Search, Shirking and Labor Market Volatility

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Abstract

This paper proposes a modified version of the standard search and matching model of the labour market that combines a shirking mechanism with the assumption that firms post wages. We argue that a small shirking effect will generate a low rate of profit and lead to a low rate of vacancy creation, implying that the vacancy filling rate is high. Through this mechanism we show that our model delivers a close match of the simulated volatilities, correlations and autocorrelations of unemployment, vacancies, labour market tightness and the job finding rate with values observed in US data. In doing so, it outperforms prominent alternative models.

Keywords: search frictions, shirking, unemployment volatilty puzzle

JEL Classification: E23, E32, J23, J30, J64

1 Introduction

Although the currently dominant approach to modelling labour markets, the search frictions model pioneered by, among others, Diamond (1982), Mortensen and Pissarides (1994) and Pissarides (2000), provides a simple framework for the analysis of the labour market and associated policy issues, it has some well-known difficulties. In the most prominent statement of these difficulties, Shimer (2005) compares the volatilities, autocorrelations and correlations of unemployment, vacancies, labour market tightness and the job finding rate from a calibrated and simulated version of the search frictions model with US data for 1951-2003. Two findings stand out. The simulated volatilities of these key labour market variables are much lower than those observed in the data. And the model cannot match the autocorrelation of vacancies or the co-movements of vacancies with other labour market variables. The inability of the search frictions model to match the cyclical behaviour of labour market variables, the unemployment volatility puzzle, has been extensively analysed by a large and growing literature (e.g. Hall, 2005, Hall and Milgrom, 2008, Hagedorn and Manovskii,

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2008, Gertler and Trigari, 2009, Pissarides, 2009, Rogerson and Shimer, 2010, Ljungqvist and Sargent, 2016, Christiano et al, 2016). The particular weakness of the search frictions model in explaining vacancies has received less attention.

This paper argues that these weaknesses can be addressed by a modified version of the search frictions model that incorporates a shirking mechanism and which assumes that wages are determined through wage posting rather than by worker-firm bargaining. Shirking arises because firms have imperfect information about the effort exerted by workers; we model this by assuming firms have an exogenous probability of detecting and firing a shirking worker. This implies that workers must balance the utility benefits of shirking against the costs, in the form of a higher probability of becoming unemployed. The optimal choice of a wage posting firm is therefore to set the wage at the lowest value that induces the worker to choose not to shirk (Shapiro and Stiglitz, 1984); the no-shirking constraint. Calibrating and simulating this model using, where possible, standard values from the literature, we can closely match the volatilities of unemployment, vacancies and labour market tightness and can also match the autocorrelation of vacancies and the correlations between vacancies and the other variables. Our calibration assumes a small shirking effect as the utility benefit of shirking is small and the probability of detection is high. This small friction is sufficient to generate a large volatility of unemployment and other labour market variables.

The model delivers substantial volatility of unemployment through a mechanism similar to that highlighted by Hagedorn and Manovskii (2008). In our model, the shirking effect leads firms to set a relatively high wage. Combined with the assumption of free entry of firms, this implies that profits are low. This implies that firms put few resources into recruiting, posting only a small number of vacancies. Since vacancies are low relative to the number of unemployed workers, vacancies are filled quickly. This high vacancy filling rate implies that hiring is highly sensitive to the number of vacancies; as a consequence, variations in job vacancies in response to shocks lead to large variations in unemployment[1]. Since a low rate of profit implies that vacancies are highly sensitive to ouput, unemployment is highly sensitive to productivity shocks. In the standard search frictions model, volatilities of key labour market variables comparable to those observed in the data are only obtained if workers have very little bargaining power and if the value of leisure is large (Hagedorn and Makovskii, 2008). This is problematic as it is not consistent with standard calibrated parameter values used in the literature[2]. In our model, large volatilities are obtained using using standard parameter calibrations[3].

[1] Amaral et al (2016) emphasise the importance of a high vacancy-filling rate in addressing the unemployment volatility puzzle. The low simulated vacancy-filling rate obtained in Shimer (2005) is central in generating small volatilities of unemployment and vacancies.

[2] Other extensions of the standard search frictions model also imply low profits. For example, Pissarides (2009) introduces a fixed cost of matching in addition to costs of posting vacancies and Petrosky-Nadeau and Wasmer (2013) introduce credit frictions.

