The Lumpy Job Separation Rate

Reconciling Search Models with the Ins and Outs of Unemployment*

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Abstract

This paper presents a search model with an asymmetric and "lumpy" job separation margin, which is consistent with recent micro evidence on establishment behavior: the job separation rate can increase following negative labor demand shocks but is kept constant following positive labor demand shocks. The model is consistent with the cyclical behavior of labor market variables and can account for three stylized facts about unemployment that the Mortensen-Pissarides (1994) model has difficulties explaining jointly: (i) the unemployment-vacancy correlation is negative, (ii) the contribution of the job separation rate to unemployment fluctuations is small but non-trivial, (iii) movements in the job separation rate are sharp and short-lived while movements in the job finding rate are persistent. In addition, the model can rationalize two hitherto unexplained findings: why unemployment inflows were less important in the last two decades, and why the asymmetric behavior of unemployment weakened after 1985.

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1 Introduction

The Mortensen-Pissarides (1994, henceforth MP) search and matching model has emerged as a powerful tool to study unemployment and the labor market, and an extensive literature has introduced equilibrium unemployment into general equilibrium models through a search framework.[1] In parallel to these theoretical developments, many studies have documented the empirical properties of job and worker flows over the business cycle.[2] Shimer (2007) focuses on individual workers' transition rates and finds that the contribution of the job separation rate (JS) to unemployment's variance is small over the post-war period and even smaller since the mid-80s. Movements in the job finding rate (JF), on the other hand, account for three-quarters of unemployment's variance over the post-war period.[3] However, the MP model has difficulties explaining the low contribution of the job separation rate as well as other stylized facts about unemployment and its transition probabilities.

This paper presents a simple search and matching model with an asymmetric and lumpy job separation margin, which is consistent with Davis, Faberman and Haltiwanger's (2006) micro evidence on establishment behavior. In the model, and unlike in the MP framework, the job separation rate can increase following large negative labor demand shocks but is kept constant following positive shocks. Despite a small number of parameters, the model is consistent with the behavior of labor market variables, can rationalize a low, yet non-trivial, contribution of the job separation rate and can explain the declining contribution of JS since 1985.

Shimer's (2007) evidence on the low contribution of the job separation rate led to a recent modeling trend that treats the job separation rate as acyclical.[4] However, such a conclusion

[1]See, for example, Merz (1995), Andolfatto (1996), den Haan, Ramey and Watson (2000), Walsh (2004), Blanchard and Gali (2008), Gertler and Trigari (2009), Trigari (2009) among many others.

[2]For work on gross worker flows and gross job flows, see, among others, Darby, Plant and Haltiwanger (1986), Blanchard and Diamond (1989, 1990), Davis and Haltiwanger (1992), Bleakley et al (1999), Fallick and Fleischman (2004), Fujita and Ramey (2006) and Fujita (2009). Shimer (2007), Elsby, Michaels and Solon (2008), Elsby, Hobijn, and Sahin (2008) and Fujita and Ramey (2008) focus instead on transition rates between employment, unemployment and out of labor force.

[3]In this paper, as in much of the literature on unemployment fluctuations, I omit fluctuations in inactivity-unemployment flows, and focus only on employment-unemployment flows. See Shimer (2007) for evidence supporting this assumption.

[4]See e.g. Hall (2005), Blanchard and Gali (2008), and Gertler and Trigari (2009).

may be too hasty. First, Shimer's (2007) estimate amounts to a non-trivial 25 percent over the post-war period. The contribution of JS indeed drops to only 5 percent over 1985-2007, but it is important to understand the reasons behind this decline. In addition, as Blanchard and Diamond (1990) first showed, the number of hires tends to *increase* in recessions while the job finding rate decreases. This happens because the pool of unemployed increases proportionally more than unemployment outflows and suggests that unemployment inflows play an important role in recessions. Finally, an important characteristic of unemployment is its asymmetric behavior, the fact that increases in the unemployment rate are steeper than decreases, and I find that this asymmetry disappears after 1985. Again, this suggests that an asymmetric mechanism such as job separation is driving the response of unemployment to shocks, but that this mechanism is weaker since the mid-80s.

A natural candidate to account for both unemployment outflows and inflows is the MP model with endogenous separation, but the model has difficulties generating three stylized facts about cyclical unemployment and its transition probabilities: (i) the unemployment-vacancy correlation is negative, (ii) JS is half as volatile as JF but is three times more volatile than detrended real GDP and (iii) movements in JS are sharp and short-lived while movements in JF are persistent and mirror the behavior of unemployment. Indeed, Ramey (2008) and Elsby and Michaels (2008) show that for plausible parameter values, the MP model generates an upward-sloping Beveridge curve as well as too much volatility in JS relative to JF.[5] Moreover, I simulate a MP model with AR(1) productivity shocks and find that it generates counterfactually similar dynamic properties for the job finding rate and the job separation rate.

These empirical issues arise because in a MP model calibrated with plausible idiosyncratic productivity shocks, job destruction is the main margin of adjustment in employment and "drives" the job creation margin; a burst of layoffs generates higher unemployment, makes workers easier to find and stimulates the posting of vacancies. This mechanism explains why

[5]See also Costain and Reiter (2008) and Krause and Lubik (2007) for similar claims but with a search and matching framework that is slightly different than Mortensen and Pissarides (1994). See Section 6 for a review of the literature.

the MP model can generate a counterfactually positive unemployment-vacancy correlation and counterfactually similar impulse responses for -JF and JS.

This paper argues that an important feature of the data, the existence of an inaction region in which firms' job separation rate is constant, could be responsible for the empirical properties of labor market flows, and hence for the inability of the standard MP model to explain the data. One key assumption made by the MP model or its extensions (e.g., Walsh (2005), Krause and Lubik (2007) or Trigari (2009)) is the existence of a continuum of jobs with different productivity levels. As a result, at any point in time, there is always a marginal job right at the margin between termination and continued operation. Thus, job separation is a continuous process, and there is no inaction ('sS' type) band over which firms keep the job separation rate constant independently of economic conditions. This property of the model stands at odds with firms' behavior. Davis, Faberman and Haltiwanger (2006) find that, while shrinking establishments resort to the job separation margin to adjust employment levels, stable or growing establishments display a roughly constant job separation rate and only use the hiring margin to adjust employment. Moreover, and consistent with the existence of an inaction band for JS, I find that the cyclical component of the job separation rate is heavily skewed and has a high kurtosis because it displays long periods of small variations followed by short but violent bursts during recessions.

An inaction band can arise when there is no continuum of matches with different productivity levels within the firm, and I consider the simplest case of a search model with large homogenous firms hiring homogenous workers. Despite its simplicity, the model is consistent with the three stylized facts about unemployment and its transition probabilities. In a frictional labor market, firms have the choice between two labor inputs; an extensive margin (number of workers) subject to hiring frictions and a flexible but more expensive intensive margin (hours per worker). Firing is costless and instantaneous, but because of hiring frictions, firms hoard labor and an inaction band emerges as firms only use the job separation margin for large negative shocks. With JS only used in exceptional circumstances, there is no contradiction in observing occasionally large values of JS along with a low average contribution to unemployment fluctuations. Consistent with fact (ii), JS is less volatile than JF, and the contribution of JS to unemployment fluctuations is not necessarily large. In fact, the model can closely match an empirical contribution of JS of 25 percent over the post-war period. Further, contrary to a standard MP model, vacancy posting is the main variable of adjustment of employment, and job separation is only used in exceptional circumstances. As a result, and consistent with fact (iii), adjustments in JS are sharp and short-lived while JF inherits the persistence of the labor demand shocks. As in the MP model, a burst of layoffs increases unemployment and decreases the expected cost of filling a vacancy, so that firms want to profit from exceptionally low labor market tightness to increase their number of new hires. However, the incentive is much weaker than in the MP model. Gross hires may go up in recessions, in line with Blanchard and Diamond (1990), but consistent with fact (i), firms post fewer vacancies, and the unemployment-vacancy correlation is negative.

Another contribution of the paper is to provide an explanation for the decline in the contribution of JS and the weaker asymmetry in unemployment since 1985. The model implies that these two findings are by-products of the Great Moderation.[6] Because of hiring frictions, firms hoard labor and do not lay-off workers in small recessions, preferring to reduce hours per worker. Since the last two recessions (1991 and 2001) were relatively mild, firms made little use of the job separation margin, and the contribution of JS, as well as the asymmetric behavior of unemployment, declined.[7] Interestingly, the current recession that started in December 2007 is a lot more pronounced and is witnessing a large increase in the job separation rate (Barnichon, 2009), consistent with the model's prediction. Therefore, treating JS as acyclical may be especially inappropriate in times of higher macroeconomic volatility.

