Unemployment equilibrium and on-the-job search

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Abstract

This paper uses the search and matching framework to explore the impact of employed job search on the labour market. The specific features of our model are endogenous employed job search, flows in and out of the labour force, endogenous job destruction and heterogenous job creation. Also, job flows and workers flows do not coincide as we allow for job-to-job flows, firms' churning of workers and labour force entries and exits.

Employed job search is shown to have a substantial impact on unemployment dynamics but a negligible one on the level of unemployment. More on-the-job search leads to lower unemployment inflow and outflow, i.e. a more stagnant unemployment pool. With employed job search, the stock of vacancies is more cyclically sensitive, the unemployment outflow less cyclically sensitive and the unemployment inflow more cyclically sensitive than without employed job search.

With our model, the impact of a change in unemployment benefit does not only occur through the conventional decrease in the unemployment outflow rate, but also through an increase in the unemployment inflow rate.

The calibrated version of our model replicates well the cyclical behaviour of job and worker flows observed in the data.

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1 Introduction

There is much evidence that a large fraction of new hires comes from the ranks of the employed. On-the-job search has been identified (Burgess, 1993, Pissarides, 1994) as having an impact on unemployment equilibrium as well as on the dynamics of the labour market. Job flows and worker flows have been documented to be large, even in an economy in a steady-state, and exhibit different behaviour over the business cycle (Burda and Wyplosz, 1994, Davis and Haltiwanger, 1992). Importantly, these flows are not identical. Job creation and job destruction do not coincide with unemployment inflows and outflows. This is because workers move from job to job, in and out of the labour force, and firms churn workers. These churning flows and labour force flows have been shown to be large and sensitive to the business cycle (Burgess, Lane and Stevens, 2000, Burda and Wyplosz, 1994). Hence it seems useful to incorporate these features into a model of unemployment to understand the impact of on-the-job search flows and labour force flows on unemployment flows, job creation and job destruction.

In this paper, we use the Mortensen-Pissarides framework and extend it to include the above features[1]. On-the-job search, job creation and job destruction are all endogenous. Workers are allowed to flow into and out of the labour force at an exogenously determined rate, and we are able to look at the impact of the size of these flows on unemployment equilibrium. These flows are thought to be mainly `demographic' flows of individuals either retiring or joining the labour force when leaving education. These new entrants then have to be `processed' by the labour market in that they have to find a match with a vacant job and that they create congestion on the workers' side of the labour market while they search. Importantly, jobs quit by individuals retiring or moving to another job are not necessarily destroyed. Firms are heterogenous and the value of their output is decomposed in terms of a common aggregate component and an idiosyncratic component. The idiosyncratic component is subject to unanticipated shocks. In section 4, anticipated shocks to the aggregate component are also considered. Vacancies themselves are heterogenous[2] and all but the marginal vacancy are profitable. They offer heterogeneous wages, which justifies on-the-job search for some workers. Wages are determined by Nash bargaining at the time of the match and are kept fixed after the match, even when either an idiosyncratic or an aggregate shock occurs. In steady state, job destruction occurs after idiosyncratic shocks. Because wages are fixed at the time of the match, the probability of job destruction rates is heterogenous across firms.

[1] Pissarides (1994) introduced on-the-job search into his model, but kept job desctruction exogenous. Mortensen and Pissarides (1994) made job destruction endogenous, but did not consider on-the-job search. Mortensen (1994) allowed for endogenous job destruction and on-the-job search, but assumed that all jobs quit were destroyed, hence job flows and worker flows coincide.

[2] As opposed to vacancies in the standard model which are all posted at the maximum productivity and all make zero profit. As a result, in the standard model, there is a unique potential wage rate at the match for all job seekers, i.e. no wage distribution at the time of the match.

The main results of the paper are as follows: the presence of on-the-job search has a substantial impact on labour market equilibrium. More on-the-job search leads to lower matching probability for workers, i.e. a lower unemployment outflow rate and also to a lower layoff rate, i.e. a lower unemployment inflow rate. The net effect on the unemployment stock is negligible. Only the dynamics of unemployment are affected as the unemployment pool has become more stagnant. As predicted by Burgess (1993), on-the-job search renders unemployment inflow rate more sensitive to the cycle and unemployment outflow rate less sensitive to the cycle. In all cases, the inflow rate is found to be more cyclically sensitive than the outflow rate, suggesting that most unemployment dynamics occur through this channel. This confirms empirical results for Great Britain by Burgess and Turon (2000). The number of employed job seekers is very sensitive to the cycle and positively correlated with it. Also, the presence of on-the-job search decreases the impact of changes in unemployment benefit on unemployment duration. Such changes are shown to have a considerable impact on the job destruction rate.

The calibrated version of our model matches empirical facts well: unemployment flows are countercyclical, job flows are countercyclical and worker flows are procyclical. It hence reconciles the different behaviours over the business cycle of job flows and worker flows.

We derive the model in the next section and present the calibration and the results in section 3. In section 4, we introduce aggregate shocks into the model and see how the anticipation of aggregate shocks by firms and workers changes the results. Section 5 concludes.

2 Model

Our model builds on the Mortensen-Pissarides framework and incorporates on-the-job search[3]. We also introduce some flows in and out of the labour force. We do not model the out-of-the-labour-force state and keep these flows exogenous. Garibaldi and Wasmer (2001) analyse these flows in more depth, but without considering on-the-job search[4]. In our model, the flows in and out of the labour force are exogenous and assumed to be both equal to s times the stock of the employed, s_tE. The stock of the labour force is constant and normalised to 1. The labour force inflow represents new entrants coming from education and re-entrants coming back after a career break. All labour force entries flow into unemployment. The labour market, through the matching mechanism, has to `process' these workers before they find a match. The labour force outflow represents retirements and individuals going onto career breaks. For simplicity, all labour force exits occur from the state of employment. As documented by Burda and Wyplosz (1994) both these labour force flows occur in fact to and

[3] See Pissarides (2000) or Mortensen and Pissarides (1999) for the derivation of the original model.

[4] An interesting extension of both models would include endogenous on-the-job search and labour force entries and exits as both features are shown to affect unemployment dynamics.

from both states of employment and unemployment, in cyclically sensitive proportions. But their evidence supports that total labour force flows are roughly constant over the cycle.