[3] Ljungqvist and Sargent (2016) argue that a small value for the "fundamental surplus", the surplus of output over the minimum value of the wage that is consistent with positive output, is required in order to address the unemployment volatility puzzle; we explore this in

There is a robust body of evidence supporting the existence of shirking effects (Wolfers and Zilinsky, 2015). Burda et al (2015) analyse empirical measures of shirking and argue that the data are consistent with a model in which "workers are paid efficiency wages to refrain from loafing on the job." Groshen and Krueger (1990) and Rebitzer (2005) find an inverse relationship between wages and monitoring costs. Capelli and Chauvin (1991) and Reich et al (2003) find that firms take less disciplinary action against workers in workplaces where relative wages are higher. Pfeifer (2010) and Zhang et al (2013) find that absenteeism is inversely related to wages. Malcomson and Mavroeidis (2010) estimate aggregate wage equations on U.S time series data and argue that their estimates are consistent with the shirking model. The potential of a shirking mechanism in explaining the unemployment volatility puzzle has been raised previously in the literature, for example by Rogerson and Shimer (2010). Costain and Jansen (2009) develop a model with a shirking mechanism but, in contrast to our approach, assume that wages are determined through bargaining. They find that this model does not help address the unemployment volatility puzzle. Uhlig and Xu (1996) assess the ability of a different type of efficiency wage model[4] to explain large cyclical movements in unemployment using a real business cycle model without search frictions[5]. A related strand of the literature (e.g. Danthine and Donaldson,1990 and Danthine and Kurmann, 2010) incorporates efficiency wage effects into DSGE models but does not investigate the unemployment volatility puzzle.

The remainder of the paper is structured as follows. We outline our model in section 2). We discuss calibration and present our results in Section 3). Section 4) sumarises and raises issues for subsequent research.

2 The Model

We use a stochastic discrete time version of the search frictions model.

2.1 Workers

There is a continuum of identical workers on the unit interval. In period t a worker is in one of three states, employed and not shirking, employed and shirking or unemployed. All employed workers suffer a disutility[6] of χ; workers who do not shirk incur additional disutility of e. The value function for a worker who is employed and not shirking is

$$L_t = w_t - \chi - e + \frac{1}{1+r} E_t[(1-\tau_t)M_{t+1} + \tau_t U_{t+1}] \tag{1}$$

section 3.4) below.

[4] They assume that effort is a continuous function of the wage, similar to Solow (1979).

[5] Poeschel (2010) uses a model with shirking and wage posting to analyse the "Diamond Paradox" (Diamond, 1971); his model differs from ours in several respacts, including the possibility that firms might renege on the wage they offer in order to recruit workers.

[6] Following Hall (2005), this might equivalently be modeled as the utility of leisure enjoyed only by the unemployed.

where $M_t = \max(L_t, S_t)$ and S is the value function for a worker who is employed and shirking. This worker earns (and consumes) real wage w_t and experiences disutility of working[7] of $\chi + e$. The job match dissolves at the end of the period with exogenous but time-varying probability τ_t. We assume that the separation rate is stochastic: $\tau_t = \tau e^{\varepsilon_t^\tau}$; ε_t^τ is a separation rate shock where $\varepsilon_t^\tau = \rho^\tau \varepsilon_{t-1}^\tau + \eta_t^\tau$ and η_t^τ is distributed as $N(0, \sigma_\tau^2)$. Although the worker does not currently shirk, they may choose to do so in the next period, if the job match survives. The value function for a worker who is employed and shirking is

$$S_t = w_t - \chi + \frac{1}{1+r} E_t[(1 - \tau_t - d)M_{t+1} + (\tau_t + d)U_{t+1}] \tag{2}$$

where the worker is detected as shirking and fired with exogenous probability d. Compared to a non-shirker, this worker incurs less disutility while at work but has a higher probability of becoming unemployed. The value function for an unemployed worker is

$$U_t = b + \frac{1}{1+r} E_t[f_t M_{t+1} + (1 - f_t)U_{t+1}] \tag{3}$$

where b denotes real unemployment benefits. If unemployed, an individual finds a job and is employed in the next period with endogenous probability f_t.

The worker will choose not to shirk if and only if $L_t \geq S_t$. This implies the No-Shirking Constraint

$$L_t - U_t \geq (1 + r)\frac{e}{d} \tag{4}$$

If the utility premium of workers who are employed and not shirking over unemployed workers does not satisfy this condition, the utility benefit from shirking exceeds the risk-weighted cost from a higher likelihood of becoming unemployed.

