CPS)

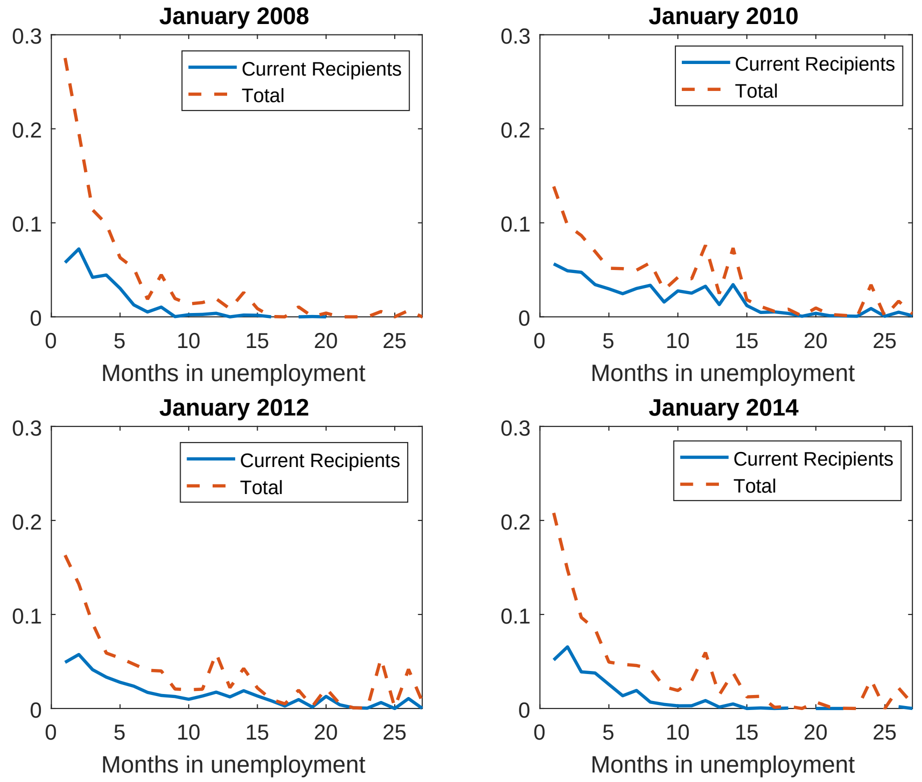


Figure 8: Shares (%) of current UI recipients over total unemployment in each monthly duration bins (Source: CPS)

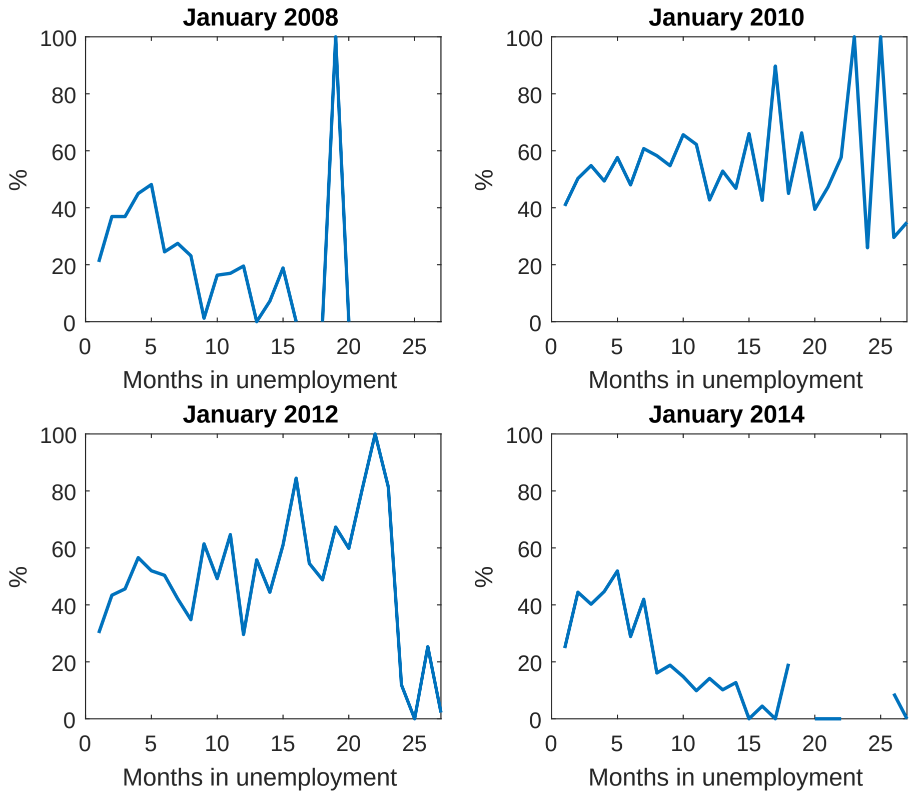


Figure 9: Shares (%) of Current UI Recepients in 2 Subgroups: Long-term Unemployment and Newly Unemployed Workers (Source: CPS)

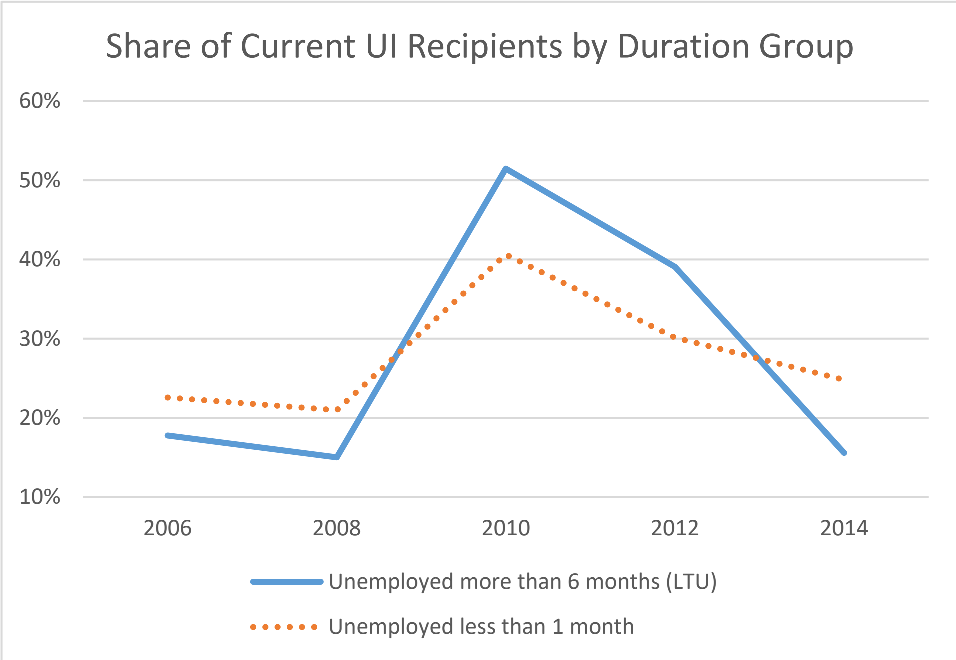


Figure 10: Aggregate Productivity Series (z) as Constructed to Match Output Deviations from HP Trend

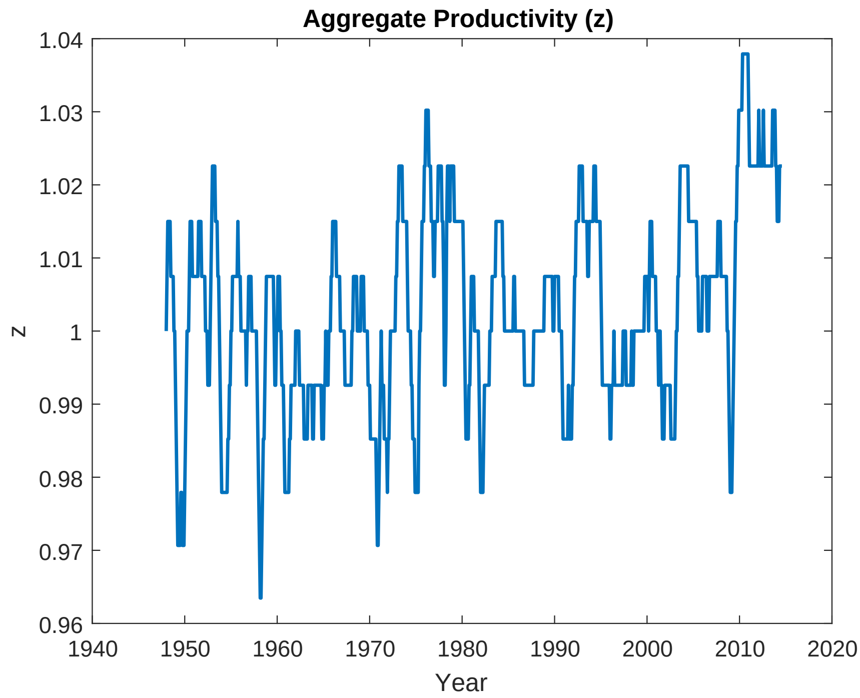


Figure 11: UI Extensions from the Model and the Data (Data source: ETA)

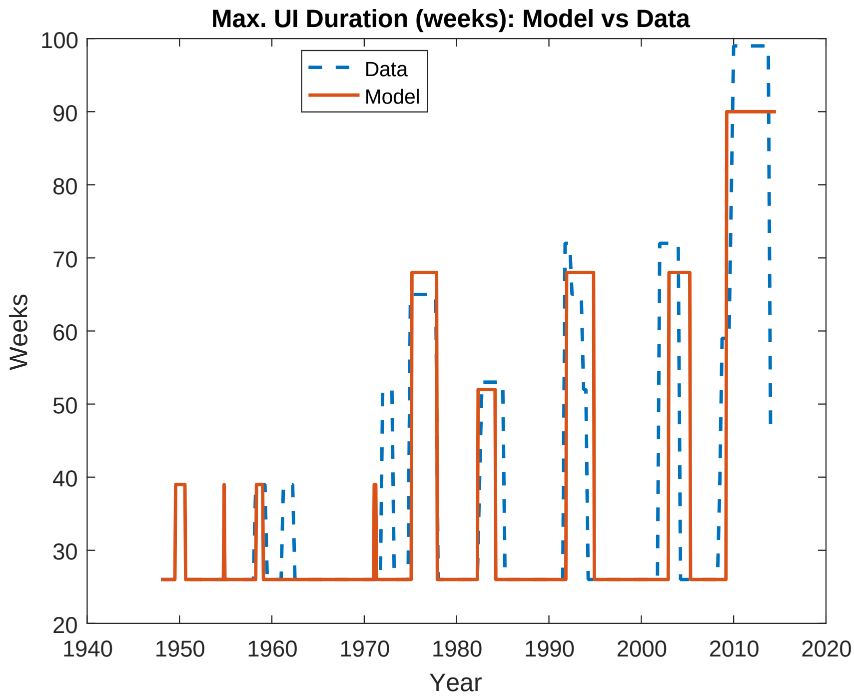


Figure 12: Unemployment Rate (%) from the Model and the Data (Data source: CPS)