2.1 Firms

The value of the output produced by firms is decomposed into two components: the aggregate component, p, which is held constant in this section (we will allow for aggregate cyclical shocks in section 4) and the idiosyncratic component of price, ε, which is uniformly distributed over the interval $(-1; 1)$ and subject to idiosyncratic shocks. When ε is above some threshold jc it is worthwhile opening a vacancy. ε is subject to idiosyncratic shocks occurring at rate γ. These shocks are not anticipated by either firms or workers. The wage is negotiated at the time of matching and is not re-negotiated after either an idiosyncratic shock to ε or an aggregate shock to p. This absence of renegotiation is documented by Hall (1999, pp.1155-6) and leads to inefficient layoffs and quits. When the idiosyncratic component of price is below some threshold ojs the worker will find it worthwhile to be searching on the job and the firm knows this. So the state value of a vacancy will have a different expression when ε is in the range $(jc; ojs)$, denoted V_o, from when ε is in the range $(ojs; 1)$, denoted V_n, because the state value of the filled job with a non-searching worker, J_n, is different from the state value of a filled job with an on-the-job searcher, J_o. Vacant jobs have a probability λ of being matched with a job searcher, determined by the matching function (see section 2.3). We assume that all vacant jobs have the same probability of being matched, irrespective of their idiosyncratic productivity ε. We also assume that, while jobs are vacant, they are not subject to idiosyncratic shocks.

$$r \cdot V_o(\varepsilon) = -k + \lambda \cdot (J_o(\varepsilon) - V_o(\varepsilon)) \quad (1)$$
$$r \cdot V_n(\varepsilon) = -k + \lambda \cdot (J_n(\varepsilon) - V_n(\varepsilon)) \quad (2)$$

where r is the discount rate and k the per-period cost of opening a vacancy. As in the Pissarides model, vacant jobs are created until the exhaustion of rents. What is different here is that all vacancies but the marginal one will make a positive profit[5]. The job creation threshold is determined as:

$$V_o(jc) = 0 \quad (3)$$

As seen above, when the idiosyncratic price component is in the interval $(jc; ojs)$, the job will be filled by a worker who will carry on job-searching.

[5] In Mortensen and Pissarides (1994), all new jobs were created at the same idiosyncratic productivity - for which the profits from a vacancy is zero. Here, jobs are created over a range of idiosyncratic productivities $(jc; 1)$ and the profits from a vacancy are zero at jc and positive over the rest of the range. In den Haan et al. (2001, pp. 8-10), new matches are `accepted' by worker and firm as long as the relationship-specific productivity is greater than some threshold for which the joint surplus of the match is zero. Blanchard and Diamond (1989, p.9) already suggested that, in the short run, the profits from a vacancy were not necessarily zero.

The firm hence expects the job to become vacant again, with probability μ (the matching probability for workers). It also expects the worker to leave the labour force with probability s[6]. When the job becomes vacant it keeps its level of idiosyncratic productivity ε. The state values of a job filled with a worker searching on the job, $J_o(\varepsilon)$, and of a job filled by a non-searching worker, $J_n(\varepsilon)$, are:

$$r \cdot J_o(\varepsilon) = p + \varepsilon - w_o(\varepsilon) + (s + \mu) \cdot (V_o(\varepsilon) - J_o(\varepsilon)) \tag{4}$$

$$r \cdot J_n(\varepsilon) = p + \varepsilon - w_n(\varepsilon) + s \cdot (V_n(\varepsilon) - J_n(\varepsilon)) \tag{5}$$

The wage negotiated with a worker continuing job search, $w_o(\varepsilon)$, will be different from the wage negotiated with a worker who stops searching, $w_n(\varepsilon)$. Wage determination is detailed in section 2.3. Whether a worker searches on the job or not does not depend on the worker but on the idiosyncratic productivity of the job, ε. All workers employed in jobs with ε less than ojs will be looking for another job, whilst no worker employed in jobs with ε more than ojs will be doing so.

2.2 Workers

The level of the on-the-job search threshold, ojs, is such that expected gains from search are just offset by the costs of searching over the expected duration of search. We assume that employed job searchers have the same matching probability as unemployed job searchers, μ. The per-period search cost is denoted c. Following Jovanovic (1979), we assume that the job match is an experience good, so the idiosyncratic productivity of the job is unknown to the worker at the time of the match. Therefore employed job seekers sample all the available vacancies and their matching probability (μ) as well as their expected value of employment in their next job (EE) do not depend on the ε in their current job. For employed workers in jobs with idiosyncratic productivity ε below ojs, the state value of being employed and searching on-the-job, $E_o(\varepsilon)$, is therefore:

$$r \cdot E_o(\varepsilon) = w_o(\varepsilon) + s \cdot (U - E_o(\varepsilon)) + \mu \cdot (EE - E_o(\varepsilon)) - c \tag{6}$$

As we do not model the out-of-the-labour-force state, we assume that its state value equals U, the state value of being unemployed. EE denotes the expected state value of being employed:

$$EE = \frac{1}{1 - jc} \left(\int_{jc}^{ojs} E_o(\varepsilon)\, d\varepsilon + \int_{ojs}^{1} E_n(\varepsilon)\, d\varepsilon \right) \tag{7}$$

The state value of being employed and not searching, $E_n(\varepsilon)$, is:

$$r \cdot E_n(\varepsilon) = w_n(\varepsilon) + s \cdot (U - E_n(\varepsilon)) \tag{8}$$

[6] Note that in case of retirement or quit to another job, the firm plans to re-advertise the job. So separations and job destruction are different.

The idiosyncratic productivity at which workers are indifferent between continuing or stopping search is the on-the-job threshold mentioned above and satisfies:

$$E_n(ojs) = E_o(ojs) \tag{9}$$

if this gives a solution[7] greater than jc. Otherwise $ojs = jc$ and there are no employed job seekers[8].

The state value of being unemployed is:

$$r \cdot U = b + \mu \cdot (EE - U) \tag{10}$$

where b is the per-period sum of the unemployment benefit and the value of leisure, net of job search costs.

2.3 Wage bargaining and matching

The wage rate is determined by Nash bargaining between worker and firm, as in the Mortensen-Pissarides framework[9]. Here, the idiosyncratic productivity of the job, ϵ, is unknown to the worker at the time of the match. It is only revealed to him when he starts in the job. So the firm offers a wage contract that will, once ϵ is observed, share the surplus from the match between worker and firm according to their bargaining power. From the equations above, we see that the surplus will have a different expression for jobs in which the worker carries on searching and in jobs where the worker stops searching. Because the value of the surplus is only observed once the worker is in the job, we assume that the worker's outside option is unemployment in both cases[10]. The two wage rates $w_o(\epsilon)$ and $w_n(\epsilon)$ resulting from the Nash bargaining will satisfy the following conditions:

$$\beta \cdot (J_o(\epsilon) - V_o(\epsilon)) = (1 - \beta) \cdot (E_o(\epsilon) - U) \tag{11}$$

$$\beta \cdot (J_n(\epsilon) - V_n(\epsilon)) = (1 - \beta) \cdot (E_n(\epsilon) - U) \tag{12}$$

where β is the worker's share of the surplus.

[7] $E_n(\epsilon)$ and $E_o(\epsilon)$ are linear functions of ϵ, usually with different slopes, so equation (9) will lead to a unique solution.

[8] In fact, there is a range of values of ϵ over which workers would like to be paid the non-searching wage w_n but still carry on searching. If job search is unobservable by the firm, this may occur and firms may consider that these workers do search and pay them a wage w_o. Workers would however prefer not to search and get paid w_n. So over this range, incentives are desirable to stop workers from quitting. There is (anecdotal) evidence that firms discourage quits in some cases by paying lump sums or bonuses on the condition that the worker stays within the firm. We hence assume that job search does not occur above the threshold ojs.

[9] There has been a growing literature on alternative models of wage determination over the past decade, particularly models with wage-posting games (see Mortensen and Pissarides, 1999 for a survey). Here, wage dispersion is obtained with Nash bargaining wage determination.

[10] Because the worker who has quit his previous job does not have the option to go back to it.

Firm heterogeneity, embodied in the variance of ε, and labour market frictions, embodied by the matching function, lead to some wage dispersion[11]. This dispersion in turn is an incentive for some workers paid at the lower end of the wage distribution to engage in on-the-job search.