2.2 Firms

There is a continuum of identical firms on the unit interval. Each firm can hire up to one worker and a firm with an employed and non-shirking worker produces an amount y_t, where $y_t = e^{\varepsilon_t^s}$; ε_t^s is a technology shock, where $\varepsilon_t^s = \rho^s \varepsilon_{t-1}^s + \eta_t^s$ and η_t^s is distributed as $N(0, \sigma_s^2)$. Output is zero if the worker shirks. The value function of a filled job with a non-shirking worker is

$$J_t = y_t - w_t + \frac{1}{1+r} E_t[(1 - \tau_t)H_{t+1} + \tau_t V_{t+1}] \tag{5}$$

where V is the value function of a vacancy, $H = J$ if the worker chooses not to shirk and $H = F$ otherwise. F is the value function of a filled job with a shirking worker, given by

$$F_t = -w_t + \frac{1}{1+r} E_t[(1 - \tau_t - d)H_{t+1} + (\tau_t + d)V_{t+1}] \tag{6}$$

[7] Our approach differs slightly from Burda et al (2015), who assign a utility benefit to shirking whereas we assign a utility cost to not shirking. This alternative approach leads to the same results.

The value function for a vacant job is

$$V_t = -\gamma + \frac{1}{1+r}E_t[q_{t+1}H_{t+1} + (1-q_{t+1})V_{t+1}] \tag{7}$$

Firms must pay a real cost of γ to post a vacancy. Vacancies are then filled at the start of the next period with probability q. We follow the timing convention of Gertler et al (2009) and assume that new job matches become productive immediately if the worker chooses not to shirk.

We assume free entry of firms, so $V_t = 0$. This implies that the value function for vacancies simplifies to

$$H_t = (1+r)\frac{\gamma}{q_t} \tag{8}$$

and so the value function for a filled job with a non-shirking worker becomes

$$(1+r)\frac{\gamma}{q_t} = y_t - w_t + (1-\tau_t)E_t\frac{\gamma}{q_{t+1}} \tag{9}$$

or

$$y_t = w_t + \lambda_t \tag{10}$$

where $\lambda_t = \gamma[(1+r)\frac{1}{q_t} - (1-\tau_t)E_t\frac{1}{q_{t+1}}]$ is the real cost of hiring a worker.

2.3 The Labour Market

The labour market is characterised by search frictions. Aggregate hiring is determined by the matching function

$$h_t = mu_t^{\alpha}v_t^{1-\alpha} \tag{11}$$

where h is the number of workers hired, u is the unemployment rate and v is the vacancy rate. m and α are parameters characterising the matching function. Defining labour market tightness as

$$\theta_t = \frac{v_t}{u_t} \tag{12}$$

the matching function can also be written as

$$h_t = mu_t\theta_t^{1-\alpha} \tag{13}$$

The vacancy filling rate, the probability of a firm filling a vacancy, is

$$q_t = \frac{h_t}{v_t} = m\theta_t^{-\alpha} \tag{14}$$

while the job finding rate, the probability that an unemployed worker finds a job, is

$$f_t = \frac{h_t}{u_t} = \theta_t q_t \tag{15}$$

2.4 Optimal Wage-Setting

The firm chooses the wage. It will choose the lowest wage compatible with no shirking, so $L_t = S_t$ and $H_t = J_t$. From (4) the wage is determined by

$$L_t - U_t = (1+r)\frac{e}{d} \tag{16}$$

Combining (1) and (3) to give

$$L_t - U_t = w_t - e - b - \chi + \frac{1}{1+r}(1 - \tau_t - f_t)E_t(L_{t+1} - U_{t+1}) \tag{17}$$

and using (16), the wage is

$$w_t = b + \chi + e + \frac{e}{d}(r + \tau_t + f_t) \tag{18}$$

This generalises the wage equation derived by Shapiro and Stiglitz (1984) to account for search frictions. In order to understand the implications of this wage equation, it is useful to make a comparison with the standard search frictions model with wage bargaining. That model is obtained if there is no utility premium to shirking, $e = 0$, and if wages are determined through worker-firm bargaining. Denoting the relative bargaining power of workers as ϕ, the wage can then be expressed as (e.g. Mortensen and Nagypal, 2007)

$$w_t = \phi(y_t + \gamma\theta_t) + (1-\phi)(b+\chi) \tag{19}$$

In contrast to the standard search frictions model, the wage in (18) does not depend on the level of output and is a function of the job finding rate of unemployed workers rather than of labour market tightness.

3 Simulation Results

3.1 Calibration Strategy

In calibration, where possible, we follow earlier studies. Thus all parameters, except those specific to the shirking mechanism, are calibrated using values taken from the literature. The remaining parameters, d and e, are chosen so that our model matches the average values of the unemployment rate and labour market tightness in US data. We simulate our model using stochastic processes for productivity and job separation shocks that match those observed in the data. We then compare simulated volatilities for the unemployment rate, vacancies, labour market tightness and the rate at which unemployed workers find a job with the data based measures presented in Shimer (2005)[8].