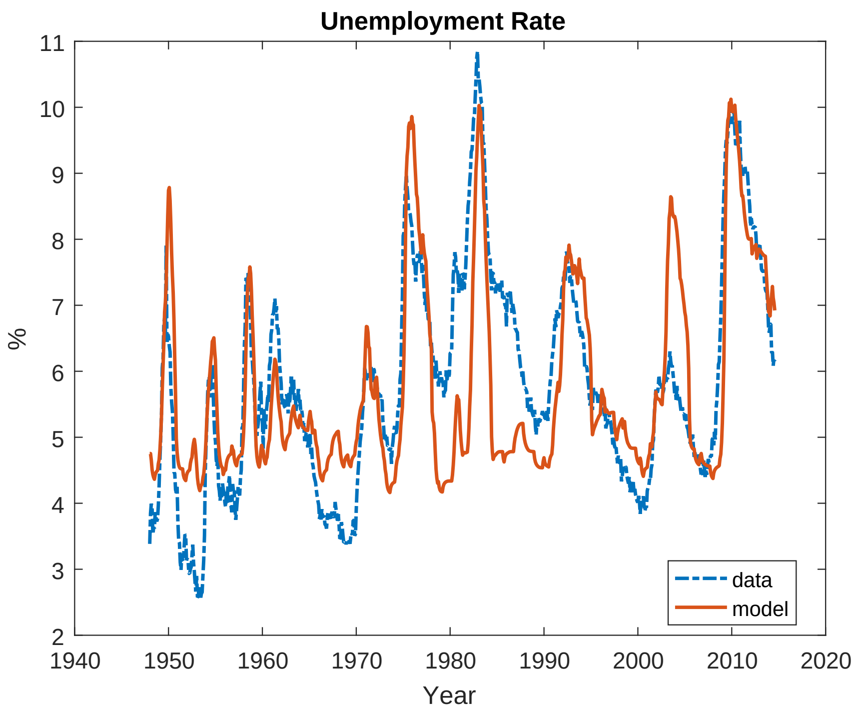


Figure 13: Long-term Unemployment Rate (%) from the Model and the Data (Data source: CPS)

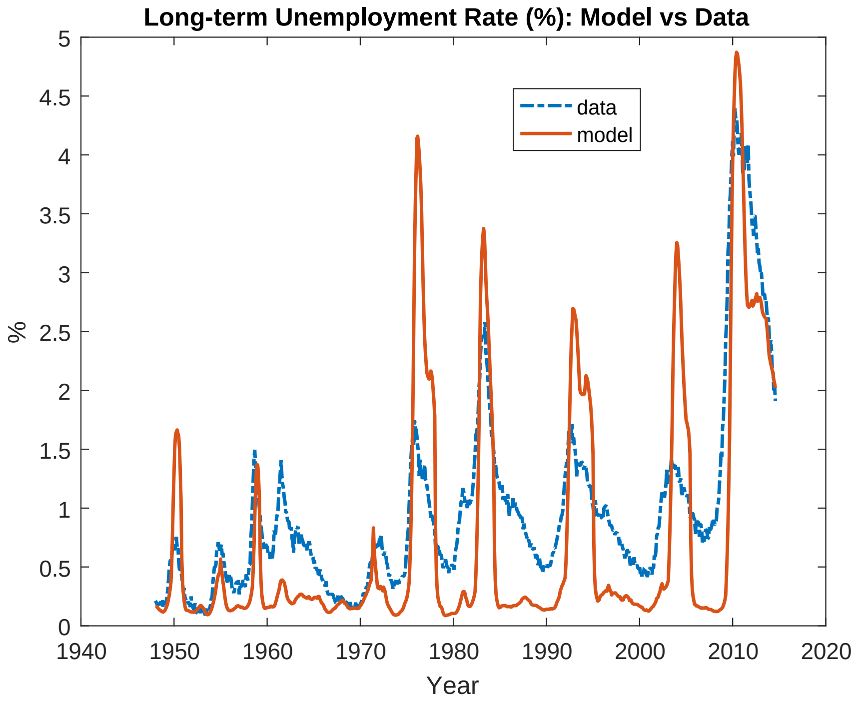


Figure 14: Average Unemployment Duration from the Model and the Data (Data source: CPS)

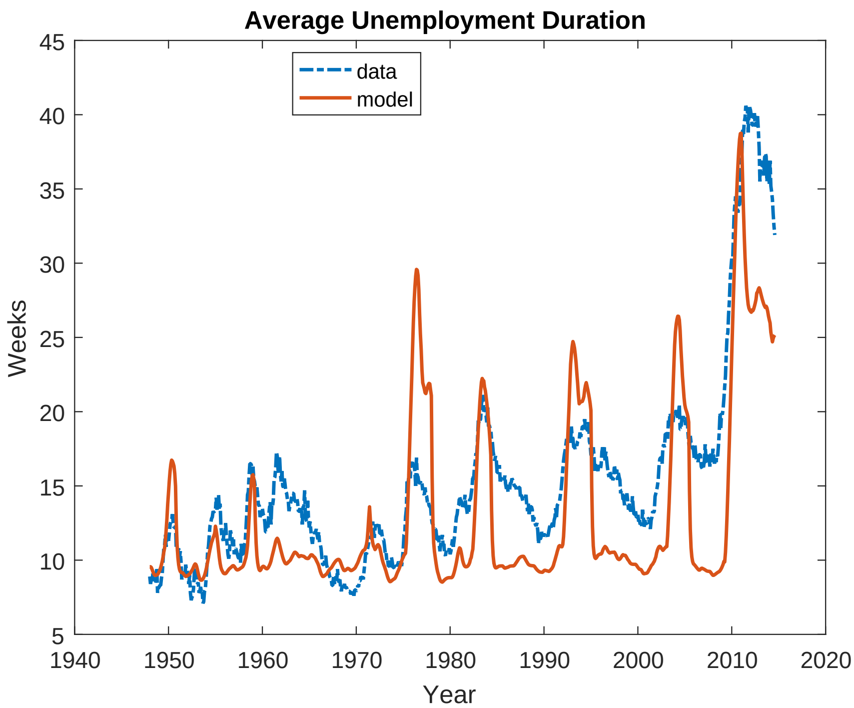


Figure 15: Distribution of Unemployment Durations during the Great Recession (Data source: CPS)

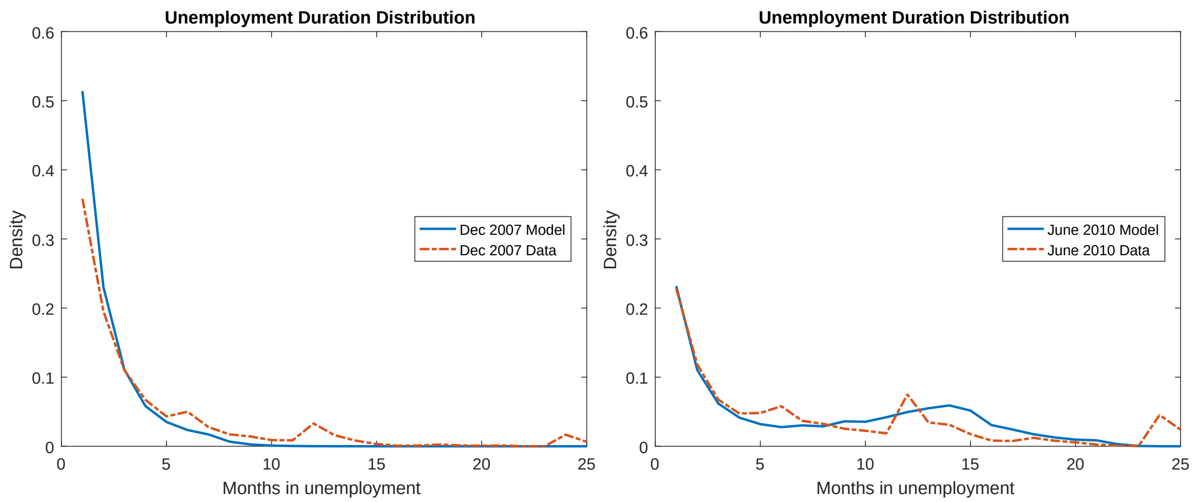


Figure 16: Unemployment Shares (%) by Durations (Data source: CPS)