Matches between searching workers and vacant jobs occur at a rate determined by the matching function, which we assume to exhibit constant returns to scale. The pool of job searchers comprises all the unemployed job seekers, stU plus the employed workers engaged in on-the-job search, $stOJS$:

$$\text{Number of matches} = eff \cdot (stU + stOJS)^{(1-\alpha)} \cdot stV^{\alpha} \tag{13}$$

where eff is the matching efficiency, α the matching elasticity with respect to vacant jobs and stV the stock of vacancies. If we denote θ the labour market tightness:

$$\theta = \frac{stV}{stU + stOJS} \tag{14}$$

we have the following expressions for the workers' (μ) and vacancies' (λ) matching probabilities:

$$\mu = eff \cdot \theta^{\alpha} \tag{15}$$

$$\lambda = eff \cdot \theta^{\alpha - 1} \tag{16}$$

2.4 Job destruction and churning

As mentioned above, the wage rate is negotiated at the time of the match and held fixed thereafter. This means that when the job's idiosyncratic productivity ε (or in section 4 the aggregate component of productivity p) has been hit by a shock, the wage does not share the match surplus efficiently anymore, which may lead to inefficient quits and layoffs of the type described by Hall (1999). In the absence of aggregate shocks, idiosyncratic shocks do not impact on the employed job search decision because they are unanticipated at the time of the match. Once they occur, the worker has no incentive to alter his search decision as both his current wage and his potential wage are unchanged. They do however lead to unanticipated job destruction and layoffs. To see this, we derive the expression of the state value of a filled job which exhibited an idiosyncratic productivity of ε_0 at the time of the match with its worker, leading to a negotiated wage $w(\varepsilon_0)$, and now exhibits an idiosyncratic productivity of ε after a shock. This new ε is drawn from a uniform distribution between -1 and 1. The expression of this state value is different whether the worker engages into job search or not:

$$r \cdot J_{\varepsilon o}(\varepsilon; \varepsilon_0) = p + \varepsilon - w_o(\varepsilon_0) + (s + \mu) \cdot (V_o(\varepsilon) - J_{\varepsilon o}(\varepsilon; \varepsilon_0)) \tag{17}$$

$$r \cdot J_{\varepsilon n}(\varepsilon; \varepsilon_0) = p + \varepsilon - w_n(\varepsilon_0) + s \cdot (V_n(\varepsilon) - J_{\varepsilon n}(\varepsilon; \varepsilon_0)) \tag{18}$$

[11] Following Burdett and Mortensen (1998), there are a number of models of equilibrium wage dispersion with wage-posting firms. For example, Postel-Vinay and Robin (2002) present a search model where both workers and firms are heterogenous. They estimate that worker heterogeneity contributes 0 to 40% of the wage variance, firm heterogeneity 10 to 50% and labour market frictions about 50%.

For the firm, an idiosyncratic shock affects the productivity of the job and the value of the vacant job that it might become, but not the wage it pays out to the worker. If the new idiosyncratic productivity falls below some threshold value, it will not be profitable anymore for the firm to keep the job filled, even though it has to pay firing costs f to destroy the job. This threshold productivity depends on the idiosyncratic productivity at which the wage was negotiated and is denoted $jd(\epsilon_0)$. It is determined as:

$$J_{\epsilon o}(jd_o(\epsilon_0);\epsilon_0) = -f \quad \text{when } \epsilon_o < ojs \tag{19}$$
$$J_{\epsilon n}(jd_n(\epsilon_0);\epsilon_0) = -f \quad \text{when } \epsilon_o > ojs \tag{20}$$

As ϵ is drawn uniformly from the interval $(-1;1)$ and idiosyncratic shocks occur at a rate of o, the probability that a job filled when its idiosyncratic productivity was ϵ_0 is destroyed equals $0.5\cdot o\cdot(jd_i(\epsilon_0)+1)$. As ϵ_0 is uniformly distributed over $(jc;1)$, for the whole employment stock, the job destruction rate is:

$$JD = \frac{0.5\cdot o}{(1-jc)}\cdot\left[\int_{jc}^{ojs}(jd_o(\epsilon_0)+1)\,d\epsilon_o + \int_{ojs}^{1}(jd_n(\epsilon_0)+1)\,d\epsilon_o\right] \tag{21}$$

Job destruction only leads to a layoff if the worker has not left the labour force or quit in the same period. So the layoff rate due to job destruction for the employment stock is:

$$La = \frac{0.5\cdot o}{(1-jc)}\cdot\left[\begin{array}{l}(1-s-{}^{1})\cdot\int_{jc}^{ojs}(jd_o(\epsilon_0)+1)\,d\epsilon_o\\ +(1-s)\cdot\int_{ojs}^{1}(jd_n(\epsilon_0)+1)\,d\epsilon_o\end{array}\right] \tag{22}$$

From the firm's point of view, it may also be that the new idiosyncratic productivity is such that it is worth laying off the worker and re-advertising the job at the current productivity in view of paying the wage rate corresponding to the new productivity. This happens if ϵ falls below some threshold $ch(\epsilon_0)$ and above jc as it has to be profitable to open the vacancy. This threshold is defined as:

$$J_{\epsilon o}(ch_o(\epsilon_0);\epsilon_0) = V_o(ch_o(\epsilon_0)) - f \quad \text{when } \epsilon_o < ojs \tag{23}$$
$$J_{\epsilon n}(ch_n(\epsilon_0);\epsilon_0) = V_n(ch_n(\epsilon_0)) - f \quad \text{when } \epsilon_o > ojs \tag{24}$$

As above, this translate to a churning rate for the whole employment stock of:

$$CH_f = \frac{0.5\cdot o}{(1-jc)}\cdot\left[\int_{jc}^{ojs}(ch_o(\epsilon_0)-jc)\,d\epsilon_o + \int_{ojs}^{1}(ch_n(\epsilon_0)-jc)\,d\epsilon_o\right] \tag{25}$$

From the worker's point of view, firm's churning only leads to layoff if the worker has not left the job to leave the labour force or to take another job. So the churning rate of workers that leads to unemployment inflow takes the following expression:

$$CH_w = \frac{0.5\cdot o}{(1-jc)}\cdot\left[\begin{array}{l}(1-s-{}^{1})\cdot\int_{jc}^{ojs}(ch_o(\epsilon_0)-jc)\,d\epsilon_o\\ +(1-s)\cdot\int_{ojs}^{1}(ch_n(\epsilon_0)-jc)\,d\epsilon_o\end{array}\right] \tag{26}$$

We can see from the previous equations that worker flows and job flows do not coincide because of job-to-job flows, labour force entries and exits and firms' churning.