[8] There are two approaches to simulation in the literature. In the first (used by, among others, Shimer, 2005 and Hall, 2005), productivity can take a number of discrete values, where transition between productivity values is described by a Markov process. The model is solved for each simulated value of productivity. In the second (used by, among others, Rogerson and Shimer, 2010, Petrosky-Nadeau and Wasmer, 2013 and Gertler et al, 2015), the model is linearised around the steady-state and then simulated. In this paper, we follow the second approach.

3.2 Calibrated Parameter Values

We normalize a time period to be one quarter. Our calibrated parameter values are outlined in Table 1). The discount rate is set as $r = 1\%$. The average job separation rate is $\tau = 0.1$, following Shimer (2005) and Hall (2005); this implies that on average 3.3% of employed workers exit employment every month[9]. The cost of posting a vacancy is set as $\gamma = 0.213$, following Shimer (2005)[10]. Real unemployment benefits are set as $b = 0.4$. This is the same value as Shimer (2005)[11]. The disutility of labour is assumed to be $\chi = 0.43$. This is the value of leisure estimated by Hall (2006). For the matching function, we follow Pissarides (2009) and assume $m = 2.1$[12] and follow Petrongolo and Pissarides (2001) by assuming $\alpha = 0.5$.

Table 1— Values of Calibrated Parameters

Parameter	Interpretation	Value
τ	Separation Rate	0.1
r	Risk-Free Interest Rate	0.01
y	Labour productivity	1
b	Unemployment Benefit	0.4
γ	Vacancy Cost	0.213
u	Utility of Leisure	0.43
m	Matching Coefficient	2.1
α	Matching Elasticity	0.5
δ	Detection Rate	0.94
e	Disutility of Effort	0.06

For the processes driving productivity and job separations shocks, we assume $\rho^s = 0.733$ and $\rho^\tau = 0.875$ for the autoregressive component and $\sigma_s = 0.05$ and $\sigma_\tau = 0.01$ for the volatilities of the underlying shocks. These values generate shocks that match the autocorrelations and standard deviations of labour productivity and job separation in U.S data for 1951-2003 reported in Shimer (2005)[13].

There are no previous calibrations of parameters comparable to e and d in the literature. We solve the model comprising (10)-(15) and (18) in steady-state, together with the condition $fu = \tau(1-u)$, using the parameter values in Table 1). We select values of e and d for which the solution gives values of u and

[9] In the literature, monthly values of τ vary between 0.03 (Hall and Milgrom, 2008) and 0.036 (Pissarides, 2009).

[10] There is a wide range of alternative calibrated values for γ in the literature. Hagedorn and Manovskii (2008) use a weekly vacancy cost of 0.584. Hall (2005) assumes a monthly cost of 0.986 while Pissarides (2009) assumes 0.420. Our use of a relatively small vacancy posting cost gives firms a greater incentive to post vacancies; our finding of a low rate of vacancy setting, and therefore a high vacancy filling rate, is therefore noteworthy.

[11] In the literature, values of b vary between 0.4 (Shimer, 2005) and 0.955 (Hagedorn and Mankovskii 2008).

[12] Pissarides (2009) sets $m = 0.7$ in his monthly based calibration. The quarterly equivalent of this is $m = 2.1$.

[13] The volatlities of y and s are 0.020 and 0.075 respectively, while their auotcorrelations are 0.878 and 0.733. These are the same as the corresponding values in Shimer (2005).

θ that match average values observed in the data. For the target steady-state unemployment rate, we use $u = 0.058$, the average unemployment rate from 1955 to 2003. For target steady-state labour market tightness, we follow Hall and Milgrom (2008) *who find* $\theta = 0.5$ *using* JOLTS data[14]. The results are shown in Table 2). We find the closest match to our targeted values of u and θ when $d = 0.94$ and $e = 0.06$[15]. With these calibrated parameter values, we obtain steady-state values of $u = 0.063$ and $\theta = 0.504$, close to the targeted values. We also find a monthly average job finding rate of $f = 0.497$. This is close to the value of $f = 0.517$ reported by Hall and Milgrom (2008)[16]. Thus our model also provides a good fit to this non-targeted variable. Dividing the simulated job finding rate by the simulated value of θ, we obtain the implied average vacancy filling rate in the model as $q = 0.986$. As discussed above, the high rate of vacancy filling implies that variations in the number of vacancies posted leads to large variations in unemployment.