The remainder of the paper is organized as follows: Section 2 discusses the importance

[6] The so-called "Great Moderation" refers to the dramatic decline in macroeconomic volatility enjoyed by the US economy since the mid 80s. (see, for example, McConnell and Perez-Quiros, 2000)

[7] Interestingly, Petrongolo and Pissarides (2008) show that the UK also experienced a remarkable decline in the contributions of JS, but only after 1993. This is consistent with the predictions of the model as the UK had its last large recession (excluding the current one) during the 1992-1993 EMS crisis.

of understanding fluctuations in the job separation rate; Section 3 documents three stylized facts about unemployment and its flows that the MP model has difficulties explaining; Section 4 presents a search model with a lumpy job separation rate and Section 5 confronts it with the data; Section 6 reviews the literature on the empirical performance of MP models with endogenous job destruction, and Section 7 offers some concluding remarks.

2 The importance of understanding unemployment inflows

In this section, I highlight a number of empirical points that suggest that job separation plays an important role in unemployment fluctuations and that assuming a constant job separation rate can lead to misinformed conclusions about the behavior of unemployment.

2.1 The small and declining contribution of unemployment inflows

In two influential papers, Shimer (2007) and Hall (2005) argue that the contribution of unemployment inflows to unemployment fluctuations is much smaller than the contribution of unemployment outflows, and more dramatically that fluctuations in the employment exit probability are quantitatively irrelevant in the last two decades. Indeed, Shimer (2007) shows that fluctuations in the job separation rate accounts for 25% of the variance of the cyclical component of unemployment over 1948-2007 but for only 5% over the last 20 years.[8] As a result, a large number of recent papers assume a constant separation rate when modeling search unemployment.[9] However, a contribution of 25 percent is not trivial. Furthermore, if assuming a constant separation rate seems reasonable over the last two decades, it brushes aside the reasons behind the decline in the contribution of JS since the mid-80s. Since the assumption's validity depends on whether the smaller contribution of JS is a permanent or temporary phenomenon, one needs to understand the reasons behind the decline in the importance of unemployment inflows.

[8] See also Elsby, Michaels and Solon (2009) and Fujita and Ramey (2008).

[9] Examples include Hall (2005), Shimer (2005), Trigari (2006), Hagedorn and Manovskii (2008), Costain and Reiter (2008), Blanchard and Gali (2008), Thomas (2008), Gertler and Trigari (2009), Barnichon (2010).

2.2 Gross hires tend to increase in recessions

Analyzing gross flows data, Blanchard and Diamond (1990), Fujita and Ramey (2006) and Elsby, Michaels and Solon (2008) show that the number of hires tends to *increase* in recessions while the job finding rate decreases. Since the flow from unemployment to employment is equal to the job finding probability times the number of unemployed, this implies that the pool of unemployed increases proportionately more than the flow. This observation is hard to reconcile with a constant job separation rate, but a burst of layoffs would increase unemployment independently of JF and could explain why unemployment increases faster than the job finding rate in recessions.

2.3 Unemployment displays asymmetry in steepness

An important characteristic of unemployment is its asymmetric behavior, and a large literature has documented a non-trivial asymmetry in steepness for the cyclical component of unemployment.[10] Put differently, increases in unemployment are steeper than decreases. Table 1 presents the skewness coefficients for the first-differences of monthly unemployment and industrial production.[11] Unemployment presents strong evidence of asymmetry in steepness but this is not the case of industrial production. As Table 2 shows, the job separation rate is highly positively skewed while the job finding rate presents little evidence of skewness. This suggests that an asymmetric mechanism such as job separation is driving the response of unemployment to shocks. Note also that, while JF has an almost normal kurtosis, JS presents a strongly positive excess kurtosis, suggesting that job separation is responsible for rare but violent fluctuations in unemployment.

Finally, Table 1 shows that the asymmetric behavior of unemployment became much weaker over 1985-2007. Again, before assuming a constant separation rate and no asymmetry in

[10]See, among others, Neftci (1984), Delong and Summers (1984), Sichel (1993) and McKay and Reis (2008) for evidence of asymmetry at quarterly frequencies.

[11]Following Sichel (1993), I report Newey-West standard errors that are consistent with the presence of heteroskedasticity and serial correlation up to order 8. The results do not change when allowing for higher orders.

unemployment, it is important to understand the reasons behind this phenomenon.

3 Unemployment transition probabilities and the MP model

The evidence presented in the previous section underscores the importance of understanding both unemployment flows; the outflows as well as the inflows. The Mortensen-Pissarides (1994) search and matching model with endogenous separation explicitly model both flows and is a natural candidate to study the determinants of unemployment. In this section, I study the empirical performances of the MP model with respect to unemployment and its flows.

3.1 Three facts about unemployment and its transition probabilities

I now highlight three stylized facts about unemployment and its transition probabilities. Table 3 summarizes the detrended US data for unemployment, vacancies, labor market tightness, job finding probability, job separation probability, hours per worker and real GDP over 1951-2006.

Fact 1: *The Beveridge Curve and the correlations between JF, JS and unemployment*

A well documented fact about the labor market is the strong negative relationship between unemployment and vacancies, the so-called Beveridge curve. At quarterly frequencies, Table 3 shows that the correlation equals -0.90 over 1951-2006. A point that has attracted less attention is the fact that JF is very highly correlated with unemployment (-0.95) but that this is less the case for the JS-unemployment correlation (0.61). Finally, the JF-JS correlation is negative and equals -0.48.

Fact 2: *The job separation rate is half as volatile as the job finding rate and is three times more volatile than output*

As Shimer (2007) first emphasized and as Table 3 shows, the employment exit probability is about 55% less volatile than the job finding probability. Moreover, JS and JF are respectively three times and six times more volatile than detrended real GDP.[12]

[12] The latter observation is similar to Shimer's (2005) finding that the job finding rate is roughly six times more volatile than detrended labor productivity.

Fact 3: *Movements in the job separation rate are sharp and short-lived while movements in the job finding rate are persistent and mirror the behavior of unemployment.*

Looking at the autocorrelation coefficients for the flow probability series from Shimer (2007) over 1951-2006, Table 3 shows that the employment exit probability is much less persistent than the job finding probability with respective coefficients equal to 0.65 and 0.91.

Fujita and Ramey (2007) document the cross-correlations of the job separation rate, the job finding rate, and unemployment at various leads and lags, and observe that while the job finding rate seems to move contemporaneously with unemployment, the job separation rate leads unemployment. This is apparent in Figure 1 which plots the cross-correlations using Shimer's (2007) data for the job separation probability and the job finding probability. In addition, while correlations with JF are spread symmetrically around zero, correlations with JS display a very strong asymmetry. The unemployment-job separation rate correlation decreases very fast at positive lags of unemployment and is virtually nil after one year. Using real GDP instead of unemployment, similar conclusions emerge. In addition, we can see that the employment exit probability leads GDP while the job separation probability lags GDP.[13]

Another way to assess the dynamic properties of unemployment and its transition probabilities is to consider the impulse response functions to technology shocks and monetary policy shocks in structural VARs. Following Barnichon (2010), Canova, Michelacci and Lopez-Salido (2008) and Fujita (2009), I use long-run restrictions in a VAR with output per hour, unemployment, job finding probability and employment exit probability over 1951-2006 as in Gali (1999) to identify the impact of technology shocks, and I use a VAR with a recursive ordering with unemployment, job finding probability, employment exit probability and the federal funds rate over 1960-2006 to estimate the effect of monetary policy shocks.[14] Figure 2 plots the impulse response functions to a positive technology shock and a monetary shock. In both cases, the

[13] Similarly, administrative data on New Claims for the Federal-State Unemployment Insurance Program (see e.g. Davis, 2008) are routinely used by forecasters as a leading indicator of the business cycle.

[14] For the two VARs, I use the same dataset as the one reported to construct Table 2. Labor productivity x_t is taken from the U.S. Bureau of Labor Statistics (BLS) over 1951:Q1 to 2006:Q4 and is measured as real average output per hour in the non-farm business sector. Following Fernald (2007), I allow for two breaks in $\Delta \ln x_t$, 1973:Q1 and 1997:Q1, and I filter unemployment, JF and JS with a quadratic trend.

employment exit probability is much less persistent than the job finding probability. Moreover, the job finding probability response mirrors that of unemployment while the employment exit probability response leads the response of unemployment and reverts to its long-run value a year before the other variables.

3.2 Confronting the MP models with the Facts

In this section, I examine whether the MP model can account for the stylized facts. A number of variants of the MP model have been developed since the seminal work of Mortensen and Pissarides (1994). This section focuses on the standard MP model but in Section 6, I review the different variants and study how they fare relative to the standard MP model.

To illustrate my statements, I log-linearize and simulate a calibrated version of a MP model with AR(1) productivity shocks. The model and its calibration are standard, and I leave the details for the Appendix. Figure 3 plots the impulse responses of labor market variables to a negative productivity shock, and Table 4 presents summary statistics for simulated data.

Fact 1 and *2* are difficult to reproduce, a point forcefully made by Ramey (2008) and Elsby and Michaels (2008). After calibrating the MP model with plausible idiosyncratic productivity shocks and parameter values, these authors find that the model generates a positive correlation between unemployment and vacancies and too much fluctuation in JS relative to JF. Indeed, Figure 3 shows a simultaneous increase in unemployment and vacancy posting. This positive correlation emerges because a (large) burst of layoffs generates higher unemployment which makes workers easier to find and stimulates the posting of vacancies. Table 4 confirms this result and shows that the unemployment-vacancy correlation is positive at 0.96. Figure 3 also shows the much stronger response of the job separation rate relative to that of the job finding rate, and looking at Table 4, the standard deviation of JF is only 0.013 while the standard deviation of JS is much higher at 0.096.