2.5 Equilibrium

As mentioned earlier in this section, the labour force is assumed to be constant and normalised to 1, so we have the following identity between the stocks of employed stE and unemployed stU:

$$stE + stU = 1 \tag{27}$$

The stock of vacancies stV is determined by the level of jc, the ϵ threshold below which it is not profitable to open a vacancy (see equation (3)). As ϵ is drawn uniformly from $(-1; 1)$:

$$stV = \delta \cdot \frac{(1 - jc)}{2} \tag{28}$$

where δ is a scaling parameter. All the workers employed in jobs with ϵ less than ojs are engaged in on-the-job search. So the stock of employed job seekers equals:

$$stOJS = \frac{ojs - jc}{1 - jc} \cdot stE \tag{29}$$

The inflow into unemployment comprises workers flowing in from employment following job destruction or churning and individuals entering the labour force:

$$U\,inflow = (La + CH_w + s) \cdot stE \tag{30}$$

The outflow from unemployment equals the number of matches coming from the ranks of the unemployed as workers only leave the labour force from employment:

$$Uoutflow = \mu \cdot stU \tag{31}$$

The steady-state stock of unemployment is therefore, using (30), (31) and (27):

$$stU = \frac{La + CH_w + s}{La + CH_w + s + \mu} \tag{32}$$

With equation (14), the model is now closed.

3 Results

In this section we calibrate the model to obtain a solution that mirrors reality in terms of the sizes of the various stocks and flows. The literature gives us guidance on the range of values that the various parameters can take. There are eleven parameters in the model: the per-period cost of opening a vacancy, k, the per-period cost of searching on-the-job, c, the parameter b measuring the value of the unemployment bene¯t plus the value of leisure net of search cost for the unemployed, the discount rate r, the scaling parameter ±, the worker's share of the surplus in the Nash wage bargaining ¯, the rate at which workers leave/enter the labour force s, the ¯ring cost f, the rate at which idiosyncratic shocks occur º, the matching e±ciency ef f and the matching elasticity with respect to vacant jobs ®.

Here we are only concerned with steady states without anticipation of aggregate shocks. These will be introduced in the next section. The dynamic adjustment of this model over the business cycle is left for future research.

3.1 Calibration

In the calibration process we aim to reach a solution where the stocks of unemployed and employed jobs seekers are of a similar size and about 10% of the labour force. This is because there is evidence (Burgess, 1993) that half the new hires come from the ranks of the employed and we assumed that employed and unemployed job seekers had the same matching probability. We also aim for the matching probabilities to be about 0.40 for the job seekers and 0.90 for the vacant jobs, and for the layo® rate to be about 4% of the labour force[12]. We think of the unit time period to be a quarter and use a discount rate r of 0.02. A summary of all parameter values for the base case is shown in Table 1.

Table 1: Parameter values

r	¯	b	s	k	f	º	ef f	®	±	c
0.02	0.5	0.6	0.02	0.2	1	0.1	0.6	0.5	0.2	0.05

With these parameter values we obtain a labour market tightness µ of 0.46 and matching probabilities of 0.41 and 0.89 for workers and vacancies respectively. The resulting stocks of unemployed and employed job seekers are respectively 0.13 and 0.12, while the stock of vacant jobs is 0.12. The layo® rate is 0.04 and the churning rate is 0. The average productivity is 1.43 and the wage at the average productivity is 0.94, which corresponds to a labour share of income of 66%

3.2 Impact of on-the-job search

In order to assess the impact of the extent of employed job search, we allow the parameter c to vary, which will have a direct impact on the number of employed job seekers. Results are reported in Table 2. We see that the stock of employed

[12] These values were chosen to match data from Great Britain (NOMIS and Burgess and Turon, 2000).

job seekers, stOJS, responds negatively to a change in c. Over these three cases, the elasticity of this stock to the search cost c is -0.5.

Table 2: Impact of on-the-job search

	Base	c = 0:08	c = 0:02
µ	0.46	0.52	0.42
¹	0.407	0.433	0.389
¸	0.885	0.832	0.926
stU	0.127	0.126	0.127
stOJS	0.119	0.086	0.157
stV	0.115	0.109	0.119
La	0.039	0.042	0.036
avge	1.43	1.45	1.40
w (avge)	0.94	0.97	0.91
ls (avge)	0.66	0.67	0.65

avge = (1 + jc) / 2 is the average productivity. ls(avge) = w (avge) /avge is the labour share at average productivity.

The increase in the number of employed job seekers has a negative impact on ¹. So the employed job seekers create congestion for the unemployed. There is a very small impact on the stock of vacancies. The increase in the number of employed job seekers is accompanied by a decrease in the layo® rate, but the net e®ect of this decrease and of the decrease in ¹ is no change in the stock of unemployment. So the stock of unemployment is una®ected by the change in the stock of employed job seekers, but it is more stagnant as both in°ow and out°ow are smaller. This agrees with the results of Boeri (1999) who observes that countries with a high fraction of employed job search exhibit lower unemployment turnover rates.

3.3 Impact of the business cycle

We now look at the impact of a change in the aggregate price component p. Results of the model for the base case, an increase in p by 50% and a decrease in p by 50% are shown in columns 2, 3 and 4 of Table 3. As observed in real data, the labour market tightness µ, the workers' matching probability ¹, the stock of employed job seekers stOJS and the stock of vacancies stV are procyclical while the vacancies' matching probability ¸, the stock of unemployment stU and the layo® rate La are countercyclical.

The stock of employed job searchers is very sensitive to the business cycle: its elasticity with respect to p is 1.26 when p increases from 1 to 1.5, and 2.17 when p decreases from 1 to 0.5. This also suggests a concave relationship between p and stOJS, whereby, when job opportunities become plentiful, more employed workers engage into job search but the rate of increase in their number decreases if the economy is already buoyant. As the matching probability ¹ for workers is procyclical too, the quit rate will be super-procyclical, as observed in real data.

Table 3: Impact of business cycle and on-the-job search

	$p = 0.5$	Base	$p = 1.5$	$p = 0.5$ no OJS	$p = 1$ no OJS	$p = 1.5$ no OJS
θ	0.40	0.46	0.58	0.40	0.74	1.18
μ	0.379	0.407	0.457	0.379	0.516	0.652
λ	0.949	0.885	0.788	0.949	0.697	0.552
stU	0.182	0.127	0.082	0.182	0.123	0.091
stOJS	0	0.119	0.194	0	0	0
stV	0.067	0.115	0.160	0.067	0.091	0.107
La	0.064	0.039	0.017	0.064	0.052	0.045
avge	1.16	1.43	1.70	1.16	1.54	1.96
w (avge)	0.83	0.94	1.09	0.83	1.09	1.44
ls (avge)	0.71	0.66	0.64	0.71	0.71	0.73

avge=(1+jc)/2 is the average productivity. ls(avge)=w(avge)/avge is the labour share at average productivity.

Layoffs are countercyclical and exhibit an elasticity of -1.20 with respect to p. The elasticity of the worker's matching probability μ, which is also the unemployment outflow rate exhibits an elasticity with respect to p of 0.2. As layoffs account for over half the unemployment inflow (the remaining part of the inflow, coming from out of the labour force, is constant and equal to 0.02) the unemployment inflow is more sensitive to the cycle than the unemployment outflow. Columns 5 to 7 in Table 3 show model results when there is no employed job search. Comparing these with results with employed job search shows how employed job search affects the cyclical sensitivity of unemployment flow rates. With no employed job search the elasticity of layoffs with respect to p is -0.37 (instead of -1.20 with employed job search) and the elasticity of the workers' matching probability μ with respect to p is 0.53 (instead of 0.20 with employed job search). So we see that the presence of employed job search renders the unemployment inflow rate more sensitive to the cycle and the unemployment outflow rate less sensitive to the cycle, as predicted by Burgess (1993).

