# Unemployment Insurance and Labour Productivity over the Business Cycle*

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**Abstract**

This paper quantifies the effects of the increasing generosity of the maximum UI duration during recessions in the U.S. on the fall in the procyclicality of labour productivity over the business cycle using a search and matching model with finite UI duration, heterogeneous match quality, variable search intensity and on-the-job search. It is found that the proposed model can explain over half of the drop in the correlation between output and labour productivity. The model also performs very well in matching key statistics in the labour markets. Most of the success is due to the fact that the countercyclicality of the UI duration translates to the non-linearity in aggregate shocks of the policy functions, which are match surpluses and workers' job search efforts, and helps reduce the co-movement between output and labour productivity, particularly during recessions.

**JEL Classification.** E32, J24, J64, J65.
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# 1 Introduction/Motivation

The U.S. economy in the last few decades has experienced a significant fall in the procyclicality of its labour productivity which is less in line with the stylised business cycle facts. It has been commonly perceived that the labour productivity has a rather strong positive correlation with output, and this is certainly the case during 1948Q1-1985Q1 where the correlation is as high as 0.70.[1] However, from 1985Q2 to present, this correlation drops significantly to only around 0.30, less than half of what it used to be.[2] This change in the procyclicality of the labour productivity is usually coined "the labour productivity puzzle".

On another nearby topic, it can be observed that the U.S. policy on maximum unemployment insurance (UI) duration following a given recession has also become more generous over time.[3] Up to 1985Q1, the standard maximum UI duration stands at 26 weeks and in most recessions the U.S. government issued policies that extended the maximum UI duration to be up to 52 weeks on average. From 1985Q2 to present, while the standard maximum UI duration remains to be 26 weeks, a UI-eligible unemployed worker could claim benefits in a recession for up to 78 weeks on average, and as high as 99 weeks following the Great Recession.

This paper has been motivated by this stark increase in the generosity of the UI policy to quantify its effects on the decreasing procyclicality of the labour productivity over the business cycle. This paper proposes that the increase in the generosity of the maximum UI duration during recessions helps break the links between output and output per worker due to the fact that the generous UI policy raises the worker's outside option and makes it more difficult for any worker-firm relationship with a low idiosyncratic productivity to be in production. In addition, UI extensions also affect negatively the efforts that unemployed workers put into job search leading to lower job findings and employment which further accentuate the UI effects.

[1] This number is computed with the labour productivity being defined as output per worker. The rest of the paper follows this definition.

[2] This change in the correlation is depicted in Figure 1. While the literature mostly use the end of 1983 as the separator which is motivated by the Great Moderation, the periods when the output volatility declines dramatically, as documented in McConnell and Perez-Quiros (2000), I use instead the period 1985Q1 so that it is in line with the observed change in the generosity of the UI policy.

[3] Figure 2 summarises this increasing generosity in the UI duration policy.

It is important to understand what explains the falling correlation between output and labour productivity since both are widely used as key indicators of economic activities. At the same time, the standard real business cycle model tends to predict a very high procyclicality of the labour productivity, and the standard Mortensen-Pissarides search and matching model even employs the labour productivity as its main aggregate shock representing the state of the economy. Finding out what has been driving the labour productivity, especially away from output, over the business cycle could therefore help us formulate economic problems as well as utilise empirical data more consistently.

The labour productivity puzzle has motivated a number of literature to find its cause(s). As one would expect, many of the proposed explanations are related to the states of the labour markets. Galí and van Rens (2014) suggest it is due to the decreasing employment adjustment costs, and can generate a substantial fall in the procyclicality of the labour productivity. However, the proposed explanation may be difficult to reconcile with the slow employment recoveries as observed in recent recessions. Berger (2012) explains the puzzle using a competitive industry model with the countercyclical restructuring of firms where lower-quality workers are more likely to be shed during recessions, and this occurs more often in recent times due to the decreasing labour union power. Whilst this is very plausible, the model generates a correlation between output and labour productivity as well as its drop after the mid 1980s that are still quite far from the data. Garin, Pries and Sims (2013) deliver realistic values for both the level of and the drop in the labour productivity's procyclicality using a model with aggregate and island-specific shocks as well as complete markets. They propose that this is due to the relatively lower importance of aggregate shocks. However, even with employment lotteries and indivisible labour, their model is still not able to generate realistic fluctuations in the key variables in the labour markets, and overlooks job findings/creation and job destructions altogether.[4]

The goal of this paper is to quantify the effect of UI duration policy on the change in the correlation between output and labour productivity in the U.S.. The idea is that, with a countercylical UI policy, there is a higher expected in-

[4]McGrattan and Prescott (2012) also study the causes of the labour productivity puzzle by considering intangible capital and sectoral productivity shocks whilst Schaal (2012) uses idiosyncratic uncertainty shocks. However, the focus of these papers is on the Great Recession only.

come during unemployment in a recession which in turns puts upward pressure on the labour productivity. This occurs via two main channels in this paper. The first is through match formations. With a higher value of outside options, workers become more selective about the quality of the match they would like to be in, and the low quality matches are no longer sustainable. The second channel is the job search effort of the insured unemployed workers that falls in a recession due to the longer expected benefits. This lowers employment and, with other things being equal, increases the labour productivity. Since the UI duration policy has become more generous over time, the upward pressure on the labour productivity is expected to be stronger in recent recessions than in earlier ones, and therefore contribute to the fall in the procyclicality of labour productivity over time.

There are a number of studies showing significant effects of changes in the UI policy on macroeconomic variables including the labour productivity and wages. From a theoretical perspective, Acemoglu and Shimer (2000) show that an increase in both the duration and the level of UI benefits can increase labour productivity and wages in a model with risk aversion and precautionary savings. Marimon and Zilibotti (1999), using a search and matching model with risk-neutral agents and two-sided heterogeneity, show in an extreme case that a positive replacement rate with unlimited duration also leads to a higher labour productivity when compared to the case without UI. Empirical results from Ehrenberg and Oaxaca (1976) suggest that a higher UI benefit level has a positive impact on re-employment wages. Caliendo, Tatsiramos and Uhlendorff (2013) find that a longer UI duration increases re-employment wages, match quality and match stability.

To measure the explanatory power of the increase in the UI duration on the decrease in the labour productivity's procyclicality, I extend the standard Mortensen-Pissarides search and matching model to incorporate finite UI duration, match-specific productivity, search intensity choice and on-the-job search. The proposed model has a potential to match the key characteristics in the labour markets in a systematic way as well as reflects the heterogeneous productivities in worker-firm relationships. By allowing for variable search intensity, I can separate the contributions of the two proposed channels, namely, match formations and job search efforts, on the behaviour of labour productivity over the business cycle. Lastly, searching on the job is allowed so that the model can produce realistic correlation between unemployment and vacancies.[5]

It is found that the countercyclical UI policy could generate a significant drop in the correlation between output and labour productivity of 50% of the empirical counterpart. The reason for the relative success of the proposed model is due to the non-linearity in aggregate shocks of the policy functions caused by the countercyclicality of the UI duration that creates highly different rates of responses of output and unemployment depending on the severity of the negative shocks.

The paper is organised as follows. Section 2 describes the model. Section 3 explains the data used in this study. Section 4 discusses the calibration exercises. Section 5 analyses the results. Section 6 concludes.

# 2 Model

## 2.1 Setup

The model is based on the standard Mortensen-Pissarides search and matching model with the incorporation of aggregate productivity shocks, finite UI duration, stochastic match quality, variable search intensity and on-the-job search. The time is discrete and of monthly frequency. There are a continuum of workers of measure one and a larger continuum of firms. They are infinitely-lived and risk-neutral, and discount future utility flows or profits each period by a constant factor $\beta \in (0,1)$.

### 2.1.1 Workers

Workers maximise the expected discounted lifetime utility

$$E_0 \sum_{t=0}^{\infty} \beta^t \left[c_t - \nu(s_t)\right]$$

where $E_0(\cdot)$ is the expectation operator taken at period 0, $c_t$ is consumption and $\nu(s_t)$ is the disutility of job search effort which can be exerted during

[5]Fujita & Ramey (2012) show that a search and matching model with endogenous separation alone produces counterfactual Beveridge curve relationship due to the fact that high inflows of unemployment during recessions lower the cost of posting vacancies. This offsets the negative effects from low productivity shocks and induces more vacancy posting in bad times. Adding on-the-job search to the model helps prevent this as the pool of searchers now fluctuates much less from the inclusion of employed workers.

both unemployment and employment. There are three types of workers: employed ($e$), unemployed with UI ($u^{UI}$), and unemployed without UI ($u^{UU}$).

An employed worker in period $t$ with match-specific quality $m$ works and receives wage $w_{m,t}$ from her matched firm. She searches on the job with intensity $s^e_{m,t}$ that costs disutility of $\nu_e(s^e_{m,t}) = a_e(s^e_{m,t})^{1+d_e}$, where $a_e$ and $d_e$ are positive constants. Towards the end of the period: (i) her current match is exogenously destroyed with probability $\delta$ in which case she becomes unemployed immediately, (ii) her match-specific productivity for $t+1$ is redrawn from a time-invariant distribution $F(m)$ with probability $\lambda$, and (iii) if her match is not exogenously destroyed, she meets a new vacant firm with probability $p(s^e_{m,t})$, draws a new match quality $m$ and decide whether to stay with the current firm. If becoming unemployed in $t+1$, an employed worker in period $t$ is eligible for UI benefits in period $t+1$ with probability $\psi \in (0,1)$[6]. She can always exit employment if desired at the end of period $t$.

Given a set of state variables $\omega \equiv \{z, u, u^{UI}, u^{UU}, e_m; \forall m\}$[7], an employed worker with last period's employment status $j \in \{e, UI, UU\}$ has the follow-

[6]This probability captures the fact that not all newly unemployed workers are eligible for or actually claim UI benefits.