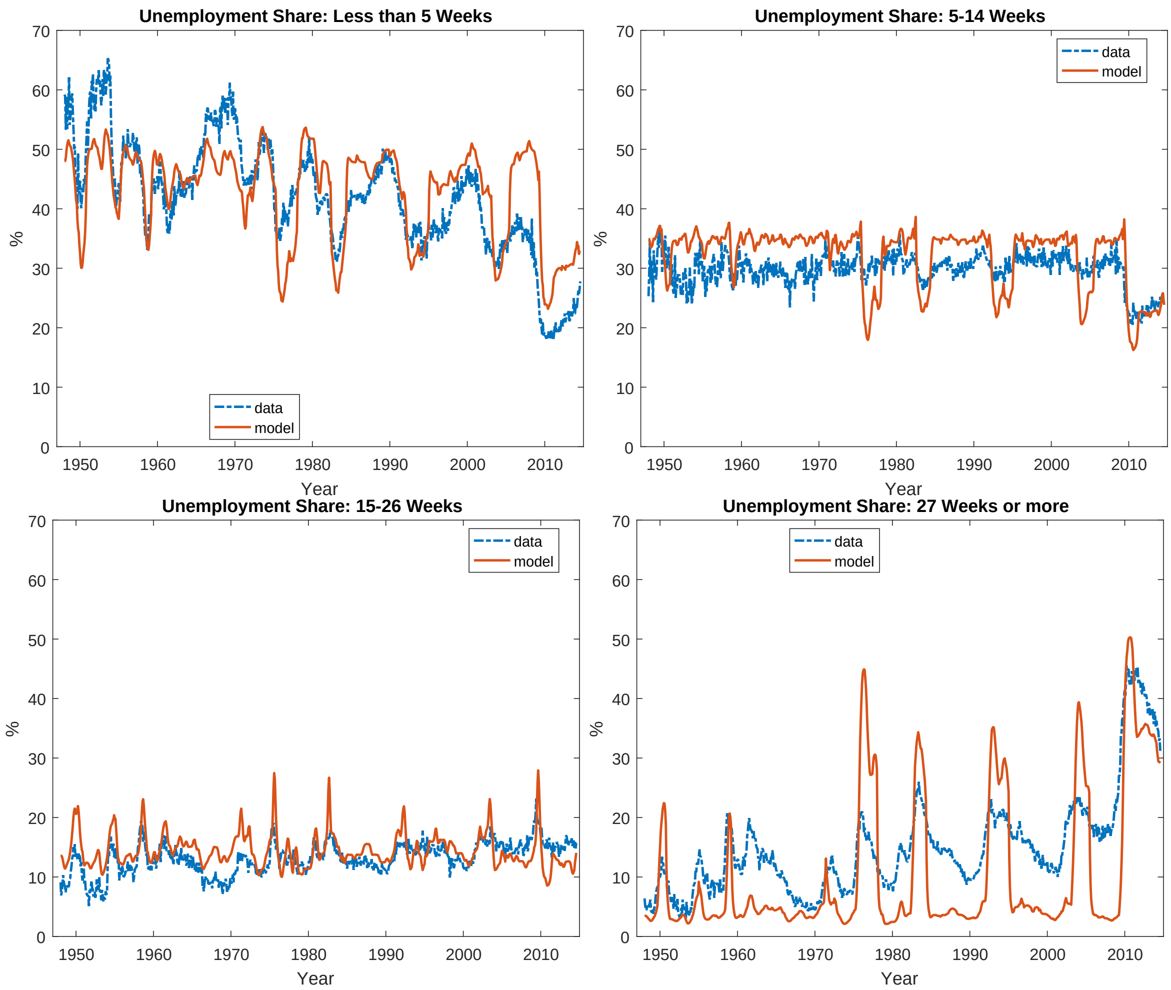


Figure 17: Job Finding (left panel) and Job Separation Rates (right panel) (%) as Observed in the Data and as Generated by the Model (Data source: CPS)

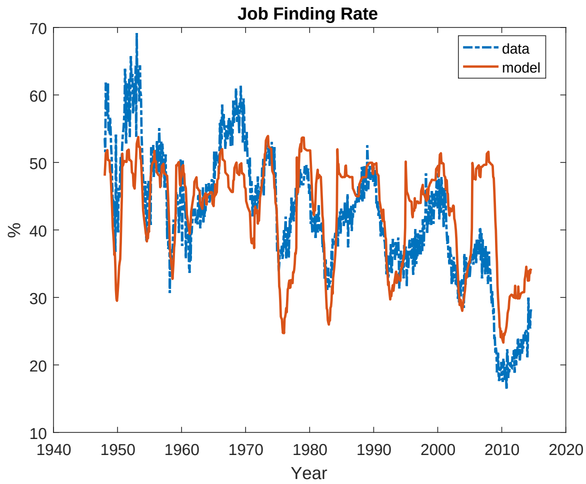


Figure 18: Unemployment Exit Rate (%) by UI Status (left panel) and Worker's Productivity (right panel)

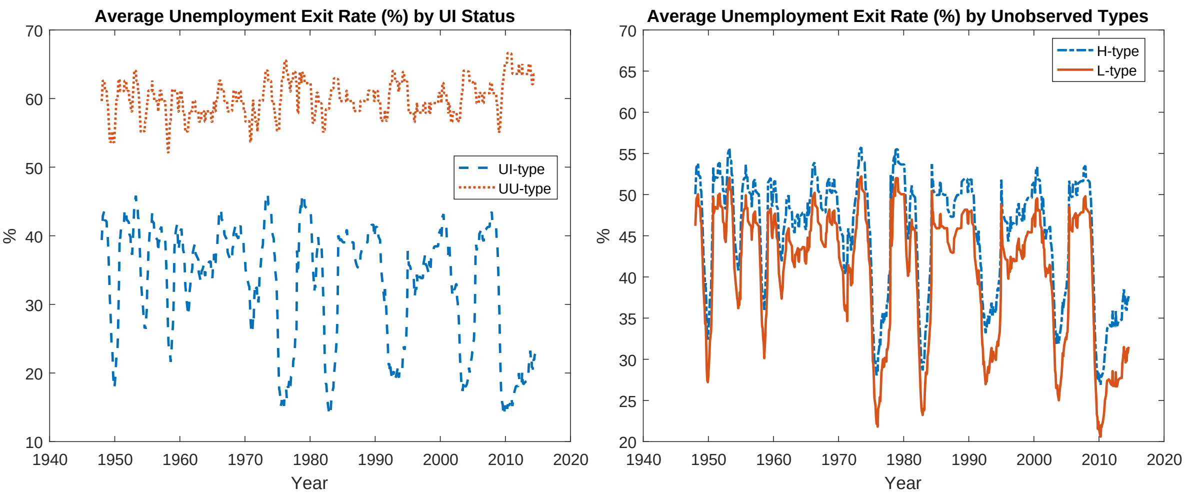


Figure 19: Conditional Job finding rate (%) as a function of unemployment by UI status $(p^e_H(\tilde{m}), p^{UI}_H(\tilde{m}), p^{UU}_H)$: For solid (dashed) lines, maximum UI duration is 39 (90) weeks

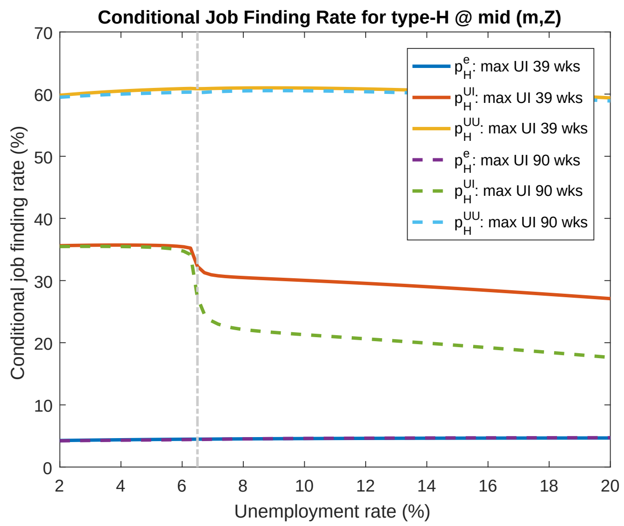


Figure 20: Conditional Job finding rate (%) as a function of unemployment by UI benefit levels ($p^{UI}_H(\tilde{m})$ by $\tilde{m}$) (left panel) and by Worker's Productivity $(p^{UI}_H(\tilde{m}), p^{UI}_L(\tilde{m}))$ (right panel): For solid (dashed) lines, maximum UI duration is 39 (90) weeks

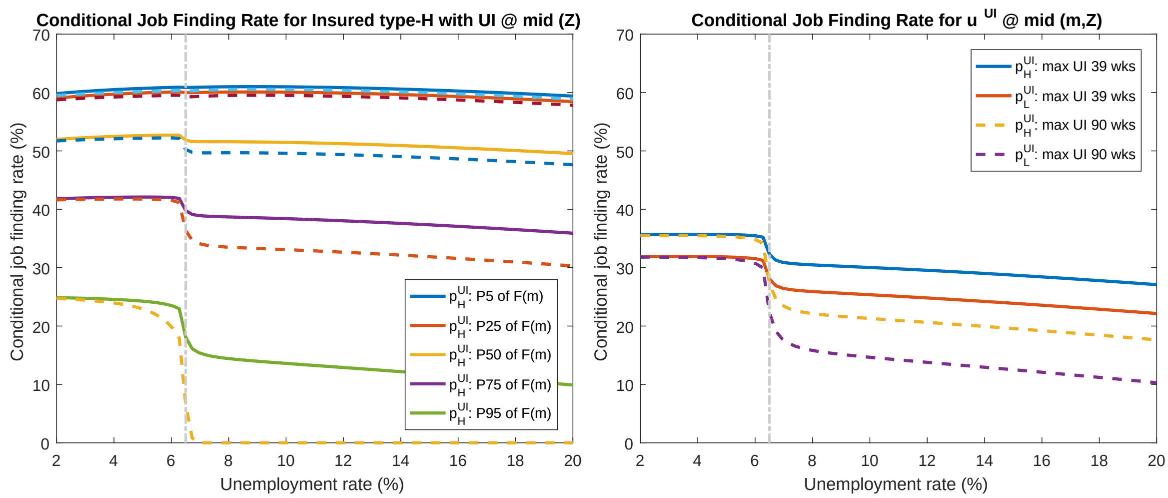


Figure 21: Total Match Surplus as a function of unemployment by UI status $(S_H^{e(\tilde{m})}(m), S_H^{UI(\tilde{m})}(m), S_H^{UU}(m))$ (left panel) and by worker's productivity $(S_H^{UI(\tilde{m})}(m), S_L^{UI(\tilde{m})}(m))$ (right panel): For solid (dashed) lines, maximum UI duration is 39 (90) weeks