The stock of vacancies stV is procyclical and exhibits an elasticity of 0.8 with respect to p when there is employed job search (0.44 without employed job search) while the stock of unemployment stU is countercyclical and exhibits an elasticity of -0.79 with respect to p (-0.74 without employed job search). This corresponds to the often observed negative correlation between unemployment and vacancies over the business cycle -the Beveridge curve. The fact that the stock of vacancies is more sensitive to the cycle when there is employed job search agrees with Pissarides's (1994) findings. He also finds that employed job search renders unemployment less cyclically sensitive, which we do not as elasticities are about equal.

With employed job search, we also observe that the stock of vacancies is more cyclically sensitive than the unemployment outflow rate μ (the respective elasticities are 0.8 and 0.2). This is explained by the fact that, when there are more vacancies around, more employed workers engage into job search attracted by these increased opportunities and they `crowd out' unemployed workers. The increase in matching probability for the workers is hence less than it would have been without employed job search. This smoothing e®ect is not present when there are no employed job searchers: the respective elasticities of the vacancies stock and workers' matching probability are 0.44 and 0.53.

The last three lines of Table 3 show that both the average productivity and the average wage are procyclical and that wages are less sensitive to the cycle than productivity. The labour share of income is hence countercyclical in our model, which replicates the behaviour of labour share in real data. It should be noted from the last three columns that, without employed job search, the model looses the feature of a countercyclical labour share (it is about acyclical).

3.4 Impact of unemployment bene¯t, worker's bargaining power and idiosyncratic productivity variance

We now turn to the impact of model parameters relevant for policy purposes: the unemployment bene¯t b, the worker's bargaining power ¯, the variance of ², the idiosyncratic productivity, the rate at which individuals °ow in and out of the labour force s and the ¯ring costs f. Results are shown in Table 4.

Table 4: Impact of unemployment bene¯t, worker's share, variance of idiosyncratic productivity and labour force °ows

	Base	b = 0:8	b = 0:4	¯ = 0:6	¯ = 0:4	¾ = 1:3	¾ = 0:7	s = 0:04	s = 0
µ	0.46	0.42	0.51	0.35	0.69	0.40	0.63	0.43	0.50
¹	0.407	0.389	0.428	0.355	0.498	0.379	0.476	0.393	0.424
¸	0.885	0.926	0.840	1.014	0.722	0.949	0.756	0.915	0.849
stU	0.127	0.150	0.107	0.143	0.112	0.137	0.115	0.166	0.086
stOJS	0.119	0.077	0.154	0.183	0.049	0.146	0.062	0.102	0.139
stV	0.115	0.096	0.133	0.116	0.110	0.113	0.111	0.115	0.114
La	0.039	0.049	0.030	0.038	0.043	0.040	0.042	0.039	0.04
avge	1.43	1.52	1.34	1.42	1.45	1.41	1.46	1.42	1.43
w (avge)	0.94	1.08	0.80	0.97	0.94	0.97	0.97	0.93	0.95
ls (avge)	0.66	0.71	0.60	0.68	0.65	0.67	0.66	0.65	0.67

avge = (1 + jc)/2 is the average productivity. ls(avge) = w(avge)/avge is the labour share at average productivity.

Columns 3 and 4 show the impact of a change in the unemployment bene¯t b: An increase in b leads to an increase in stU and a decrease in ¹ as predicted by unemployed job search theory. Here, the model also predicts that an increase in b has a large impact on the job destruction and layo® rates. In the wage bargaining, the workers' outside option, U, is worth more when b is higher, so the negotiated wage rate will be higher. The consequence is that some jobs with low idiosyncratic productivity ² will now not be pro¯table anymore. In other words, the job creation threshold jc will be higher and less vacancies will be advertised. For the same reason, the job destruction thresholds jd($²_0$) will be higher, so the probability that the idiosyncratic productivity falls below that threshold after a shock will be higher, hence the higher job destruction and layoff rates. A consequence of this is that the average productivity is positively correlated with unemployment benefit, as in den Haan et al. (2001, p.21). If we compare the impact of an increase in unemployment benefit on workers' matching probability and layoff rate by comparing their elasticities with respect to b, we obtain -0.14 and 0.72 respectively. So the impact on the layoff rate is much larger than the impact on μ, which means that most of the impact of b on stU occurs through its impact on the unemployment inflow rate rather than on the outflow rate. As the matching probability is lower and the variance of job opportunities is lower, employed job search is much less attractive: the elasticity of stOJS with respect to b is -0.97. This means that the congestion on the workers's side of the labour market eases and μ increases, although not enough as to completely offset its initial decrease. The impact of unemployment benefit on unemployment exit rate is hence smaller in the presence of employed job search. There is a large literature on the impact of unemployment benefit on unemployment duration. Narendranathan, Nickell and Stern (1985) estimated the elasticity of unemployment duration for men with respect to unemployment benefit to be in the range 0.28 to 0.36. Our model predicts this elasticity to be 0.14.

In columns 5 and 6, a rise in the worker's share of the surplus in the Nash bargaining β by 20% is shown to lead to a substantial (50%) rise in employed job search and a decrease (by 12%) of the workers' matching probability μ. Layoffs are unaffected so the stock of unemployment itself increases by 12%. The stock of vacancies remains fairly constant, which suggests that most of the impact of the change in β on unemployment occurs through its impact on employed job search.

In columns 7 and 8, we look at the impact of a change in the variance of the distribution of idiosyncratic productivity. We now consider that ϵ is uniformly distributed over the interval $(-\sigma; \sigma)$ and vary the value of σ. An increase in σ has a very similar impact on the labour market as an increase in β. Again, most of the final impact on unemployment occurs through the response of employed job search to this shock.

In columns 9 and 10, we see that an increase in s leads to a substantial increase in stU and a substantial decrease in stOJS. A higher s means a higher inflow into unemployment, which leads to more congestion on the workers' side of the labour market, so a decrease in the workers' matching probability μ. This, together with the fact that the rate at which workers leave the labour force (also s) is higher, renders employed job search less attractive as the probability of finding a better job is lower and the expected time the worker would be in that better job before leaving the labour force is shorter. This in turn eases the congestion on the workers's side of the market and increases μ but not enough to completely offset the initial decrease in μ. So the presence of employed job search lessens the impact on μ and hence on stU that a change in s occurs.

Results not shown in the table show that firing costs have very little impact on the model results. The main effect is that, when firing costs are set to zero, churning from ¯rms become pro¯table, and we have 1% of the employed being laid-o® because of ¯rms' churning. As a result, the unemployment rate rises to 0.149 compared to 0.127 in the base case. Other model results are hardly a®ected by the change in ¯ring costs. We will see in the next section that ¯ring costs do however have a considerable impact on job destruction following a negative aggregate shock. In the literature (e.g. Bertola (1990), Millard (1994), Garibaldi (1998)), ¯ring costs have usually been found to reduce job reallocation but not to a®ect greatly the level of unemployment itself (except in Millard (1994) where ¯ring costs increase unemployment). Here, steady state job reallocation is not much a®ected by ¯ring costs, although it is reduced by ¯ring costs in the direct aftermath of a cyclical shock.

