Unemployment Insurance and Labour Productivity over the Business Cycle[*]

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Abstract

This paper quantifies the effects of the increasing maximum unemployment insurance (UI) duration during recessions on the drop in the correlation between output and labour productivity in the U.S. since the early 1980's - the so-called productivity puzzle. Using a general equilibrium search and matching model with stochastic UI duration, heterogeneous match quality, variable search intensity and on-the-job search, I demonstrate that the model can explain over 40 percent of the drop in this correlation (28 percent when the Great Moderation is taken into account). More generous UI extensions during recent recessions cause workers to be more selective with job offers and lower job search effort. The former channel raises the overall productivity in bad times. The latter prolongs UI extensions since in the U.S. they are triggered by high unemployment.

JEL Classification. E32, J24, J64, J65.

Keywords. Business cycles, labour productivity, unemployment insurance

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1 Introduction/Motivation

The labour productivity has become significantly less procyclical in the U.S. since the early 1980's. In particular, the cross correlation between output and labour productivity has fallen from 0.70 in the 1948-1985 period to only around 0.30 thereafter.[1] This change in the procyclicality of the labour productivity is usually coined "the labour productivity puzzle". Moreover, it can be observed that the fall in the correlation between output and labour productivity mostly happened right after recessionary periods since the 1980's as depected in Figure 2.

This paper explores the hypothesis that the fall in the procyclicality of labour productivity is related to the systematic change in the generosity of the U.S. unemployment insurance (UI) system. One distinctive feature of its UI system is the extension of the maximum UI duration that is triggered when the unemployment rate is above a certain threshold making the policy countercyclical. While the standard UI duration is 26 weeks, the extended UI duration has increased from the average of 52 weeks during 1948-1985 to 78 weeks after 1985.[2]

This increase in the generosity of the UI duration during the times of high unemployment, often associated with recessions, weakens the links between output and output per worker via two channels. First, a generous UI policy raises the worker's outside option, making the workers become more selective with respect to the quality of job offers; as a result, an upward pressure on the labour productivity can be expected during the recessions. Second, UI extensions lower job search effort of the unemployed causing a slower job-worker matching and more persistent unemployment which further prolongs the extensions themselves. With the UI extensions being more generous in the post-1985 period, the UI effect on the labour productivity is expected to be stronger in recent recessions than in earlier ones. This contributes to the fall in the procyclicality of labour productivity.

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[1]This change in the correlation is depicted in Figure 1.

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

I extend the Mortensen-Pissarides general equilibrium search and matching model to incorporate stochastic UI duration, heterogeneous match quality, variable search intensity and on-the-job search. To my knowledge, this paper is the first to realistically incorporate the feature where UI extensions are a function of the unemployment rate which is the case in the U.S.. The cyclical behaviour of the average match quality is vital in explaining the correlation between output and output per worker in the model. By allowing for variable search intensity, I can separately identify the contributions of the two proposed channels, namely, match formation and job search effort, on the fluctuations in the labour productivity over the business cycle. Lastly, searching on the job is allowed so that the model produces a realistic correlation between unemployment and vacancies.

I find that the countercyclical UI policy can account for 43 percent of the drop in the contemporaneous correlation between output and labour productivity observed in the U.S. data. By isolating the contributions of the two channels, I find that both match formations and job search effort have a significant explanatory power over the correlation between output and labour productivity. By shutting down one channel, the other can explain around half of the drop in the correlation that the model can produce. Additionally, the model generates realistic moments of key labour market variables in the U.S., including the share of insured unemployed workers over the business cycle.

As a robustness check, I extend to the model to take into account the Great Moderation, the phenomenon where there is a reduction in the macroeconomic volatility also starting around the mid 1980's. The decreased volatility does reduce the impact of the generous UI extensions because it implies less extreme negative shocks that can trigger UI extensions; however, the overall UI effect is still significant and explains around 28 percent of the drop in the procyclicality of the labour productivity. Lastly, I show that the model can generate the downward-sloping duration-dependent job finding probability that is qualitatively similar to the data despite the fact that unemployment duration is not modelled explicitly. This is due to different job finding rates amongst the unemployed.

I am not the first to investigate the source of the decline in the correlation between output and labour productivity. Galí and van Rens (2014) suggest that decreasing employment adjustment costs have generated a substantial fall in the procyclicality of the labour productivity. Berger (2018) explains the puzzle using a quantitative 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. Garin, Pries and Sims (2016) use a model with aggregate and island-specific shocks as well as complete markets, and show that the falling correlation between output and labour productivity is from the relatively lower importance of aggregate shocks. McGrattan and Prescott (2012) also study the sources of the labour productivity puzzle by considering intangible capital and sectoral productivity shocks. The source of the labour productivity puzzle in this paper, namely, UI extensions, can be directly verified from the data, and this hypothesis is also supported by existing literature on UI extensions.

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 that a positive replacement rate with unlimited UI duration also leads to a higher labour productivity when compared to the case without UI. This paper extends from Acemoglu and Shimer (2000) and Marimon and Zilibotti (1999) by allowing for stochastic aggregate productivity so that the business cycle properties of the model, particularly the co-movement between labour productivity and output, can be studied. Furthermore, there are empirical results that support the hypothesis in this paper. Findings 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.

It is useful to compare the model in this paper, particularly the UI duration policy, with that in Mitman and Rabinovich (2014) who study the effects of maximum UI duration in the U.S. on jobless recoveries[3], and Faig, Zhang and Zhang (2012) who study the contribution of countercyclical UI duration policy on the labour market dynamics. Mitman and Rabinovich (2014) assume all UI extensions are unexpected and perceived to last forever by the agents. Although the model in this paper may not be able to replicate exactly the timing of UI extensions like in theirs, 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. I assume the UI duration policy varies with the unemployment rate instead of the aggregate total factor productivity like in Faig et al. (2012). Whilst this offers a more accurate length of UI extensions (since unemployment tends to be more persistent than does the total factor productivity), the model is computationally more difficult to solve since the entire distribution of workers by employment status and heterogeneous match quality becomes a state variable. I provide an algorithm that solves the model and delivers results with high accuracy.

The paper is organised as follows: Section 2 describes the model. Section 3 discusses the calibration exercise. Section 4 analyses the results. Section 5 concludes.

2 Model

2.1 Setup

The model is based on the Mortensen-Pissarides general equilibrium search and matching model with the incorporation of aggregate productivity shocks, stochastic UI duration, heterogeneous match quality, variable search intensity and on-the-job search. Time is discrete and of monthly frequency. Search is assumed to be random. There is a continuum of workers of measure one and a larger continuum of firms each with either zero or one employee. They are

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[3]In Mitman and Rabinovich (2015), they also study the optimal UI policy where unemployed workers can vary their job search intensity. Since matches in this paper differ by match qualities, I also allow for on-the-job search.

infinitely-lived and risk-neutral, and they discount future utility flows or profits each period by a constant factor $\beta \in (0,1)$.

2.1.1 Production

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

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

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

Match Quality   By assumption, variations in the labour productivity in this model only come from the changes in the average match quality given the aggregate state. This match-specific productivity drawn at the start of any worker-firm relationship is distributed according to a Beta distribution with parameters $\{\beta_1, \beta_2\}$. The distribution function is

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

where $\underline{m} > 0$ is the lowest productivity level, and $1 + \underline{m}$ is the highest. Each match-specific productivity m will remain until the match is either destroyed (with probability δ) or hit by a shock that causes the match to redraw m from $F(m)$ (with probability λ) in each period.

Aggregate Productivity Shocks   There is only one exogenous aggregate shock in the model which is the shock to the total factor productivity, z, whose natural logarithm has an AR(1) representation with ρ_z being its AR parameter. Specifically,

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

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

2.1.2 Workers

Workers maximise the expected discounted lifetime utility

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

where $E_t(\cdot)$ is the expectation operator conditional on period-t information, c_t is consumption and $v(\cdot)$ is the disutility of job search effort s_t which can be exerted during both unemployment and employment. Workers can be in one of the three states: 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 $v_e(s^e_{m,t}) = a_e \cdot (s^e_{m,t})^{1+d_e}$ where a_e and d_e are positive constants. At the end of the period: (i) her current match is exogenously destroyed with probability δ 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 λ, (iii) she meets a vacant firm with probability $p(s^e_{m,t}) \equiv p^e_{m,t}$, draws a new match quality m and decides whether to stay with her current firm, and (iv) the wage is renegotiated for the production next period. If becoming unemployed in $t+1$, an employed worker in period t is eligible for UI benefits in period $t+1$ with probability $(1-\psi) \in (0,1]$. $(1-\psi)$ can be smaller than one to reflect how some newly unemployed workers are ineligible for or do not claim UI benefits.[4] The employed can always exit employment if desired at the end of period t.

The aggregate states variables in this economy are $\{z, u, u^{UI}, u^{UU}, e_m; \forall m\}$. Respectively, they are the total factor productivity, the unemployment rate, the insured unemployment rate, the uninsured unemployment rate and the measure of employed workers in every level of match quality. I let ω denote this set of state variables. Given the recursive nature of the problem, the time subscripts are dropped and variables with superscript $'$ are of the next period. Variables

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[4]In the U.S., the average ratio of the insured unemployed to the total unemployed is 36% between 1967-2014.

with subscripts m and/or ω 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, $F(m)$.