Turning to *Fact 3*, MP models generate counterfactually similar dynamic properties for the job finding rate and the job separation rate in response to AR(1) productivity shocks. As

Figure 3 shows, the response of the productivity threshold $\tilde{a}_t$ below which firm and worker decide to separate mirrors the response of the aggregate productivity shock A_t, and JS inherits the persistence of the aggregate shock. Further, the job finding probability depends directly on the vacancy-unemployment ratio via the matching function. As a result, the large and persistent increase in job separation leads to a persistent decrease in labor market tightness, and hence to a persistent fall in JF. Thus, JF and JS display very similar impulse responses and share the same autocorrelation coefficient (Table 4). However, Figure 2 shows that in the data, the job separation rate returns faster to its long run level than the job finding rate, and Table 3 shows that JS is a lot less persistent than JF.

4 A search and matching model with endogenous separation

4.1 The model

I develop a partial equilibrium model with aggregate demand constraints and aggregate demand shocks.[15] Since my goal is to evaluate the model along the labor market dimension, I follow a reduced-form approach that allows for more tractability and facilitates computation.[16]

This search model builds on Krause and Lubik (2007) in that it assumes large demand-constrained firms with many workers. However, unlike Krause and Lubik (2007), there is not a continuum of jobs within the firm with different productivity levels. Instead, workers are homogenous. When faced with lower than expected demand, firms can choose to layoff extra workers to save on labor costs.

[15] The assumption of aggregate demand constraints is made for convenience and is not central to the results of the paper, and the Appendix presents a similar model without demand constraints. Aggregate demand constraints allow to side-step a number of issues faced by more traditional search models with aggregate productivity shocks. The MP model generates too little unemployment volatility (Shimer, 2005), and while some calibrations circumvent that issue (Hagedoorn and Manovskii, 2006), this can be at the cost of unrealistic properties (Costain and Reiter, 2008). Moreover, the unemployment-productivity correlation has been positive over the last 25 years. This in contradiction with the transmission mechanism of a standard MP model with productivity shocks, but can be rationalized in a model with aggregate demand constraints (Barnichon, 2010).

[16] Thanks to the reduced-form approach, the model has only two state variables and is easier to solve numerically.

Firms and the labor market

I consider an economy populated by a continuum of households of measure one and a large representative firm. At each point in time, the firm needs to satisfy demand for its product y_{it}^d and hires N_{it} workers to produce a quantity

$$y_{it}^s = N_{it} h_{it}^\alpha \tag{1}$$

where I normalize the aggregate technology index to one, and h_{it} is the number of hours supplied by each worker and $0 < \alpha \leq 1$.[17]

In a search and matching model of the labor market, firms post vacancies at a unitary cost c (in units of utility of consumption), and unemployed workers search for jobs. Vacancies are matched to searching workers at a rate that depends on the number of searchers on each side of the market. I assume that the matching function takes the usual Cobb-Douglas form so that the flow m_t of successful matches within period t is given by $m_t = m_0 u_t^\eta v_t^{1-\eta}$where m_0 is a positive constant, $\eta \in (0,1)$, u_t denotes the number of unemployed and v_t=$\int_0^1 v_{it} di$ the total number of vacancies posted by all firms. Accordingly, the probability of a vacancy being filled in the next period is $q(\theta_t) \equiv m(u_t, v_t)/v_t = m_0 \theta^{-\eta}$ where $\theta_t \equiv \frac{v_t}{u_t}$ is the labor market tightness. Similarly, the probability for an unemployed worker to find a job is $JF_t = (u_t, v_t)/u_t = m_0 \theta_t^{1-\eta}$. Because of hiring frictions, a match formed at t will only start producing at $t+1$. Matches are terminated at an exogenous rate $\bar{\rho}$ but the firm can also choose to destroy an additional fraction ρ_{it} of its jobs, so that the average job separation rate is $JS_t = \bar{\rho} + \int \rho_{it} di$.

The timing of the model is similar to that of Krause and Lubik (2007). At the beginning of each period, a fraction $\bar{\rho} + \rho_{it}$ of the jobs are destroyed. The firm then begins production with $(1 - \rho - \rho_{it}) n_{it}$ workers and pays the corresponding wage bill, and at the end of the period,

[17] The model does not explicitly consider capital for tractability reasons but (1) can be rationalized by assuming a constant capital-worker ratio $\frac{K_{it}}{N_{it}}$ and a standard Cobb-Douglas production function $y_{it} = A_t \left(N_{it} h_{it}\right)^\alpha K_{it}^{1-\alpha}$. Assuming instead decreasing returns in employment does not change the conclusions of the paper. Similarly, assuming $\alpha = 1$ does not change any of the results.

$q(\theta_t)v_{it}$ matches are created. The law of motion for employment is given by

$$n_{it+1} = (1 - \bar{\rho} - \rho_{it})n_{it} + q(\theta_t)v_{it}$$

and the production function takes the form

$$y_{it}^s = (1 - \bar{\rho} - \rho_{it})\, n_{it} h_{it}^{\alpha}.$$

Households

I follow Merz (1995) and Andolfatto (1996) in assuming that households form an extended family that pools its income. There are $1 - n_t$ unemployed workers who receive unemployment benefits b in units of utility of consumption, and n_t employed workers who receive the wage payment w_{it} from firm i for providing hours h_{it}. Consequently, the value of unemployment U_t in terms of current consumption is

$$U_t = \frac{b}{\lambda_t} + E_t\beta_{t+1}\left[\theta_t q(\theta_t)\,(1 - JS_{t+1})\,W(w_{t+1}) + (1 - \theta_t q(\theta_t))U_{t+1} + \theta_t q(\theta_t) JS_{t+1} U(w_{t+1})\right]$$

and the value W_t from employment for a worker working for firm i in terms of current consumption is

$$W(w_{it}) = w_{it} - \frac{1}{\lambda_t}\frac{\lambda_h}{1 + \sigma_h} h_{it}^{1+\sigma_h} + E_t\beta_{t+1}[(1 - JS_{it+1})W(w_{t+1}) + JS_{it+1}U_{t+1}] \qquad (2)$$

where λ_h and σ_h are positive constants, $\lambda_t = \frac{1}{C_t}$ the marginal utility of consumption, C_t aggregate consumption and $\beta_{t+1} = \beta\frac{\lambda_{t+1}}{\lambda_t}$ the stochastic discount factor.

Wage bill setting

The firms and workers bargain individually about the real wage. To keep the model simple, it is assumed that the firm owns all the bargaining power and pays a wage equal to the worker's reservation wage $\underline{w}_{it}$.[18] The wage then takes the form[19]

$$w_{it} = \frac{b}{\lambda_t} + \lambda_h \frac{h_t^{1+\sigma_h}}{\lambda_t(1+\sigma_h)}. \tag{3}$$

The firm's problem

Firm i will choose a sequence of vacancies $\{v_{it}\}$ and job separation $\{\rho_{it}\}$ to minimize its expected present discounted cost of satisfying demand for its product $\{y_{it}^d\}$ subject to the law of motion for employment. Formally, the firm minimizes

$$\min_{\{v_{it},\rho_{it}\geq 0, n_{it}\}} E_t \sum_j \beta^j \frac{u'(C_{t+j})}{u'(C_t)} \left[\left(1-\bar{\rho}-\rho_{it+j}\right) n_{it+j} w_{it+j} + \frac{c}{\lambda_{t+j}} v_{it+j} \right]$$

subject to the demand constraint

$$y_{it}^d = \left(1-\bar{\rho}-\rho_t\right) n_{it} h_{it}^{\alpha}$$

the law of motion for employment

$$n_{it+1} = (1-\bar{\rho}-\rho_{it}) n_{it} + q(\theta_t) v_{it}$$

and taking the wage schedule as given.

Closing the model

The law of motion for aggregate demand is

$$\ln Y_t = \rho_y \ln Y_{t-1} + \varepsilon_t^y \quad \text{with } \varepsilon_t^y \sim N(0, \sigma^y)$$

[18]The Appendix presents the general case where the worker's bargaining power is $\gamma \in [0,1]$ and shows that the wage satisfies $w_t = \gamma \frac{c}{\lambda_t}\theta_t + (1-\gamma)\frac{b}{\lambda_t} + (1-\gamma)\varkappa \frac{h_t^{1+\sigma_h}}{\lambda_t}$ with $\varkappa$ a constant.

[19]Note that with CRRA utility, the real wage is procyclical despite the zero bargaining power of workers, and hence despite the absence of a direct feedback from labor market tightness to compensation. This happens because the real wage is proportional to the inverse of marginal utility of consumption and because $C_t = Y_t$ in equilibrium.

and since firms are identical, in equilibrium, $y_{it} = Y_t \ \ \forall\, i$. Averaging firms' employment, total employment evolves according to $n_{t+1} = (1 - \rho - \rho_{t+1})n_t + v_t q(\theta_t)$, and the labor force being normalized to one, the number of unemployed workers is $u_t = 1 - n_{t.}$ Finally, as in Krause and Lubik (2007), vacancy posting costs are distributed to the aggregate households so that $C_t = Y_t$ in equilibrium.