Throughout this section, we have seen that variations in employed job search following a change in one of the model parameters play a very important role in the overall impact of this shock on the steady-state level of unemployment. The presence and sensitivity to various labour market parameters of employed job search is hence a crucial aspect of the labour market's response to shocks to institutions or to the economy.

3.5 Job °ows and worker °ows

In our model, job °ows and worker °ows do not coincide. Not all the job destroyed incur layo®s because some workers either leave the labour force or take another job. Unemployment in°ows include not only layo®s but also entries into the labour force. Job creation and unemployment out°ows do not coincide either as some new jobs (about half of them) are taken by employed job searchers and because job-to-job moves give rise to new vacancies without job creation when the ¯rm decides to replace those workers who quit. We present in Table 5 some measures of job °ows and worker °ows in the base case, in a recession ($p = 0{:}5$) and in a boom ($p = 1{:}5$).

Table 5: Job °ows and worker °ows

	p = 0:5	p = 1	p = 1:5
Job °ows	0.053	0.037	0.018
Layo®s	0.052	0.034	0.016
Separations	0.069	0.100	0.123
U °ows	0.069	0.052	0.034
L °ows	0.016	0.017	0.018
JJ °ows	0.000	0.048	0.089
Worker °ows	0.085	0.117	0.141
JF / WF	0.63	0.31	0.13
UF / JF	1.29	1.41	1.85
JD/separations	0.77	0.37	0.15

U flows: Unemployment inflow and outflow in steady state. L flows: Flows in and out of the labour force.

JJ flows: Job-to-job flows. WF: worker flows. JF: job flows.

Row 5 of Table 5 shows that our model produces countercyclical unemployment °ows, consistent with the data presented by Burda and Wyplosz (1994) for four European countries. Job °ows (row 2) are also countercyclical, whereas worker °ows (row 8) are procyclical. The ratios in rows 9 and 10 show that unemployment °ows, worker °ows and job °ows have very di®erent cyclical behaviour. As mentioned in section 3.3, job-to-job °ows, i.e. quits, are very procyclical. In our model, job destruction does not coincide with job separations, as is often assumed in the literature. Indeed, the ratio between the two (row 11) not only is much smaller than 1, but is very sensitive to the business cycle, varying from 0.77 in a recession to 0.15 in a boom. So models assuming that all jobs quit are destroyed ignore a signi¯cant aspect of labour market dynamics.

4 Model with anticipation of aggregate shocks

In this section we consider that the aggregate price component p is subject to shocks occurring at a rate of q. These shocks are anticipated by both ¯rms and workers. As before, wages are negotiated at the time of the match and not renegotiated thereafter in the event of either an idiosyncratic or aggregate shock to the job's productivity. The aggregate economy now moves between a state 1 (boom) where $p = 1{:}5$ and a state 2 (recession) where $p = 1$. Jobs created in state 1 (i.e. for which the wage was negotiated in a boom) are worth J_{11} in state 1 and J_{12} in state 2. For a ¯rm, a negative aggregate shock means that the price its sells its product at is lower but the wage it pays to the worker is still the same. As a consequence, some jobs J_{12} will be destroyed right after the shock. All jobs with idiosyncratic productivity below some threshold jdcyc will be destroyed[13]. From the workers' point of view, there is no incentive to move from a job J_{12} as its pay a `boom' wage $w_1$ in a recession. So there is no employed job search from jobs $J_{12}$. Vacancies $V_1$ posted in a boom advertise jobs o®ering a wage $w_1$. When a recession hits, they are all destroyed on impact and `recession' vacancies V_2 are posted, advertising jobs with wages w_2. When they are matched with a worker, jobs J_{22} are ¯lled. If then a positive aggregate shock occurs, these jobs are worth J_{21} and carry on paying `recession' wages. So workers occupying those jobs always ¯nd it worthwhile to engage in on-the-job search in order to be paid a `boom ' wage instead. For ¯rms, jobs J_{21} can sell their product at a `boom' price while still paying a `recession' wage, so there is no job destruction on impact. Vacancies V_2 disappear on impact and vacancies V_1 are posted in greater number as the new job creation threshold jc_1 will be lower than the `recession' job creation threshold jc2.

For workers, E_{ij} is the value of being employed in a job J_{ij}, i.e. to be

[13] In simulations not reported here, we found that the threshold jdcyc, and hence the amount of job destruction on impact after a negative shock, is very sensitive to the level of ¯ring costs f. So, although f does not a®ect the steady states, it a®ects the dynamics between the steady states, i.e. the speed at which the economy moves from a boom steady state to a recession steady state. It will not however a®ect the transition from a recession to a boom.

employed at a wage negotiated in state i while the current state of the economy is j. The value of being unemployed in a boom and in a recession are U_1 and U_2 respectively.

On-the-job search and job destruction in jobs J_{11} and J_{22} are determined in the same way as in the previous section. The equations of the model when we allow for anticipated aggregate shocks are shown in the Appendix. The model was solved for several values of q which measures the frequency of aggregate shocks - or at least the frequency at which ¯rms and workers expect them to occur. Results are shown in Table 6.

Table 6: Impact of anticipation of aggregate shocks

	$q = 0$	$q = 0{:}02$	$q = 0{:}04$	$q = 0{:}08$
μ_1	0.59	0.58	0.53	0.46
μ_2	0.46	0.47	0.49	0.53
stU_1	0.076	0.082	0.087	0.094
stU_2	0.127	0.113	0.111	0.108
$stOJS_1$	0.196	0.182	0.198	0.228
$stOJS_2$	0.119	0.157	0.153	0.136
stV_1	0.159	0.153	0.152	0.149
stV_2	0.115	0.128	0.129	0.128
La_1	0.018	0.021	0.021	0.022
La_2	0.039	0.033	0.032	0.033
¹$_1$	0.461	0.457	0.437	0.407
¹$_2$	0.407	0.411	0.420	0.437

It is clear from the results that the fact that agents anticipate an aggregate shock renders the two steady states of boom and recession closer together in terms of all our measures of the labour market. As q increases, the boom economy becomes less of a boom and the recession economy becomes less of a recession. Anticipation of aggregate shocks smooths aggregate °uctuations. When $q = 0{:}08$, the unemployment stock only varies between 9.4% and 10.8%, whereas these variations range between 7.6% and 12.7% when aggregate shocks are not anticipated. The ratio of layo® rates between recession and boom is 2.2 when shocks are unanticipated compared to 1.5 when agents expect an aggregate shock in the next quarter with a probability of 8%. The ratio of workers' matching probability between boom and recession is 1.13 when no shocks are anticipated compared to 0.93 when shocks are anticipated with a probability of 8%. So even when there is anticipation of aggregate shocks, the layo® rate remains more sensitive to the cycle than the matching probability.

5 Conclusion

This paper uses the search and matching framework to explore the role of employed job search on the labour market. With our model, we can analyse its impact in terms of unemployment level and dynamics, job creation and job destruction. The speci¯c features of the model are endogenous employed job search, °ows in and out of the labour force, endogenous job destruction and heterogenous job creation. In our model, job °ows and workers °ows do not coincide as we allow for job-to-job °ows, ¯rms' churning of workers and labour force entries and exits.