Given ω, an employed worker with match quality m and last period's employment status $j \in \{e, UI, UU\}$ has the following value function:

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

where $W^{e+}(m;\omega') \equiv \max\{W^e(m;\omega'),(1-\psi)U^{UI}(\omega')+\psi U^{UU}(\omega')\}$ showing that, conditional on the match not being exogenously destroyed, an employed worker can choose to either remain employed in the next period and receive the value $W^e(\cdot;\cdot)$[5] or return to unemployment and risk not having UI benefits (which occurs at rate ψ). Last period's employment status $j \in \{e, UI, UU\}$ matters for the workers as it represents the outside option they have when negotiating for wages. $U^{UI}(\omega)$ and $U^{UU}(\omega)$ are the values of being insured and uninsured unemployed respectively. $p^e(m;\omega)$ is the probability that an employed worker whose current match quality is m meets a vacant firm which depends on her search intensity $s^e(m;\omega)$. δ and λ are respectively the match destruction prob-

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[5]The value $W^e(\cdot;\cdot)$ for the next period can vary depending on whether the worker-firm match has to redraw its match quality and whether the worker makes a job-to-job transtion.

ability and the probability that the match redraws its match quality. The expression for the optimal search intensity for employed workers can be found in Appendix B.

An insured unemployed worker in period t receives UI benefits b and leisure flow h.[6] She also exerts job search effort s_t^{UI} that comes with a disutility cost of $v_u(s_t^{UI}) = a_u \cdot (s_t^{UI})^{1+d_u}$ where a_u and d_u are positive constants. She meets a vacant firm with probability $p(s_t^{UI}) \equiv p_t^{UI}$. 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 of t. Since the inverse of $\phi(u_t)$ is the expected duration of being able to receive UI, I use this function to control for the maximum UI duration that changes with the unemployment rate (as in the case in the U.S.). The properties of $\phi(u_t)$ will be discussed in more detail in the next subsection.[7] Insured unemployed workers that meet a firm but decide to remain unemployed and continue to search for a job may additionally lose UI eligibility with probability ξ.[8] This parameter can be greater than zero to reflect the job search monitoring in UI recipients.

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 $v_u(s_t^{UU}) = a_u(s_t^{UU})^{1+d_u}$, and she meets a vacant firm with probability $p(s_t^{UU}) \equiv p_t^{UU}$.

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[6]This flow h can be interpreted as the value of leisure, home production, food stamps, etc.

[7]This setting for the UI duration policy, first used in Fredriksson and Holmlund (2001), helps reduce the state space greatly.

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

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

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

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

where $p^{UI}(\omega)$ is the probability that an insured unemployed worker meets a vacant firm which depends on her search intensity $s^{UI}(\omega)$, and $p^{UU}(\omega)$ is analogously defined. We can see from equation (2) that, for insured unemployed workers, the outside option for those meeting a vacant firm is smaller than for those not meeting a vacant firm, i.e. $(1-\phi(u))(1-\xi) < \phi(u)$ and $U^{UI}(\omega) > U^{UU}(\omega)$. This is due to the possibility of being UI ineligible after turning down a job offer. Note that if the UI exhaustion rate becomes unity, i.e. no one is insured unemployed, there will be no difference between equations (2) and (3). The expressions for the optimal search intensities for insured and uninsured unemployed workers can be found in Appendix B.

2.1.3 UI Duration Policy: $\phi(u_t)$

Empirically, there are three main categories of UI duration policy in the U.S.: (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 ad-hoc programmes that are often issued in the recessions and also triggered by the state unemployment rate providing additional UI rang-

ing from 13 to 53 weeks. To capture these features, I combine the extensions in (ii) and (iii) together and make them a function of the unemployment rate u.[9] Specifically, $\phi(u)$ can take one of the two values: a low value which implies a longer UI duration for the recessionary episodes and a high value for the normal time. There is a threshold unemployment rate $\bar{u}$ such that whenever $u \geq \bar{u}$, the maximum UI duration increases, and $\phi(u)$ takes the low value ϕ_L, and whenever $u < \bar{u}$, the maximum UI duration remains standard at 26 weeks, and $\phi(u)$ takes the high value ϕ_H where $0 < \phi_L < \phi_H < 1$. In summary,

$$\phi(u_t) = \phi_L \mathbb{1}\{u_t \geq \bar{u}\} + \phi_H \mathbb{1}\{u_t < \bar{u}\}; \ \forall t$$

I assume this UI duration policy $\phi(u)$ is known to all agents; therefore, they expect a longer UI duration when the unemployment rate is expected to exceed $\bar{u}$.[10] That is, agents have a rational expectation about the timings of UI extensions. In order to finance UI benefits, the government collects lump sum tax τ_t from all firms that are in production. The tax is set to satisfy the government budget constraint in each period. Namely,

$$\tau_t = \frac{b u_t^{UI}}{1 - u_t}; \ \forall t$$

2.1.4 Firms

Firms maximise the expected discounted profits. They are matched with either one or zero worker. A firm in operation (matched with a worker) in period t sells output $y_{m,t}$, pays wage $w_{m,t}$ to the worker and pays lump sum tax τ_t. Analogous to an employed worker, it faces an exogenous match-destruction shock and a shock to redraw its match-specific productivity (at rate δ and λ respectively). Further, it becomes unmatched when its worker takes up a new job offer.[11] The

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[9]This is the reason why 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.

[10]As explained in Appendix A, 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 *around* recessionary periods (particularly with a high unemployment rate), just not exactly when the policy is implemented.

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

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 its worker's employment status last period $j \in \{e, UI, UU\}$, and V the value of posting a vacancy. The Bellman equation for an operating firm is

$$
\begin{aligned}
J^j(m; \omega) = \ & y(m; \omega) - w^j(m; \omega) - \tau(\omega) + \beta E_{\omega'|\omega} \Bigg[\\
& (1 - \delta)(1 - \lambda)\Big((1 - p^e(m; \omega)(1 - F(m)))J^{e+}(m; \omega')\Big) \\
& + (1 - \delta)\lambda E_{m'}\Big[(1 - p^e(m; \omega)(1 - F(m')))J^{e+}(m'; \omega')\Big] \\
& + \delta V(\omega') \Bigg]
\end{aligned}
\tag{4}
$$

where $J^{e+}(m; \omega') \equiv \max\{J^e(m; \omega'), V(\omega')\}$ showing that the firm can freely choose to either remain with its current worker and receive $J^e(m; \omega')$ or become unmatched and receive $V(\omega')$ in the next period.

A vacant firm pays a flow cost of κ 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 type(s) of workers to meet and therefore needs to take into account the distribution of workers over the employment status and, if employed, match-specific productivity as well as their search effort. I assume that the free entry condition holds which means that the value of a vacant firm is always zero, i.e. $V(\omega) = 0, \forall \omega$.

The value of posting a vacancy is

$$
\begin{aligned}
V(\omega) = \ & -\kappa + \beta q(\omega) E_{\omega'|\omega} \Bigg[\sum_m \zeta^e(m; \omega)(1 - F(m)) E_{m'|m'>m}[J^{e+}(m'; \omega')] \\
& + \zeta^{UI}(\omega) E_{m'}[J^{UI+}(m'; \omega')] + \zeta^{UU}(\omega) E_{m'}[J^{UU+}(m'; \omega')] \Bigg]
\end{aligned}
\tag{5}
$$

where ζ's represent the probability that a vacant firm meets a certain type of worker by employment status and, if the worker is currently employed, match

quality given that a worker-firm meeting takes place. Particularly,

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

$$\zeta^{UI} = \frac{s^{UI} u^{UI}}{s^e e + s^{UI} u^{UI} + s^{UU} u^{UU}}; \quad \zeta^{UU} = \frac{s^{UU} u^{UU}}{s^e e + s^{UI} u^{UI} + s^{UU} u^{UU}}$$

2.1.5 Meeting Function

The meeting function $M(s_t, v_t)$ takes the aggregate search intensity s_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.[12] The function has constant returns to scale, and it is increasing and concave in its arguments. In particular, I assume:[13]

$$M(s_t, v_t) = \frac{s_t v_t}{\left(s_t^l + v_t^l\right)^{\frac{1}{l}}} \tag{6}$$

Let $\theta_t = v_t/s_t$ denote the market tightness. The worker's meeting rate per search unit is $M(s_t, v_t)/s_t = M(1, \theta_t)$ which I also call the conditional job finding rate per search unit since a positive match surplus is required for a job to be created. The conditional job finding rate for an unemployed worker of type $i \in \{UI, UU\}$ is thus $s_t^i M(1, \theta_t) = p_t^i$. Analogously, it is $s_{m,t}^e M(1, \theta_t) = p_{m,t}^e$ for an employed worker with match quality m. The conditional job filling rate for a vacant firm is $M(s_t, v_t)/v_t = M(1/\theta_t, 1) = q_t$.

2.2 Wage and Match Surplus

Wages are negotiated at the end of each period after the match quality for the next period is realised. They are determined 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 the match quality and the aggregate state variables $(m; \omega)$, the generalised Nash bargaining rule implies three different wages depending on the worker's employment status last period $j \in \{e, UI, UU\}$ due to their different outside

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[12]s_t is the sum of aggregate search intensity of employed and unemployed workers in time t.

[13]This matching function is similar to the one introduced by den Haan, Ramey and Watson (2000) with an addition of the variable search intensity.

options. Namely,

$$w^j(m;\omega) \;\; = \;\; \text{argmax} \left(WS^j(m;\omega)\right)^{\mu} \left(J^j(m;\omega)\right)^{(1-\mu)} \tag{7}$$

where WS^j is the surplus from working for type-j employed workers which are as follows:

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

We can see from here that workers with different status j have different outside options because they face different probabilities of being able to receive UI in case they walk away from the negotiation.[14] Further, the total match surplus (or joint surplus) of a worker-firm match given the worker's previous employment status $j \in \{e, UI, UU\}$ can be defined as

$$S^j(m;\omega) \;\; = \;\; WS^j(m;\omega) + J^j(m;\omega)$$

The firm's surplus from being matched with a worker is simply the value of being matched with a worker (J) itself because of the free entry condition. The expressions for these employment-history-dependent surpluses can be found in Appendix B. With the Nash bargaining rule, we have

$$
\begin{aligned}
WS^j(m;\omega) &= \mu S^j(m;\omega) \tag{8} \\
J^j(m;\omega) &= (1-\mu)S^j(m;\omega) \tag{9}
\end{aligned}
$$

Therefore, both the worker and the firm always agree it is profitable to form a match if and only if their total match surplus is positive, i.e. $S^j(m;\omega) > 0$.