Table 2— Values of Endogenous Variables for Calibration

Parameter	Interpretation	U.S Data	This Paper
u	Unemployment Rate	0.058	0.063
θ	Labour Market Tightness	0.500	0.504
f	Job Finding Rate	0.517	0.497

Source: Unemployment Rate, BLS data, 1955Q1-2003Q4
Labour Market Tightness, JOLTS data, see Hall and Milgrom (2008)
Job Finding Rate, JOLTS data, see Hall and Milgrom (2008)

Using our calibrated parameters values and the value of f in Table 2) we obtain $w = 0.99$ from the wage equation in (18). Thus the relatively small friction from shirking effects implied by our values of e and d implies a low level of profit for firms. The implications of this will be explored in section 3.4) below.

3.3 Volatilities

Column (i) of Table 3) shows the observed volatilities of the unemployment rate, vacancies, labour market tightness and the job finding rate in US data

[14] Labour market tightness is hard to calibrate (Elsby et al, 2013). Shimer (2005) assumes that $\theta = 1$ in steady-state and uses this assumption to derive a measure of vacancy costs.

[15] Combining (10) and (18) in steady-state, the firm's optimality condition is

$$1 - (r + \tau)\frac{\gamma}{m}\theta^{\alpha} = b + \chi + e + \frac{e}{d}(r + \tau + m\theta^{1-\alpha})$$

Substituting the other parameter values from Table 1) and the target value of θ from Table 2), this can be written as

$$0.162 = e(1 + \frac{1.652}{d})$$

The solution to this requires a small value of e and a large value of d.

[16] Hall and Milgrom (2008) report that the daily job finding rate should be 2.4%. The monthly equivalent of this is 0.517.

reported in Shimer (2005); column (ii) shows the simulated volatilities from our model; columns (iii)-(iv) show, for comparison, the simulation results reported by Hagedorn and Manovskii (2008) and Shimer (2005). The volatility of unemployment in the data is 0.190; in our simulations it is 0.190. The volatilities of vacancies, labour market tightness and the job finding rate in the data are 0.202, 0.382 and 0.118 respectively; the corresponding simulated volatilities are 0.206, 0.370 and 0.185. It is thus clear that our model is able to match the observed volatilities in the data well[17], much better than the simulations of the standard search frictions model reported in Shimer (2005). Comparison with the volatilities reported by Hagedorn and Manovskii (2008) is complicated by the fact that they use a less volatile (and less autocorrelated) measure of productivity than Shimer (2005)[18]; a feature that lowers the simulated labour market volatilities in their model. The ratio of their simulated unemployment volatility to the volatility of productivity they use is 11.2. This ratio is 9.5 in our simulations. This compares to empirical ratios of 9.5 and 9.6 reported by Shimer (2005) and Hagedorn and Manovskii (2008) respectively.

Table 3— Volatilities

Standard Deviation of Key Labour Market Variables	U.S Data Shimer (2005)	This Paper	Hagedorn and Manovskii (2008)	Standard DMP Model Shimer (2005)
u	0.190	0.190	0.145	0.031
v	0.202	0.206	0.169	0.011
θ	0.382	0.370	0.292	0.037
f	0.118	0.185	–	0.014

The simulated job finding rate is more volatile than the data indicates. Therefore the model places too much emphasis on job creation, and too little emphasis on job destruction, in explaining business cycle movements in labour market variables[19]. Nonetheless, the over-prediction of this volatility on our model is much smaller than the under-prediction in the standard search frictions model.

3.4 Explaining the Volatility Results

3.4.1 Solutions to the volatility puzzle

Since unemployment, vacancies and the job-finding rate can be expressed as functions of labour market tightness (eg Shimer, 2005), the volatility of labour

[17]Similar results are obtained if we supress separations shocks. This is line with the literature, which finds that these shocks have little role in explaining cyclical movements in key labour market variables

[18] They follow Shimer (2005) in using a Hodrick-Prescott filter, but use a much smaller smoothing parameter.

[19]Exogenous job separations have little effect on labour market tightness. Therefore highly volatile labour market tightness requires large volatility in job creation. Given the relatively low levels of vacancies in the model, this create the excess volatility in the job finding rate documented in Table 3).

market tightness relative to the volatility of productivity shocks is at the core of the unemployment volatility puzzle. In steady-state, this relative volatility equals the elasticity of labour market tightness with respect to output (Mortensen and Nagypal, 2007). This elasticity has therefore become central to the debate on the volatility puzzle.