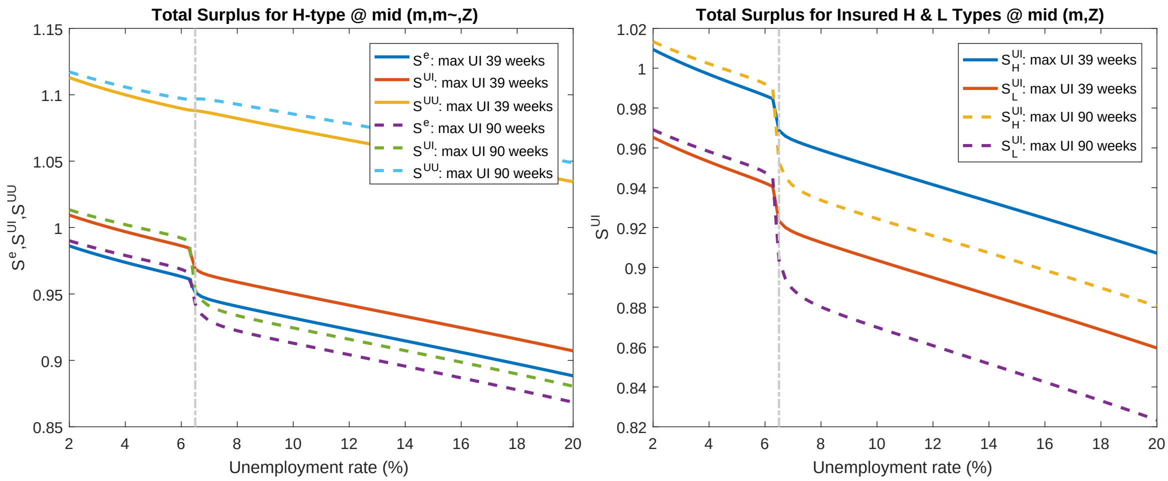


Figure 22: Total Match Surplus as a function of unemployment for the insured unemployed by future match quality ($S_H^{UI(\tilde{m})}(m)$ by m) (left panel) and by benefit level ($S_H^{UI(\tilde{m})}(m)$ by $\tilde{m}$) (right panel): For solid (dashed) lines, maximum UI duration is 39 (90) weeks

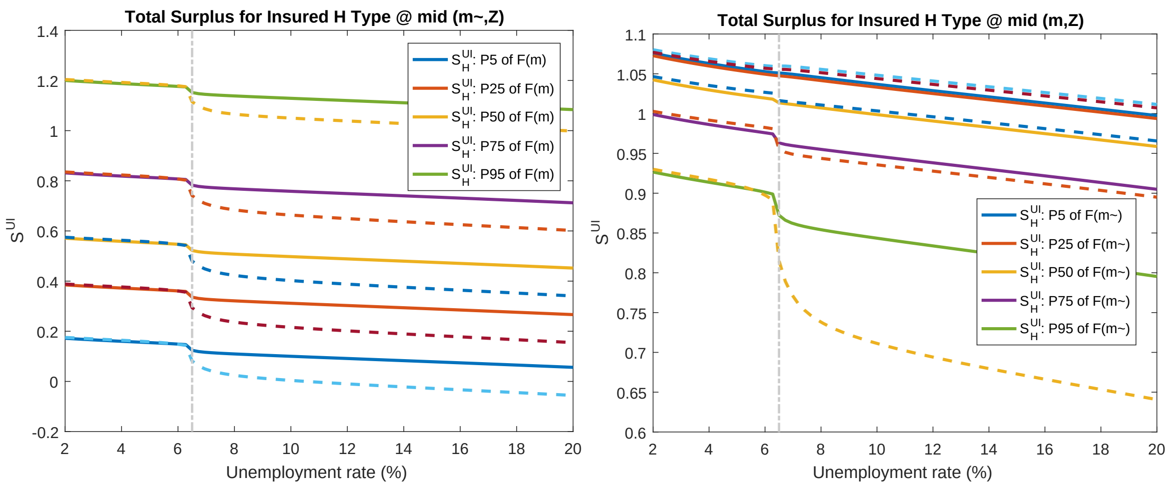


Figure 23: The success rate of meetings between unemployed workers and firms (fractions of meetings that lead to viable matches)

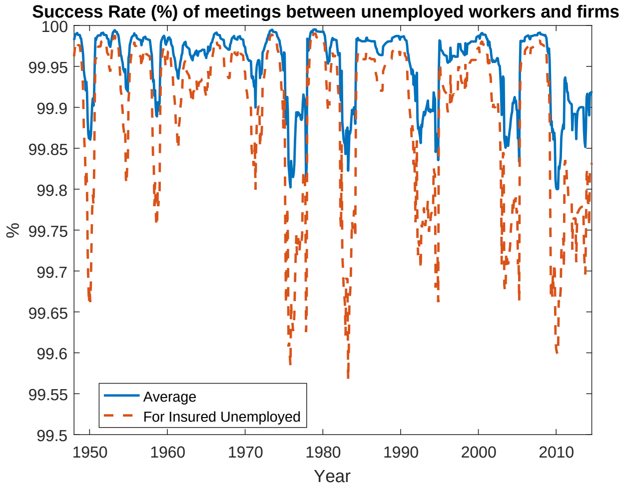
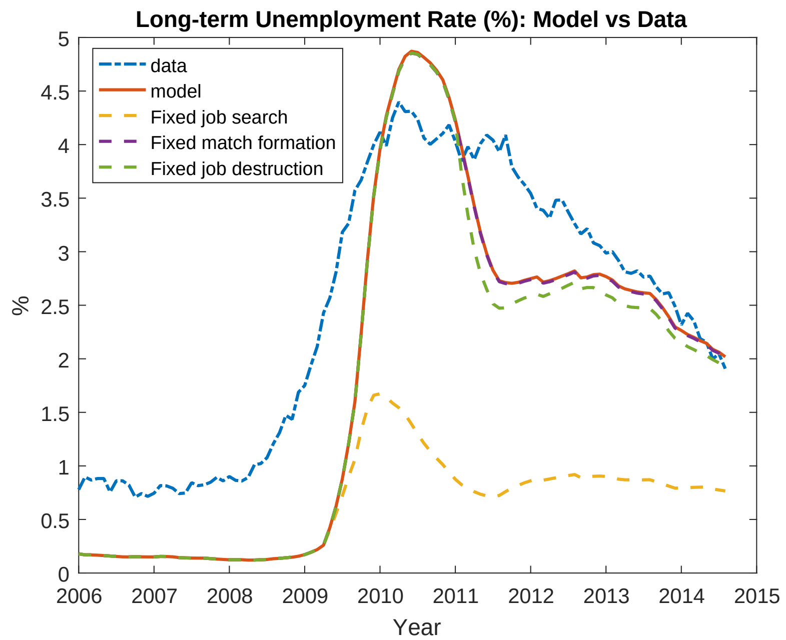


Figure 24: Decomposition of the Effect of UI Extensions on Long-term Unemployment (%): Data, Baseline Model and Counterfactual (each of the following channels is fixed: job search behavior, match formation and job destruction) (Data source: CPS)

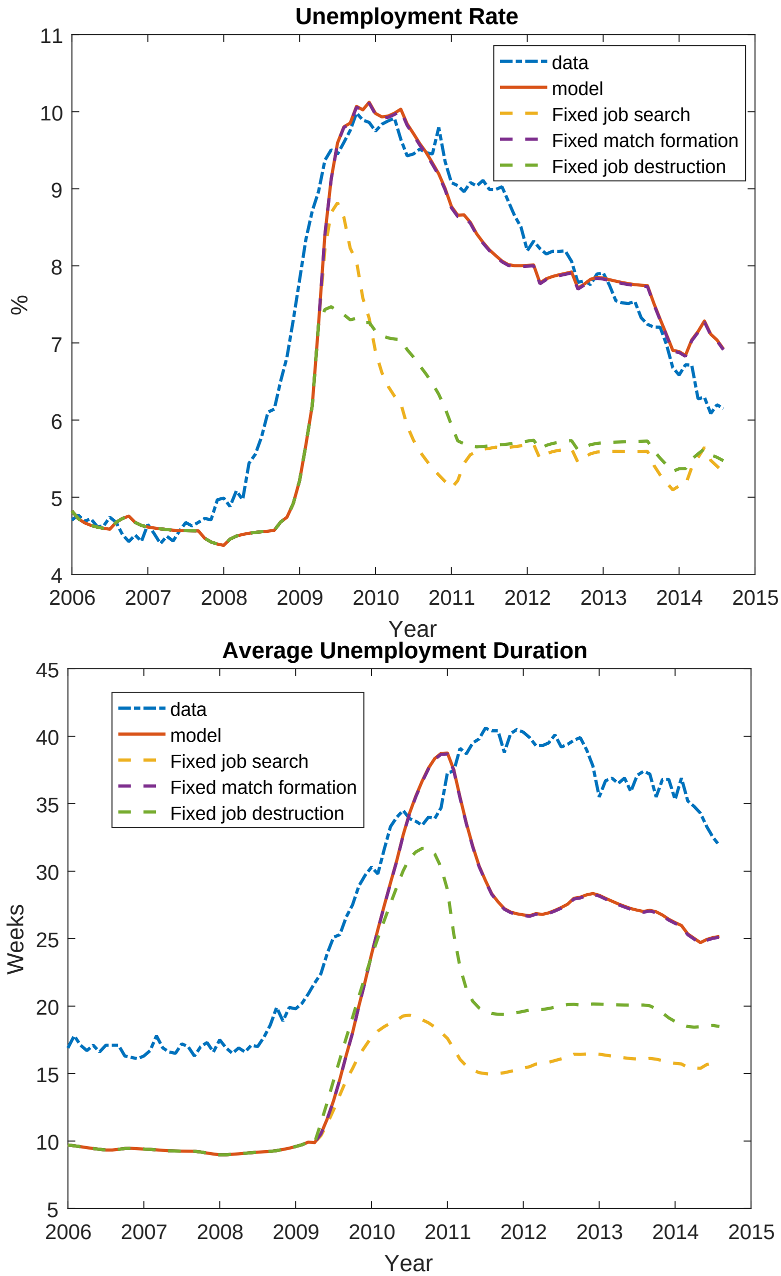


Fixed job search: job search intensity $(s_i^e(\tilde{m}), s_i^{UI}(\tilde{m}), s_i^{UU})$ does not respond to UI extensions