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[14]Note that, for employed workers, I assume that their outside option is to return to unemployment and not remaining in the current match. This assumption is made for simplicity as otherwise the entire history of match qualities of an employed worker will become a state variable.

2.3 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 the employment status 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 (16), (17) and (18)

3. The wage functions satisfy the FOCs for the generalised Nash bargaining rule (equation (7))

4. The government's budget constraint is satisfied each period

5. The distribution of workers evolves according to the transition equations (19), (20) and (21), which can be found in Appendix C, consistent with the maximising behaviour of agents.

2.4 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 employment status and match quality $\{e_m \; \forall m, u^{UI}, u^{UU}\}$ as they enter the vacancy creation condition (equation (5)). In order to predict next-period unemployment rate, they need to know the inflow to 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 unemployment rate and the total unemployment rate as a function of current unemployment rate (u) and TFP shock (z). As the distribution of employed workers by match quality does not vary much over time, I use the stochastic steady state distributions as its proxy. I report the performance of this approximation in Appendix D.

3 Calibration

I estimate a subset of the parameters by matching key statistics of the U.S. economy, particularly its labour market. To obtain the counterparts of 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 including the correlations between output and labour productivity for these two periods.[15]

In the simulation, the only difference between pre- and post-1985 periods is the UI duration policy $\phi(u)$. Specifically, I allow for an increase in its generosity during recessions from pre- to post-1985 periods. As a result, there are two UI duration regimes. When $u < \bar{u}$, the maximum UI duration is six months (standard) in both regimes; however, when $u \geq \bar{u}$, the maximum UI duration is extended to be in total of:

1. Twelve months from period 1 to T_1 representing January 1948 to March 1985 (the average extended UI duration during the pre-1985 period)

2. Eighteen months from $T_1 + 1$ to T representing April 1985 to June 2014 (the average extended UI duration during the post-1985 period).

Table 2 summarises all the pre-specified parameters while Table 3 describes the calibrated parameters in the model.

Discretisation I discretise the total factor productivity (z) using Rouwenhorst (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 $F(m)$.

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[15]Specifically, T is 5,320 and T_1 is 2,980 so that they are proportional to the data used in this paper. Additionally, I include 200 burn-in periods.

3.1 Pre-specified Parameters

The pre-specified parameters in the model are summarised in Table 2. For the discount factor β, 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 κ to be 0.0392 using survey evidence on vacancy durations and hours spent on vacancy posting.[16] I assign μ, the worker's bargaining power, to be 0.5 following den Haan, Ramey and Watson (2000).[17]

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

To determine the flow values of unemployed workers, h and, if insured, b, I use the results in Gruber (1997). In particular, he finds the drop in consumption for the newly unemployed workers is 10% when receiving UI and 24% when not receiving UI given the replacement rate of 50%. To obtain the values of h and b given a set of parameters, I first guess the mean wage for the newly unemployed, set the values of h and b to be 76% and 14% of the guess respectively, and solve the model to obtain the policy functions. I then simulate the model to check if the guess is close to the simulated counterpart. If it is not, I replace the guessed wage for the newly unemployed with the one from the simulation, obtain new values of h and b and repeat the same process until the two are close enough.

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[16]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.

[17]As a robustness check, I also report the main results with the worker's bargaining power being 0.7 as used in Shimer (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, 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 et al. (2005) and Yashiv (2000). That is, the search cost function is quadratic.

3.2 Calibrated Parameters

I use the simulated method of moments 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 moments.[18] The values of these parameters are reported in Table 3. The targeted moments used in the calibration are:

- The first and second moments of the unemployment rate, the job destruction rate and the job finding rate,

- The first moment of the job-to-job transtion rate, the average unemployment duration and the insured unemployment rate,

- The second moment and the autocorrelation coefficient of the labour productivity, and

- The correlation between output and labour productivity during the pre-1985 period.

I describe the data source in this calibration exercise in Appendix A. The model's generated moments are reported in Table 4 along with their empirical counterparts. Table 5 shows other related moments not targeted in the calibration. Both tables also report the results under the case with an alternative worker's bargaining power ($\mu = 0.7$) as a robustness check.

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

4 Results

4.1 Performance

As shown in Table 4, the baseline model, despite being over-identified, matches the twelve targeted moments quite well overall including the first moments of the unemployment rate, the job finding rate, the job destruction rate and the job-to-job transition rate. It can also match the characteristics of the labour productivity quite well. The average job finding rate is somewhat higher than the data whilst unemployment and job findings exhibit slightly higher fluctuations than the data. The mean unemployment duration is lower than the data but this is partly due to the Great Recession period where there was an unprecedented spike in average duration of unemployment. I will provide the analysis of non-targeted business cycle moments in the later subsection.

Additionally, I also find the path of TFP shocks that yields a detrended output series identical to the data (using the parameters in Table 2 and 3). With this path of TFP shocks, I compare the model-generated series of relevant macroeconomic variables to the data. Figure 6 shows that the model produces similar dynamics of unemployment, job findings and unemployment durations while job destructions fluctuate too little comparing to the data. It is expected that the detrended series from the model may be different from the data since low frequency changes are not accounted for. That being said, the empirical average unemployment duration is much higher than the model counterpart. However, the model's insured unemployment series is close to the data from both the cyclical and raw-data aspects, as shown in Figure 8 and 9, especially during recessions when the insured unemployment rate spikes.

4.2 The Correlation Between Output and Labour Productivity

With respect to the labour productivity puzzle, the model can explain a significant part of the drop in the procyclicality of the labour productivity. Particularly, it can generate over 40 percent of the observed fall in the correlation between output and labour productivity from pre- to post-1985 periods (a drop from 0.76 to 0.59 as compared to a drop from 0.70 to 0.30) as shown in Table 6. Note that a

standard search and matching model without any change in the UI duration will not be able to produce any shift in this correlation since the policy functions will remain the same in both pre-1985 and post-1985 periods. Despite not targeted, the overall correlation produced by the model is in fact quite close to the data (0.65 as compared to 0.62). The model-generated pre-1985 correlation, which is targeted in the calibration, is slightly higher than that in the data (0.76 as compared to 0.70), and the correlation difference is larger for the post-1985 period (0.59 as compared to 0.30). The last column in Table 6 shows that the results remain largely the same when a different parameter for the worker's bargaining power is used.

The success of the model in generating a sizeable drop in the correlation is due to the fall in the UI exhaustion rate during high unemployment (the change in ϕ_L) from the pre-1985 to post-1985 periods which alters the policy functions in the model: (i) match surplus and (ii) job search effort as a function of unemployment. A smaller ϕ_L in the post-1985 period lowers match surpluses, making worker-firm matches with low match qualities unviable, and lifts up the average labour productivity during the recessions. At the same time, a smaller ϕ_L lowers the job search effort and, in effect, employment, thereby prolonging the UI extensions once triggered.

Match Surplus The discontinuity in the UI duration function $\phi(u)$ creates a discontinuity in the match surplus as a function of unemployment as shown in Figure 4.[19] Whenever unemployment is above the threshold ($u \geq \bar{u}$), the function $\phi(u)$ falls from ϕ_H to ϕ_L. The fall in $\phi(u)$ increases the outside option of workers and decreases the surpluses from working for most workers.[20] Therefore, it is less likely for matches to be/remain formed, especially those with low match quality m. This puts an upward pressure on the average labour productivity against negative shocks to z and results in a less-than-perfect correlation between output and labour productivity. Since $\phi_{L,post85} < \phi_{L,pre85}$, the post-1985

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[19]The surplus in Figure 4 is plotted for the middle nodes on the grids of match quality m and aggregate productivity z. The match surplus indeed increases in these two arguments but not in a discontinuous fashion like in the dimension of unemployment u.

[20]Specifically, the surpluses of workers with history $\{e, UI\}$ fall as shown in Figure 4. We can see that the surplus for workers with history UU, however, increases slightly with lower $\phi(u)$ because it is better for this type of workers to become re-employed and increase the likelihood of receiving UI in the event that they return to unemployment.

match surpluses fall even further whenever $u \geq \bar{u}$ comparing to those in the pre-1985 period, and only the matches with higher match qualities exist in post-1985 recessions. This means, in the post-1985 period, the positive response of labour productivity upon a negative shock is stronger and results in a lower correlation between output and labour productivity compared to the pre-1985 period.

Job Search Effort   Similar to the previous argument, the discontinuity in $\phi(u)$ creates a drop in the job search effort and the job finding rate for the insured unemployed around $\bar{u}$ where $\phi(u)$ falls from ϕ_H to ϕ_L as seen in Figure 5. When $u \geq \bar{u}$, there are fewer meetings and, as a result, higher unemployment which feeds back to the UI policy $\phi(u)$ to remain low at ϕ_L for longer.[21] With $\phi_{L,post85} < \phi_{L,pre85}$, the post-1985 job search effort fall even further whenever $u \geq \bar{u}$ compared to those in pre-1985 periods. Unemployment is thus more likely to remain high and lengthen the effects the UI extensions have on the falling correlation between output and labour productivity in the post-1985 period.

It is worth noting that the UI effect via the match surplus channel also captures the responses of vacancy creation and wage negotiation to UI extensions. For the vacancy creation, since unemployment is a state variable, we can see from equation (5) and (9) that vacant firms optimally adjust the number of vacancies according to the existing match surplus (via the matched firm's surplus in equilibrium) left to be split. For the wage channel, any change in the wage negotiation due to UI extensions also results in a change in the match surplus according to equation (7), (8) and (9). Therefore, subsequent analyses on the response of the match surplus will inherently encapsulate responses of vacancy creation and wage negotiation.