Employed job search is shown to have a substantial impact on unemployment dynamics but a negligible one on the level of unemployment. More on-the-job search leads to lower unemployment in°ow and out°ow, i.e. a more stagnant unemployment pool. The sensitivity of the labour market to the business cycle is a®ected too: with employed job search, the stock of vacancies is more cyclically sensitive, the unemployment out°ow less cyclically sensitive and the unemployment in°ow more cyclically sensitive than without employed job search. One consequence is that most unemployment dynamics arise through the in°ow response to cyclical shocks.

With our model, the impact of a change in unemployment bene¯t does not only occur through the behaviour of unemployed job seekers. A higher unemployment bene¯t leads to less job creation, more job destruction and less on-the-job search. So we obtain a rise in equilibrium unemployment coming not only from the conventional decrease in the unemployment out°ow rate, but also from an increase in the unemployment in°ow rate. The latter e®ect is in fact stronger than the former. Also, changes in the worker's bargaining power and in the variance of the idiosyncratic productivity a®ect unemployment mainly through their impact on employed job search.

The calibrated version of our model matches empirically observed facts well. The unemployment level and layo®s are countercyclical, the unemployment out°ow rate, the stock of vacancies and the number of employed job seekers are procyclical. Also, wages are less sensitive to the cycle than prices so that the labour's share of total income is countercyclical.

Our model also does well at replicating the cyclical behaviour of job and worker °ows. Unemployment °ows are countercyclical, job-to-job °ows (very) procyclical, job °ows countercyclical and worker °ows procyclical. Two features of our model are crucial for these results: we allow for employed job search and jobs that have been quit are not necessarily destroyed.

Given the important role we ¯nd for employed job search in the determination and cyclical behaviour of labour market equilibrium, it would be interesting to assess empirically the size of and the main in°uences on employed job search. For example, recent labour market developments such as decreasing job security and increased use of ¯xed-term contracts may well have an impact on the number of employed job seekers, which in turn will a®ect unemployment dynamics.

Appendix

The expressions of all state values depend on the value of ϵ as it affects the outcome for the worker/job should the state of the economy change. The matching probabilities will be different in booms and recessions, respectively λ_1, μ_1 and λ_2, μ_2.

The state value equations for vacancies are:

$$
\begin{aligned}
r \cdot V_{1o}(\epsilon) &= -k + \lambda_1 \cdot (J_{11o}(\epsilon) - V_{1o}(\epsilon)) + q \cdot (0 - V_{1o}(\epsilon)) \\
&\qquad \text{when } \epsilon \text{ in } (jc1, ojs1) && \text{(A.1)} \\
r \cdot V_{1n}(\epsilon) &= -k + \lambda_1 \cdot (J_{11n}(\epsilon) - V_{1n}(\epsilon)) + q \cdot (0 - V_{1n}(\epsilon)) \\
&\qquad \text{when } \epsilon \text{ in } (ojs1, jc2) && \text{(A.2)} \\
r \cdot V_{1n}(\epsilon) &= -k + \lambda_1 \cdot (J_{11n}(\epsilon) - V_{1n}(\epsilon)) + q \cdot (V_{2o}(\epsilon) - V_{1n}(\epsilon)) \\
&\qquad \text{when } \epsilon \text{ in } (jc2, ojs2) && \text{(A.3)} \\
r \cdot V_{1n}(\epsilon) &= -k + \lambda_1 \cdot (J_{11n}(\epsilon) - V_{1n}(\epsilon)) + q \cdot (V_{2n}(\epsilon) - V_{1n}(\epsilon)) \\
&\qquad \text{when } \epsilon \text{ in } (ojs2, \infty) && \text{(A.4)}
\end{aligned}
$$

and

$$
\begin{aligned}
r \cdot V_{2o}(\epsilon) &= -k + \lambda_2 \cdot (J_{22o}(\epsilon) - V_{2o}(\epsilon)) + q \cdot (V_{1n}(\epsilon) - V_{2o}(\epsilon)) \\
&\qquad \text{when } \epsilon \text{ in } (jc2, ojs2) && \text{(A.5)} \\
r \cdot V_{2n}(\epsilon) &= -k + \lambda_2 \cdot (J_{22n}(\epsilon) - V_{2n}(\epsilon)) + q \cdot (V_{1n}(\epsilon) - V_{2n}(\epsilon)) \\
&\qquad \text{when } \epsilon \text{ in } (ojs2, \infty) && \text{(A.6)}
\end{aligned}
$$

For jobs that were filled is state 1, the state values are, in state 1:

$$
\begin{aligned}
r \cdot J_{11o}(\epsilon) &= p_1 + \epsilon - w_{1o}(\epsilon) + (s + \mu_1) \cdot (V_{1o}(\epsilon) - J_{11o}(\epsilon)) + q \cdot (0 - J_{11o}(\epsilon)) \\
&\qquad \text{when } \epsilon \text{ in } (jc1, ojs1) && \text{(A.7)} \\
r \cdot J_{11n}(\epsilon) &= p_1 + \epsilon - w_{1n}(\epsilon) + s \cdot (V_{1n}(\epsilon) - J_{11n}(\epsilon)) + q \cdot (0 - J_{11n}(\epsilon)) \\
&\qquad \text{when } \epsilon \text{ in } (ojs1, jc2) && \text{(A.8)} \\
r \cdot J_{11n}(\epsilon) &= p_1 + \epsilon - w_{1n}(\epsilon) + s \cdot (V_{1n}(\epsilon) - J_{11n}(\epsilon)) + q \cdot (V_{2o}(\epsilon) - J_{11n}(\epsilon)) \\
&\qquad \text{when } \epsilon \text{ in } (jc2, ojs2) && \text{(A.9)} \\
r \cdot J_{11n}(\epsilon) &= p_1 + \epsilon - w_{1n}(\epsilon) + s \cdot (V_{1n}(\epsilon) - J_{11n}(\epsilon)) + q \cdot (V_{2n}(\epsilon) - J_{11n}(\epsilon)) \\
&\qquad \text{when } \epsilon \text{ in } (ojs2, jdcyc) && \text{(A.10)} \\
r \cdot J_{11n}(\epsilon) &= p_1 + \epsilon - w_{1n}(\epsilon) + s \cdot (V_{1n}(\epsilon) - J_{11n}(\epsilon)) + q \cdot (J_{12n}(\epsilon) - J_{11n}(\epsilon)) \\
&\qquad \text{when } \epsilon \text{ in } (jdcyc, \infty) && \text{(A.11)}
\end{aligned}
$$

and in state 2:

$$
\begin{aligned}
r \cdot J_{12n}(\epsilon) &= p_2 + \epsilon - w_{1n}(\epsilon) + s \cdot (V_{2n}(\epsilon) - J_{12n}(\epsilon)) + q \cdot (J_{11n}(\epsilon) - J_{12n}(\epsilon)) \\
&\qquad \text{when } \epsilon \text{ in } (jdcyc, \infty) && \text{(A.12)}
\end{aligned}
$$