In this debate, emphasis is placed on the elasticity of wages with respect to output (stressed by Shimer, 2005, in his explanation of why the canonical search frictions model failed to match the data, also see Hall, 2005, and Hall and Milgrom, 2008) and on the rate of profit (eg Mortensen and Nagypal, 2007, and Hagedorn and Manovskii, 2008). To analyse the role of these factors, we can express the firm's optimality condition in steady-state as

$$y = w + \lambda \tag{20}$$

where $\lambda = \frac{\gamma(r+\tau)}{q}$. This implies

$$\varepsilon_{y,\theta} = (1-\pi)\varepsilon_{w,\theta} + \pi\varepsilon_{\lambda,\theta} \tag{21}$$

where $\varepsilon_{y,\theta}$ $\varepsilon_{w,\theta}$ and $\varepsilon_{\lambda,\theta}$ are respectively the elasticities of output, wages and hiring costs with respect to labour market tightness and $\pi = \frac{y-w}{y}$ is the rate of profit. Using (14) and the definition of λ, $\varepsilon_{\lambda,\theta} = \alpha$. Since $\varepsilon_{w,\theta} = \varepsilon_{w,y}\varepsilon_{y,\theta}$, (21) can be written as

$$\varepsilon_{y,\theta} = (1-\pi)\varepsilon_{w,y}\varepsilon_{y,\theta} + \alpha\pi \tag{22}$$

and so

$$\varepsilon_{\theta,y} = \frac{1-(1-\pi)\varepsilon_{w,y}}{\alpha\pi} \tag{23}$$

Equation (23) shows how the factors highlighted in the existing literature, the elasticity of wages with respect to output and the rate of profit, interact to determine the elasticity of labour market tightness with respect to output. We note that this elasticity is larger when wages are less responsive to output and when the rate of profit is smaller[20]. We also note that the wage elasticity has *a larger* impact if the rate of profit is small; this supports Hagedorn and Manovskii"s assertion that the wage elasticity only matters relative to the rate of profit.

3.4.2 Volatility in the shirking model

Using (18), $\frac{\partial w}{\partial \theta} = \frac{e}{d}\frac{\partial f}{\partial \theta}$ or, since $f = \theta q$, $\frac{\partial w}{\partial \theta} = \frac{e}{d}q(1+\frac{\theta}{q}\frac{\partial q}{\partial \theta})$. Using (14), this implies

$$\varepsilon_{w,\theta} = (1-\alpha)\frac{e}{d}\frac{f}{(1-\pi)} \tag{24}$$

Combining this with (21), we obtain

$$\varepsilon_{\theta,y} = \frac{1}{(1-\alpha)\frac{e}{d}f + \alpha\pi} \tag{25}$$

[20]We note that $\frac{\partial \varepsilon_{\theta,y}}{\partial \varepsilon_{w,y}} = -\frac{1-\pi}{\alpha\pi} < 0$ and $\frac{\partial \varepsilon_{\theta,y}}{\partial \pi} = -\frac{1-\varepsilon_{w,y}}{\alpha\pi} < 0$, (if $\varepsilon_{w,y} < 1$).

Using our parameter values and the average values of f from Table 2), the elasticity of labour market tightness with respect to the productivity shock is 17.89. This is close to the ratio of the volatility of labour market tightness to the volatility of productivity shocks in Table 2).

In our model, productivity shocks are transmitted to labour market tightness through their impact on wages and on profits (the first term in the denominator of (25) contains the impact of productivity on wages, while the second term in the denominator contains the impact of productivity on profits). Equation (25) shows that our model is able to generate a large volatility of labour market tightness because of a small value of $\frac{e}{d}$ and a small rate of profit. This latter point is consistent with arguments in Hagedorn and Manovskii (2008) that a large volatility of labour market tightness requires a low rate of profit. Low profits induce firms to put relatively few resources into recruiting, leading to a low level of labour market tightness and a high vacancy filling rate. This in turn implies that variations in vacancies in response to productivity shocks are transmitted strongly into variations in unemployment

Using

$$\varepsilon_{w,y} = (1-\alpha)m\frac{e}{d}\frac{\theta}{1-\pi}\varepsilon_{\theta,y} \tag{26}$$

with our calibrated parameters values, we obtain $\varepsilon_{w,y} = 0.9$. This is close to empirical values reported by Pissarides (2009). Thus a weak response of wages to output is not central to the ability of our model to generate large volatilities of unemployment and output.