4.3   Impulse Response Functions

The impulse response functions (IRFs) of key variables in the model are useful in demonstrating how the UI duration policy affects the correlation between output and labour productivity. Figure 10 and 11 show respectively the IRFs of output (y), labour productivity (LP) and average match quality ($E(m)$) to 1%

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[21]In this model, the persistence of UI extensions interacts with the persistence of unemployment which is in line with the hypothesis in Mitman and Rabinovich (2014) where a longer UI duration increases the persistence of unemployment.

and 2% negative TFP (z) shocks from its steady state for pre-1985 (solid lines) and post-1985 (dashed lines) periods.

In the case of a 1% negative deviation, there is not much difference between the responses of variables in pre- and post-1985 periods because unemployment does not exceed $\bar{u}$ and trigger the UI extension. We can see that the labour productivity recovers as soon as the shock subsides while output reaches its trough 6 months after the shock hits for both pre- and post-1985 periods. Therefore, the correlation between output and labour productivity is less than perfect under a 1% negative TFP shock but there is hardly any difference between pre- and post-1985 periods.

On the contrary, the IRFs between pre- and post-1985 periods are very different when the size of the shock is instead 2% negative deviation from the steady state. This is solely because the UI extension is triggered for the post-1985 period (from the fifth month onwards) but not in the pre-1985 period where the IRFs are almost identical to the 1% deviation case.[22] As discussed in the previous subsection, an extension of UI tends to raise the overall match quality as can be seen in Figure 11. The post-1985 average match quality responds positively throughout once the UI extension is triggered. The labour productivity also behaves similarly. Despite its negative response throughout, output per worker recovers at a faster rate than in the pre-1985 period once UI extension is in place. More starkly is the response of output that reaches its trough 15 months after the initial shock, almost one year later than the cases without UI extension (the pre-1985 period with 2% shock and both pre- and post-1985 periods with 1% shock). The quicker recovery of the labour productivity combined with the highly persistent negative output response makes the correlation between output and labour productivity in the post-1985 period much smaller than that in the pre-1985 period.

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[22]If there was no change in the maximum UI duration, Figure 10 and 11 would have looked identical with only a change in the scale.

4.4 Decomposition of Countercyclical UI Duration Effects

The increase in the generosity of the UI duration policy affects the procyclicality of labour productivity via the responses of match surplus and job search effort (on top of the increase in the maximum UI duration). In this exercise, I decompose the effect of the UI extensions to study the contribution of these two channels.

In the first case, I study the contribution of the job search effort response (following a more generous UI duration policy) on the falling procyclicality of the labour productivity. I do this by assuming that both workers and firms 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 do not change from pre- to post-1985 periods). Therefore, any change in the cyclicality of the labour productivity comes from the response of the job search effort to the increase in the UI generosity. Analogously, in the second case where I study the contribution of the change in the joint match surpluses, I fix the job search effort policy functions at the pre-1985 period to measure the impact of the response of the match surpluses, which is due to the increase in the generosity of UI duration policy, on the procyclicality of the labour productivity.

It turns out that both job search effort and match surpluses explain a substantial part of the drop in the output-labour-productivity correlation and deliver a higher overall correlation of 0.72-0.73 as shown in Table 7. It is rather surprising that the search effort channel contributes almost as much as the match surplus channel to the drop (respectively 50% and 60% of the model's generated drop - equivalent to 21% and 25% of the empirical drop) since the search effort channel only affects the insured unemployed workers whilst the response of the match surplus affects most workers. This finding shows that in order to obtain a sizeable 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. Assuming search effort to be constant can undermine the effect of UI duration policy on the behaviour of the labour productivity over the business cycles.

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4.5 On the Great Moderation

Since the mid 1980's, apart from a significant drop in the procyclicality of the labour productivity, the U.S. economy (among others) also experienced a substantial reduction in the output volatility. This phenomenon is coined "the Great Moderation".[23] The Great Moderation can potentially change the effect of the countercyclical UI duration policy on the labour productivity since the decreased volatility of the business cycle fluctuations implies that large negative shocks are less likely to occur after the mid 1980's and, therefore, high unemployment that triggers UI extensions is less likely to occur.

To quantify how much the Great Moderation can impact the UI effect on the labour productivity, I introduce a drop in the variance of the aggregate productivity z from the pre-1985 period to the post-1985 period ($\sigma_{z,pre85} > \sigma_{z,post85}$). I set the difference between the two variances based on the empirical values of the labour productivity series. Specifically, I compute the ratio of the pre-1985 standard deviation to the overall standard deviation of the detrended labour productivity series and multiply it with the calibrated value of the standard deviation of the aggregate productivity shock σ_z to get $\sigma_{z,pre85}$. I do the same for the post-1985 period to obtain $\sigma_{z,post85}$. I report the values in Table 2. Based on these values, I solve the model again where not only the UI duration policy changes from the pre-1985 to post-1985 periods but the standard deviation of the TFP shocks also drops from the pre-1985 to post-1985 periods. With the resulting policy functions (total match surplus and job search effort), I redo the simulation where the Great Moderation is featured and report correlation statistics in Table 6.

Table 6 shows that the Great Moderation does have a negative impact on the effect the countercyclical UI policy has on the labour productivity. In particular, the drop in the correlation between output and labour productivity from pre- to post-1985 periods is smaller when the volatility of TFP shocks is reduced after the mid 1980's (a drop of 0.11 as compared to 0.17 in the baseline case). That being said, the fall in the procyclicality of the labour productivity is still sizeable and amounts to 28 percent of the empirical drop in this correlation.

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[23]McConnell and Perez-Quiros (2000) is amongst the first to document this phenomenon.

4.6 Other Business Cycle Properties

With regards to related moments that are not targeted (shown in Table 5), the model does a good job in matching the dynamics of the employment rate and the insured unemployment rate as well as the cyclicality of unemployment, job findings and job destructions. The correlation between unemployment and vacancies is however moderately negative (-0.37) while it is strongly negative in the data (-0.88).[24]

Apart from the fall in the procyclicality of labour productivity, the correlations between output and a few labour market variables have also become somewhat smaller (including the job finding rate, the job separation rate and vacancies) from the pre-1985 to the post-1985 periods. Without targeting them, the model can produce these weakened correlations as also shown in Table 5.

Hagedorn and Manovskii (2011) study the correlations between labour productivity and labour market variables such as unemployment, vacancies and labour market tightness. Whilst a standard Mortensen-Pissarides model implies high values for these correlations, they are much weaker in the data. They extend the standard model to include a stochastic value of worker's outside option (home production) and a time to build a vacancy that help reconcile these discrepancies.[25] I can relate the stochastic value of home production to the state-dependent UI duration in my model since it implies that the outside options of workers evolve stochastically. As the model is this paper breaks down the tight link between output and labour productivity, a correlation between labour productivity and unemployment (-0.59 as shown in Table 5) is consequently very close to the data (-0.63) whilst a productivity-driven MP model would imply a very strong correlation. However, the labour productivity implied by both my model and that in Hagedorn and Manovskii (2011) is somewhat more highly correlated with the labour market tightness and vacancies than in the data. The model-implied correlations are nonetheless significantly smaller than one.

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[24]Hagedorn and Manovskii (2011) show that a longer model period emphasises the time aggregation issues and lowers the correlation between unemployment and vacancies.

[25]Furthermore, they also show that some of the discrepancies is related to the data being used. Specifically, if the labour productivity series is constructed using the employment data from the Current Population Survey (CPS) instead of the Current Employment Statistics (CES), the correlations between labour productivity and other labour market variables become stronger.

4.7 Hazard Rate of Exiting Unemployment

Despite the assumption that the unemployment duration is not part of the state variable, and, therefore, the job finding probability of a worker does not vary with her unemployment duration, the heterogeneity amongst unemployed workers in the model still has an implication for the duration-dependent job finding probabilities at the aggregate level. 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 at which an unemployed worker finds a job by durations of unemployment. Empirically, this rate is decreasing and usually convex in the time spent in unemployment. As depicted by Figure 12, the model can replicate these properties.

I present the hazard functions in two cases: (i) the insured unemployed workers remain insured throughout the unemployment spell, and (ii) the insured unemployed become uninsured with probability ϕ_H each period (implying the standard UI duration during normal times) as these are the lower and upper bounds for the realised maximum UI durations. The hazard rate is decreasing in the unemployment duration due to the changing composition of unemployed workers. Uninsured unemployed workers have a higher job finding rate and therefore exit unemployment faster than the insured type. With time, unemployed workers are more represented by the insured type, the exit rate therefore falls with the unemployment duration and only becomes constant when there is no uninsured type left in the unemployment pool.

When compared to the data, Kroft, Lange, Notowidigdo and Katz (2016) have 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 at zero duration) drops sharply during the first 8-10 months after which the rate becomes stable around 0.4-0.5. Their hazard function drops slightly faster than what this model can produce given that the insured unemployed remain insured throughout the spell (case (i)). However, when the stochastic UI exhaustion rate is taken into account (case (ii)), the model can only partially explain the drop in the hazard function during the first months of unemployment. The model's true performance lies between these two

functions as the maximum UI durations can vary between 6 months to almost 2 years. This implies that the heterogeneity in the job finding rates by employment status can explain only partially the persistence of unemployment and its duration structure.

5 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 stochastic UI duration, heterogeneous match quality, variable search intensity and on-the-job search. This model can produce over 40 percent of the empirical drop in the correlation between output and labour productivity. The countercyclical UI duration policy lowers the total match surpluses in bad times causing matches with low qualities to be unviable and, therefore, raises the average labour productivity while output is more negatively affected.