For jobs that were filled is state 2, the state values are, in state 2:

$$
\begin{aligned}
r \cdot J_{22o}(\epsilon) &= p_2 + \epsilon - w_{2o}(\epsilon) + (s + \mu_2) \cdot (V_{2o}(\epsilon) - J_{22o}(\epsilon)) + q \cdot (J_{21o}(\epsilon) - J_{22o}(\epsilon)) \\
&\qquad \text{when } \epsilon \text{ in } (jc2, ojs2) && \text{(A.13)} \\
r \cdot J_{22n}(\epsilon) &= p_2 + \epsilon - w_{2n}(\epsilon) + s \cdot (V_{2n}(\epsilon) - J_{22n}(\epsilon)) + q \cdot (J_{21o}(\epsilon) - J_{22n}(\epsilon)) \\
&\qquad \text{when } \epsilon \text{ in } (ojs2, \infty) && \text{(A.14)}
\end{aligned}
$$

and in state 1:

$$
\begin{aligned}
r \cdot J_{21o}(\epsilon) &= p_1 + \epsilon - w_{2o}(\epsilon) + (s + \lambda_1) \cdot (V_{1n}(\epsilon) - J_{21o}(\epsilon)) + q \cdot (J_{22o}(\epsilon) - J_{21o}(\epsilon)) \\
&\quad \text{when } \epsilon \text{ in } (jc2; ojs2) && \text{(A.15)} \\
r \cdot J_{21o}(\epsilon) &= p_1 + \epsilon - w_{2n}(\epsilon) + (s + \lambda_1) \cdot (V_{1n}(\epsilon) - J_{21o}(\epsilon)) + q \cdot (J_{22n}(\epsilon) - J_{21o}(\epsilon)) \\
&\quad \text{when } \epsilon \text{ in } (jc2; ojs2) && \text{(A.16)}
\end{aligned}
$$

For workers, the value of being unemployed in state 1 and 2 is:

$$
\begin{aligned}
r \cdot U_1 &= b + \lambda_1 \cdot (EE1 - U_1) + q \cdot (U_2 - U_1) && \text{(A.17)} \\
r \cdot U_2 &= b + \lambda_2 \cdot (EE2 - U_2) + q \cdot (U_1 - U_2) && \text{(A.18)}
\end{aligned}
$$

where

$$
\begin{aligned}
EE1 &= \frac{1}{1 - jc1} \cdot \left[\int_{jc1}^{ojs1} E_{11o}(\epsilon)\, d\epsilon + \int_{ojs1}^{1} E_{11n}(\epsilon)\, d\epsilon \right] && \text{(A.19)} \\
EE2 &= \frac{1}{1 - jc2} \cdot \left[\int_{jc2}^{ojs2} E_{22o}(\epsilon)\, d\epsilon + \int_{ojs2}^{1} E_{22n}(\epsilon)\, d\epsilon \right] && \text{(A.20)}
\end{aligned}
$$

The value of being employed in a job filled in state 1, when the economy is in state 1 is:

$$
\begin{aligned}
r \cdot E_{11o}(\epsilon) &= w_{1o}(\epsilon) + s \cdot (U_1 - E_{11o}(\epsilon)) + \lambda_1 \cdot (EE1 - E_{11o}(\epsilon)) - c + q \cdot (U_2 - E_{11o}(\epsilon)) \\
&\quad \text{when } \epsilon \text{ in } (jc1; ojs1) && \text{(A.21)} \\
r \cdot E_{11n}(\epsilon) &= w_{1n}(\epsilon) + s \cdot (U_1 - E_{11n}(\epsilon)) + q \cdot (U_2 - E_{11n}(\epsilon)) \\
&\quad \text{when } \epsilon \text{ in } (ojs1; jdcyc) && \text{(A.22)} \\
r \cdot E_{11n}(\epsilon) &= w_{1n}(\epsilon) + s \cdot (U_1 - E_{11n}(\epsilon)) + q \cdot (E_{12n}(\epsilon) - E_{11n}(\epsilon)) \\
&\quad \text{when } \epsilon \text{ in } (jdcyc; 1) && \text{(A.23)}
\end{aligned}
$$

and when the economy is in state 2:

$$
\begin{aligned}
r \cdot E_{12n}(\epsilon) &= w_{1n}(\epsilon) + s \cdot (U_2 - E_{12n}(\epsilon)) + q \cdot (E_{11n}(\epsilon) - E_{12n}(\epsilon)) \\
&\quad \text{when } \epsilon \text{ in } (jdcyc; 1) && \text{(A.24)}
\end{aligned}
$$

The value of being employed in a job filled in state 2, when the economy is in state 2 is:

$$
\begin{aligned}
r \cdot E_{22o}(\epsilon) &= w_{2o}(\epsilon) + s \cdot (U_2 - E_{22o}(\epsilon)) + \lambda_2 \cdot (EE2 - E_{22o}(\epsilon)) - c + q \cdot (E_{21o}(\epsilon) - E_{22o}(\epsilon)) \\
&\quad \text{when } \epsilon \text{ in } (jc2; ojs2) && \text{(A.25)} \\
r \cdot E_{22n}(\epsilon) &= w_{2n}(\epsilon) + s \cdot (U_2 - E_{22n}(\epsilon)) + q \cdot (E_{21o}(\epsilon) - E_{22n}(\epsilon)) \\
&\quad \text{when } \epsilon \text{ in } (ojs2; 1) && \text{(A.26)}
\end{aligned}
$$

and when the economy is in state 1:

$$
\begin{aligned}
r \cdot E_{21o}(\epsilon) &= w_{2o}(\epsilon) + s \cdot (U_1 - E_{21o}(\epsilon)) + \lambda_1 \cdot (EE1 - E_{21o}(\epsilon)) - c + q \cdot (E_{22o}(\epsilon) - E_{21o}(\epsilon)) \\
&\quad \text{when } \epsilon \text{ in } (jc2; ojs2) && \text{(A.27)} \\
r \cdot E_{21o}(\epsilon) &= w_{2n}(\epsilon) + s \cdot (U_1 - E_{21o}(\epsilon)) + \lambda_1 \cdot (EE1 - E_{21o}(\epsilon)) - c + q \cdot (E_{22n}(\epsilon) - E_{21o}(\epsilon)) \\
&\quad \text{when } \epsilon \text{ in } (ojs2; 1) && \text{(A.28)}
\end{aligned}
$$

The wage rates are determined by Nash bargaining and satisfy the conditions:

$$\beta \cdot (J_{11i}(\epsilon) - V_{1i}(\epsilon)) = (1 - \beta) \cdot (E_{11i}(\epsilon) - U_1) \quad (A.29)$$

$$\beta \cdot (J_{22i}(\epsilon) - V_{2i}(\epsilon)) = (1 - \beta) \cdot (E_{22i}(\epsilon) - U_2) \quad (A.30)$$

$$\text{for } i = o; n.$$

In this version of the model, five thresholds have to be determined: jc1, jc2, ojs1, ojs2, jdcyc with the following equations:

$$V_{1o}(jc1) = 0 \quad (A.31)$$

$$V_{2o}(jc2) = 0 \quad (A.32)$$

$$E_{11o}(ojs1) = E_{11n}(ojs1) \quad (A.33)$$

$$E_{22o}(ojs2) = E_{22n}(ojs2) \quad (A.34)$$

$$J_{12n}(jdcyc) = 0 \quad (A.35)$$

Job destruction and churning rates are determined as in section 2.4. The model is closed in a similar fashion as the model without aggregate shock and we obtain tightness rates θ_1 and θ_2 for states 1 and 2 of the economy, as well as the stocks of unemployed, employed job searchers and vacancies.

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