[7]The states variables $\{z, u, u^{UI}, u^{UU}, e_m; \forall m\}$ are respectively the total factor productivity, the unemployment rate, the insured unemployment rate, the uninsured unemployment rate, and the number of employed workers in every level of match quality. As these, excluding $z$, sum to one, we can trivially drop one measure of workers from the state space. Note also that the definition of insured unemployment rate by the Bureau of Labor Statistics is "continued claims divided by covered employment" and is different from the number of insured unemployed workers $u^{UI}$ in this paper which is continued claims (or insured unemployed workers) divided by the total labour force (normalised to one).

ing value function

$$
\begin{aligned}
W^j(m;\omega) \;=\; \max_{s^e(m;\omega)} \;& w^j(m;\omega) - \nu_e(s^e(m;\omega)) + \beta E_{\omega'|\omega}\Bigg[ \ldots \\
& \underbrace{(1-\delta)(1-\lambda)}_{\text{Pr(match survives, same } m)} \Bigg( \underbrace{(1-p^e(m;\omega)(1-F(m)))}_{\text{Pr(no job-to-job transition)}} W^{e+}(m;\omega') \\
& + \underbrace{p^e(m;\omega)(1-F(m))}_{\text{Pr(make job-to-job transition)}} E_{m'|m'>m}[W^{e+}(m';\omega')] \Bigg) \\
& + \underbrace{(1-\delta)\lambda}_{\text{Pr(match survives, changing } m)} E_{m'} \Bigg[ \underbrace{(1-p^e(m;\omega)(1-F(m')))}_{\text{Pr(no job-to-job transition)}} W^{e+}(m';\omega') \\
& + \underbrace{p^e(m;\omega)(1-F(m'))}_{\text{Pr(make job-to-job transition)}} E_{m''|m''>m'}[W^{e+}(m'';\omega')] \Bigg] \\
& + \underbrace{\delta}_{\text{Pr(match destroyed)}} \Big( (1-\psi)U^{UI}(\omega') + \psi U^{UU}(\omega') \Big) \Bigg]
\end{aligned}
\tag{1}
$$

where $W^{e+}(m;\omega') \equiv \max\{W^e(m;\omega'), (1-\psi)U^{UI}(\omega') + \psi U^{UU}(\omega')\}$.[8] Given the recursive nature of the problem, the time scripts are dropped and variables with superscript $'$ are of the next period. Variables with subscripts $m$ and/or $\omega$ depend on the match-specific productivity and/or the set of aggregate state variables. $E_{\omega'|\omega}[\cdot]$ is the mathematical expectation operator over the distribution of $\omega'|\omega$. $E_m[\cdot]$ is similarly defined but taken over the invariant distribution of $m$, $F(m)$. $U^{UI}(\omega)$ and $U^{UU}(\omega)$ are the values of being insured and uninsured unemployed respectively.

An insured unemployed worker in period $t$ receives UI benefits $b$ and leisure flow $h$.[9] She also exerts job search effort $s_t^{UI}$ that comes at the utility cost of $\nu_u(s_t^{UI}) = a_u(s_t^u)^{1+d_u}$, where $a_u$ and $d_u$ are positive constants. She meets a vacant firm with probability $p(s_t^{UI})$. A new worker-firm match draws a match-specific productivity for their production in $t+1$ from the time-invariant distribution $F(m)$. They can dissolve the match and return to the unemployment/vacancy pool if the draw is not good enough. An insured unemployed worker in $t$ who fails to be employed in $t+1$ loses her UI eligibility in $t+1$ with probability $\phi(u_t)$ where $u_t$ is the unemployment rate at the beginning

[8] The max operator between two values implies that a worker can freely enter unemployment in the next period if she desires.

[9] This flow $h$ could include the value of leisure, home production, food stamps, etc.

of $t$.[10] Those that get to meet a firm but decide to remain unemployed and continue searching for a job additionally lose UI eligibility with probability $\xi$.[11]

For an uninsured unemployed worker, the setting is analogous except she does not receive the UI benefits $b$ and when failing to become employed she simply remains unemployed without UI. She also exerts job search effort $s_t^{UU}$ that comes at the utility cost of $\nu_u(s_t^{UU})$, and meets a vacant firm with probability $p(s_t^{UU})$.

The Bellman equations for the insured and uninsured unemployed workers can respectively be written as

$$\begin{aligned} U^{UI}(\omega) &= \max_{s^{UI}(\omega)} \quad b + h - \nu_u(s^{UI}(\omega)) + \beta p^{UI}(\omega) E_{m'\omega'|\omega}\Big[ ... \\ & \max\Big\{W^{UI}(m';\omega'), \\ & \underbrace{(1-\phi(u))(1-\xi)}_{\text{Pr(UI eligible|turn down a firm)}} U^{UI}(\omega') + \underbrace{\Big(\phi(u) + (1-\phi(u))\xi\Big)}_{\text{Pr(UI ineligible|turn down a firm)}} U^{UU}(\omega')\Big\}\Big] \\ & +\beta(1-p^{UI}(\omega))E_{\omega'|\omega}\Big[\underbrace{(1-\phi(u))}_{\text{Pr(UI eligible|no meeting)}} U^{UI}(\omega') + \phi(u)U^{UU}(\omega')\Big] \end{aligned} \tag{2}$$

and

$$\begin{aligned} U^{UU}(\omega) &= \max_{s^{UU}(\omega)} \quad h - \nu_u(s^{UU}(\omega)) \\ & +\beta p^{UU}(\omega) E_{m'\omega'|\omega}\Big[\max\{W^{UU}(m';\omega'), U^{UU}(\omega')\}\Big] \\ & +\beta(1-p^{UU}(\omega))E_{\omega'|\omega}[U^{UU}(\omega')] \end{aligned} \tag{3}$$

**Optimal Search Intensity** Throughout the paper, I assume workers maximise their discounted expected utility with respect to job search efforts when-

[10] Note that the probability $\phi(u_t)$ is directly linked to the expected duration of receiving UI. This setting for the UI duration policy, first utilised in Fredriksson and Holmlund (2001), helps reduce the state space greatly as otherwise the duration of unemployment for an unemployed worker must also be a state variable in case we are to model the UI duration policy literally. Since workers in the model are risk neutral, this is rather innocuous but once risk aversion and precautionary savings are considered, this shortcut would imply unnecessary uncertainty to workers in the model.

[11] The effective probability of an insured unemployed worker being eligible for UI next period given she turns down a match formation is therefore $(1-\phi(u_t))(1-\xi)$.

ever the values of workers are being considered. Given the Bellman equations for the three types of workers $\{e, UI, UU\}$, we can take the first derivative to find the optimal search efforts for these workers. The first order conditions are as follows

$$\begin{aligned} \nu_e'(s^e(m;\omega)) &= -\beta(1-\delta)M(\theta(\omega))E_{\omega'|\omega}\Big[\cdots \\ &\quad (1-\lambda)(1-F(m))\Big(WS^{e+}(m;\omega') - E_{m'|m'>m}[WS^{e+}(m';\omega')]\Big) \\ &\quad + \lambda E_{m'}\Big[(1-F(m'))(WS^{e+}(m';\omega') - E_{m''|m''>m'}[WS^{e+}(m'';\omega')])\Big]\Big] \end{aligned} \tag{4}$$

$$\nu_u'(s^{UI}(\omega)) = \beta M(\theta(\omega))E_{m'\omega'|\omega}\Big[\max\{WS^{UI}(m';\omega'), 0\} - \xi(1-\phi)US(\omega')\Big] \tag{5}$$

$$\nu_u'(s^{UU}(\omega)) = \beta M(\theta(\omega))E_{m'\omega'|\omega}\Big[\max\{WS^{UU}(m';\omega'), 0\}\Big] \tag{6}$$

where $\nu_i'(s^i) = a_i(1+d_i)(s^i)^{d_i}; i \in \{e, u\}$.

### 2.1.2 UI Duration Policy: $\phi(u_t)$

Empirically, the maximum duration of unemployment benefits in the U.S. varies over time. The main determinants are the unemployment rate and the insured unemployment rate in each state. In addition, the U.S. government often extends the maximum UI duration conditional on the total (and/or state) unemployment rate during a recession. To capture this feature of the UI duration policy in the model, I allow the maximum UI duration to vary with the unemployment rate $u$.[12] Specifically, $\phi(u)$ can assume two values: a low value for the recessionary periods and a high one for the normal periods. There is a threshold unemployment rate $\bar{u}$ such that when $u \geq \bar{u}$, the maximum UI duration increases and is represented by $\phi_L$, and when $u < \bar{u}$, the maximum UI duration remains standard and is represented by $\phi_H$, where $0 < \phi_L < \phi_H < 1$.

I assume this UI duration policy is known to all agents; therefore, they expect a more generous UI duration when the economy's unemployment rate is (going to be) greater than $\bar{u}$.[13] It is useful to compare the UI duration pol-

[12] This implies that the unemployment rate is a state variable for the policy functions, and so is the composition of employed and unemployed workers due to the endogenous destruction margin.

[13] As will be explained in the Data section, some UI extensions are not anticipated per se but due to the fact that the U.S. government has always issued ad-hoc UI extensions during the recessions, it can be argued that in reality agents expect these additional ad-hoc UI extensions

icy modelled in this paper with that in Mitman and Rabinovich (2012) who study the effects of maximum UI duration in the U.S. on jobless recoveries, and Faig, Zhang and Zhang (2012) who study the contribution of counter-cyclical UI duration policy on the labour market dynamics. Mitman and Rabinovich (2012) assume all UI extensions are completely unexpected and perceived to last forever to the agents. While this offers a precise control on the timing and the length of each UI extension, the responses of agents would be significantly more drastic as the rational expectation regarding changes in the current and future UI durations has been muted completely. Although the model in this paper may not be able to replicate exactly the timing of UI extensions, it can match quite well most of the characteristics in the labour markets usually associated with the UI duration policy, whilst preserving the agents' rational expectation. Faig et al (2012) let the UI duraiton policy vary with aggregate TFP shocks instead of unemployment rates. However, the fact that unemployment lags output and is highly persistent, letting the UI policy be a function of TFP shocks instead of unemployment rates would change the dynamics of the macroeconomic aggregates in study and underestimate the effect of UI policy on the procyclicality of labour productivity which is the focus of this paper.

In order to finance these benefits, the government collects lump sum tax $\tau_t$ from all firms that are in production. The tax is set to satisfy the government budget constraint in each period.[14]

#### 2.1.3 Production

**Production Function** The production technology of a worker-firm match in period $t$ with match-specific quality $m$ is

$$y_{m,t} = z_t m$$

where $y_{m,t}$ is the output the match produces, $z_t$ is the common factor productivity (TFP). The price of $y_{m,t}$ is normalised to unity.

**Match-specific Productivity** A match-specific productivity drawn at the start of any worker-firm relationship is distributed according to a Beta distribution

*around* recessionary periods (particularly with a high unemployment rate), just not exactly when the policy is implemented.

[14]The results do not differ significantly when the government budget constraint is set to be satisfied on average instead.

with parameters $\{\beta_1, \beta_2\}$. The probability function is

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

where $\underline{m} > 0$ is the lowest productivity level. This idiosyncratic productivity will remain until the match is either separated or hit by a shock that changes this match-specific quality that occurs with probability $\lambda$ in each period.[15]

**Aggregate Productivity Shocks** There is only one exognenous aggregate shock in the model which is the shock to $z$, the total factor productivity (TFP), whose natural logarithm has an AR(1) representation with $\rho_z$ being its persistence. Specifically,

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

where $\epsilon_t$ is normally and independently distributed with mean zero and standard deviation $\sigma_z > 0, \forall t$.

### 2.1.4 Firms

Firms maximise the expected discounted profits. They are either in operation, with a vacancy, or idle.

A firm in operation (being matched with a worker) in period $t$ sells output $y_{m,t}$, and pays wage $w_{m,t}$ to its matched worker. It also pays tax $\tau_t$. Analogous to an employed worker, it faces a shock to the match-specific productivity and an exogeneous match-destruction shock. Further, it becomes unmatched when its worker takes up a new job offer.[16] The producing firm can walk away from the match if desired at the end of period.