At the same time, this UI policy lowers the job search effort of the insured unemployed causing unemployment to be more persistent. Thus, it prolongs the UI extensions themselves and their effect on the correlation between output and labour productivity (since the UI policy is a function of the unemployment rate). As the UI duration policy is more generous after 1985, its effect via these two channels is stronger than that in the pre-1985 period which gives rise to the falling procyclicality of the labour productivity. A decomposition study shows that both channels are important in explaining this cyclicality change. Lastly, the model performs very well in producing key statistics in the labour markets, especially the insured unemployment rate over the business cycles.

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A 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.

A.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.[26] They do not include persons marginally attached to the labour force. The ratio of these two series forms the official definition of unemployment rate ('U3' as labelled by BLS).

A.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.[27]

A.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.[28] As converting

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

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

[28]By correcting for the time aggregation bias, the destruction rates will be higher and closer to the BLS data. However, since Shimer (2005)'s correction means a newly unemployed worker has on average half a month to find a new job before being recorded as unemployed, one must also adjust the Bellman equations in a discrete-time model accordingly, otherwise the implied unemployment will be too high when the model period is longer than half a month.

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 unemployment (u_t^{mo}) instead.

$$u_{t+1}^{mo} = (1 - \rho_{f,t}^{mo})u_t^{mo} + \rho_{x,t}^{mo}(1 - u_t^{mo}) \tag{10}$$

$$u_{t+2}^{mo} = (1 - \rho_{f,t+1}^{mo})u_{t+1}^{mo} + \rho_{x,t+1}^{mo}(1 - u_{t+1}^{mo}) \tag{11}$$

$$u_{t+3}^{mo} = (1 - \rho_{f,t+2}^{mo})u_{t+2}^{mo} + \rho_{x,t+2}^{mo}(1 - u_{t+2}^{mo}) \tag{12}$$

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 (12) with u_t^{mo} using (10) and (11) and setting $u_{t+1}^q \equiv u_{t+3}^{mo}$ and $u_t^q \equiv u_t^{mo}$, one can obtain[29]

$$u_{t+1}^q = (1 - \rho_{f,t}^q)u_t^q + \rho_{x,t}^q(1 - u_t^q) \tag{13}$$

where

$$\rho_{x,t}^q = \rho_{x,t+2}^{mo} + \rho_{x,t+1}^{mo}(1 - \rho_{x,t+2}^{mo} - \rho_{f,t+2}^{mo})$$
$$+ \rho_{x,t}^{mo}(1 - \rho_{x,t+1}^{mo} - \rho_{f,t+1}^{mo})(1 - \rho_{x,t+2}^{mo} - \rho_{f,t+2}^{mo}) \tag{14}$$

$$\rho_{f,t}^q = 1 - \rho_{x,t} - \prod_{i=0}^{2}(1 - \rho_{x,t+i}^{mo} - \rho_{f,t+i}^{mo}) \tag{15}$$

A.4   UI Duration Policy

Data on UI extensions in the U.S. are 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 ad-hoc programmes that are often issued in the recessions and also triggered by the state

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[29]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.

unemployment rate providing additional UI ranging from 13 to 53 weeks.[30] The maximum duration of unemployment benefits in the U.S. is shown chronologically in Figure 3 where I sum together all types of UI durations. Apart from the early 1980's recessions, the extended UI duration has been steadily increasing throughout the 1948-2014 period with its highest level at 99 weeks during the Great Recession.

B Expressions for Optimal Search Intensity and Match Surplus

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

$$
\begin{aligned}
v_e'(s^e(m;\omega)) &= -\beta(1-\delta)M(1,\theta(\omega))E_{\omega'|\omega}\Bigg[... \qquad (16)\\
&\quad (1-\lambda)(1-F(m))\Big(WS^{e+}(m;\omega') - E_{m'|m'>m}[WS^{e+}(m';\omega')]\Big)\\
&\quad + \lambda E_{m'}\Big[(1-F(m'))(WS^{e+}(m';\omega') - E_{m''|m''>m'}[WS^{e+}(m'';\omega')])\Big]\Bigg]\\
v_u'(s^{UI}(\omega)) &= \beta M(1,\theta(\omega)) \times\\
&\quad E_{m'\omega'|\omega}\Bigg[\max\{WS^{UI}(m';\omega'),0\} - \xi(1-\phi)US(\omega')\Bigg] \qquad (17)\\
v_u'(s^{UU}(\omega)) &= \beta M(1,\theta(\omega))E_{m'\omega'|\omega}\Bigg[\max\{WS^{UU}(m';\omega'),0\}\Bigg] \qquad (18)
\end{aligned}
$$

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

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 expressions for the total surpluses of worker-firm matches given the workers' previous employment statuses (e, UI, UU) and the surplus of being

---

[30]For a more detailed account, see the ETA website. Appendix B of Mitman and Rabinovich (2014) also provides a good summary.

insured unemployed are respectively:

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

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

35

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

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

C   Transitions

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

$$
\begin{aligned}
e_{m,t+1} \;=\;& \Big((1-\delta)(1-\lambda)(1-p^e_{m,t}+p^e_{m,t}F(m))e_{m,t} \\
& + (1-\delta)(1-\lambda)f(m)\int_{m'<m} p^e_{m',t}e_{m',t}dm' \\
& + (1-\delta)\lambda f(m)\int_{m'}(1-p^e_{m',t}+p^e_{m',t}F(m))e_{m',t}dm' \\
& + (1-\delta)\lambda F(m)f(m)\int_{m'} p^e_{m',t}e_{m',t}dm'\Big)\mathbb{1}\{S^e_{m,t+1}>0\} \\
& + f(m)(u^{UI}_t p^{UI}_t)\mathbb{1}\{S^{UI}_{m,t+1}>0\} \\
& + f(m)(u^{UU}_t p^{UU}_t)\mathbb{1}\{S^{UU}_{m,t+1}>0\} \qquad (19)
\end{aligned}
$$

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

Job Destructions   The job destruction rate of employed workers of type m and the average job destruction rate are respectively

$$\rho_{x,t}(m) = \begin{cases} \delta & \text{if } S^e_{m,t+1} > 0, \\ 1 & \text{otherwise} \end{cases}$$

$$\rho_{x,t} = \frac{\delta \int_{\{m:S^e_{m,t+1}>0\}} e^{post}_{m,t} dm + \int_{\{m:S^e_{m,t+1}\leq 0\}} e^{post}_{m,t} dm}{e_t}$$

where $e^{post}_{m,t}$ $=$ $(1-\lambda)(1-p^e_{m,t}+p^e_{m,t}F(m))e_{m,t}$

$$+(1-\lambda)f(m)\int_{m'<m} p^e_{m',t}e_{m',t}dm'$$

$$+\lambda f(m)\int_{m'} (1-p^e_{m',t}+p^e_{m',t}F(m))e_{m',t}dm'$$

$$+\lambda F(m)f(m)\int_{m'} p^e_{m',t}e_{m',t}dm'$$

denotes employed workers with match productivity m at the end of the period t.

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

$$\rho^i_{f,t} = \int \rho^i_{f,t}(m)f(m)dm$$

$$\rho_{f,t} = \frac{u^{UI}_t \rho^{UI}_{f,t} + u^{UU}_t \rho^{UU}_{f,t}}{u^{UI}_t + u^{UU}_t}$$

where $\rho^i_{f,t}(m) = \begin{cases} p^i_t & \text{if } S^i_{m,t+1} > 0, \\ 0 & \text{otherwise} \end{cases}$

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

$$\rho^{ee}_{m,t} = (1-\delta)\Big((1-\lambda)p^e_{m,t}(1-F(m))E_{m'>m}[\mathbf{1}\{S^e_{m',t+1}>0\}]$$

$$+\lambda \int_{m'} p^e_{m,t}f(m')(1-F(m'))E_{m''>m'}[\mathbf{1}\{S^e_{m'',t+1}>0\}]dm'\Big)$$

$$\rho^{ee}_t = \frac{\int_m \rho^{ee}_{m,t}e_{m,t}dm}{e_t}$$

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

$$u_{t+1}^{UI} = \underbrace{(1-\phi_t)(1-p_t^{UI})u_t^{UI}}_{\text{unmatched, not losing UI}} + \underbrace{\chi_t^{UI}(1-\phi_t)(1-\xi)p_t^{UI}u_t^{UI}}_{\text{bad match, not losing UI}}$$

$$+ \underbrace{(1-\psi)\rho_{x,t}e_t}_{\text{destroyed match, not losing UI}} \qquad (20)$$

$$u_{t+1}^{UU} = \underbrace{\phi_t(1-p_t^{UI})u_t^{UI}}_{\text{unmatched, losing UI}} + \underbrace{\chi_t^{UI}\Big(\phi_t+(1-\phi_t)\xi\Big)p_t^{UI}u_t^{UI}}_{\text{bad match, losing UI}}$$

$$+(1-\rho_{f,t}^{UU})u_t^{UU} + \underbrace{\psi\rho_{x,t}e_t}_{\text{destroyed match, losing UI}} \qquad (21)$$

$$u_{t+1} = u_{t+1}^{UI} + u_{t+1}^{UU} \qquad (22)$$

where $\chi_t^{UI} \equiv \int \mathbf{1}\{S_{m,t+1}^{UI} \le 0\}f(m)dm$ denotes the probability that the newly formed match between a firm and an insured unemployed worker is not viable.