3.4.3 Volatility in the standard model

The comparison with the standard search frictions model is useful here. Using (19) to write

$$\frac{\partial w}{\partial \theta} = \phi\frac{\partial y}{\partial \theta} + \phi\gamma \tag{27}$$

we obtain

$$\varepsilon_{w,\theta} = \frac{\phi}{1-\pi}(\varepsilon_{y,\theta} + \gamma\theta) \tag{28}$$

Combining this with (21), we obtain

$$\varepsilon_{\theta,y} = \frac{1}{\frac{\phi}{(1-\phi)}\gamma\theta + \frac{\alpha}{(1-\phi)}\pi} \tag{29}$$

Using (19), this is

$$\varepsilon_{\theta,y} = \frac{1}{\frac{\phi}{(1-\phi)}(1-\alpha)\gamma\theta + \alpha(1-b-\chi)} \tag{30}$$

Using the calibrated parameters in Table 1) and following Shimer (2005) in assuming $\phi = 0.72$, the elasticity of labour market tightness with respect to the productivity shock is 4.48; if we follow most of the existing literature and assume $\phi = 0.5$, the elasticity is 1.74. Both values are considerably smaller than the volatility observed in the data. As noted by Hagedorn and Makovskii (2008), the standard search frictions model can only match empirical volatilities by making the assumptions that workers have very little bargaining power and that the value of leisure is large. The impact of these assumptions is clear from (29). Low bargaining power of workers makes the first term in the denominator small while high value of leisure reduces the size of the second term[21].

3.4.4 Volatility in the strategic bargaining model

One prominent response to the volatility puzzle is the strategic wage bargain (eg Hall and Milgrom, 2008). The strategic wage bargain switches the bargainers' threat point from terminating the bargain to extending the bargain. This switch implies that the cost of delay in wage negotiations replaces the worker's outside option as a driving force in wage formation. Assuming a large fixed cost of delay reduces the wage elasticity and so delivers a large elasticity of labour market tightness with respect to output. The model might be criticised both for the assumption that the cost of delay is large (Ljungqvist and Sargent, 2016) and for the assumption that this cost is acyclical (if the cost of delay to the firm is pro-cyclical, reflecting lost output, then the threat point becomes pro-cyclical and so the resulting wage becomes more sensitive to output).

3.4.5 The fundamental surplus

Ljungqvist and Sargent (2016) argue that all proposed solutions to the unemployment volatility puzzle require a small value for the "fundamental surplus", the "upper bound on the fraction of a job's output that the invisible hand can allocate to vacancy creation"; this is equivalent to the lowest value of the wage that is consistent with (20). Ljungqvist and Sargent (2016) express the elasticity of labour market tightness with respect to the productivity shock as

$$\frac{\partial \theta}{\partial y}\frac{y}{\theta} = \Gamma \frac{y}{y-\xi} \tag{31}$$

where ξ is the fundamental surplus and $\frac{y-\xi}{y}$ is the fundamental surplus share. In our model, the no-shirking constraint gives the lowest wage that is consistent with positive output, so $\xi = w$ and so the fundamental surplus share is simply the rate of profit. We can show that $\Gamma = \frac{(r+\tau)\gamma\theta}{\alpha(r+\tau)\gamma+(1-\alpha)\frac{e}{d}fq}$. As with (25), the low rate of profit in our model generates a large volatility of labour market tightness. In the standard search frictions model, the fundamental surplus is $\xi = b + \chi$, as this is the lowest value of the wage that is consistent with non-zero output. In this case, $\Gamma = \frac{(r+\tau)+\phi f}{\alpha(r+\tau)+\phi f}$. The inability of the standard search frictions model to address the volatility puzzle is reflected in the relatively small

[21] Amaral et al (2016) raise concerns about the parameterisation of Hagedorn and Makovskii (2008), arguing that their results rely on a small elasticity of wages, contrary to evidence including Pissarides (2009).

values of Γ and ξ obtained by Ljungqvist and Sargent (2016) using standard calibrations. The value of $\frac{y}{y-\xi}$ is only large enough to generate substantial volatility in θ when the value of $b+\chi$ is assumed to be large, following Hagedorn and Makovskii (2008). In the case of the strategic bargaining model of Hall and Milgrom (2008) (see also Christiano et al, 2016), the fundamental surplus is $\xi = b + \chi + \frac{(1-\tau)}{1+r}\gamma$, where γ is the fixed cost of delay incurred by the firm; in this case, $\Gamma = \frac{1}{\alpha}$. Ljungqvist and Sargent (2016) argue that a large cost of delay is required to generate a large volatility of labour market tightness.