Let $J^j$ denote the value of a filled job given hired worker's employment status last period being $j \in \{e, UI, UU\}$, and $V$ the value of posting a vacancy. An idle firm simply does not produce or pay for anything, and therefore has

[15]The persistence in the match-specific productivity reflects the persistence in wages and labour skills, and is also related to the persistence in job destructions. The randomisation of the match quality also presents a degree of mismatching.

[16]The probability that this event happens depends on the match-specific productivity they will have next period.

zero value. The Bellman equation for an operating firm is

$$\begin{aligned}
J^j(m;\omega) &= y(m;\omega) - w^j(m;\omega) - \tau(\omega) + \beta E_{\omega'|\omega}\Big[ \\
&\quad (1-\delta)(1-\lambda)\Big((1-p^e(m;\omega)(1-F(m)))J^{e+}(m;\omega')\Big) \\
&\quad +(1-\delta)\lambda E_{m'}\Big[(1-p^e(m;\omega)(1-F(m')))J^{e+}(m';\omega')\Big] \\
&\quad +\delta \max\{V(\omega'),0\}\Big] \qquad (7)
\end{aligned}$$

where $J^{e+}(m;\omega') \equiv \max\{J^e(m;\omega'), V(\omega'), 0\}$.

A vacant firm pays a flow cost of $\kappa$ each period to post a vacancy. It meets a worker with probability $q_t$, and together they draw a match-specific productivity for $t+1$ and decide whether to continue with the production. It cannot directly choose the types of workers to meet and therefore needs to take into account the distribution of workers over the match-specific productivity and employment status.

The value of posting a vacancy is

$$\begin{aligned}
V(\omega) &= -\kappa + \beta q(\omega) E_{\omega'|\omega}\Big[\sum_m \zeta^e(m;\omega)(1-F(m))E_{m'|m'>m}[J^{e+}(m';\omega')] \\
&\quad +\zeta^{UI}(\omega)E_{m'}[J^{UI+}(m';\omega')] + \zeta^{UU}(\omega)E_{m'}[J^{UU+}(m';\omega')]\Big] \qquad (8)
\end{aligned}$$

where

$$\begin{aligned}
\zeta^e(m) &= \frac{(1-\lambda)s^e_m e_m + \lambda f(m) s^e e}{s^e e + s^{UI}u^{UI} + s^{UU}u^{UU}}; \quad s^e e = \sum_m s^e_m e_m \\
\zeta^{UI} &= \frac{s^{UI}u^{UI}}{s^e e + s^{UI}u^{UI} + s^{UU}u^{UU}}; \quad \zeta^{UU} = \frac{s^{UU}u^{UU}}{s^e e + s^{UI}u^{UI} + s^{UU}u^{UU}}
\end{aligned}$$

Free entry condition implies $V(\omega) = 0, \forall \omega$.

### 2.1.5 Meeting Function

The meeting function $M(s_{agg,t}, v_t)$ takes the aggregate search intensity $s_{agg,t}$ and the number of job vacancies $v_t$ in period $t$ as inputs, and gives a number of meetings between workers and firms as output.[17] The function has

[17] $s_{agg}$ is the sum of aggregate search intensity of employed and unemployed workers.

constant returns to scale, and is increasing and concave in its arguments.[18] Particularly,

$$M(s_{agg,t}, v_t) \quad = \quad \frac{s_{agg,t} v_t}{\left(s_{agg,t}^l + v_t^l\right)^{\frac{1}{l}}} \tag{9}$$

Let us define $\theta_t \equiv \frac{v_t}{s_{agg,t}}$ as the market tightness. The worker's meeting rate per search unit is $\frac{M(s_{agg,t}, v_t)}{s_{agg,t}} = M(1, \theta_t)$ which I also call the 'conditional' job finding rate per search unit since a viable match-specific quality is required for a successful match. The conditional job finding rate for an unemployed worker who exerts $s_t^i$ search units is thus $s_t^i M(1, \theta_t) \equiv p(s_t^i)$. Similarly, the 'conditonal' job filling rate for a firm with a vacancy is $\frac{M(s_{agg,t}, v_t)}{v_t} = M(\frac{1}{\theta_t}, 1) \equiv q_t$.

## 2.2 Wages

Wages are determined each period using a generalised Nash bargaining rule. The bargaining power of a worker is $\mu \in (0, 1)$ and that of a firm is $1 - \mu$. Given $(m; \omega)$, the generalised Nash bargaining rule implies three different wages depending on the worker's employment status last period $j \in \{e, UI, UU\}$. Namely,

$$w^j(m; \omega) \quad = \quad \text{argmax} \left(WS^j(m; \omega)\right)^{\mu} \left(J^j(m; \omega)\right)^{(1-\mu)} \tag{10}$$

where $WS^j$ is the surplus from working of type-$j$ employed workers whose definition is discussed below.

## 2.3 Surplus Definitions

Similar to Robin (2011) and Mitman and Rabinovich (2012), I use the notion of surpluses to help reduce the number of variables and equations. The surpluses from working of employed workers with three different previous

[18] This matching function is similar to the one introduced by den Haan, Ramey and Watson (2000) with an addition of the variable search intensity. One advantage this function has over the standard Cobb-Douglas specification is that it automatically satisfies the necessary condition that $M(s_{agg}, v) \leq \min\{s_{agg}, v\}$.

employment statuses $(e, UI, UU)$ are defined as

$$\begin{aligned} WS^e(m;\omega) &\equiv W^e(m;\omega) - (1-\psi)U^{UI}(\omega) - \psi U^{UU}(\omega) \\ WS^{UI}(m;\omega) &\equiv W^{UI}(m;\omega) - (1-\phi(u))(1-\xi)U^{UI}(\omega) \\ &\quad -(\phi(u) + (1-\phi(u))\xi)U^{UU}(\omega) \\ WS^{UU}(m;\omega) &\equiv W^{UU}(m;\omega) - U^{UU}(\omega) \end{aligned}$$

and the surplus from being insured (as opposed to uninsured) of unemployed workers is defined as

$$US(\omega) \equiv U^{UI}(\omega) - U^{UU}(\omega)$$

The total surpluses of worker-firm matches given employed workers' previous employment statuses $(e, UI, UU)$ are defined as

$$\begin{aligned} S^e(m;\omega) &\equiv WS^e(m;\omega) + J^e(m;\omega) \\ S^{UI}(m;\omega) &\equiv WS^{UI}(m;\omega) + J^{UI}(m;\omega) \\ S^{UU}(m;\omega) &\equiv WS^{UU}(m;\omega) + J^{UU}(m;\omega) \end{aligned}$$

The expressions for these surpluses are shown in Appendix B. With Nash bargaining rule we have $WS^j(m;\omega) = \mu S^j(m;\omega)$ and $J^j(m;\omega) = (1-\mu)S^j(m;\omega)$ for $j = \{e, UI, UU\}$.

## 2.4 Transitions

### 2.4.1 Employment and Output

The mass of employed agents in $t$ with match quality $m$, $e_{m,t}$, evolves as follows (the states are subscripted)

$$\begin{aligned} e_{m,t+1} = & \Big( (1-\delta)(1-\lambda)(1 - p^e_{m,t} + p^e_{m,t}F(m))e_{m,t} \\ & +(1-\delta)(1-\lambda)f(m)\int_{m'<m} p^e_{m',t}e_{m',t}dm' \\ & +(1-\delta)\lambda f(m)\int_{m'}(1 - p^e_{m',t} + p^e_{m',t}F(m))e_{m',t}dm' \\ & +(1-\delta)\lambda F(m)f(m)\int_{m'} p^e_{m',t}e_{m',t}dm' \Big) \mathbf{1}\{S^e_{m,t+1} > 0\} \\ & +f(m)(u^{UI}_t p^{UI}_t)\mathbf{1}\{S^{UI}_{m,t+1} > 0\} \\ & +f(m)(u^{UU}_t p^{UU}_t)\mathbf{1}\{S^{UU}_{m,t+1} > 0\} \end{aligned} \quad (11)$$

where $F(m) \equiv Pr(m' < m)$ with $m'$ being a random variable and $f(m)$ is the probability density function of match quality $m$. This shows that, given $m$ is viable in $t+1$, $e_{m,t+1}$ consists of (i) the original $e_{m,t}$ whose matches are not exogenously separated, whose match qualities are unchanged, and who do not make a job-to-job transition (ii) a fraction of the entire $e_t$ whose matches are not exogenously separated, whose match qualities are unchanged, and who make a job-to-job transition to matches with quality $m$, (iii) a fraction of the entire $e_t$ whose matches are not exogenously separated, who get $m$ from the new match quality draw and do not make a job-to-job transition, (iv) a fraction of the entire $e_t$ whose matches are not exogenously separated, who get any $m' \neq m$ from the new match quality draw and make a job-to-job transition, and (v) a fraction of $u_t$ who are matched with firms and get $m$ from the match quality draw. Any $e_{m,t+1}$ with $m$ that renders a negative match surplus has a zero mass. The total employment is simply the sum of all employed workers over the match qualities

$$e_t = \int e_{m,t} \, dm$$

and the aggregate output in period $t$ can also be computed as

$$y_t = z_t \int m \cdot e_{m,t} \, dm$$

### 2.4.2 Job Destructions

The job destruction rate of employed workers of type $m$ and the average job destruction rate can be defined as[19]

$$
\begin{aligned}
\rho_{x,t}(m) &= \begin{cases} \delta & \text{if } S^e_{m,t+1} > 0, \\ 1 & \text{otherwise} \end{cases} \\
\rho_{x,t} &= \frac{\delta \int_{\{m:S^e_{m,t+1}>0\}} e^{post}_{m,t} dm + \int_{\{m:S^e_{m,t+1}\leq 0\}} e^{post}_{m,t} dm}{e_t} \\
( &\equiv \rho^{exo}_{x,t} + \rho^{endo}_{x,t})
\end{aligned}
$$

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

For employed workers of type $m$ at the end of period $t$, the match-specific job destruction rate $\rho_{x,t}(m)$ is equal to $\delta$ when the match is still viable in $t+1$ (exogenous destructions), and unity otherwise (endogenous destructions). The job destruction rate $\rho_{x,t}$ can be computed as the average destruction rate across employed workers with different match productivities *after* possible changes in $m$ occur as denoted by $e^{post}_{m,t}$.

### 2.4.3 Job Findings

The job finding rate for an unemployed worker of type $i = \{UI, UU\}$ and the average job finding rate are respectively

$$
\begin{aligned}
\rho^i_{f,t} &= \int \rho^i_{f,t}(m) f(m) dm \\
\rho_{f,t} &= \frac{u^{UI}_t \rho^{UI}_{f,t} + u^{UU}_t \rho^{UU}_{f,t}}{u^{UI}_t + u^{UU}_t} \\
\text{where } \rho^i_{f,t}(m) &= \begin{cases} p^i_{\omega_t} & \text{if } S^i_{m',t+1} > 0, \\ 0 & \text{otherwise} \end{cases}
\end{aligned}
$$

[19] Note that job destructions in the paper only refer to the case where both matched workers and firms return to the unemployment/vacancy pool, i.e., they exclude any workers transitioning from one job to another.