D 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 the 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 deviation (%)	Mean	S.E.
1st moment	0.5650	0.3953
2nd moment	0.4670	0.4499
3rd moment	3.6819	3.4767
4th moment	0.2009	0.2936

Table 2: Pre-specified Parameters For Baseline Model (Monthly)

Parameter	Description	Value	Source/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
$\phi_{L,I}$	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	0.1302	Gruber (1997) given $E(w) = 0.93$
h	Leisure flow	0.7068	Gruber (1997) given $E(w) = 0.93$
$\bar{u}$	UI policy threshold	0.06	ETA
a_u	Search cost function	0.1291	Normalisation
d_u, d_e	Search cost function	1	Christensen et al. (2004), Yashiv (2000)
	Additional parameters for the version with the Great Moderation		
$\sigma_{z,pre85}$	SD of TFP shocks	0.0070	BLS and author's own calculation
$\sigma_{z,post85}$	SD of TFP shocks	0.0490	BLS and author's own calculation

Table 3: Calibrated Parameters For Baseline Model (Monthly)

Parameter	Description	Value
l	Matching function	0.5346
δ	Exogenous destruction	0.0239
λ	Redrawing new m	0.5000
ψ	Losing UI after becoming unemp.	0.4900
ξ	Losing UI after meeting firm	0.4605
a_e	Search cost function	0.1430
$\underline{m}$	Lowest match-specific prod.	0.4621
β_1	Match-specific prod. distribution	2.9646
β_2	Match-specific prod. distribution	4.4546
ρ_z	Persistence of TFP	0.9724
σ_z	Standard deviation of TFP shocks	0.0061

Table 4: Targeted Moments

Moment	Data	Baseline Model	Great Moderation	$\mu = 0.7$
$E(u)$	0.0583	0.0564	0.0567	0.0634
		(0.0048)	(0.0053)	(0.0051)
$E(\rho_f)$	0.4194	0.4387	0.4611	0.4335
		(0.0194)	(0.0209)	(0.0166)
$E(\rho_x)$	0.0248	0.0256	0.0256	0.0274
		(0.0007)	(0.0007)	(0.0009)
$E(\rho_{ee})$	0.0320	0.0317	0.0317	0.0316
		(0.0004)	(0.0003)	(0.0003)
$E(u_{dur})$ (weeks)	15.4287	12.3667	11.8921	12.0494
		(1.3213)	(1.4983)	(0.8769)
$E(u^{UI}/u)$	0.0290	0.0331	0.0332	0.0358
		(0.0038)	(0.0042)	(0.0038)
$std(u)$	0.1454	0.1637	0.1717	0.1765
		(0.0229)	(0.0259)	(0.0158)
$std(\rho_f)$	0.0999	0.1207	0.1290	0.1149
		(0.0144)	(0.0159)	(0.009)
$std(\rho_x)$	0.0890	0.0836	0.0772	0.0952
		(0.0158)	(0.018)	(0.0115)
$std(LP)$	0.0131	0.0124	0.0122	0.0120
		(0.0006)	(0.0006)	(0.0005)
$corr(LP,LP_{-1})$	0.7612	0.7660	0.7656	0.7626
		(0.0196)	(0.0201)	(0.0192)
$corr(y,LP)_{pre85}$	0.7015	0.7620	0.7272	0.7567
		(0.0958)	(0.1273)	(0.0954)

Note: Standard errors are in parentheses.

Table 5: Moments Not Targeted

Moment	Data	Baseline Model	Moment	Data	Baseline Model
std(u_{dur}) (weeks)	6.9941	5.3255	corr(y,ρ_f)$_{pre85}$	0.8788	0.9282
		(2.5117)			(0.0323)
std(u^{UI})	0.1657	0.2136	corr(y,ρ_f)$_{post85}$	0.8691	0.8337
		(0.0271)			(0.0633)
std(v)	0.1408	0.0781	corr(y,ρ_x)$_{pre85}$	-0.8493	-0.7568
		(0.0044)			(0.0549)
std(u)/std(y)	8.7921	7.2199	corr(y,ρ_x)$_{post85}$	-0.8098	-0.7417
		(38.7559)			(0.0451)
std(e)/std(y)	0.5412	0.6566	corr(y,u)$_{pre85}$	-0.8831	-0.9084
		(3.754)			(0.0218)
std(w)/std(y)	0.3878	0.5167	corr(y,u)$_{post85}$	-0.8915	-0.8946
		(3.0179)			(0.0395)
corr(y,ρ_f)	0.8009	0.9118	corr(y,v)$_{pre85}$	0.8981	0.6655
		(0.0291)			(0.1011)
corr(y,ρ_x)	-0.8414	-0.7873	corr(y,v)$_{post85}$	0.8693	0.5
		(0.0385)			(0.0873)
corr(y,u)	-0.8825	-0.8914	$E(m)_{pre85}$	-	0.8874
		(0.0191)			(0.0003)
corr(y,v)	0.8850	0.6253	$E(m)_{post85}$	-	0.8884
		(0.0821)			(0.0006)
corr(LP,θ)	0.703	0.8740	corr(LP,u)	-0.633	-0.5932
		(0.0334)			(0.0351)
corr(u,v)	-0.8786	-0.3638	corr(LP,v)	0.719	0.8823
		(0.0465)			(0.0313)

Note: Standard errors are in parentheses. Empirical data on corr($LP,\cdot$) are from Hagedorn and Manovskii (2011).

Table 6: Correlation Between Output (y) and Labour Productivity (LP)

	Data	Baseline Model	Great Moderation	$\mu = 0.7$
corr(y, LP)	0.6186	0.6553	0.6718	0.6569
		(0.0991)	(0.1027)	(0.0980)
corr(y, LP)$_{pre85}$	0.7015	0.7620	0.7272	0.7567
		(0.0958)	(0.1273)	(0.0954)
corr(y, LP)$_{post85}$	0.2954	0.5911	0.6128	0.6106
		(0.1201)	(0.118)	(0.1173)
Δcorr(y, LP)	0.4061	0.1709	0.1144	0.1461

Note: Standard errors are in parentheses.

Table 7: Decomposition of UI Effects on $corr(y, LP)$

	Data	Baseline Model	S-fixed	s-fixed
corr(y, LP)	0.6186	0.6553	0.7275	0.7165
		(0.0991)	(0.072)	(0.1274)
corr(y, LP)$_{pre85}$	0.7015	0.7620	0.7801	0.7920
		(0.0958)	(0.0852)	(0.1081)
corr(y, LP)$_{post85}$	0.2954	0.5911	0.6955	0.6920
		(0.1201)	(0.08)	(0.1461)
Δcorr(y, LP)	0.4061	0.1709	0.0846	0.1000

Note: S-fixed (s-fixed) denotes the case where the match surplus (job search effort) is fixed to the pre-1985 period throughout the simulation. Standard errors are in parentheses.

Figure 1: Correlations between output and output per worker for 1948Q1-1985Q1 and 1985Q2-2014Q2 (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)
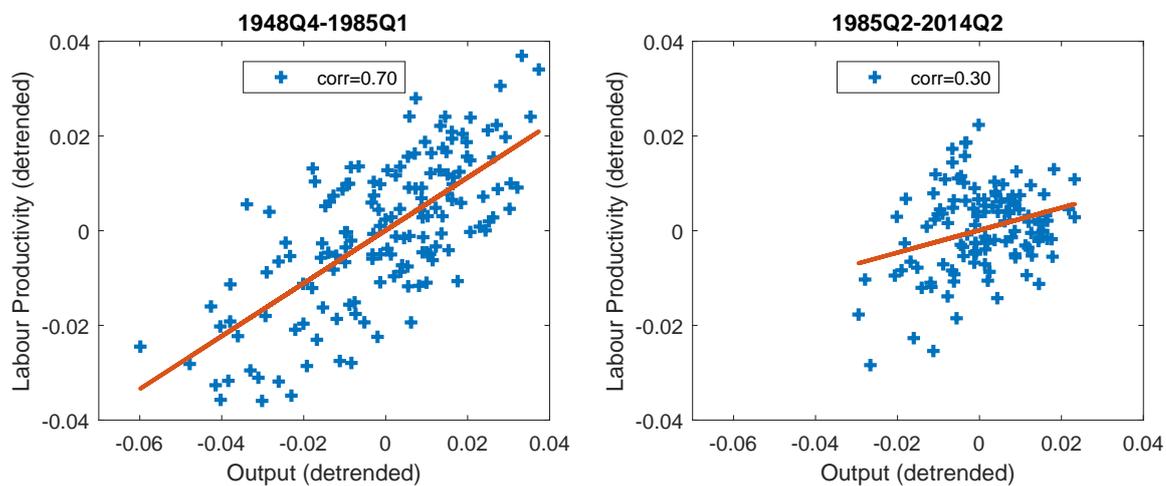
Figure 2: Rolling Correlation Coefficients between output and output per worker from 1948Q1 (up until 2014Q2) (both variables are of quarterly frequency and detrended using the HP filter with a smoothing parameter of 1,600) (shaded areas denote recessions) (Source: BEA and BLS)
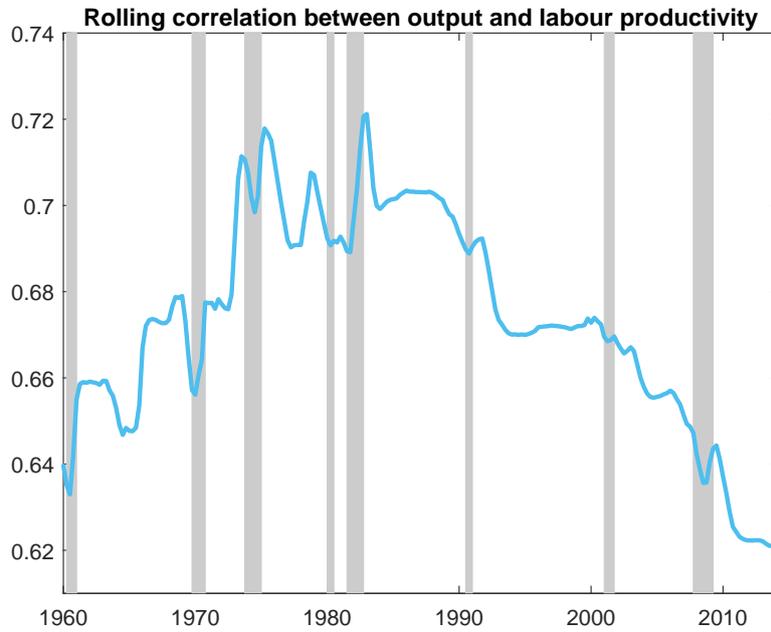
Figure 3: Maximum UI duration (in weeks) as plotted as against time periods from 1948Q1 to 2014Q2 (shaded areas denote recessions) (Source: ETA)
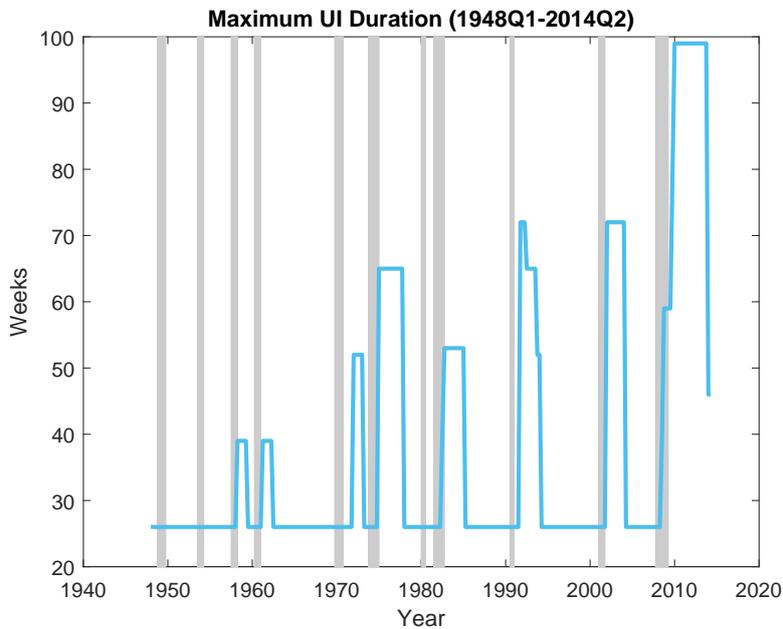
Figure 4: Total match surpluses $S^i; i \in \{e, UI, UU\}$ plotted against unemployment rate (u): For the match-specific and total factor productivities at the middle nodes