4.2 Dynamics of the model

I now present the first-order conditions for vacancy posting and job separation and discuss some properties of the model. Because hiring is costly and time consuming, a trade-off emerges between the intensive (h_{it})and the extensive (n_{it}) labor margin. Firms hoard labor and only fire workers when demand falls below a certain threshold. An increase in output volatility raises the contribution of unemployment inflows since firms are more likely to face large negative shocks and resort to the job separation margin.

The vacancy posting condition

Combining the first-order condition with respect to v_{it} with the Envelope condition with the state variable n_{it}, I get the optimal vacancy posting condition

$$\frac{c_t}{q(\theta_t)} = E_t \beta_{t+1}(1 - \bar{\rho} - \rho_{it+1}) \left[\chi_{it+1} + \frac{c_{t+1}}{q(\theta_{t+1})}\right] \tag{4}$$

with $c_t = \frac{c}{\lambda_t}$ and χ_t, the shadow value of a marginal worker, given by

$$\chi_{it} = -\frac{\partial n_{it} w_{it}}{\partial n_{it}} = -w_{it}\left(h_{it}\right) + \frac{1}{\alpha} h_{it} \frac{\partial w_{it}}{\partial h_{it}}$$

Each firm posts vacancies until the expected cost of hiring a worker $\frac{c_t}{q(\theta_t)}$ equals the expected discounted future benefits $\left\{\chi_{it+j}\right\}_{j=1}^{\infty}$ from an extra worker. Because the firm is demand constrained, the flow value of a marginal worker is not his contribution to revenue but his reduction of the firm's wage bill. The first term of χ_{it} is the wage payment going to an extra worker, while the second term represents the savings due to the decrease in hours and effort achieved with that extra worker. Indeed, looking at the wage equation (3), we can see that the firm can reduce hours per worker and lower the wage bill by increasing its number of workers. With $\chi_{it} > 0$, the marginal worker reduces the cost of satisfying a given level of demand.[20]

Using the wage equation (3),the marginal worker's value becomes

$$\chi_{it} = -\frac{b}{\lambda_t} + \left(\frac{1+\sigma_h}{\alpha} - 1\right) \lambda_h \frac{h_{it}^{1+\sigma_h}}{\lambda_t\left(1+\sigma_h\right)}. \tag{5}$$

Since $h_{it} = \left(\frac{y_{it}^d}{(1-\bar{\rho}-\rho_{it})n_{it}}\right)^{\frac{1}{\alpha}}$ and n_{it} is a state variable, the firm relies on the intensive margin to satisfy demand in the short-run, and the level of hours per worker captures "demand pressures" and the firm's incentives to post vacancies. With $\frac{1+\sigma_h}{\alpha} > 1$, the longer hours are, the larger is the wage bill reduction obtained with an extra worker. As hours increase because of higher demand for the firm's products, the worker's marginal value increases, and the firm posts more vacancies to increase employment.[21]

The job separation condition

The job separation condition is given by

$$\begin{cases} \frac{\partial(1-\bar{\rho}-\rho_{it})n_{it}w_{it}}{\partial\rho_{it}} = -n_{it}E_t\beta_{t+1}(1-\bar{\rho}-\rho_{it+1})\left[\chi_{it+1} + \frac{c_{t+1}}{q(\theta_{t+1})}\right] & \text{if } \rho_{it} > 0 \\ \text{or } \rho_{it} = 0 \end{cases}$$

[20] Similarly to Woodford's (2004) New-Keynesian model with endogenous capital, the marginal contribution of an additional worker is to reduce the wage bill through substitution of one input for another. Here, the intensive and the extensive margins are two different inputs. The former is flexible but costly, while the latter takes time and resources to adjust. The firm chooses the combination of labor margins that minimizes the cost of supplying the required amount of output.

[21] $\frac{1+\sigma_h}{\alpha} - 1$ measures the difference between the two labor inputs (the intensive and the extensive margins) in terms of the cost of providing the required amount of output. The intensive margin displays decreasing returns with $\alpha<1$ and its cost increases at the rate $1+\sigma_h$ so that the cost of producing a given quantity y_{it}^d increases at the rate $\frac{1+\sigma_h}{\alpha} > 1$. For the extensive margin, on the other hand, both output and costs increase linearly, so that the rate is one. The larger the difference between the two rates, the stronger is the firm's incentive to avoid increases in hours per worker, and the more volatile are vacancy posting and unemployment.

that I can rewrite using the vacancy posting condition (4) as

$$-\chi_{it} = \frac{c_t}{q(\theta_t)} \qquad \text{if } \ \rho_{it} > 0. \tag{6}$$

Because hiring is costly, the firm hoards labor and does not lay-off workers with a small negative marginal value. If $-\frac{c_t}{q(\theta_t)} \leq \chi_{it} \leq 0$, the marginal value is negative but the firm still prefers to keep its workers to avoid having to rehire them later. In this case, $\rho_{it} = 0$ and v_t satisfies (4). The firm will only fire workers when demand is so low that the marginal value of firing a worker $-\chi_{it}$ is large enough to equal the cost of hiring a worker (or equivalently, the expected benefit of keeping that worker). Formally, the firm will fire workers when $\chi_{it} < -\frac{c_t}{q(\theta_t)}$, and ρ_{it} and v_{it} will satisfy the system defined by (4) and (6).

Furthermore, (6) implies that there cannot be any endogenous separation in steady state, so that the firm *must* post vacancies to increase employment. In steady-state, because of a constant rate of attrition $\bar{\rho}$, the firm must replenish its stock of workers by constantly posting a minimal number of vacancies. This implies that the firm is satisfying its vacancy posting condition, and from (4), the steady-state marginal value of a worker is $\chi^* = \frac{c}{\beta q(\theta^*)}\left(1 - \beta(1-\bar{\rho})\right)$. Since $\chi^* > 0$, the firm does not satisfy its job separation condition and $\rho = 0$, so that $JS^* = \bar{\rho}$. Thus, starting from the steady-state equilibrium, a positive shock does not lead to less firing because the firm cannot lower $\rho_t \geq 0$ (i.e. keep workers that it would have otherwise fired) and must use the job creation margin.

To visualize the mechanisms driving vacancy posting and job separation, Figure 4 plots the relationship between the marginal value of a worker and hours per worker, a proxy for "demand pressure". In steady-state, the value of a marginal worker is positive and equals the net cost of hiring. When demand goes up, hours per worker increase and with them the marginal value of a worker, leading the firm to post more vacancies. For small negative shocks such that $-\frac{c_t}{q(\theta_t)} \leq \chi_{it} \leq 0$, the firm hoards labor and posts fewer vacancies. For large negative shocks, however, $\chi_{it} \leq -\frac{c_t}{q(\theta_t)}$, and the firm uses the job separation margin, and one can observe a burst of layoffs.

Finally, an implication of labor hoarding is that an increase in output volatility raises the contribution of the job separation rate to unemployment fluctuations since the firm is more likely to face large negative shocks and resort to the job separation margin. For the same reason, the asymmetric behavior of unemployment will be less pronounced in times of lower output volatility.

5 Confronting the model with the data

In this section, I study whether a calibrated version of the model generates realistic impulse response functions, can quantitatively account for the stylized facts about unemployment and its transition probabilities, and can rationalize the small and declining contribution of unemployment inflows, the increase in gross hiring during recessions as well as the weaker asymmetry in unemployment since 1985.

5.1 Calibration

First, I discuss the calibration of the model; and Table 5 lists the parameter values. Whenever possible, I use the values typically used in the literature. I assume a monthly frequency, as a monthly calibration is better able to capture the high rate of job finding in the US. I set the monthly discount factor β to 0.99^3 and the returns to hours α to 0.65. Turning to the labor market, I set the matching function elasticity to $\eta = 0.72$ as in Shimer (2005). I set the exogenous component of the separation rate to 0.032, which is the average value of the 5-year rolling lower-bound of Shimer's (2007) employment exit probability series.[22] A worker finds a job with probability $\theta q(\theta) = 0.3$ so that equilibrium unemployment equals 10 percent.[23]

[22] Recall that endogenous separation cannot be negative in the model, so that the empirical counterpart of the exogenous job separation rate $\bar{\rho}$ is the lower bound of JS. Since JS displays low-frequency movements (see e.g. Davis, 2008) that I abstract from in this paper, I estimate $\bar{\rho}$ as the mean of the 5-year rolling lower-bound of JS. The results of the paper do not rely on this particular estimate of $\bar{\rho}$.

[23] A steady-state unemployment equal to 10 percent is reasonable if, as in Merz (1995), Andolfatto (1996), den Haan, Ramey, and Watson (2000) and others, model unemployment also includes those individuals registered as inactive that are actively searching.