For unemployed workers of type $i$, the match-specific job finding rate $\rho^i_{f,t}(m)$ is $p^i_{\omega_t}$ when the formed match is viable in $t+1$, and zero otherwise. The job finding rate $\rho_{f,t}$ can be computed as the average job finding rate across both types of unemployed workers.

### 2.4.4 Job-to-job Transitions

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

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

For employed workers with match quality $m$, their job-to-job transition rate $\rho^{ee}_{m,t}$ depends if they must redraw $m$ for next period (which happens at the rate $\lambda$) and if they come in contact with vacant firms (with probability $p^e_{m,t}$). The job-to-job transition rate $\rho^{ee}_t$ can be computed as the average job-to-job transition rate across employed workers with different match productivities.

### 2.4.5 Unemployment

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

$$\begin{aligned}
u^{UI}_{t+1} &= \underbrace{(1-\phi_t)(1-p^{UI}_t)u^{UI}_t}_{\text{unmatched, not losing UI}} + \underbrace{\chi^{UI}_t(1-\phi_t)(1-\xi)p^{UI}_t u^{UI}_t}_{\text{bad match, not losing UI}} \\
&\quad + \underbrace{(1-\psi)\rho_{x,t}e_t}_{\text{separated match, not losing UI}} \qquad (12)
\end{aligned}$$

$$\begin{aligned}
u^{UU}_{t+1} &= \underbrace{\phi_t(1-p^{UI}_t)u^{UI}_t}_{\text{unmatched, losing UI}} + \underbrace{\chi^{UI}_t\Big(\phi_t+(1-\phi_t)\xi\Big)p^{UI}_t u^{UI}_t}_{\text{bad match, losing UI}} \\
&\quad +(1-\rho^{UU}_{f,t})u^{UU}_t + \underbrace{\psi\rho_{x,t}e_t}_{\text{separated match, losing UI}} \qquad (13)
\end{aligned}$$

$$u_{t+1} = u^{UI}_{t+1} + u^{UU}_{t+1} \qquad (14)$$

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

The next-period insured unemployed workers $u^{UI}_{t+1}$ consist of (i) the currently insured unemployed that do not meet a firm and are still eligible for UI benefits, (ii) the currently insured unemployed that do meet a firm but decide to remain unemployed, and are still eligible for UI benefits, and (iii) the newly unemployed that are eligible for UI benefits. The next-period uninsured unemployed workers $u^{UU}_{t+1}$ consist of (i) the currently insured unemployed that do not meet a firm and are no longer eligible for UI benefits, (ii) the currently insured unemployed that do meet a firm but decide to remain unemployed, and are no longer eligible for UI benefits, (iii) the currently uninsured unemployed that do not meet a firm, and (iv) the newly unemployed that are ineligible for UI benefits. The unemployment rate is just the sum of these two types of unemployed workers.

## 2.5 Recursive Competitive Equilibrium

A recursive competitive equilibrium consists of value functions, $W^e(m;\omega)$, $W^{UI}(m;\omega)$, $W^{UU}(m;\omega)$, $U^{UI}(\omega)$, $U^{UU}(\omega)$, $J^e(m;\omega)$, $J^{UI}(m;\omega)$, $J^{UU}(m;\omega)$, and $V(\omega)$; market tightness $\theta(\omega)$; search policy $s^e(m;\omega)$, $s^{UI}(\omega)$ and $s^{UU}(\omega)$; and wage functions $w^e(m;\omega)$, $w^{UI}(m;\omega)$, and $w^{UU}(m;\omega)$, such that, given the initial distribution of workers over employment statuses and match productivities, 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), (7) and (8)
2. The search decisions satisfy the FOCs for optimal search intensity, which are equations (4), (5) and (6)
3. The wage functions satisfy the FOCs for the generalised Nash bargaining rule (equation (10))
4. The government's budget constraint is satisfied each period
5. The distribution of workers evolves according to the transition equations (11), (12) and (13), consistent with the maximising behaviour of agents

# 3 Data

Both empirical and simulated (logged) data in this paper are detrended by using the Hodrick-Prescott (HP) filter with a smoothing parameter of 1600 for quarterly data and of 129600 for monthly data following Ravn & Uhlig (2002). When necessary, monthly empirical series are converted to quarterly frequency by using a quarterly average except for the job finding rate and the job destruction rate whose quarterly series are obtained by iterating the law of motion for unemployment. The range of data (unless stated otherwise) is from January 1948 to June 2014. All series are seasonally adjusted.

## 3.1 Unemployment

Monthly data on unemployment level and labour force level are obtained from the Current Population Survey (CPS) provided by the Bureau of Labor Statistics (BLS), U.S. Department of Labor, from January 1948 to June 2014.[20] The ratio of these two series forms the official definition of unemployment rate ('U3' as labelled by BLS).

## 3.2 Output and Labour Productivity

For output, I use the quarterly real GDP series provided by the Bureau of Economic Analysis (BEA), U.S. Department of Commerce, and I use the BLS quarterly series for non-farm output per job to represent the labour productivity.[21]

## 3.3 Transition Rates

I obtain the monthly job finding rates and job destruction rates as is done in Shimer (2005) without correcting for time aggregation bias.[22] As converting the monthly turnover rates to quarterly ones by simply computing a quarterly average would overestimate the job finding rates and underestimate the job destruction rates, one should iterate the law of motion for monthly unem-

[20] The series IDs are respectively LNS13000000 and LNS11000000.

[21] The series ID for labour productivity is PRS85006163.

[22] By correcting for the time aggregation bias, the destruction rates should be higher and closer to the BLS data. However, one must also adjust the Bellman equations in the model accordingly, otherwise the implied unemployment will be too high.

ployment ($u_t^{mo}$) instead.

$$\begin{aligned} u_{t+1}^{mo} &= (1-\rho_{f,t}^{mo})u_t^{mo} + \rho_{x,t}^{mo}(1-u_t^{mo}) && (15) \\ u_{t+2}^{mo} &= (1-\rho_{f,t+1}^{mo})u_{t+1}^{mo} + \rho_{x,t+1}^{mo}(1-u_{t+1}^{mo}) && (16) \\ u_{t+3}^{mo} &= (1-\rho_{f,t+2}^{mo})u_{t+2}^{mo} + \rho_{x,t+2}^{mo}(1-u_{t+2}^{mo}) && (17) \end{aligned}$$

where $\rho_{f,t}^{mo}$ and $\rho_{x,t}^{mo}$ are respectively the monthly job finding and destruction rates at time $t$. Replacing $u_{t+2}^{mo}$ in (17) with $u_t^{mo}$ using (15) and (16) and setting $u_{t+1}^q \equiv u_{t+3}^{mo}$ and $u_t^q \equiv u_t^{mo}$, one can obtain[23]

$$u_{t+1}^q = (1-\rho_{f,t}^q)u_t^q + \rho_{x,t}^q(1-u_t^q) \qquad (18)$$

where

$$\begin{aligned} \rho_{x,t}^q &= \rho_{x,t+2}^{mo} + \rho_{x,t+1}^{mo}(1-\rho_{x,t+2}^{mo}-\rho_{f,t+2}^{mo}) \\ &\quad +\rho_{x,t}^{mo}(1-\rho_{x,t+1}^{mo}-\rho_{f,t+1}^{mo})(1-\rho_{x,t+2}^{mo}-\rho_{f,t+2}^{mo}) && (19) \\ \rho_{f,t}^q &= 1-\rho_{x,t}-\prod_{i=0}^{2}(1-\rho_{x,t+i}^{mo}-\rho_{f,t+i}^{mo}) && (20) \end{aligned}$$

## 3.4 UI Duration Policy

Data on UI extensions in the U.S. is provided by Employment and Training Administration (ETA), U.S. Department of Labor, which collects and summarises the Federal Unemployment Compensation Laws dating back to August 1935. There are 3 main types of UI durations: (i) the standard UI duration of 26 weeks (ii) the automatic extension programme that is triggered by the state unemployment rate (either total, insured or both) called "Extended Benefits (EB)" programme which extends UI further by 13-20 weeks, and (iii) the more ad-hoc programmes that are often issued in the recessions and also triggered by the state unemployment rate providing additional UI ranging from 13 to 53 weeks.[24] The maximum duration of unemployment benefits in the U.S. are shown chronologically in Figure 2.

[23] We could also obtain the quarterly series of unemployment rates by collecting the first monthly unemployment rate of every quarter as in Robin (2011) instead of averaging every 3 months. This does not change significantly the statistics reported in this paper.

[24] For a more detailed account, see the ETA website. Appendix C of Mitman and Rabinovich (2012) also provides a good summary.

# 4 Calibration

Not all the parameters in the model are pre-specified. I obtain the free parameters by calibrating the model to match key statistics of the U.S. economy, especially its labour market. To obtain these statistics from the model, I solve for the policy functions, and simulate an economy for $T$ periods where $T$ is large and repeat for 1,000 times. In each simulation, I split the pre- and post-1985 periods at $T_1$ where $1 < T_1 < T$ and compute relevant statistics accordingly.[25]

With respect to the UI duration policy, I allow for an increase in the generosity during recessions from pre- to post-1985 periods. As a result, there are two main duration regimes. When $u < \bar{u}$, the maximum UI duration is always six months (standard), when $u \geq \bar{u}$, the maximum UI duration is extended to be in total:

1. Twelve months during the first $T_1$ periods representing January 1948 to March 1985
2. Eighteen months from $T_1 + 1$ to $T$ representing April 1985 to June 2014

Table 1 summarises all the pre-specificed parameters while Table 2 describes the calibrated parameters in the model.

## 4.1 Discretisation

To discretise the common factor productivity ($z$), I use the method proposed by Tauchen (1986) to approximate an AR(1) process using a finite-state Markov chain with 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 $F'(m)$ denotes the probability density function of $F(m)$.

[25]Specifically, $T$ is 5,320 and $T_1$ is 2,980 so that they are proportional to the available empirical data. Additionally, I use 200 burn-in periods.

## 4.2 Pre-specified Parameters

All the pre-specified parameters in the model are summarised in Table 1. For the discount factor $\beta$, I use the value of 0.9967 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 $\kappa$ to be 0.0392 using survey evidence on vacancy durations and hours spent on vacancy posting.[26] I assign $\mu$, the worker's bargaining power, to be 0.5 which is in line with Petrongolo & Pissarides (2001).