3.5 Autocorrelations and Correlations

Table 4) presents the autocorrelations of key labour market variables. Column (i) shows the observed autocorrelations of the unemployment rate, vacancies, labour market tightness and the job finding rate in US data reported in Shimer (2005); column (ii) shows the simulated autocorrelations from our model; columns (iii)-(iv) show, for comparison, the simulation results reported by Shimer (2005) and Hagedorn and Manovskii (2008). Our model is better able to match the autocorrelation of vacancies observed in the data. Shimer (2005) reports an autocorrelation of 0.291 for vacancies and Hagedorn and Manovskii (2008) report 0.575. The autocorrelation of vacancies in our model is 0.866, closer than alternative models to the observed value. Our model is able to match the high persistence of vacancies in the data because the low rate of profit in our model makes vacancy creation highly sensitive to output and thus the persistence of vacancies matches the high rate of persistence of output.

Table 4— Quarterly Autocorrelation of Key Labour Market Variables

Key Labour Market Variables	U.S Data Shimer (2005)	This Paper	Hagedorn and Manovskii (2008)	Standard DMP Shimer (2005)
u	0.936	0.853	0.830	0.933
v	0.940	0.866	0.575	0.291
θ	0.941	0.878	0.751	0.878
f	0.908	0.878	—	0.878

Table 5) presents the correlations between unemployment, vacancies, labour market tightness and the job finding rate obtained from simulations of our model and compares these to correlations in US data and to those reported by Shimer (2005) and Hagedorn and Manovskii (2008). Our model produces similar correlations to Hagedorn and Manovskii (2008) and delivers a relatively close match to the data. For example, Shimer (2005) reports a correlation between unemployment and vacancies of -0.427, compared to -0.894 in the data. In our model, this correlation is -0.747, similar to the value of -0.724 reported by Hagedorn and Manovskii (2008). This relatively high correlation reflects the high vacancy filling rate in our model, which implies that variations in vacancies lead to similar variations in unemployment.

Table 5— Correlations of Key Labour Market Variables

		u	v	θ	f
U.S Data	u	1	-0.894	-0.971	-0.949
This Paper	u	1	-0.747	-0.929	-0.929
Shimer (2005)	u	1	-0.427	-0.964	-0.964
H&M (2008)	u	1	-0.724	-0.916	–
US Data	v	–	1	0.975	0.897
This Paper	v	–	1	0.940	0.940
Shimer (2005)	v	–	1	0.650	0.650
H&M (2008)	v	–	1	0.940	–
U.S Data	θ	–	–	1	0.948
This Paper	θ	–	–	1	1
Shimer (2005)	θ	–	–	1	1
H&M (2008)	θ	–	–	1	–

4 Conclusions

This paper has developed a modified version of the standard search frictions model developed by Diamond (1982), Mortensen and Pissarides (1994) and Pissarides (2000), introducing a shirking mechanism and assuming that firms post wages. Simulations of the model show a close match to the observed volatilities, correlations and autocorrelations of unemployment, vacancies, labour market tightness and the job finding rate in US data. The model is better able to match key features of the data than prominent alternative models that have been proposed in response to the unemployment volatility puzzle. The key mechanism underlying these results is that even a small shirking effect leads to a small rate of proft. This leads to a low rate of vacancy creation which, since vacancies are low relative to the number of unemployed workers, implies a high vacancy filling rate. This in turn implies that hiring is highly sensitive to the number of vacancies; as a consequence, variations in job vacancies in response to shocks lead to large variations in unemployment. Since a low rate of profit also implies that vacancies are highly sensitive to ouput, unemployment is highly sensitive to productivity shocks.

This analysis could be developed in several ways. We might investigate whether the ability to generate high volatility of key labour market variables is a generic property of efficiency wage models. This paper has argued that a combination of wage posting with a mechansim to ensure low profts can generate a large volatility of unemployment and other labour market variables. In principle, all efficiency wage models share this feature. This paper extends the model of Shapiro and Stiglitz (1984) to a search frictions context. One might similarly extend models in which in which effort is a continuous function of the wage rather than binary (Solow, 1979) and examine whether these can also generate high levels of labour market volatility.

We can also develop our analysis by investigating whether the model has explanatory power beyond the average characteristics of the the US labour market. There are two aspects to this. First, we can analyse the performance of the model in different environments, for example in the European labour market where the vacancy-filling rate is lower than in the US. Doing so has proved a challenge for existing models of serach frictions (eg Amaral and Tasci, 2016). Second, we might use our model to address the changes in the cyclicality of the US and other labour markets that have been identified by, among others, Gali and van Rens (2014), in which the volatility of employment and wages has increased. Some explanations of this point to the increase in wage contracts that are linked to performance (eg Lemieux et al, 2009). An analysis based around the incentives of workers to supply effort may well be able to contribute to this debate.

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