The scale parameter of the matching functions m_0 is chosen such that, as in den Haan and Kaltenbrunner (2009), a firm fills a vacancy with a probability $q(\theta) = 0.34$. Shimer (2005) sets the income replacement ratio to 40 percent, so that with a labor income share of 65 percent, the unemployment benefits-output ratio $b = 0.28$. The steady-state ratio of vacancy-posting costs to GDP is set to 1% following most of the literature.[24] As in Trigari (2009) and Christoffel, Kuester and Linzert (2006), I choose $\sigma_h = 10$, i.e. an hours per worker elasticity of 0.1.[25] Finally, I set the standard deviation of output shocks $\sigma^y = 0.0079$ and the first-order coefficient $\rho_y = 0.93$ to match the persistence and volatility of HP-detrended real GDP, converted to monthly frequency. I numerically solve the model using policy function iterations with intergrid cubic spline interpolation on a grid with $(30, 30)$ points for (n_t, y_t). Employment n_t is discretized over $[0.8, 1]$, and I follow Tauchen (1986) to construct the transition matrix for y_t. The Appendix describes the numerical algorithm used to solve the firm's problem.

5.2 Impulse response functions

Figure 5 and 6 show the simulated impulse response functions of unemployment, hours per worker, the job finding rate, and the job separation rate after respectively a positive and a negative one standard-deviation aggregate demand shock. The asymmetric nature of the labor market is clearly apparent. Following a positive aggregate demand shock, unemployment declines progressively while hours per worker react on impact. After two quarters, hours per worker are back to their long-run value while unemployment starts its mean reversion. After a negative shock, however, unemployment responds on impact because of a burst of layoffs. Thanks to the strong response of the job separation rate, firms rely less on their intensive margin and make a smaller adjustment to their number of posted vacancies. Note that vacancy posting decreases but does not drop to zero, so that the firms are simultaneously firing and posting vacancy. This is due to the AR(1) structure of the shocks hitting the economy. Since

[24] See e.g. Andolfatto (1996), Blanchard and Gali (2006) and Gertler and Trigari (2009).

[25] Cooper, Haltiwanger and Willis (2008) use a lower value for σ_h. In the Appendix, I present a robustness exercise where I allow for a higher hours per worker elasticity of 0.5 ($\sigma_h = 2$).

hiring takes one period and since shocks are mean-reverting, the firm anticipates the need for future higher employment and post vacancies (albeit less so than in normal times) to satisfy the expected increase in demand next period.[26]

Because it is costless to adjust the number of workers through the separation margin, layoffs show no persistence: firms fire as many workers as necessary, and endogenous job separation reverts quickly to zero. The job finding rate, on the other hand, is persistent and mirrors the behavior of unemployment after two quarters.

An increase in job separation does not lead to an increase in vacancy postings, and unemployment and vacancy are negatively correlated. The intuition for these results is as follows. Looking at Figure 4, firms use the job separation margin when the marginal value of a worker falls below $-\frac{c_t}{q(\theta_t)}$. However, after this burst of layoffs, the marginal value of a worker lies at the boundary between the labor hoarding region and the lay-off region since $\chi_t = -\frac{c_t}{q(\theta_t)}$. This implies that if aggregate demand is persistent, the worker's marginal value in the next period will not be far off the labor hoarding-layoff threshold, and there will not be another large burst of layoffs. Since the labor hoarding-layoff boundary is located in a region in which firms lower the number of posted vacancies, the firm is unlikely to post more vacancies as it lays off workers.[27]

The existence of a Beveridge curve in the present framework contrasts with the MP model (see Figure 3) or its extensions with demand constraints (e.g., Walsh (2005), Krause and Lubik (2007) or Trigari (2009)). In all search models, an increase in the job separation rate reduces labor market tightness θ_t, which makes hiring cheaper. However, in an MP-type model, this effect is compounded by the fact that, as matches increase their productivity threshold below

[26] This result can be proven by contradiction. If vacancy posting dropped to zero after a large adverse demand shock, labor market tightness would drop to zero, and hiring cost would be null. With no hiring frictions, the firm has no reason to hoard labor, the problem becomes static and the firm fires as many workers as necessary to satisfy its current period optimal allocation between hours per worker and number of workers. The firm would then layoff enough workers to satisfy (6), i.e. $\chi_t = 0$. However, with a mean-reverting shock, the firm expects higher demand next period, will need more workers and therefore posts vacancies (at no cost since $\theta = 0$). In addition, the firm will post vacancies to replace the jobs that were exogenously destroyed. This contradicts my initial assumption, so that labor market tightness cannot be zero.

[27] However, this is not necessarily the case if the shock is not persistent. In that case, $\{\chi_{it}\}$ is more likely to shift quickly from negative values (with firing) to positive values (with more vacancies).

which job termination occurs, the expected productivity of a marginal worker increases, which further stimulates vacancy posting. This second effect is quantitatively important in calibrated versions of MP models (e.g., Ramey, 2009) because, in order to match the volatility of JS, MP-type models require a large volatility of idiosyncratic shocks, which generates large movements in expected productivity.[28]

Figure 7 shows that the model is consistent with the fact that gross hiring tends to *increase* during recessions and with Fujita's (2009) empirical impulse response for gross hires. A burst of layoffs decreases labor market tightness and lowers hiring costs as the expected cost of filling a vacancy declines. This leads the firm to profit from an exceptionally low labor market tightness to increase new hires: the job finding rate goes down but less than unemployment, and hiring increases. An interesting implication of the model is that this phenomenon becomes stronger with the size of the shock. As Figure 7 illustrates, the larger the adverse demand shock, the more the firm resorts to the job separation margin, the more labor market tightness decreases and the stronger is the firm's incentive to profit from lower hiring costs by increasing gross hires.

5.3 Simulation

Using a calibrated version of the model, I simulate 600 months (i.e. 50 years) of data, and I repeat this exercise 500 times. I first evaluate the model by considering the moments of simulated data to test whether the model is consistent with the three facts about unemployment and its transition probabilities. Then I study whether the model can account for the small and declining contribution of unemployment inflows, as well as the fact that unemployment displays no steepness asymmetry since 1985.

Table 6 presents the summary statistics for quarterly averages of the monthly series. A general conclusion is that given the model simplicity and its small number of parameters,

[28] A fruitful avenue for future research would thus be to combine workers heterogeneity and the existence of an inaction band for the job separation margin. In this regard, considering the case of a discrete productivity distribution of workers in which the job separation rate is constant in steady-state would be an interesting extension of the present model.

the model is remarkably successful at explaining the behavior of labor market variables: the moments all have the correct sign and are close to their empirical values.[29] First, the model has no problem generating *Fact 1*, i.e. a Beveridge curve and a negative job finding rate-job separation rate correlation. The model can also explain the *strong* unemployment-vacancies correlation (-0.81 versus -0.90 in the data) as well as the *weaker* JF-JS correlation (-0.59 versus -0.48 in the data). Similarly, and consistent with the data, the model generates a high job finding rate-unemployment correlation (-0.91 versus -0.95 in the data) and a smaller job separation rate-unemployment correlation (0.47 versus 0.61 in the data). These results stem from the asymmetric nature of the labor market and the fact that firms can adjust employment with the job creation margin at all times but can only use the job separation margin for negative demand shocks. For positive demand shocks, the job separation rate does not move and the correlation with unemployment or the job finding rate is nil. As a result, the JS-unemployment correlation and the JF-JS correlation are closer to a half than to one.

Table 6 also shows that the model is consistent with *Fact 2*, as the job finding rate is more volatile than the job separation rate.[30] JF is slightly too volatile, a problem with search models of unemployment already pointed out by Fujita and Ramey (2004). This is due to the excessively rapid response of vacancies; and incorporating sunk costs for vacancy creation as in Fujita and Ramey (2004) would presumably correct this shortcoming. Finally, the job separation rate's volatility is close to its empirical value. Unlike standard MP models, the separation margin is only used for large negative shocks as firms hoard labor and only use the job separation margin for large negative shocks.

[29] It is important to note that I am only focusing on labor market variables. As long as aggregate demand constraints persist long enough so that my model is a correct description of firms' labor demand in the short-run, I can judge of the model's success by considering the unconditional moments of labor market variables.

[30] The fact that the model can match the relative volatilities of unemployment and output follows from the assumption of demand constraints and high disutility cost of hours per worker. In order to satisfy an expanding demand, firms must increase either their extensive or their intensive margin. Since the intensive margin is relatively costly because of the high disutility cost of longer hours, most of the adjustment occurs through employment. From the log-linearized production function $\hat{y} = \alpha\hat{h} - \frac{1-u}{u}\hat{u}$, unemployment will be roughly 10 times more volatile than output (with an unemployment rate around 10 percent) if $\hat{h}$ is small. While the model takes the existence of demand constraints as given, the fact that the model can match the relative volatility of hours and employment in the data suggests that this mechanism may be important to understand the Shimer puzzle (2005).

Turning to *Fact 3* and the dynamic properties of JF and JS, Figure 8 shows that the model is very successful at reproducing the cross-correlograms of JF, JS and unemployment. JS is not persistent enough as most of the adjustment along the job separation margin takes place in one period, but assuming convex costs in firing would probably correct this shortcoming. JF is slightly less persistent than in the data, and this is again due to excessively rapid response of vacancies. Finally, the low persistence of model JF and JS explains the low persistence of model hours per worker as the intensive margin adjusts to movements in employment to ensure that the firm satisfies demand at all times.