$\phi_H$ and $\phi_L$ are respectively the UI exhaustion rates during normal periods and recessions. I set $\phi_H$ to be $1/6$ which implies the standard maximum UI duration of 6 months given the monthly frequency. The UI exhaustion rates when $u \geq \bar{u}$ are set to be $\phi_{L,pre85} \equiv 1/12$ for the pre-1985 periods and $\phi_{L,post85} \equiv 1/18$ for the post-1985 periods implying the maximum UI duration of 12 months (pre-1985 average) and 18 months (post-1985 average) respectively. I set $\bar{u}$, the unemployment rate that triggers the UI extensions to be 6% which is on the lower bound for the observed UI extensions.

To determine the per-period flow values of unemployed workers ($h$ and, if insured, $b$), I base on the results in Gruber (1997). In particular, the drop in consumption for the newly unemployed workers is 10% when having UI and 24% when not having UI given the 50% replacement rate.[27]

Similar to Nagypál (2005), 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. 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).

## 4.3 Calibrated Parameters

I use the simulated method of moment to assign values to the remaining eleven parameters $\{l, \delta, \lambda, \psi, \xi, a_e, \underline{m}, \beta_1, \beta_2, \rho_z, \sigma_z\}$ by matching twelve mo-

[26]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 quarter. The actual mean productivity may be higher than (but not greatly different from) unity due to truncation from below of the match-specific quality.

[27]To find the implied $h$ and $b$ given a set of parameters, I first guess the mean wage for the newly fired and solve the model to obtain the policy functions. I then simulate the model to check if the guess is close to its counterpart from the simulation. If it is not, I replace the guessed wage for the newly fired with the one from the simulation and repeat until the two are close enough.

ments.[28] The values of these parameters are in Table 2. The targeted moments used in the calibration are the first and second moments of the unemployment rate, job destruction rate and job finding rate, the first moment of the job-to-job transtion rate, average unemployment duration, and insured unemployment rate, the second moment and autocorrelation of labour productivity, and the correlation between output and labour productivity. The model's performance in matching these statistics is reported in Table 3. Table 4 reports other related moments not targeted in the calibration.

## 4.4 Model's General Performance

As shown in Table 3, the baseline model matches the twelve targeted moments quite well despite being over-identified. The average job finding rate is somewhat higher than in the data whilst unemployment and job findings exhibit slightly higher fluctuations than in the data. The mean unemployment duration, measured in weeks, is slightly lower than the data but it is not the case when the data is truncated to periods before the Great Recession. Additionally, I also find the path of TFP shocks to match the empirical output series and see how well the model can replicate the fluctuations in the labour market as we observe in the data. The model performs well overall in producing realistic dynamics of unemployment, job findings, job destructions and labour productivity which can be seen in Figure 9. Although the trends are somewhat far the data, it is not surprising as changes in the trends are not accounted for. The insured unemployment is, however, very close to the data from both the cyclical and trend aspects, especially in bad times when the insured unemployment rate spikes.

The correlation between unemployment and vacancies produced by the baseline model is moderately negative while it is strongly negative in the data. Hagedorn and Manovskii (2011) show that a longer model period emphasises the time aggregation issues and lowers the correlation between unemployment and vacancies. With their model in Hagedorn and Manovskii (2008), they find that a two-week model period lessens the correlation in absolute value by around 0.2 whilst a one-week model period delivers a realistic correlation. Considering that the model period in this paper is 4.3 weeks (1 month), the weak correlation between unemployment and vacancies could

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

also be (partially) accounted for by these time aggregation issues.

# 5 Results

## 5.1 Policy Functions and Wages

There are two main reasons why the countercyclical UI policy lowers the procyclicality of the labour productivity: (i) the match surplus becomes lower and drops at a sharper rate near $\bar{u}$, the threshold unemployment rate, and (ii) the job finding rate for the insured unemployed also becomes lower and drops at a sharper rate near $\bar{u}$.

### 5.1.1 Total Match Surplus

The fact that the UI policy is more generous when $u \geq \bar{u}$ means that the outside option of workers in expectation is higher which, as a consequence, lowers a given match surplus. From Figure 3, we can see this is the case for the employed and the insured unemployed. These surplus functions after 1985 become lower which implies it is more likely that both new and existing matches with lower qualities will dissolve and, ceteris paribus, raise the labour productivity through both the numerator and the denominator, whilst reducing total output. What's more, the match surplus around $\bar{u}$ shows a steeper drop in its value as $u$ increases, which is due to the significant increase in the workers' outside option. This means there are more match dissolutions around this state of the economy which result in a higher rate of increase in the average match quality and counter the negative TFP shocks more strongly.

It can be seen that the total match surplus for the uninsured unemployed increases slightly from pre- to post-1985 periods. This is because it is actually more beneficial for the uninsured unemployed to become employed once again to be able to possibly enjoy the extra durations of UI benefits.

### 5.1.2 Job Search Efforts

The job finding rates are largely independent of the unemployment rate except around $\bar{u}$ for the insured unemployed workers, as seen in Figure 4, who are directly affected by the state-dependent UI extensions. When $u \geq \bar{u}$, the UI duration is extended and the worker's outside option when insured increases. This implies a lower match surplus to be shared; therefore, search efforts for the insured unemployed fall, and workers and firms are less likely to meet. From 1985 onwards, the job findings for insured unemployed workers are lower. They imply lower employment which, ceteris paribus, puts upward pressure on the labour productivity.

### 5.1.3 Wages

Similar to the explanation for the behaviour of match surpluses, through the workers' outside option, the wage rates for the employed and insured unemployed increase when $u \geq \bar{u}$ and this increase is more emphasised post 1985 due to the longer UI duration as seen in Figure 7. On the other hand, the wage of the uninsured unemployed falls when $u \geq \bar{u}$ because it is more profitable for the uninsured unemployed to become employed when the UI duration is extended, resulting in a lower bargained wage. The longer the UI duration is extended (i.e., post 1985), the lower the wage for the uninsured unemployed is.

## 5.2 Impulse Response Functions - IRFs

*To be completed*

## 5.3 Correlation Between Output and Labour Productivity

The model can explain over half of the empirical fall in the correlation between output and labour productivity as shown in Table 5. The model also delivers a realistic value for the correlation itself which is 0.67 compared to 0.62 in the data. When splitting the observations into pre- and post-1985 periods, the model-generated correlations between output and labour productivity are slightly higher than the empirical counterparts. The standard search and matching model with a fixed maximum UI duration does not have different policy functions over the business cycle, and therefore cannot deliver any change in the correlation output and labour productivity.

While only around half of the fall in the procyclicality of labour productivity is explained by the increase in the generosity of UI duration policy, there are other candidates that could contribute to this fall such as the increase in the importance of idiosyncratic risks vis-à-vis aggregate shocks as explored by Garin et al (2013) as well as the ability of firms to make adjustment in terms of labour size as proposed by Galí and van Rens (2014) and Berger (2012), among other explanations.

## 5.4 Decomposition of Countercyclical UI Duration Effects

As a change in the UI duration policy affects the procyclicality of labour productivity through the change in match surpluses and job search efforts, I decompose its effect to measure how strongly each channel contributes to the business cycle properties of labour productivity.

In the first case, I assume both workers and firms always use the pre-1985 match surpluses throughout the simulation to make decisions on match formation and dissolution (i.e., the policy functions for match surpluses are the same for pre- and post-1985 periods), and see how much the change in job search efforts after 1985 explains the fall in the labour productivity's procyclicality. In the second case, I assume the job search efforts stay the same as the pre-1985 periods to estimate the impact of the change in match surpluses, that is due to the increase in the generosity of UI duration policy, on the procyclicality of the labour productivity.

It turns out that both match surpluses and job search efforts explain a substantial part of the drop in the output-labour-productivity correlation and deliver a higher correlation of 0.76-0.77 as shown in Table 6. It is rather surprising that the search effort channel contributes as just much to the drop as it mainly affects insured unemployed workers whilst the change in match surpluses affects all types of workers. This finding shows that in order to obtain a sizable shift in the correlation between output and labour productivity, the variable search intensity margin is just as important as the total match surpluses that workers and firms use to determine match formations and dissolutions, and simply setting search efforts to be constant could undermine the effect of UI duration policy on the behaviour of the labour productivity over the business cycles.

## 5.5 Hazard Rate of Exiting Unemployment

Modelling heterogeneity in unemployment statuses also has an implication for the duration-dependent job finding probabilities of unemployed workers. On the contrary to a constant unemployment exit rate in a standard search and matching model (with no participation margins), the model in this paper can produce a realistic feature of the rate an unemployed worker finds a job by durations of unemployment. In the data, this rate is decreasing and usually convex in the time spent in unemployment, the properties that the model can replicate as depicted by Figure 13. I split the hazard functions to two cases: 1) the insured unemployed workers remain insured throughout the unemployment spell, and 2) the insured unemployed become uninsured with probability $\phi_H$ each period (implying maximum UI duration during normal times), as these are the lower and upper bounds for the realised maximum UI durations. The main reason the hazard rate is decreasing in unemployment duration is due to the change in the composition of unemployed workers. Uninsured unemployed workers have a higher job finding rate and therefore exit unemployment earlier than the insured type. As time goes by, the unemployed workers are more represented by the insured type, the hazard rate therefore falls with unemployment duration and becomes stable once only there are no uninsured type left in the unemployment pool.

When compared to the data, Kroft, Lange, Notowidigdo and Katz (2014) have also estimated this hazard rate parametrically controlling for observable characteristics from the CPS data between 2002-2007. They find that the relative job finding rate (normalised to unity to zero duration) drops sharply during the first 8-10 months, after which the rate becomes stable around 0.4-0.5. The function is slightly lower than that from what the model can produce given that the insured unemployed remain insured throughout the spell. However, when the stochastic UI exhaustion rate is taken into account, the model's duration-dependent job findings can explain only partially the drop in the hazard function during the first months of unemployment. The model's performance is somewhere between these two functions as the maximum UI durations can vary between 6 months to almost 2 years.

# 6 Conclusion

This paper is set out to quantify how much the increasingly generous UI duration policy during recessionary periods in the U.S. contributes to the substantial fall in the procyclicality of its labour productivity over the business cycle. The results are obtained from a search and matching model with finite UI duration, endogenous job destructions, variable search intensity and on-the-job search. It is found that the proposed model, with the countercyclical UI duration policy embedded, can produce 50% of the empirical drop in the correlation between output and output per worker. The proposed model also performs very well in producing key statistics in the labour markets especially the insured unemployment dimension where the model can produce realistic fluctuations in both the trend and the cyclical components. Most of the success is due to the fact that the maximum UI duration varies with the unemployment rate and becomes more generous when the negative shocks are large enough. This translates to the non-linearity of the policy functions, which are total match surpluses and workers' job search efforts, and helps reduce the co-movement between output and labour productivity.