Total Surplus @ mid (m,Z) (solid=pre85, dashed=post85)
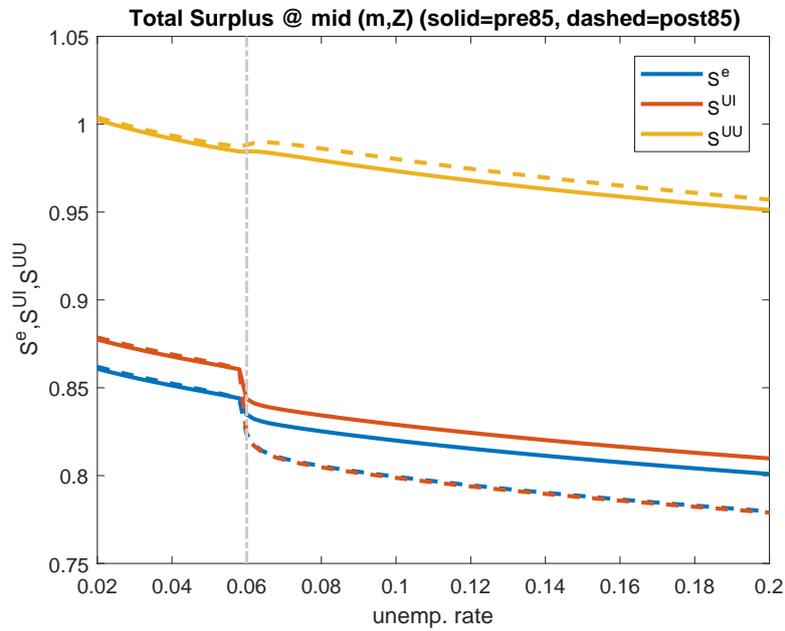
Figure 5: Conditional job finding rates (worker's meeting rates) by employment statuses plotted against unemployment rate: For the match-specific and total factor productivities at the middle nodes

Search efforts @ mid (m,Z) (solid=pre85, dashed=post85)

45
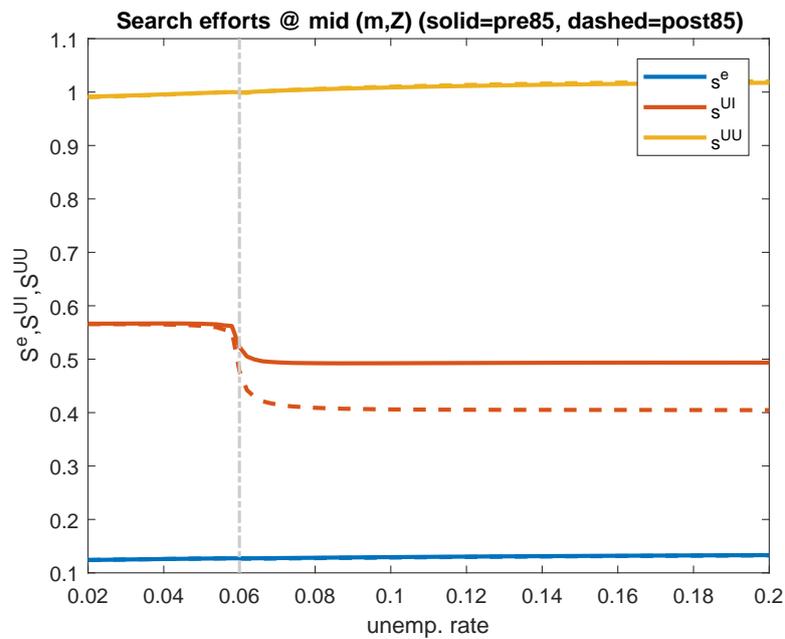
Figure 6: Model-generated (solid) and empirical (dashed) detrended series of main variables
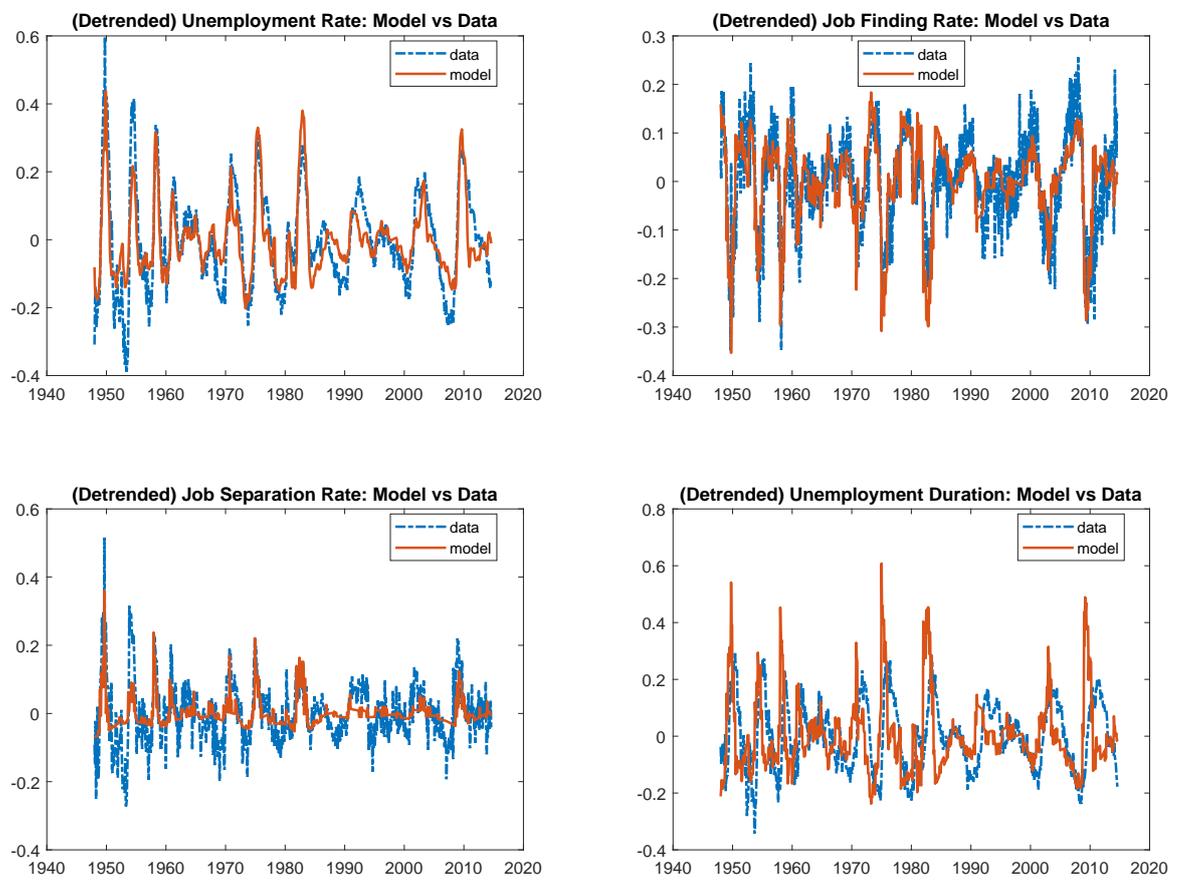
Figure 7: Model-generated (solid) and empirical (dashed) raw series of main variables
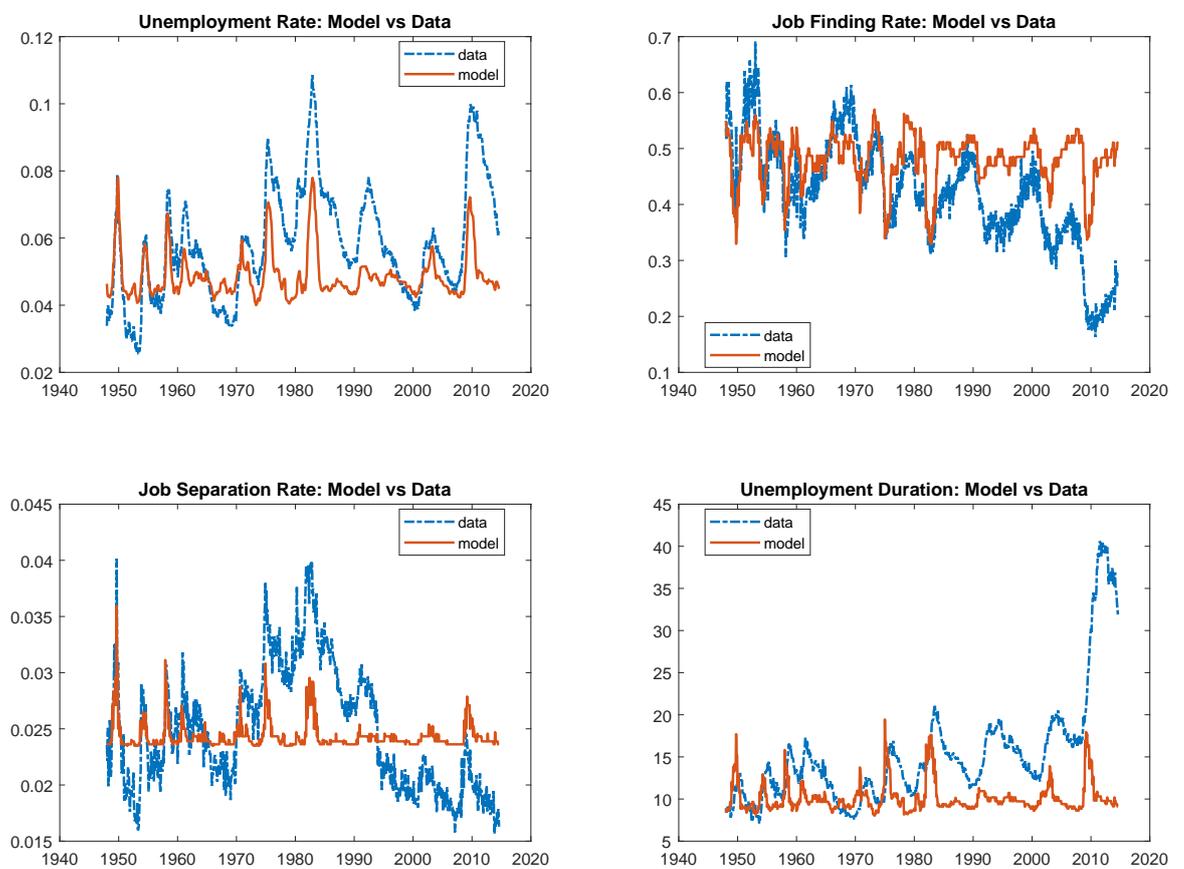
Figure 8: Model-generated (solid) and empirical (dashed) detrended series of insured unemployment rate
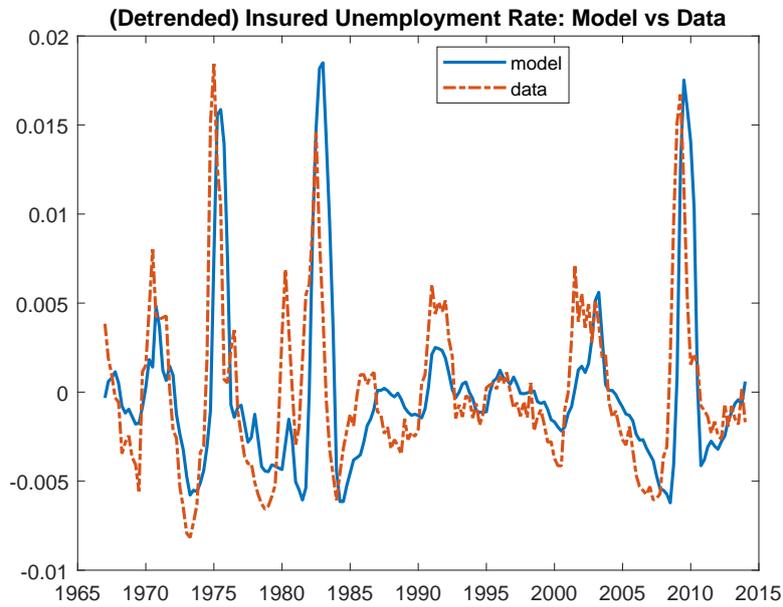