Fixed match formation: match formation decisions $(S_i^{UI(\tilde{m})}(m), S_i^{UU}(m))$ do not respond to UI extensions

Fixed job destruction: match separation decisions $(S_i^{e(\tilde{m})}(m))$ do not respond to UI extensions

Figure 25: Decomposition of the Effect of UI Extensions on Unemployment (%) (top panel) and Average Unemployment Duration (weeks) (bottom panel): Data, Baseline Model and Counterfactual (each of the following channels is fixed: job search behavior, match formation and job destruction) (Data source: CPS)



Fixed job search: job search intensity ($s_i^e(\tilde{m}), s_i^{UI}(\tilde{m}), s_i^{UU}$) does not respond to UI extensions
Fixed match formation: match formation decisions ($S_i^{UI(\tilde{m})}(m), S_i^{UU}(m)$) do not respond to UI extensions
Fixed job destruction: match separation decisions ($S_i^{e(\tilde{m})}(m)$) do not respond to UI extensions

Figure 26: UI Extensions: Data, Baseline Model and Counterfactual (with no UI extensions) (Data source: ETA)

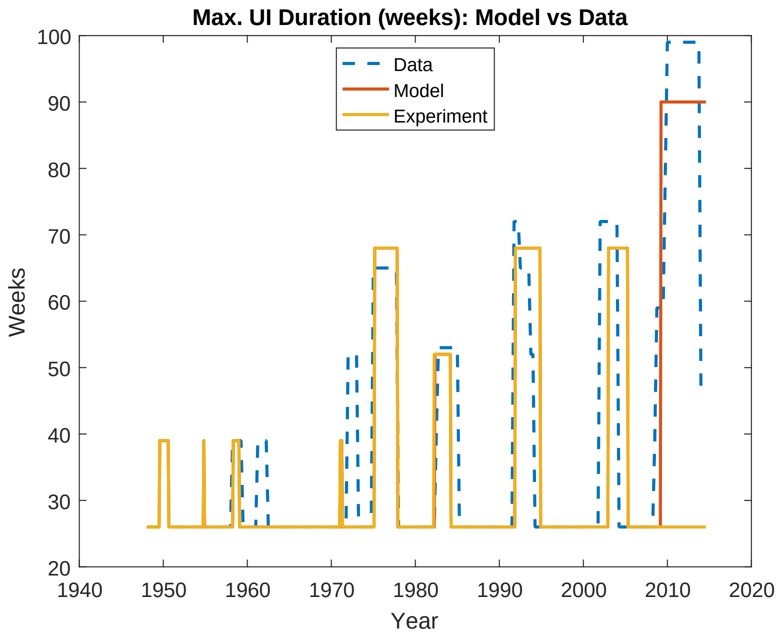
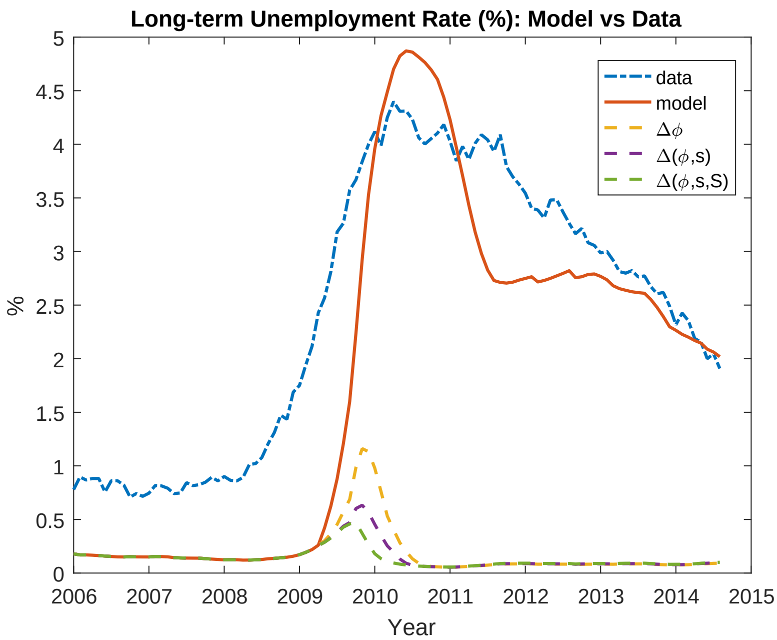


Figure 27: The Effect of Removing UI Extension on the Long-term Unemployment (%): Data, Baseline Model and Counterfactual (with no UI extensions) (Data source: CPS)

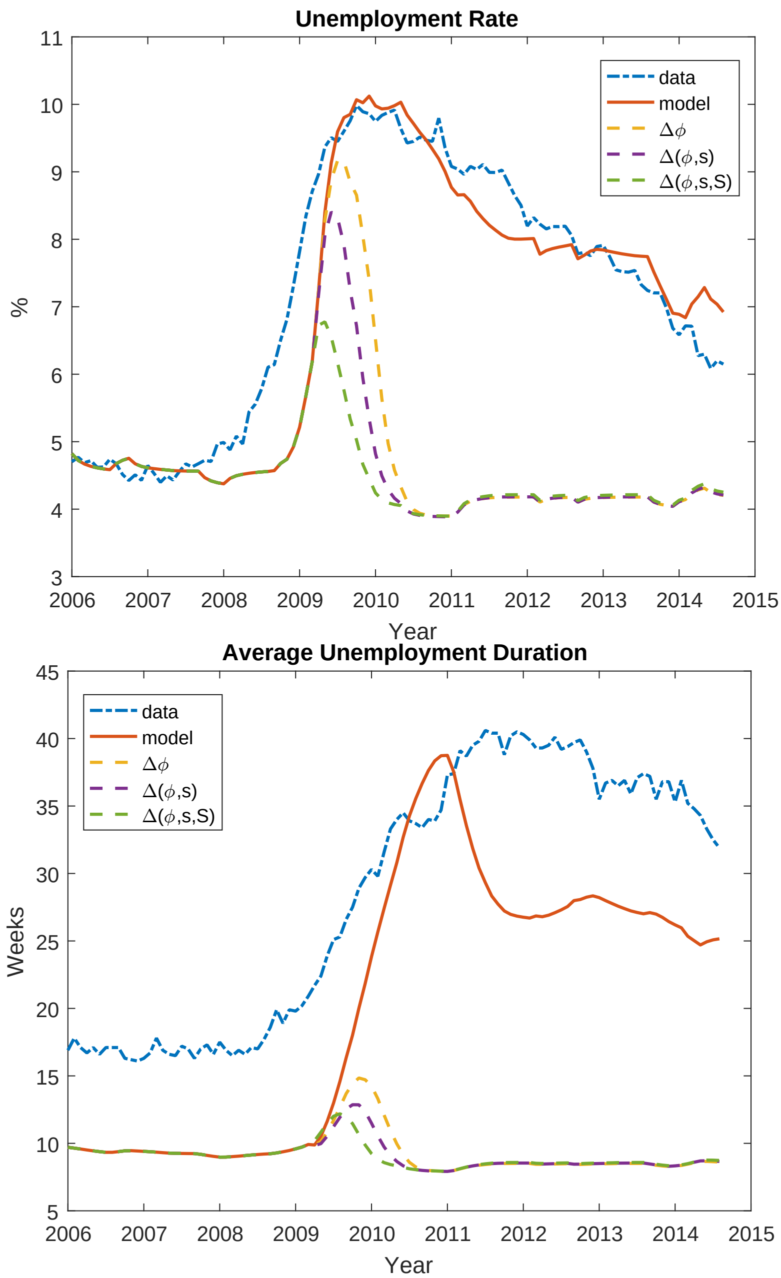


$\Delta\phi$: only maximum UI duration changes

$\Delta(\phi, s)$: maximum UI duration and job search effort change

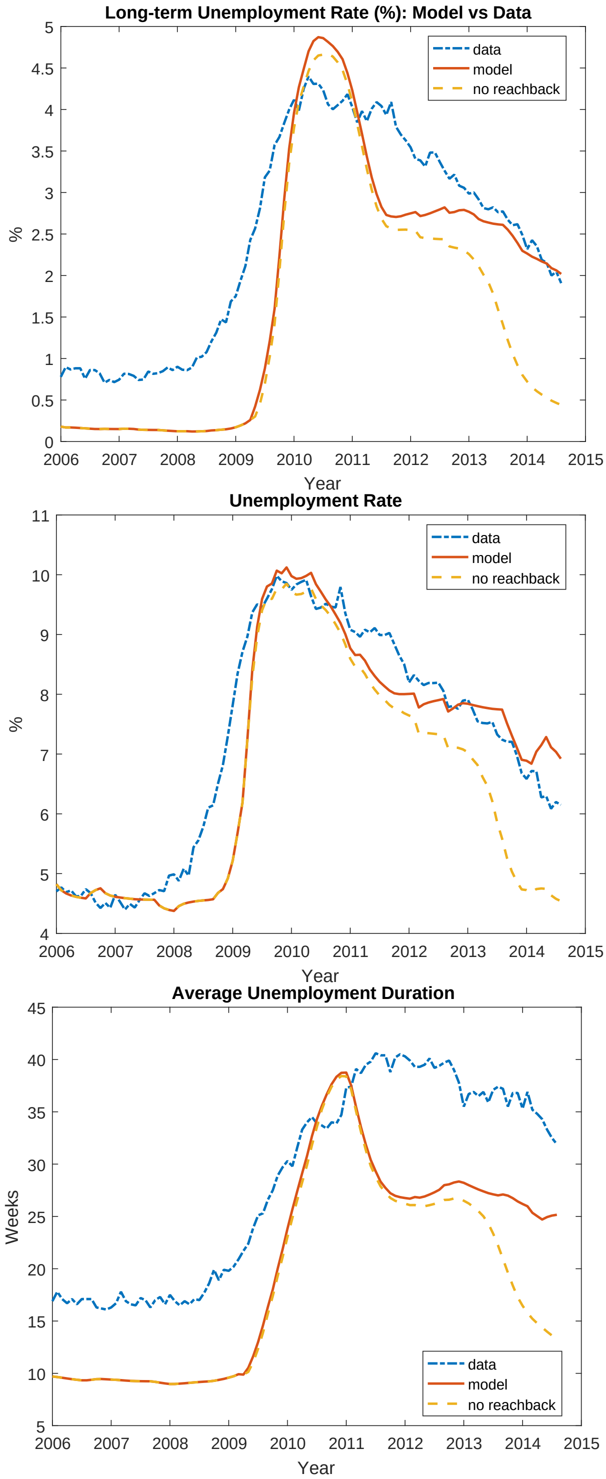
$\Delta(\phi, s, S)$: maximum UI duration, job search effort and match surplus change

Figure 28: The Effect of Removing UI Extension on Unemployment (%) (top panel) and Average Unemployment Durations (bottom panel): Data, Baseline Model and Counterfactual (with no UI extensions) (Data source: CPS)



$\Delta\phi$: only maximum UI duration changes
$\Delta(\phi,s)$: maximum UI duration and job search effort change
$\Delta(\phi,s,S)$: maximum UI duration, job search effort and match surplus change

Figure 29: The Effect of Removing Reachback Provision Programme on Long-term Unemployment (%) (top panel), Unemployment (%) (middle panel) and Average Unemployment Durations (bottom panel): Data, Baseline Model and Model without Reachback Provision (Data source: CPS)



From May 2007, the Emergency Unemployment Compensation law has included the "Reachback Provision" providing UI eligility to unemployed workers who have already exhausted their benefits prior to the extensions of UI. This programme is featured in the baseline model whilst it is not in the counterfactual experiment.