# A Surplus Expressions

The expressions for the total surpluses of worker-firm matches given the workers' previous employment statuses $(e, UI, UU)$ and the surplus of being insured unemployed can respectively be found below.

$$
\begin{aligned}
S^e(m;\omega) \quad = \quad & y_{mZ} - c_e(s^e(m;\omega)) - \tau - (1-\psi)(b + h - c_u(s^{UI}(\omega))) \\
& -\psi(h - c_u(s^{UU}(\omega))) + \beta E_{\omega'|\omega}\Bigg[ ... \\
& (1-\delta)(1-\lambda)\Big((1 - p^e(m;\omega)(1-F(m)))S^{e+}(m;\omega')... \\
& +p^e(m;\omega)(1-F(m))E_{m'|m'>m}[\mu S^{e+}(m';\omega')]\Big) \\
& +(1-\delta)\lambda E_{m'}\Big[(1 - p^e(m;\omega)(1-F(m')))S^{e+}(m';\omega')... \\
& +p^e(m;\omega)(1-F(m'))E_{m''|m''>m'}[\mu S^{e+}(m'';\omega')]\Big] \\
& -(1-\psi)p^{UI}(\omega)E_{m'}[\mu S^{UI+}(m';\omega')] \\
& -\psi p^{UU}(\omega)E_{m'}[\mu S^{UU+}(m';\omega')] \\
& +(1-\psi)\Big(\phi + p^{UI}(\omega)(1-\phi)\xi\Big)US(\omega')\Bigg]
\end{aligned}
$$

$$
\begin{aligned}
S^{UI}(m;\omega) \quad = \quad & y_{mZ} - c_e(s^e(m;\omega)) - \tau - (1-\phi)(1-\xi)(b + h - c_u(s^{UI}(\omega))) \\
& -(1-(1-\phi)(1-\xi))(h - c_u(s^{UU}(\omega))) + \beta E_{\omega'|\omega}\Bigg[ ... \\
& (1-\delta)(1-\lambda)\Big((1 - p^e(m;\omega)(1-F(m)))S^{e+}(m;\omega')... \\
& +p^e(m;\omega)(1-F(m))E_{m'|m'>m}[\mu S^{e+}(m';\omega')]\Big) \\
& +(1-\delta)\lambda E_{m'}\Big[(1 - p^e(m;\omega)(1-F(m')))S^{e+}(m';\omega')... \\
& +p^e(m;\omega)(1-F(m'))E_{m''|m''>m'}[\mu S^{e+}(m'';\omega')]\Big] \\
& -(1-\phi)(1-\xi)p^{UI}(\omega)E_{m'}[\mu S^{UI+}(m';\omega')] \\
& -\Big(1-(1-\phi)(1-\xi)\Big)p^{UU}(\omega)E_{m'}[\mu S^{UU+}(m';\omega')] \\
& +\Big(1 - \psi - (1-\phi)^2(1-\xi)(1-\xi p^{UI}(\omega))\Big)US(\omega')\Bigg]
\end{aligned}
$$

$$
\begin{aligned}
S^{UU}(m;\omega) \quad = \quad & y_{mZ} - c_e(s^e(m;\omega)) - \tau - (h - c_u(s^{UU}(\omega))) + \beta E_{\omega'|\omega}\Big[... \\
& (1-\delta)(1-\lambda)\Big((1 - p^e(m;\omega)(1-F(m)))S^{e+}(m;\omega')... \\
& + p^e(m;\omega)(1-F(m))E_{m'|m'>m}[\mu S^{e+}(m';\omega')]\Big) \\
& + (1-\delta)\lambda E_{m'}\Big[(1 - p^e(m;\omega)(1-F(m')))S^{e+}(m';\omega')... \\
& + p^e(m;\omega)(1-F(m'))E_{m''|m''>m'}[\mu S^{e+}(m'';\omega')]\Big] \\
& - p^{UU}(\omega)E_{m'}[\mu S^{UU+}(m';\omega')] \\
& + (1-\psi)US(\omega')\Big]
\end{aligned}
$$

$$
\begin{aligned}
US(\omega) \quad = \quad & b - c_u(s^{UI}(\omega)) + c_u(s^{UU}(\omega)) \\
& + \beta E_{\omega'|\omega}\Big[p^{UI}(\omega)\mu E_{m'}[S^{UI+}(m';\omega')] - p^{UU}(\omega)\mu E_{m'}[S^{UU+}(m';\omega')] \\
& (1-\phi)\Big(1 - p^{UI}(\omega) + p^{UI}(\omega)(1-\xi)\Big)US(\omega')\Big]
\end{aligned}
$$

# B Computational Algorithm

TO BE COMPLETED

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Table 1: **Pre-specified Parameters For Baseline Model (Monthly)**

| Parameter | Description | Value | Source/Remarks |
|---|---|---|---|
| $\beta$ | Discount factor | 0.9967 | Annual interest rate of 4% |
| $\kappa$ | Vacancy posting cost | 0.0392 | Fujita & Ramey (2012) |
| $\mu$ | Worker's bargaining power | 0.5 | Petrongolo & Pissarides (2001) |
| $\phi_H$ | UI exhaustion rate | 1/6 | 6 months max UI duration, ETA |
| $\phi_{L,I}$ | UI exhaustion rate | 1/12 | 12 months max UI duration, ETA |
| $\phi_{L,II}$ | UI exhaustion rate | 1/18 | 18 months max UI duration, ETA |
| $b$ | UI benefit | 0.1221 | Gruber (1997) given $E(w) = 0.872$ |
| $h$ | Leisure flow | 0.6627 | Gruber (1997) given $E(w) = 0.872$ |
| $\bar{u}$ | UI policy threshold | 0.06 | ETA |
| $a_u$ | Search cost function | 0.1287 | Normalisation |
| $d_u, d_e$ | Search cost function | 1 | Christensen et al (2004), Yashiv (2000) |

Table 2: **Calibrated Parameters For Baseline Model (Monthly)**

| Parameter | Description | Value |
|---|---|---|
| $l$ | Matching function | 0.6010 |
| $\delta$ | Exogenous destruction | 0.0234 |
| $\lambda$ | Redrawing new $m$ | 0.5000 |
| $\psi$ | Losing UI after becoming unemp. | 0.4900 |
| $\xi$ | Losing UI after meeting firm | 0.4605 |
| $a_e$ | Search cost function | 0.1100 |
| $m_{min}$ | Lowest match-specific prod. | 0.4689 |
| $\beta_1$ | Match-specific prod. distribution | 2.8024 |
| $\beta_2$ | Match-specific prod. distribution | 4.5101 |
| $\rho_z$ | Persistence of TFP | 0.9715 |
| $\sigma_z$ | Standard deviation of TFP shocks | 0.0056 |

Table 3: **Model's Performance in Matching Targeted Moments**

| Moment | Model | SD | Data |
|---|---|---|---|
| E($u$) | 0.0603 | (0.0055) | 0.0583 |
| E($\rho_f$) | 0.4387 | (0.0166) | 0.4194 |
| E($\rho_x$) | 0.0258 | (0.0008) | 0.0248 |
| E($\rho_{ee}$) | 0.0321 | (0.0003) | 0.0320 |
| E$(u_{dur})$ (weeks) | 12.7217 | (1.7336) | 15.4287 |
| E$(u^{UI}/u)$ | 0.0384 | (0.0056) | 0.0290 |
| std($u$) | 0.1633 | (0.0197) | 0.1454 |
| std($\rho_f$) | 0.1203 | (0.1129) | 0.0999 |
| std($\rho_x$) | 0.0836 | (0.0154) | 0.0890 |
| std($LP$) | 0.0123 | (0.0006) | 0.0131 |
| std$(u_{dur})$ (weeks) | 9.4988 | (8.5630) | 6.9941 |
| $corr(LP, LP_{-1})$ | 0.7716 | (0.0203) | 0.7612 |
| corr($y$,$\rho_f$)* | 0.9117 | (0.0258) | 0.8009 |
| corr($y$,$\rho_x$)* | -0.8251 | (0.0317) | -0.8414 |
| corr($y$,$u$)* | -0.9153 | (0.0245) | -0.8825 |
| corr($u, v$)* | -0.1959 | (0.0819) | -0.8786 |

Table 4: **Moments Not Targeted**

| Moment | Data | Model |
|---|---|---|
| std$(u_{dur})$ | 6.9941 | 5.7471 |
| std$(u^{UI})$ | 0.1657 | 0.2250 |
| std$(v)$ | 0.1408 | 0.0611 |
| std$(u)$/std$(y)$ | 8.8121 | 7.2951 |
| std$(e)$/std$(y)$ | 0.9900 | 0.9795 |
| std$(w)$/std$(y)$ | 0.3878 | 0.4959 |
| corr($y$,$\rho_f$) | 0.8009 | 0.9118 |
| corr($y$,$\rho_x$) | -0.8414 | -0.7973 |
| corr($y$,$u$) | -0.8825 | -0.8971 |
| corr($u, v$) | -0.8786 | -0.2675 |
| corr($y, v$) | 0.8850 | 0.5353 |
| $E(m)_{pre85}$ | - | 0.8814 |
| $E(m)_{post85}$ | - | 0.8824 |

Table 5: **Correlation Between Output ($y$) and Labour Productivity ($LP$)**

| | Data | Model |
|---|---|---|
| corr($y, LP$) | 0.6186 | 0.6663 |
| $\text{corr}(y, LP)_{pre85}$ | 0.7015 | 0.8150 |
| $\text{corr}(y, LP)_{post85}$ | 0.2954 | 0.6111 |
| $\Delta$corr($y, LP$) | 0.4061 | 0.2039 |

Table 6: **Decomposition of UI Effects on** $corr(y, LP)$

| | Data | Baseline | $S$-fixed | $s$-fixed |
|---|---|---|---|---|
| corr($y, LP$) | 0.6186 | 0.6663 | 0.7617 | 0.7727 |
| $\text{corr}(y, LP)_{pre85}$ | 0.7015 | 0.8150 | 0.8470 | 0.8490 |
| $\text{corr}(y, LP)_{post85}$ | 0.2954 | 0.6111 | 0.7239 | 0.7390 |
| $\Delta$corr($y, LP$) | 0.4061 | 0.2039 | 0.1231 | 0.1100 |

Figure 1: Correlations between output and output per worker for 1948Q1-1985Q1 and 1985Q2-2013Q1 (both variables are of quarterly frequency and detrended using the HP filter with a smoothing parameter of 1,600) (the green lines are linear fitted trends) (Source: BEA and BLS)