To measure the contribution of JF and JS, I follow Shimer (2007), Elsby et al. (2008) and Fujita and Ramey (2008), and Table 7 shows that the contribution of JS amounts to 22%, only slightly lower than the contribution measured by Shimer (2007). In contrast, in the MP model, the contribution of JS is way too high (about 80% using the MP model from Appendix A1) because JS fluctuates constantly and always contributes to movements in unemployment. The present model escapes this problem because JS is constant most of the time but displays rare and violent bursts. Importantly, this last feature of the model is consistent with the data, and Table 2 shows that the model does a good job at capturing the high skewness and kurtosis of JS. In addition, the model captures the fact that JF presents no strong departure from normality.

5.4 The weaker contribution of JS since 1985

We saw in Section 2 that the contribution of JS to the variance of unemployment declined from about 25 percent during the post-war period to only 5 percent over the last 20 years (Shimer, 2007). Moreover, the steepness asymmetry in unemployment disappeared after 1985.

The model implies that these two findings are by-products of the Great Moderation, the period of low macroeconomic volatility enjoyed by the US (and other developed countries) over 1985-2007. One insight from section 4 was that a decrease in output volatility lowers the contribution of JS and the asymmetry in unemployment as firms are less likely to face large negative shocks and resort to the job separation margin. Figure 6 shows this effect quantitatively. As the size of the shock doubles from one half to one standard-deviation of detrended GDP, the response of JS on impact more than doubles, and unemployment shows a stronger initial response. The hours per worker response, on the other hand, does not increase with the size of the shock.

To evaluate whether the decline in macroeconomic volatility can explain the weaker contribution of JS, I estimate the contribution of JS and JF on simulated data with an output volatility of $\frac{\sigma^y}{2}$, consistent with the drop in volatility experienced by the US during the Great Moderation. As Table 7 shows, the contribution of JS decreases to 14%, suggesting that the Great Moderation is responsible for some of the decline in the contribution of JS.[31]

Finally, looking at Table 7, the skewness of model unemployment also declines sharply when the volatility of output decreases, suggesting that the Great Moderation is responsible for some of the decline in the asymmetry of unemployment. With an output volatility of σ^y, the skewness of model unemployment is 0.53, close to its empirical counterpart of 0.62. But with a standard-deviation of output is $\frac{\sigma^y}{2}$, model unemployment shows no evidence of asymmetry, consistent with the US experience.

6 Related literature

In Section 2, I mainly focused on the canonical Mortensen-Pissarides (1994) search and matching model. However, a number of variants of the MP framework have been used to model unemployment. In this section, I review the literature on the different variants and their empirical performances.

First, while the original MP model assumes persistent idiosyncratic productivity shocks, the computational cost associated with keeping track of the jobs' productivity distribution lead

[31] This is not necessarily the only explanation. The increased availability of flexible labor service such as part-time work and temporary work or the switch from manufacturing to services are probably also responsible for the decline in the contribution of the job separation rate. See, for example, Schreft, Sing and Hodgson (2005).

many researchers to assume instead i.i.d. idiosyncratic productivity shocks. Indeed, only a few papers solved the original MP model with endogenous separation (Mortensen-Pissarides (1994), Ramey (2008), Elsby and Michaels (2008), Pissarides (2008)), but a vast literature has solved rich general equilibrium models with search unemployment and i.i.d. idiosyncratic productivity shocks: Den Haan, Ramey and Watson (2000), Costain and Reiter (2008), Walsh (2005), Thomas (2006), Krause and Lubik (2007), Cooper, Haltiwanger and Willis (2008), Thomas and Zanetti (2008), Trigari (2009) among others.

Second, variants of the MP model can be classified in two categories, depending on whether firms are atomistic with only one worker or large with many workers. In their seminal paper, Mortensen and Pissarides (1994) assume the existence of a finite mass of workers and of an *infinite* mass of atomistic firms. Each non-matched firm can post a vacancy to form a match with one worker only. Another line of research departs from the assumption of free entry and atomistic firms to model instead a *finite* number of large firms with a continuum of jobs. This approach has the advantage of allowing for a more realistic representation of the firm as well as providing a framework to study the interaction of labor market frictions with other frictions such as nominal rigidities. While the majority of papers pursued the first approach, Krause and Lubik (2007) provide a tractable example of the second approach in which the firms' production function displays constant returns to employment. While aggregation is more difficult with decreasing returns to employment, Elsby and Michaels (2008) present an analytically tractable model while Cooper, Haltiwanger and Willis (2008) solve and estimate a similar model with numerical methods.

Krause and Lubik (2007), for MP models with large firms, and Costain and Reiter (2008), Thomas (2006), Ramey (2008) and Elsby and Michaels (2008), for MP models with atomistic firms, make the case that *Fact 1* is difficult to reproduce. Standard MP models are unable to replicate the Beveridge curve because a burst of layoffs generates higher unemployment which makes workers easier to find, stimulating the posting of vacancies. Krause and Lubik (2007) show that introducing real wage rigidity allows the model to generate a Beveridge curve. However, the model cannot reproduce *Fact 2* as "firms adjust almost exclusively via the separation rate and job creation does not play a quantitatively significant role" (Krause and Lubik, 2007, p724). Ramey (2008) shows that a search model with on the job search can generate a Beveridge curve. However, that model cannot reproduce *Fact 2* as it generates too much volatility in the job destruction rate compared to the job finding rate (Ramey, 2007, Figure 1). Thomas (2006) shows how firing costs help the MP model in generating a Beveridge curve. However, his model cannot generate *Fact 3* as the impulse response of JF counterfactually mirrors that of JS.

While fewer papers other than Ramey (2008) and Elsby and Michaels (2008) focused on *Fact 2*, Krause and Lubik (2007) show that in MP models with large firms, the job separation rate moves too much compared to the job finding rate. This is not the case in MP models with instantaneous hiring and firing costs (Thomas and Zanetti, 2008) and in MP models with an intensive labor margin (Trigari, 2009). However, both of these models cannot generate *Fact 3*: the impulse response of JF counterfactually mirrors that of JS, displays no persistence and overshoots its long-run value.

Finally, a very promising line of research is the work from Cooper, Haltiwanger and Willis (2008) and Elsby and Michaels (2008). By considering large firms with decreasing returns to employment and idiosyncratic productivity shocks, they show that such generalized MP models can generate a Beveridge curve. Elsby and Michaels (2008) show that their model can generate elasticities of JS and JF with respect to productivity that are consistent with the data. However, it is difficult to confront these models with the last two stylized *Facts* as Cooper et al (2008) do not focus on unemployment flows and Elsby and Michaels' (2008) model has only two aggregate productivity states.

7 Conclusion

This paper argues that a key feature of the labor market, the asymmetric and lumpy behavior of the job separation rate could be responsible for the empirical properties of labor market flows, and for some of the failures of the standard MP model. I present a search model with an asymmetric and lumpy job separation rate, that can account for both the outflows and the inflows of unemployment. Despite a relatively small number of parameters, the model is successful at explaining the behavior of labor market variables and is consistent with a low, but non-trivial, contribution of JS to unemployment fluctuations. In contrast, the benchmark framework, the MP model with endogenous job separation, has difficulties explaining the low contribution of JS as well as other stylized facts.

The model interprets the decline in the contribution of JS and the weaker asymmetry in unemployment since 1985 as by-products of the Great Moderation. It also implies that the lower contribution of JS was a temporary phenomenon and that the importance of JS would increase in times of higher macroeconomic volatility such as the in current (since December 2007) recession.

While accounting for the asymmetric and lumpy behavior of the job separation rate shows promises towards an equilibrium model of unemployment with endogenous outflows and inflows, an important extension would be to capture the behavior of JS as well as firms/workers heterogeneity. Moreover, embedding the model in a general equilibrium framework would allow to study the implications of labor market asymmetries on output and inflation. Because increasing employment is more costly than lowering employment, firms tend to adjust prices rather than quantities after positive monetary shocks but do the opposite after monetary contractions. As a result, monetary policy would have a stronger ability to lower, than to raise, output. I leave these topics for future research.

Appendix:

A.1 A Mortensen-Pissarides (1994) model with i.i.d. idiosyncratic productivity shocks

I follow Thomas (2006), and I present an MP model with a finite mass of workers and an *infinite* mass of atomistic firms. Each non-matched firm can post a vacancy to form a match with one worker only.[32] Workers are hired from the unemployment pool through a costly and time-consuming job creation process. Firms post vacancies at a unitary cost c, and unemployed workers search for jobs. Vacancies are matched to searching workers at a rate that depends on the number of searchers on each side of the market. The matching function takes the usual Cobb-Douglas form so that the flow m_t of successful matches within period t is given by $m_t = m_0 u_t^{\eta} v_t^{1-\eta}$. Accordingly, the probability of a vacancy being filled in the next period is $q(\theta_t) \equiv m(u_t, v_t)/v_t = m_0 \theta^{-\eta}$ where $\theta_t \equiv \frac{v_t}{u_t}$, and the probability for an unemployed worker to find a job is $p(\theta_t) = (u_t, v_t)/u_t = m_0 \theta_t^{1-\eta}$.