Figure 30: Hazard Rate (%) of Exiting Unemployment

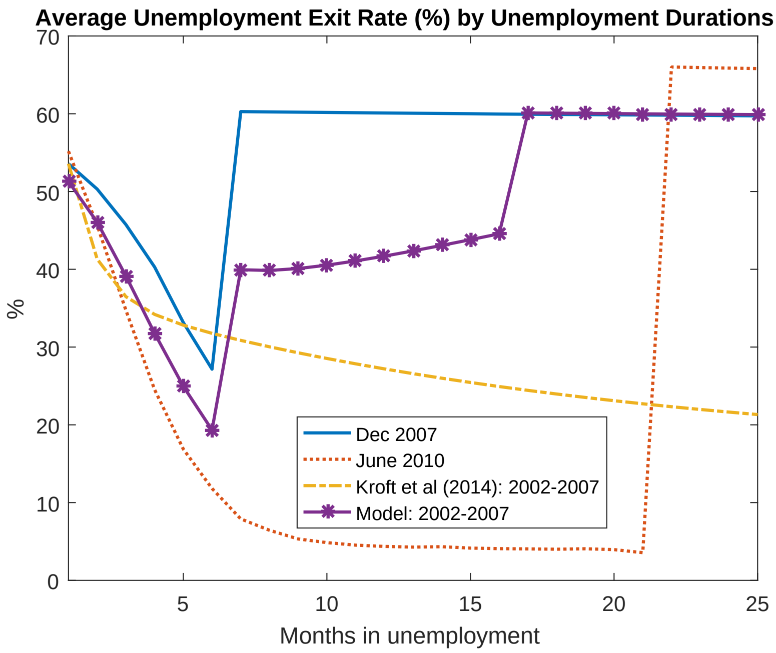


Figure 31: Probability that the newly unemployed workers of each type remain unemployed the following month: model's prediction (left panel) and empirical prediction from Ahn & Hamilton (2016) (right panel, source: Ahn & Hamilton, 2016)

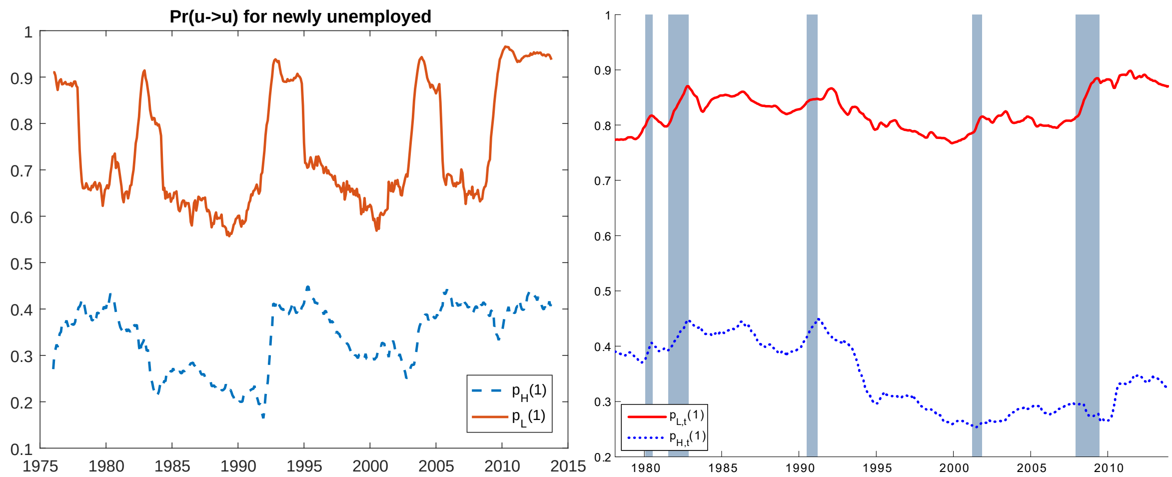


Figure 32: Number of newly unemployed workers of each type: model's prediction (left panel) and empirical prediction from Ahn & Hamilton (2016) (right panel, source: Ahn & Hamilton, 2016)

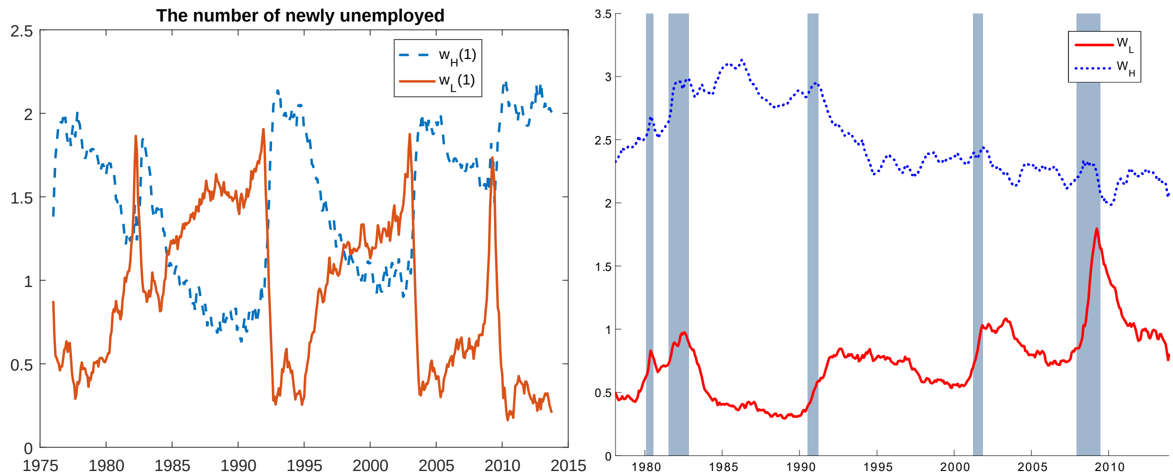


Figure 33: Share of unemployment by worker's type: model's prediction (left panel) and empirical prediction from Ahn & Hamilton (2016) (right panel, source: Ahn & Hamilton, 2016)