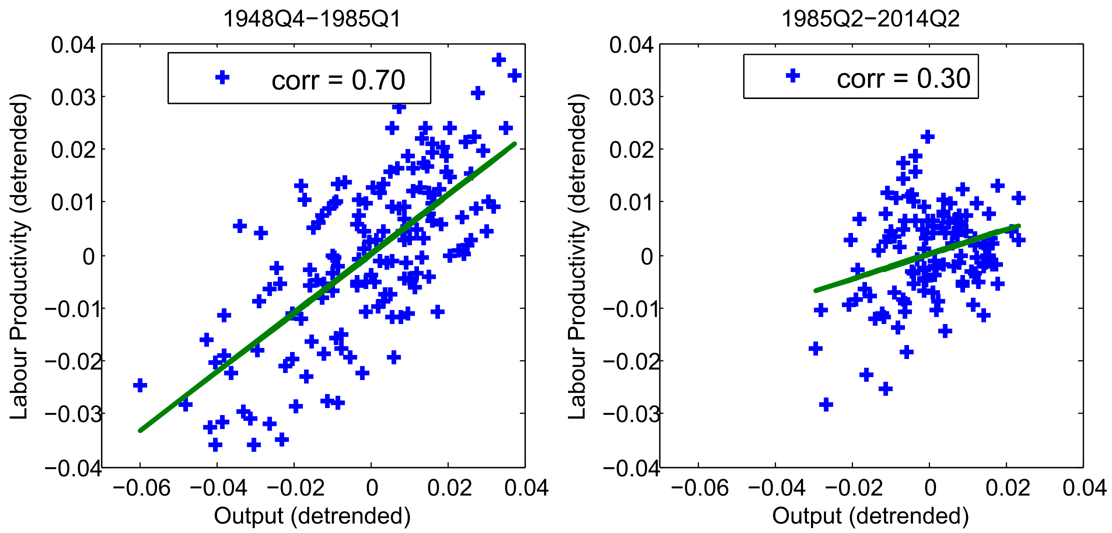


Figure 2: Maximum UI duration (in weeks) as plotted as against time periods from 1948Q1 to 2013Q1 (shaded areas denote recessions) (Source: ETA)

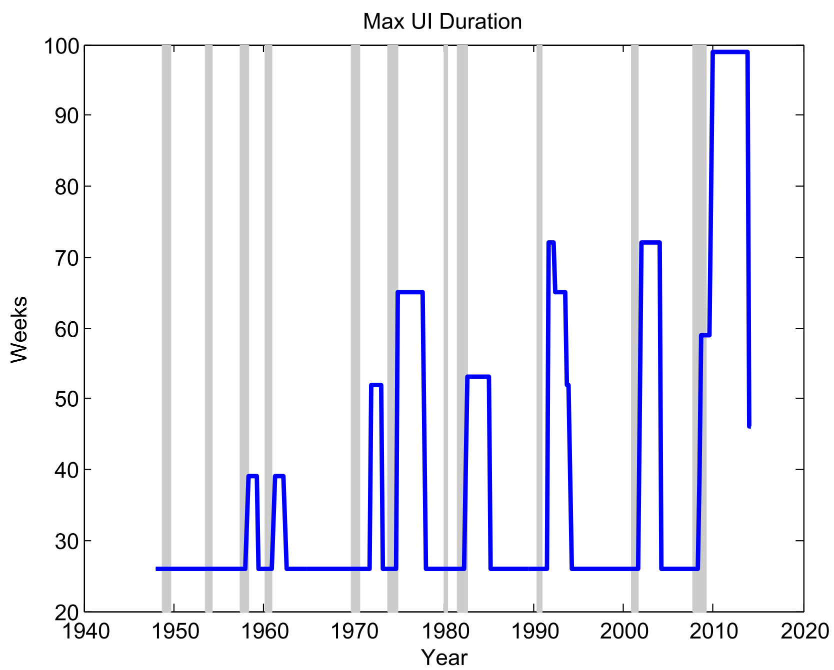

Figure 3: Total match surpluses $S^i; i \in \{e, UI, UU\}$ plotted against unemployment rates ($u$): For the match-specific and total factor productivities at the middle nodes

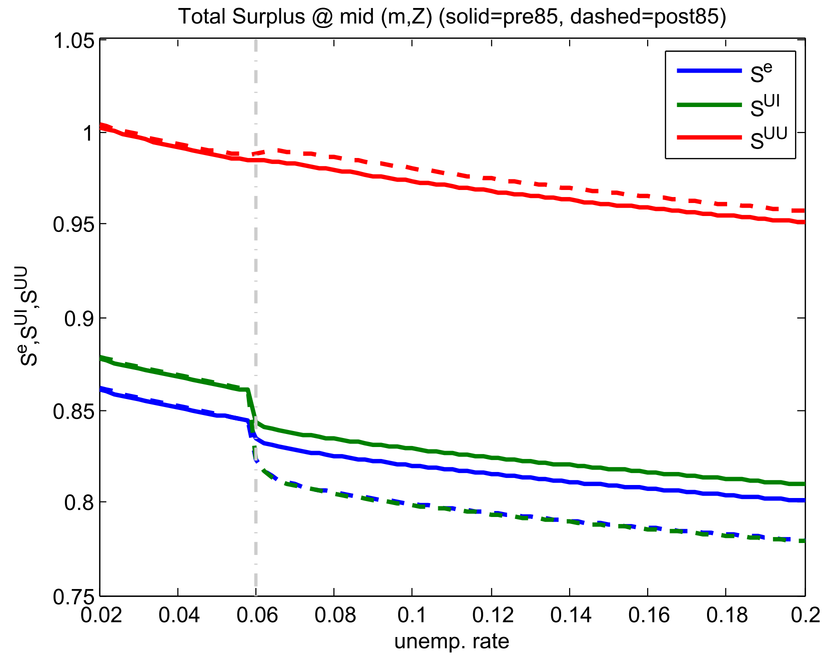


Figure 4: Conditional job finding rates (worker's meeting rates) by employment statuses plotted against unemployment rates

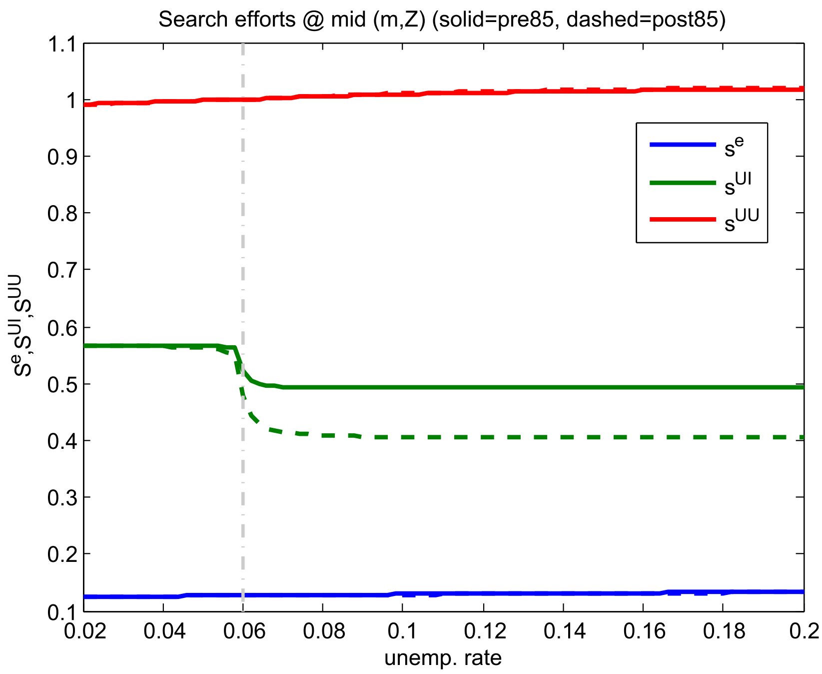

Figure 5: Total match surpluses $S^i; i \in \{e, UI, UU\}$ plotted against TFP ($Z$): For the match-specific productivity and unemployment rate at the middle nodes

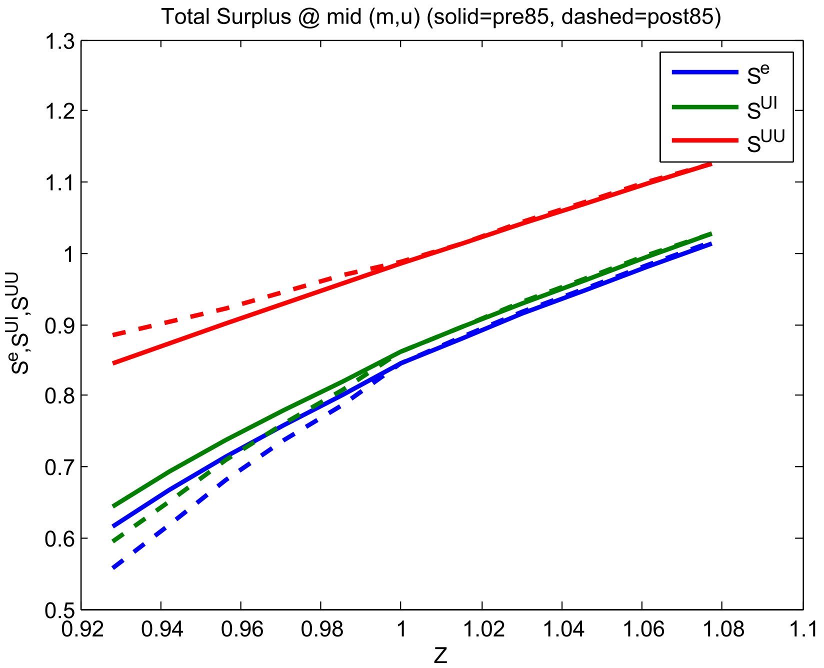


Figure 6: Conditional job finding rates (worker's meeting rates) by employment statuses plotted against TFP

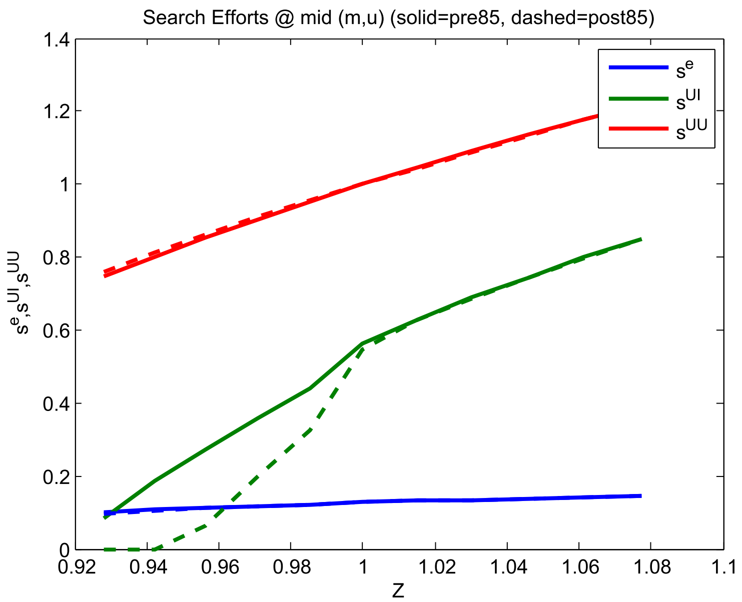

Figure 7: Wages $w^i; i \in \{e, UI, UU\}$ plotted against unemployment rates ($u$): For the match-specific and total factor productivities at the middle nodes