In this economy, jobs are subject to idiosyncratic productivity shocks drawn from a distribution with the log-normal cdf $F(a)$ with standard-deviation σ_a, and there exists a threshold productivity $\tilde{a}_t$ such that all jobs with productivity below it yield a negative surplus are destroyed. Therefore, total separation rate is $JS_t = \bar{\rho} + (1 - \bar{\rho})F(\tilde{a}_t)$ with $\bar{\rho}$ the exogenous separation rate, and the law of motion for employment is $n_t = (1 - JS_t)n_{t-1} + m(u_{t-1}, v_{t-1})$.

New jobs have maximum productivity a^N. The value of continuing a match with idiosyncratic productivity a_t and aggregate productivity A_t is given by

$$J_t(a_t) = A_t a_t - w_t(a_t) + E_t \beta (1 - \bar{\rho}) \int_{\tilde{a}_{t+1}}^{\infty} J_{t+1}(a) dF(a).$$

The assumption of free entry and exits of firms ensures that the value of posting a vacancy is zero so that

$$V_t = 0 = -c + q(\theta_t) E_t \beta J_{t+1}(a^N).$$

[32] I thank Carlos Thomas for providing his Matlab code used in Thomas (2006).

The value that a worker enjoys from holding a job with productivity a_t is given by

$$W_t(a_t) = w_t(a_t) + E_t\beta\left[(1-\bar{\rho})\int\limits_{\tilde{a}_{t+1}}^{\infty} J_{t+1}(a)dF(a) + \rho_{t+1}U_{t+1}\right]$$

and the value of being unemployed is

$$U_t = b + E_t\beta\left[p(\theta_t)W_{t+1}^N + (1-p(\theta_t))U_{t+1}\right].$$

In each period, firm and worker Nash bargain over the real wage and we have $w_t(a_t) = \gamma A_t a_t + c\theta_t + (1-\gamma)b$.

The familiar job destruction condition is then given by $J_t(\tilde{a}_t) = 0$ or

$$A_t\tilde{a}_t - b - \frac{\gamma}{1-\gamma}c\theta_t + E_t\beta(1-\rho)\int\limits_{\tilde{a}_{t+1}}^{\infty} A_{t+1}(a-\tilde{a}_{t+1})dF(a) = 0$$

and the job creation condition takes the form

$$\frac{c}{q(\theta_t)} = (1-\gamma)E_t\beta\left[A_{t+1}(a^N - \tilde{a}_{t+1})\right].$$

I then solve the model by log-linearizing around the steady-state. For the calibration, I use the same parameter values as in this paper's model (see Table 5) whenever possible. For other parameters, I follow Thomas (2006). The aggregate productivity shock A_t follows an AR(1) process such that $\ln A_t = \rho_A \ln A_{t-1} + \varepsilon_t$ with $\rho_A = 0.95$ and the standard-deviation σ^A calibrated to match the cyclical volatility of detrended US real output. Idiosyncratic productivity $\ln a_t$ has mean $\mu_a = 0$ and standard-deviation $\sigma^a = 0.22$ as in Ramey (2008) and Elsby and Michaels (2008).

A.2 A search model with homogenous firms and endogenous separation

In this section, I present a search and matching model with homogenous agents and endogenous separation. Unlike the model of the main text, this model follows the tradition of search and matching models with aggregate productivity shocks. The economy is populated by large firms and homogenous workers, but, unlike the simple MP model with exogenous separation (Pissarides, Chapter 1, 2001), matches can be terminated when aggregate productivity is too low.

Consider an economy populated by a continuum of households of measure one and a large representative firm. The firm hires N_{it} workers to produce a quantity[33]

$$y_{it} = A_t N_{it}^{\alpha}.$$

Keeping the same labor market structure as in the paper, the law of motion for employment is given by $n_{it+1} = (1 - \bar{\rho} - \rho_{it})n_{it} + q(\theta_t)v_{it}$ and the production function takes the form

$$y_{it}^{s} = A_t \left(\left(1 - \bar{\rho} - \rho_{it}\right) n_{it} \right)^{\alpha}.$$

As in the main text, to keep the model simple, I assume that the firm owns all the bargaining power and pays a wage equal to the worker's reservation wage, so that the wage is $w_{it} = b$. Unlike the model with aggregate demand constraints from the main text, unemployment benefits are constant in this model. This assumption is similar to Pissarides (2000, Chapter 1) and ensures that the wage does not absorb all movements in productivity, and that productivity shocks have a non-trivial effect on the unemployment rate.

Firm i will choose a sequence of vacancies $\{v_{it}\}$ and job separation $\{\rho_{it}\}$ to maximize its expected present profit subject to the law of motion for employment. Formally, the firm

[33] For simplicity, I omit the intensive labor margin. This does not change any of the results.

maximizes

$$\max_{\{v_{it},\rho_{it}\geq 0,n_{it}\}} E_t \sum_j \beta^j \frac{u'(C_{t+j})}{u'(C_t)} \left[A_t \left((1-\bar{\rho}-\rho_{it})\, n_{it}\right)^{\alpha} - \left(1-\bar{\rho}-\rho_{it+j}\right) n_{it+j} w_{it+j} - c_t v_{it+j}\right]$$

with $c_t = cA_t$ as in Pissarides (Chapter1, 2001) and the law of motion for employment $n_{it+1} = (1-\bar{\rho}-\rho_{it})n_{it} + q(\theta_t)v_{it}$. Finally, the law of motion for aggregate productivity is

$$\ln A_t = \rho_a \ln A_{t-1} + \varepsilon_t^a \quad \text{with } \varepsilon_t^a \sim N(0,\sigma^a).$$

The vacancy posting condition takes the form

$$\frac{c_t}{q(\theta_t)} = E_t\beta_{t+1}\left[\alpha A_{t+1}(1-\bar{\rho}-\rho_{t+1})^{\alpha} n_{t+1}^{\alpha-1} - w_t + (1-\bar{\rho}-\rho_{t+1})\frac{c_{t+1}}{q(\theta_{t+1})}\right]$$

and the job separation condition

$$\begin{cases} A_t\alpha(1-\bar{\rho}-\rho_t)^{\alpha-1}n_t^{\alpha-1} - w_t = -\frac{c_t}{q(\theta_t)} & \text{if } \rho_t > 0 \\ \text{or } \rho_t = 0 \end{cases} \tag{7}$$

Defining $\chi_t = A_t\alpha(1-\bar{\rho}-\rho_t)^{\alpha-1}n_t^{\alpha-1} - w_t$, one can rewrite (7) as $\chi_t = -\frac{c_t}{q(\theta_t)}$ if $\rho_t > 0$, so that the job separation rate remains constant unless $\chi_t < -\frac{c_t}{q(\theta_t)}$, i.e. unless aggregate productivity falls below a certain level.

The parameters are calibrated as in the main text and the productivity shocks satisfy $\sigma^a = 0.0044$ and $\rho_a = 0.90$ to match the persistence and volatility of HP-detrended labor productivity. By giving all the bargaining power to the worker, the calibration is close to that of Hagedorn and Manovskii (2008) who set $b = 0.95w$ and $\gamma = 0.05$. Table A2 shows that the model does a reasonable job at capturing the volatility of the labor market variables (albeit slightly too volatile). As in the main model, the existence of an inaction band improves substantially the performance of the standard MP model. The job separation rate is substantially less volatile than the job finding rate. In fact, a decomposition exercise shows that the job separation rate accounts for 27 percent of the volatility of unemployment, while the job finding rate accounts for the rest. To simulate the effect of the Great Moderation on the contribution of JS, I consider a reduction in the volatility to productivity consistent with the drop in volatility experienced by the US during the Great Moderation, and I find that the contribution of JS declined to 16 percent.

Table A2: Search model with lumpy job separation and aggregate productivity shocks

		u	*v*	*θ*	*jf*	*js*
Standard deviation		0.201	0.515	0.678	0.190	0.079
Quarterly autocorrelation		0.82	0.52	0.66	0.67	0.33
Correlation matrix	*u*	1	-0.75	-0.86	-0.87	0.60
	v	-	1	0.98	0.98	-0.68
	θ	-	-	1	1.00	-0.69
	jf	-	-	-	1	-0.70
	js	-	-	-	-	1

Notes: Standard errors -the standard deviation across 500 model simulations over 600 months- are reported in parentheses.

A.3 Computation

I solve the model with policy function iteration by simultaneously solving the two first-order conditions for vacancy posting and job destruction:

$$\frac{c_t}{q(\theta_t)} = E_t\beta_{t+1}\left[(1-\rho_{t+1})\chi_{t+1} + \frac{c_{t+1}}{q(\theta_{t+1})}(1-\bar{\rho}-\rho_{t+1})\right] \quad (8)$$

$$-\chi_t = \frac{c_t}{q(\theta_t)} \text{ if } \chi_t < 0 \quad (9)$$

with $\chi_t = -\frac{b}{\lambda_t} + \left(\frac{1+\sigma_h}{\alpha} - 1\right)\lambda_h \frac{h_t^{1+\sigma_h}}{\lambda_t(1+\sigma_h)}$ the value of a marginal worker.