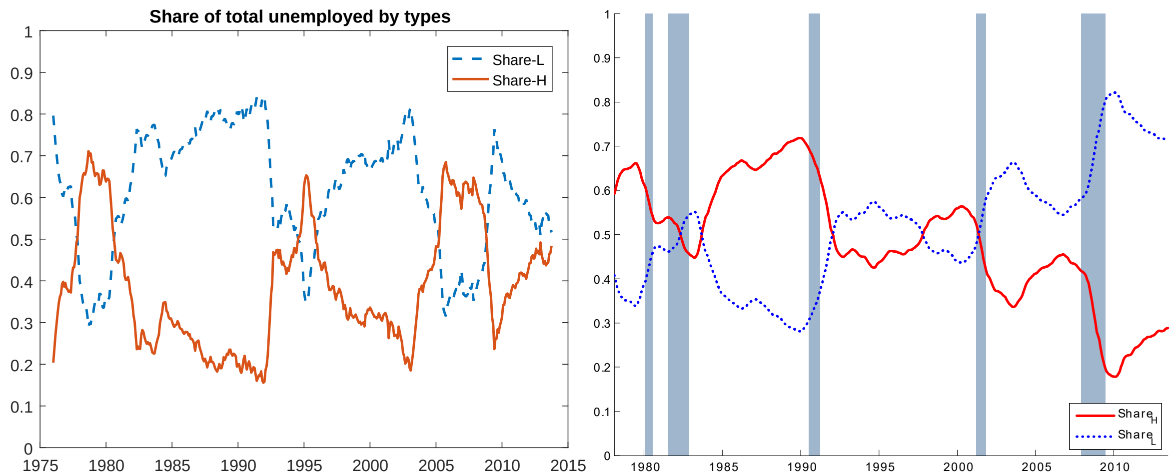


Figure 34: Shares (%) of unemployment by UI Status and Worker's Productivity

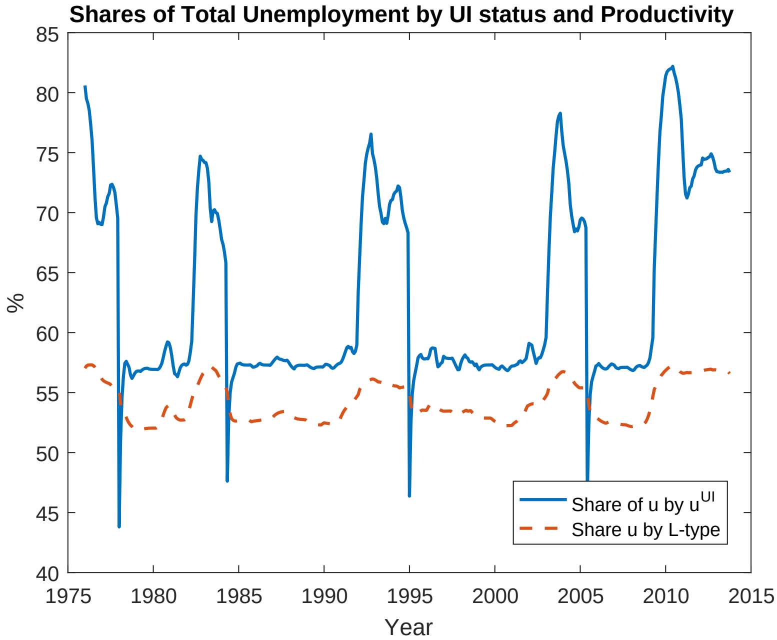
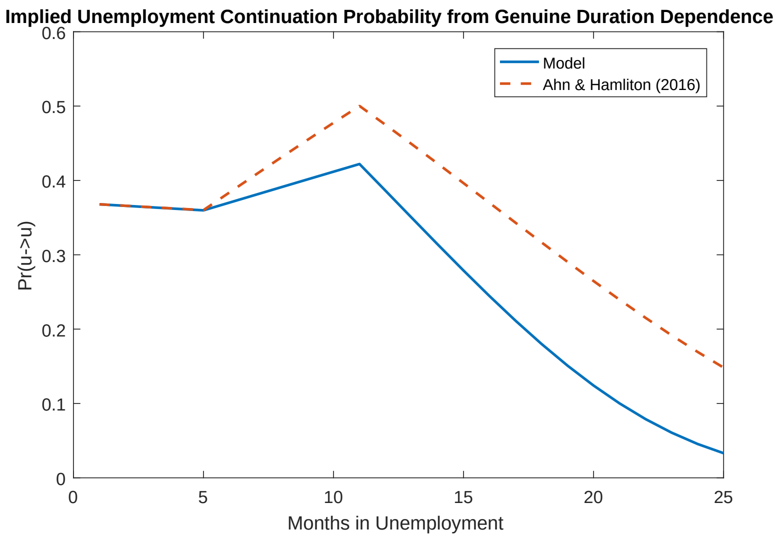


Figure 35: Implied Unemployment Continuation Probability from Genuine Duration Dependence: model's prediction (solid) and empirical prediction from Ahn & Hamilton (2016) (dashed)



- Note: The time varying factors governing the outflow rates for type-i workers (x_{it}) are normalised to zero when calculating these probabilities.

Table 2: **Unemployment-to-Employment (UE) Monthly Transition Rate (%)**

	Current UI Recipients			Non-UI Recipients		
	Jan-08	Jan-10	Δpp.	Jan-08	Jan-10	Δpp.
Age						
16 years or older	21.4	7.2	−14.2	27.5	17.8	−9.7
25−54 years	24.3	7.1	−17.1	30.7	19.7	−11.0
Gender						
Male	24.9	7.2	−17.6	28.4	18.3	−10.1
Female	16.3	7.2	−9.1	26.3	17.1	−9.2
Education						
Less than High School	25.0	4.7	−20.3	25.4	16.2	−9.2
High School	9.0	7.5	−1.5	28.9	16.0	−12.9
Some College	27.4	7.4	−20.0	28.0	20.5	−7.5
College or higher	26.8	7.4	−19.3	28.4	24.5	−3.9
Industry						
Manufacturing	22.5	6.5	−16.0	25.6	14.9	−10.7
Construction	18.3	9.6	−8.7	36.3	21.6	−14.7
Wholesale & Retail	n/a	6.4	n/a	26.0	16.3	−9.7
Prof./Business Services	45.9	4.3	−41.6	22.5	19.9	−2.6
Occupation						
High-skilled	27.4	7.8	−19.5	27.4	24.6	−2.9
Middle-skilled	18.6	6.6	−12.0	30.1	17.9	−12.2
Low-skilled	20.6	10.4	−10.2	26.6	17.6	−9.0
Reasons for Unemployment						
Temporary Layoff	50.7	12.2	−38.5	46.2	40.4	−5.8
Permanent Separation	13.6	6.7	−6.9	25.6	15.6	−10.0
Recall						
Date Given	56.4	9.9	−46.5	53.9	47.00	−6.9
No Date Given	22.4	7.7	−14.7	29.4	22.9	−6.5
Some indication	48.3	13.3	−35.0	36.6	33.8	−2.8
No indication	16.5	7.0	−9.5	22.2	17.5	−4.7

- Data source: CPS
  Δpp. ≡ change in UE rate (in percentage points) $= UE_{Jan10} - UE_{Jan08}$
  Occupation skills are defined as in the job polarisation literature (where high-, middle- and low-skilled occupations respectively are abstract, routine and manual jobs)

Table 3: **Unemployment-to-Unemployment (UU) Monthly Transition Rate (%)**

	Current UI Recipients			Non-UI Recipients		
	Jan-08	Jan-10	Δpp.	Jan-08	Jan-10	Δpp.
Age						
16 years or older	68.4	84.4	+16.0	48.0	60.2	+12.2
25−54 years	65.4	84.9	+19.6	50.8	62.6	+11.8
Gender						
Male	62.5	85.5	+23.0	50.9	63.0	+12.1
Female	77.0	81.9	+4.9	43.9	56.0	+12.1
Education						
Less than High School	60.7	82.4	+21.7	43.8	58.1	+14.3
High School	77.6	87.8	+10.2	49.8	63.2	+13.4
Some College	65.1	81.7	+16.6	49.3	58.8	+9.5
College or higher	61.1	81.2	+20.1	51.7	60.4	+8.8
Industry						
Manufacturing	68.2	82.0	+13.8	51.9	62.6	+10.7
Construction	65.6	84.4	+18.8	50.5	66.5	+16.0
Wholesale & Retail	80.9	86.1	+5.2	49.5	60.1	+10.6
Prof./Business Services	52.5	88.9	+36.3	55.5	60.2	+4.7
Occupation						
High-skilled	68.5	86.1	+17.6	49.8	60.7	+10.9
Middle-skilled	69.1	83.9	+14.8	48.3	62.3	+14.0
Low-skilled	62.9	81.0	+18.1	47.8	55.8	+8.0
Reasons for Unemployment						
Temporary Layoff	36.2	81.1	+44.9	42.2	49.5	+7.2
Permanent Separation	78.5	84.5	+6.0	57.2	69.1	+11.9
Recall						
Date Given	28.5	81.4	+52.9	35.9	47.0	+11.1
No Date Given	68.7	84.0	+15.3	52.6	63.5	+11.0
Some indication	39.5	80.9	+41.4	50.2	52.4	+2.2
No indication	77.6	84.3	+6.8	55.2	69.1	+13.9

- Data source: CPS
  Δpp. ≡ change in UU rate (in percentage points) $= UU_{Jan10} - UU_{Jan08}$
  Occupation skills are defined as in the job polarisation literature (where high-, middle- and low-skilled occupations respectively are abstract, routine and manual jobs)

Table 4: **Unemployment-to-Out-of-Labour-Force (UOLF) Monthly Transition Rate (%)**

	Current UI Recipients			Non-UI Recipients		
	Jan-08	Jan-10	Δpp.	Jan-08	Jan-10	Δpp.
Age						
16 years or older	10.3	8.5	−1.8	24.5	22.0	−2.5
25−54 years	10.4	8.0	−2.4	18.5	17.7	−0.8
Gender						
Male	12.6	7.3	−5.4	20.7	18.7	−2.0
Female	6.8	10.9	+4.1	29.8	26.8	−3.0
Education						
Less than High School	14.3	12.9	−1.4	30.8	25.7	−5.1
High School	13.4	4.6	−8.7	21.3	20.8	−0.5
Some College	7.5	11.0	+3.5	22.7	20.7	−2.0
College or higher	12.1	11.3	−0.8	19.9	15.1	−4.8
Industry						
Manufacturing	9.3	11.6	+2.3	22.5	22.5	0.0
Construction	16.1	5.9	−10.2	13.2	11.9	−1.3
Wholesale & Retail	19.1	7.5	−11.6	24.4	23.6	−0.8
Prof./Business Services	1.5	6.8	+5.3	22.0	19.9	−2.1
Occupation						
High-skilled	4.1	6.0	+1.9	22.8	14.8	−8.0
Middle-skilled	12.3	9.5	−2.8	21.7	19.9	−1.8
Low-skilled	16.5	8.6	−7.9	25.6	26.6	+1.0
Reasons for Unemployment						
Temporary Layoff	13.2	6.7	−6.4	11.6	10.2	−1.4
Permanent Separation	7.9	8.8	+0.9	17.2	15.3	−1.9
Recall						
Date Given	15.1	8.6	−6.5	10.2	6.1	−4.1
No Date Given	8.9	8.3	−0.6	18.0	13.6	−4.4
Some indication	12.3	5.8	−6.5	13.2	13.8	+0.56
No indication	6.0	8.7	+2.7	22.6	13.4	−9.2

- Data source: CPS
  Δpp. ≡ change in UOLF rate (in percentage points) = $UOLF_{Jan10} - UOLF_{Jan08}$
  Occupation skills are defined as in the job polarisation literature (where high-, middle- and low-skilled occupations respectively are abstract, routine and manual jobs)

Table 5: **Fraction (%) of Long-term Unemployment Represented by Current UI Recipients in each Subgroup**

	Jan-06	Jan-08	Jan-10	Jan-12	Jan-14	Δpp. from 2008 to 2010
Age						
16 years or older	18	15	51	39	16	+36
25-54 years	18	14	50	41	18	+36
Gender						
Male	15	13	50	38	14	+38
Female	22	18	54	40	19	+36
Education						
Less than High School	13	23	34	32	12	+11
High School	21	2	53	34	14	+51
Some College	17	21	56	44	17	+35
College or higher	22	22	56	40	22	+34
Industry						
Manufacturing	27	25	62	38	17	+37
Construction	8	16	47	40	21	+31
Wholesale & Retail	6	n/a	53	34	18	n/a
Prof./Business Services	13	11	43	35	6	+32
Occupation						
High-skilled	29	22	61	46	27	+39
Middle-skilled	14	15	53	39	12	+38
Low-skilled	11	6	29	30	14	+23
Reasons for Unemployment						
Temporary Layoff	n/a	30	61	49	12	+31
Permanent Separation	22	18	56	41	17	+38
Recall						
Date Given	n/a	n/a	42	63	10	n/a
No Date Given	15	26	60	46	26	+34
Some indication	n/a	5	68	43	12	+63
No indication	16	29	60	46	27	+31