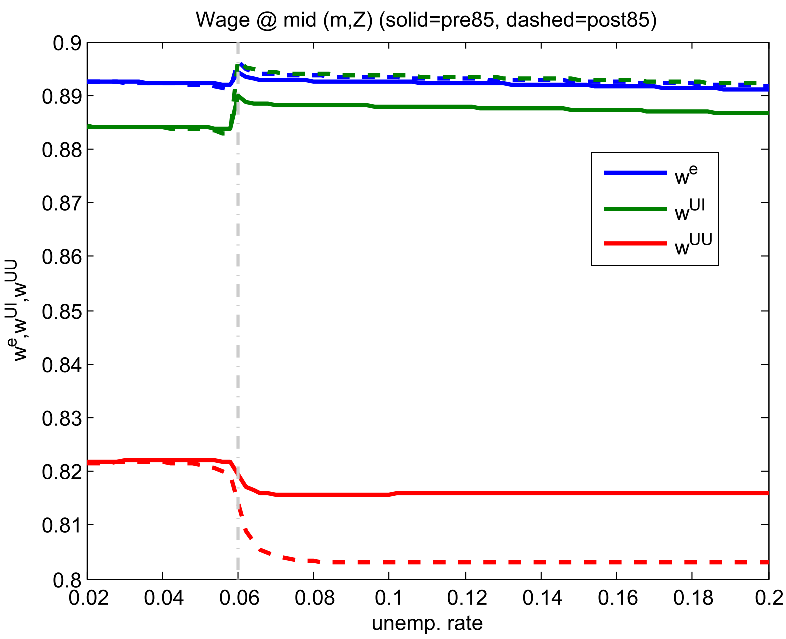


Figure 8: Wages $w^i; i \in \{e, UI, UU\}$ plotted against TFP ($Z$): For the match-specific productivity and unemployment rate at the middle nodes

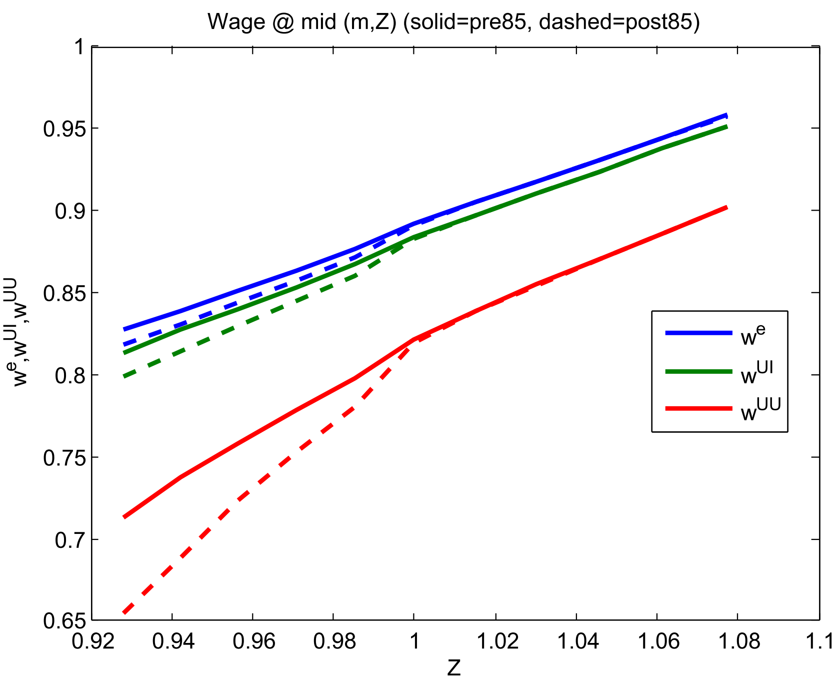

Figure 9: Model-generated (solid) and empirical (dashed) detrended series of main variables

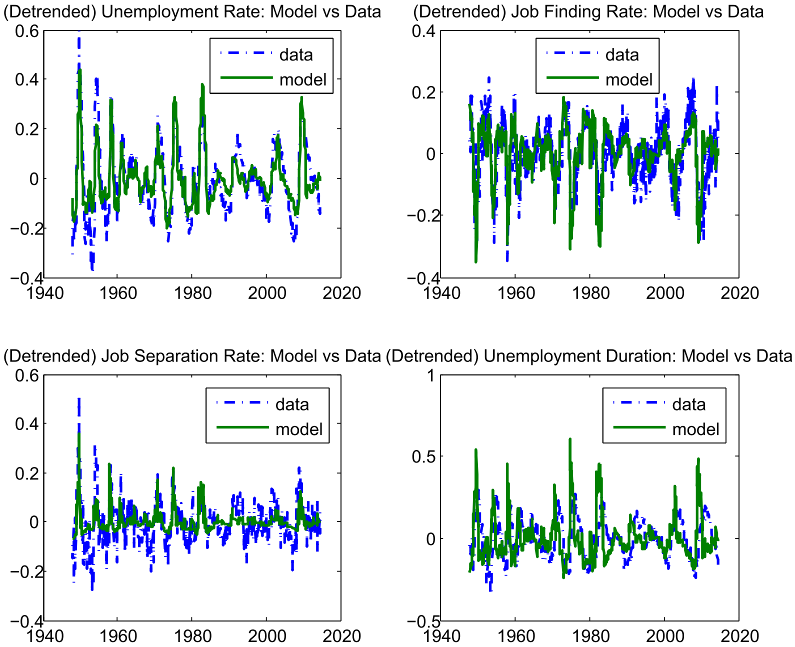


Figure 10: Model-generated (solid) and empirical (dashed) raw series of main variables

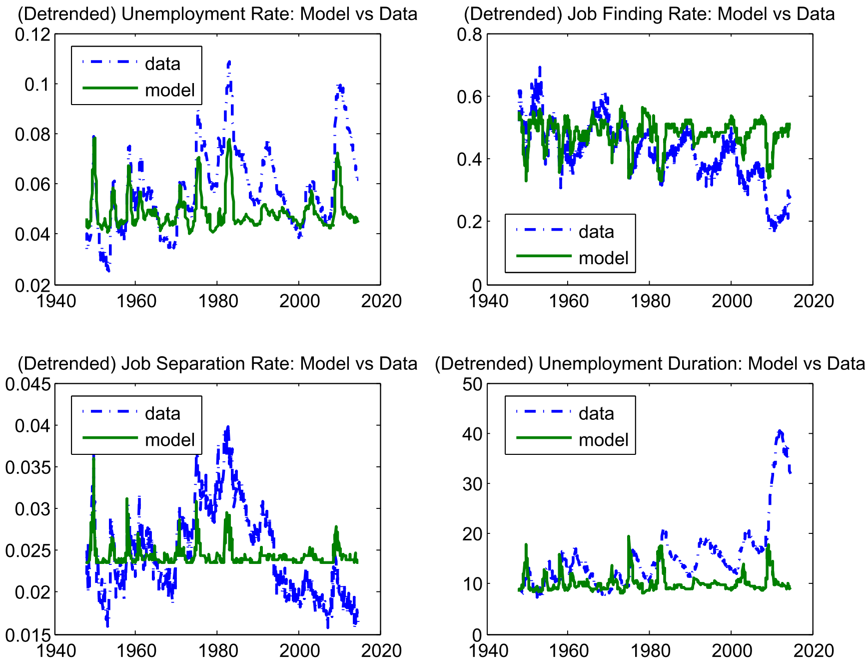

Figure 11: Model-generated (solid) and empirical (dashed) detrended series of insured unemployment rate

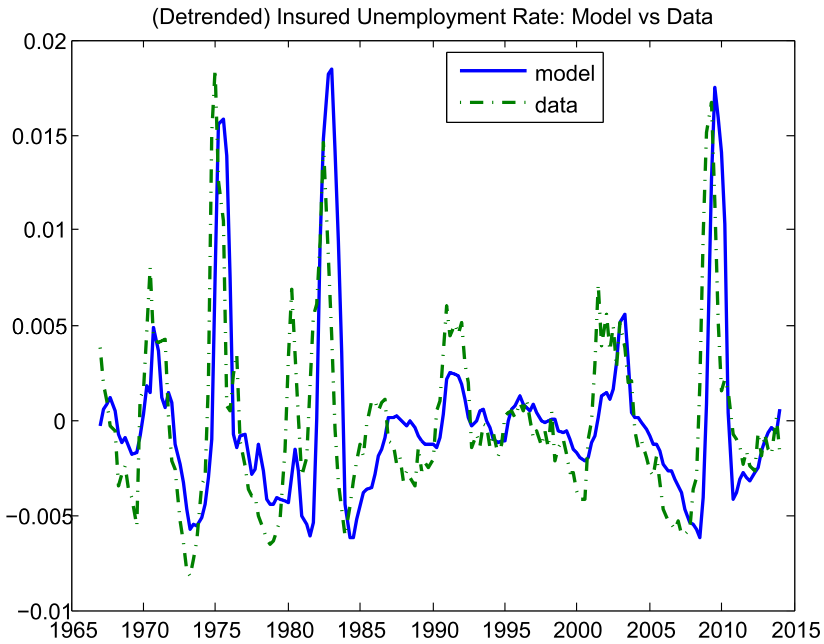


Figure 12: Model-generated (solid) and empirical (dashed) raw series of insured unemployment rate

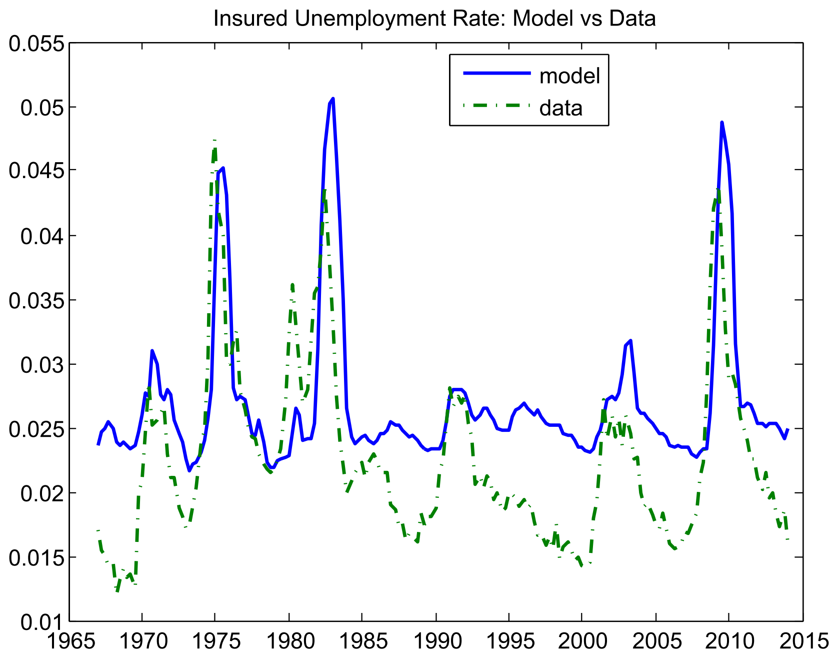

Figure 13: Duration-dependent Job Finding Probability (implied UI durations in brackets)