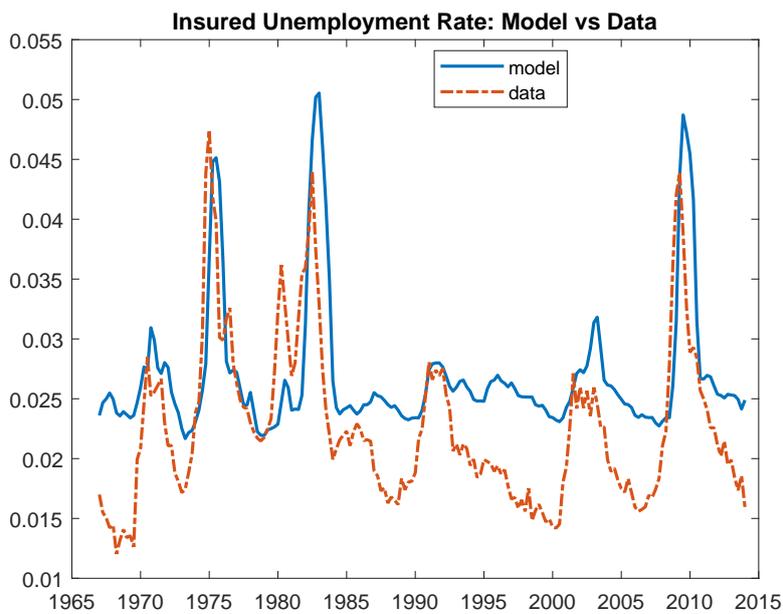Figure 9: Model-generated (solid) and empirical (dashed) raw series of insured unemployment rate
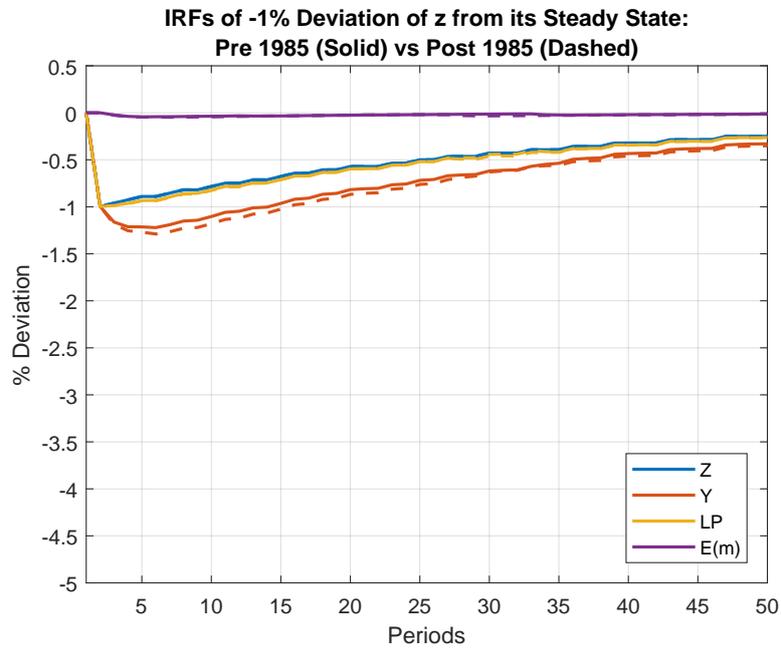
Figure 10: IRF of 1% Negative TFP Shock

**IRFs of -1% Deviation of z from its Steady State:
Pre 1985 (Solid) vs Post 1985 (Dashed)**

Figure 11: IRF of 2% Negative TFP Shock

**IRFs of -2% Deviation of z from its Steady State:
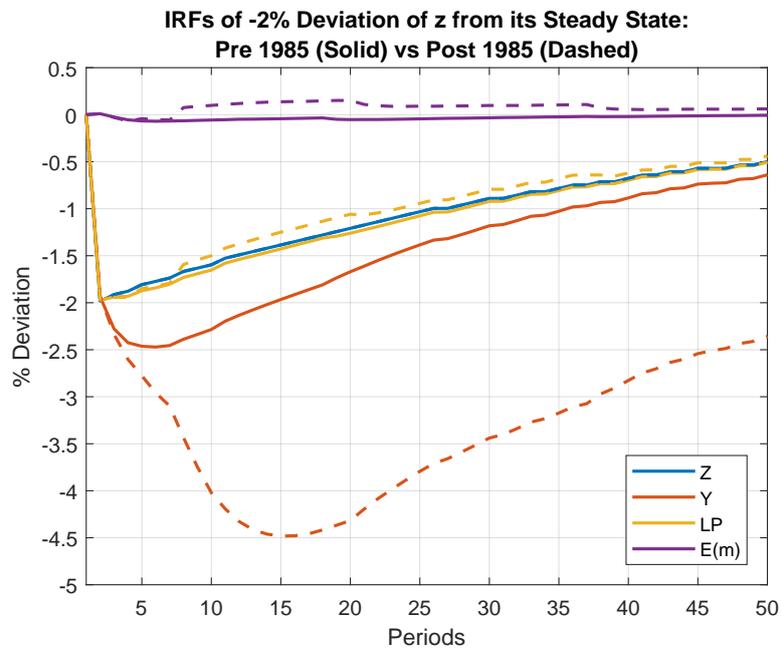Pre 1985 (Solid) vs Post 1985 (Dashed)**

Figure 12: Duration-dependent Job Finding Probability (implied UI durations in parentheses)

Job Finding Probability Relative to the Newly Unemployed