- Data source: CPS
  Long-term unemployment is defined as unemployed workers whose duration is longer than six months.
  Occupation skills are defined as in the job polarisation literature (where high-, middle- and low-skilled occupations respectively are abstract, routine and manual jobs)

Table 6: **Fraction (%) of Newly Unemployed Workers Represented by Current UI Recipients in each Subgroup**

	Jan-06	Jan-08	Jan-10	Jan-12	Jan-14	Δpp. from 2008 to 2010
Age						
16 years or older	23	21	41	30	25	+20
25-54 years	24	21	42	33	31	+21
Gender						
Male	26	20	40	33	27	+20
Female	18	23	42	26	21	+19
Education						
Less than High School	23	18	25	28	8	+7
High School	29	17	48	27	33	+30
Some College	16	26	41	33	26	+14
College or higher	18	24	46	33	30	+22
Industry						
Manufacturing	45	30	44	36	31	+15
Construction	33	17	44	45	32	+27
Wholesale & Retail	25	21	51	20	24	+30
Prof./Business Services	13	19	26	33	22	+7
Occupation						
High-skilled	22	24	55	34	30	+31
Middle-skilled	26	18	41	36	25	+23
Low-skilled	6	30	22	12	18	−8
Reasons for Unemployment						
Temporary Layoff	34	25	44	27	31	+19
Permanent Separation	25	21	47	33	28	+26
Recall						
Date Given	25	25	49	23	24	+24
No Date Given	32	30	49	34	36	+20
Some indication	39	26	42	31	40	+16
No indication	28	31	51	34	35	+19

- Data source: CPS
  Newly unemployed workers are defined as unemployed workers whose duration is less five weeks.
  Occupation skills are defined as in the job polarisation literature (where high-, middle- and low-skilled occupations respectively are abstract, routine and manual jobs)

Table 7: **Targeted Moments**

Moment	Data	Model
E(u)	0.0583	0.0577
E(ρ_{UE})	0.4194	0.4286
E(ρ_{EU})	0.0248	0.0251
E(ρ_{EE})	0.0320	0.0320
E(u_{dur})	15.416	13.063
E(u^{UI})	0.0290	0.0327
std(u)	0.1454	0.1453
std(ρ_{UE})	0.0999	0.1402
std(ρ_{EU})	0.0890	0.0641
std(u_{dur})	6.9327	6.1954
std(LP)	0.0131	0.0104
corr(LP, LP_{-1})	0.7612	0.7593

- ρ_{UE}: job finding rate // ρ_{EU}: job separation rate // ρ_{EE}: job-to-job transition rate
  u_{dur}: mean unemployment duration (weeks) // $LP = y/(1-u)$: labour productivity
  Data source: CPS

Table 8: **Fixed Parameters For Baseline Model**

Parameter	Description	Value	Sources/Remarks
β	Discount factor	0.9967	Annual interest rate of 4%
κ	Vacancy posting cost	0.0392	Fujita & Ramey (2012)
μ	Worker's bargaining power	0.5	Den Haan, Ramey & Watson (2000)
ϕ_H	UI exhaustion rate	1/6	6 months max UI duration, ETA
ϕ_{L1}	UI exhaustion rate	1/9	9 months max UI duration, ETA
ϕ_{L2}	UI exhaustion rate	1/12	12 months max UI duration, ETA
ϕ_{L3}	UI exhaustion rate	1/16	16 months max UI duration, ETA
ϕ_{L4}	UI exhaustion rate	1/21	21 months max UI duration, ETA
$\bar{u}$	UI policy threshold	0.065	ETA
a_u	Search cost function	0.1116	Normalisation
d_u, d_e	Search cost function	1	Christensen et al (2004), Yashiv (2000)
h	Leisure flow	0.5835	Gruber (1997)

Table 9: **Values of UI benefits by match quality in most recent employment and worker's productivity**

	m_{10}	m_{20}	m_{30}	m_{40}	m_{50}	m_{60}	m_{70}	m_{80}	m_{90}	m_{100}
$b_H(m)$	0.001	0.002	0.012	0.028	0.043	0.064	0.077	0.104	0.130	0.296
$b_L(m)$	0.001	0.002	0.012	0.027	0.042	0.062	0.076	0.103	0.129	0.295
m	0.526	0.563	0.618	0.655	0.692	0.748	0.785	0.859	0.933	1.396

- m_x is the x-th percentile of the match quality distribution $F(m)$

Table 10: **Calibrated Parameters For Baseline Model**

Parameter	Description	Value
l	Meeting function	0.51
δ	Exogenous separation rate	0.023
λ	Pr(redrawing new m)	0.50
ψ	Pr(losing UI after becoming unemployed)	0.49
ξ	Pr(losing UI after meeting firm)	0.50
a_e	Search cost function	0.15
$\underline{m}$	Lowest match-specific productivity	0.396
β_1	Match-specific prod. distribution	2.55
β_2	Match-specific prod. distribution	5.26
ρ_z	Persistence of TFP	0.9562
σ_z	Standard deviation of TFP shocks	0.0075
η_L	Productivity of type-L	0.985

Table 11: **Moments Not Targeted**

Moment	Data	Model
E($U1$)	0.0233	0.0237
E($U2$)	0.0172	0.0180
E($U4$)	0.0080	0.0085
E(LTU)	0.0098	0.0076
std($U1$)	0.0048	0.0017
std($U2$)	0.0046	0.0030
std($U4$)	0.0035	0.0035
std(LTU)	0.0085	0.0107
std(u^{UI})	0.1780	0.2523
std(v)	0.1226	0.0327
corr(u, v)	-0.6682	-0.1906

- $U1$: Unemployed less than 1 month // $U2$: Unemployed with 2-3 month duration
  $U4$: Unemployed with 4-6 month duration // LTU: Unemployed longer 6 months
  u_{dur}: mean unemployment duration (weeks)
  Data source: CPS

Table 12: **Performance of the Model during the Great Recession**

x	Data max(x)	Model max(x)	Data mean(x)	Model mean(x)	mean % deviation (in modulus) from data
$u(\%)$	10.0%	10.1%	8.3%	8.3%	4.6%
u_{dur} (weeks)	40.6	38.8	36.3	28.5	23.0%
$LTU(\%)$	4.4%	4.9%	3.4%	3.1%	12.9%

- LTU: Unemployed longer 6 months // u_{dur}: mean unemployment duration (weeks)
  - These statistics are computed between October 2009 (the peak of the US unemployment rate) and June 2014
  - The last column shows the time-average percentage deviation in modulus of each variable from its empirical counterpart
  - Data source: CPS

Table 13: **Counterfactual Experiments: Effects of Decreasing Maximum UI Duration from 90 Weeks to 26 Weeks during the Great Recession**

	Data	Baseline	$\Delta\phi$	$\Delta(\phi,s)$	$\Delta(\phi,s,S)$
$\max(u)$ (%)	10.0%	10.1%	9.2%	8.4%	6.8%
$\max(u_{dur})$ (weeks)	40.6	38.8	14.8	12.9	12.2
$\max(LTU)$ (%)	4.4%	4.9%	1.2%	0.6%	0.5%
Δ $\max(u)$			−0.9pp	−1.7pp	−3.4pp
Δ $\max(u_{dur})$			−24.0	−25.9	−26.6
Δ $\max(LTU)$			−3.7pp	−4.3pp	−4.4pp

- $\Delta\phi$: only maximum UI duration changes
  $\Delta(\phi,s)$: maximum UI duration and job search effort change
  $\Delta(\phi,s,S)$: maximum UI duration, job search effort and match surplus change
  LTU: Unemployed longer 6 months // u_{dur}: mean unemployment duration (weeks)
  Δ $\max(\cdot)$: difference between the model's and counterfactual experiments' maxima
  - These statistics are computed between October 2009 (the peak of the US unemployment rate) and June 2014
  - Data source: CPS

Table 14: **Counterfactual Experiments: Effects of Removing the Reachback Provision Programme during the Great Recession**

	Data	Baseline	No Reachback
$\max(u)$ (%)	10.0%	10.1%	9.8%
$\max(u_{dur})$ (weeks)	40.6	38.7	38.4
$\max(LTU)$ (%)	4.4%	4.9%	4.7%
Δ $\max(u)$			−0.3pp
Δ $\max(u_{dur})$			−0.3
Δ $\max(LTU)$			−0.2pp

- LTU: Unemployed longer 6 months // u_{dur}: mean unemployment duration (weeks)
  Δ $\max(\cdot)$: difference between the model's and counterfactual experiment's maxima
  - These statistics are computed between October 2009 (the peak of the US unemployment rate) and June 2014
  - Data source: CPS

Table 15: **Parameter Estimates from State Space Model in Ahn and Hamilton (2016)**

Parameter	A&H (2016)	Model
σ_L^w	0.0434	0.0439
	(0.0041)	(0.0086)
σ_H^w	0.0456	0.0487
	(0.0059)	(0.0060)
σ_L^x	0.0446	0.0469
	(0.0049)	(0.0096)
σ_H^x	0.0209	0.0211
	(0.0028)	(0.0030)
δ_1	0.0053	0.0055
	(0.0138)	(0.0010)
δ_2	-0.0647	-0.0283
	(0.0242)	(0.0383)
δ_3	0.0724	0.0981
	(0.0250)	(0.0231)
$R1$	0.0981	0.0966
	(0.0058)	(0.0156)
$R2.3$	0.0759	0.0755
	(0.0043)	(0.0111)
$R4.6$	0.0775	0.0765
	(0.0068)	(0.0123)
$R7.12$	0.0597	0.0626
	(0.0051)	(0.0080)
$R13+$	0.0366	0.0390
	(0.0026)	(0.0057)

- Standard errors are reported in parentheses. Please refer to Appendix E for variables' definitions