I use policy function iterations with intergrid cubic spline interpolation on a grid with $(30, 30)$ points for the two state variables n_t and y_t. Employment n_t is discretized over $[0.8, 1]$, and I follow Tauchen's method (1986) to represent the AR(1) process y_t as a Markov chain. Since employment will only rarely take extreme values, I allow for a higher grid density for employment around its steady-state value.

The general algorithm is as follows:

1. Guess policy functions for $\theta_0(n_i, y_j)$ and $\rho_0(n_i, y_j)$ and interpolate their values with intergrid cubic spline interpolation for points not on the grid

2. For all n_i and y_j:

a. If $-\chi(\theta_0(n_i, y_j), \rho_0(n_i, y_j)) > \frac{c_t}{q(\theta_0(n_i, y_j))}$

$\rho_1(n_i, y_j) = 0$ and find $\theta_1(n_i, y_j)$ to satisfy (8) using interpolated θ_0 and ρ_0 to compute the right-hand side of (8).

b. Otherwise, solve jointly (8) and (9) for $\theta_1(n_i, y_j)$ and $\rho_1(n_i, y_j)$.

3. Repeat 2. until $\| \theta_1 - \theta_0 \| < \varepsilon_\theta$ and $\| \rho_1 - \rho_0 \| < \varepsilon_\rho$.

Since it is computationally demanding to jointly solve for θ and ρ, I restrict this joint calculation to the first and latter steps of the computation loop. More precisely, I start with a loose value for ε_ρ so that once I obtain a decent approximation for ρ, I only iterate on θ taking the policy rule ρ as given. When θ converges to a good approximation, I resume solving for both θ and ρ simultaneously.

References

[1] Andolfatto, D. "Business Cycles and Labor-Market Search," *American Economic Review*, 86(1), 1996.

[2] Barnichon, R. "Productivity and Unemployment over the Business Cycle," *Journal of Monetary Economics*, Forthcoming, 2010.

[3] Barnichon, R. "Vacancy Posting, Job Separation, and Unemployment Fluctuations," Mimeo, 2009.

[4] Blanchard, O. and P. Diamond, "The cyclical behavior of the gross flows of U.S. workers," *Brookings Papers on Economic Activity*, 2, pp. 85–155, 1990.

[5] Canova, F., C. Michelacci and D. López-Salido, "Schumpeterian Technology Shocks," mimeo CEMFI, 2007.

[6] Christoffel, K., K. Kuester and T. Linzert, "Identifying the Role of Labor Markets for Monetary Policy in an Estimated DSGE Model," ECB Working Paper No 635, 2006.

[7] Cooper, R., J. Haltiwanger and J. Willis, "Search frictions: Matching aggregate and establishment observations," *Journal of Monetary Economics*, 54 pp. 56-78, 2008.

[8] Costain, J. S. and M. Reiter "Business cycles, unemployment insurance, and the calibration of matching models," *Journal of Economic Dynamics and Control*, 32(4), pp 1120-1155, 2008.

[9] Davis, S. "The Decline of Job Loss and Why It Matters," *American Economic Review P&P*, 98(2), pp. 263-267, 2008.

[10] Davis, S., J. Faberman, and J. Haltiwanger. "The Flow Approach to Labor Markets: New Data Sources and Micro-Macro Links," Journal of Economic Literature, 20(3), pp. 3-26, 2006.

[11] Davis, S., J. Faberman, J. Haltiwanger, R. Jarmin and J. Miranda. "Business Volatility, Job Destruction and Unemployment," NBER Working Paper No. 14300, 2008.

[12] den Haan, W. and G. Kaltenbrunner "Anticipated Growth and Business Cycles in Matching Models," *Journal of Monetary Economics*, Forthcoming, 2009.

[13] den Haan, W., G. Ramey and J. Watson. "Job Destruction and Propagation of Shocks," *American Economic Review*, 90 (3), pp. 482–498., 2000.

[14] DeLong, B. and L. Summers. "Are Business Cycles Asymmetrical?," *American Business Cycle: Continuity and Change*, edited by R. Gordon. Chicago: University of Chicago Press, pp 166-79, 1986.

[15] Elsby, M. and R. Michaels "Marginal Jobs, Heterogeneous Firms and Unemployment Flows," NBER Working Paper No. 13777, 2008.

[16] Elsby, M. R. Michaels and G. Solon. "The Ins and Outs of Cyclical Unemployment," *American Economic Journal: Macroeconomics,* 2009.

[17] Fujita, S. "Dynamics of Worker Flows and Vacancies: Evidence from the Sign Restriction Approach," *Journal of Applied Econometrics*, Forthcoming, 2009.

[18] Fujita, S. and G. Ramey. "The Cyclicality of Job Loss and Hiring," Federal Reserve Bank of Philadelphia, 2006.

[19] Fujita, S. and G. Ramey. "Job Matching and Propagation," *Journal of Economic Dynamics and Control*, pp. 3671-3698, 2007.

[20] Fujita, S. and G. Ramey. "The Cyclicality of Separation and Job Finding Rates," Working Paper, 2007

[21] Fernald, J. "Trend Breaks, long run Restrictions, and the Contractionary Effects of Technology Shocks," Working Paper, 2005.

[22] Galí, J. “Technology, Employment and The Business Cycle: Do Technology Shocks Explain Aggregate Fluctuations?,” *American Economic Review*, 89(1), 1999.

[23] Gertler, M. and A. Trigari “Unemployment Fluctuations with Staggered Nash Wage Bargaining,” *Journal of Political Economy*, 117(1), 2009.

[24] Hagedorn, M and I. Manovskii. “The Cyclical Behavior of Equilibrium Unemployment and Vacancies Revisited,” *American Economic Review*, 98(4), 2008.

[25] Hall, R. “Employment Efficiency and Sticky Wages: Evidence from Flows in the Labor Market,” *The Review of Economics and Statistics*, 87(3), pp. 397-407, 2005.

[26] Hall, R. “Employment Fluctuations with Equilibrium Wage Stickiness,” *American Economic Review*, 95(1), pp. 50-65, 2005.

[27] Hall, R. “Job Loss, Job Finding, and Unemployment in the U.S. Economy over the Past Fifty Years,” *NBER Macroeconomics Annual*, pp. 101-137, 2005.

[28] Krause, M and T. Lubik. “The (Ir)relevance of Real Wage Rigidity in the New Keynesian Model with Search Frictions”, *Journal of Monetary Economics*, 54 pp. 706-727, 2007.

[29] Mc Kay, A. and R. Reis. “The Brevity and Violence of Contractions and Expansions,” *Journal of Monetary Economics*, 55, pp. 738-751, 2008.

[30] Mertz, M. “Search in the Labor Market and the Real Business Cycle,” *Journal of Monetary Economics*, 49, 1995.

[31] Michelacci, C. and D. López-Salido. “Technology Shocks and Job Flows,” *Review of Economic Studies*, 74, 2007.

[32] Mortensen, D. and E. Nagypal. “More on Unemployment and Vacancy Fluctuations,” *Review of Economic Dynamics*, 10, pp. 327-347, 2007.

[33] Mortensen, D. and C. Pissarides. “Job Creation and Job Destruction in the Theory of Unemployment,” *Review of Economic Studies*, 61, pp. 397-415, 1994.

[34] Neftci, S. “Are Economic Time Series Asymmetric over the Business Cycle?,” Journal of Political Economy, 92, pp 307-28, 1984.

[35] Petrongolo, B. and C. Pissarides. “The Ins and Outs of European Unemployment,” *American Economic Review P&P*, 98(2), 256-262, 2008.

[36] Pissarides, C. *Equilibrium Unemployment Theory*, 2nd ed, MIT Press, 2000.

[37] Pissarides, C. “The Unemployment Volatility Puzzle: Is Wage Stickiness the Answer?,” *Econometrica*, Forthcoming, 2009.

[38] Ramey, G. “Exogenous vs. Endogenous Separation,” Working Paper, 2007.

[39] Schreft, S. A. Singh and A. Hodgson. “Jobless Recoveries and the Wait-and-See Hypothesis,” *Economic Journal-Federal Reserve Bank of Kansas City*, 4th Quarter, pp 81-99, 2005.

[40] Shimer, R. “The Cyclical Behavior of Equilibrium Unemployment and Vacancies,” *American Economic Review*, 95(1), pp. 25-49, 2005.

[41] Shimer, R. “Reassessing the Ins and Outs of Unemployment,” NBER Working Paper No. 13421, 2007.

[42] Sichel, D. “Business Cycle Asymmetry: a Deeper Look,” *Economic Inquiry*, 31, pp. 224-36, 1993.

[43] Thomas, C. “Firing costs, labor market search and the business cycle",” Working Paper, 2006.

[44] Thomas, C. “Search and matching frictions and optimal monetary policy,” *Journal of Monetary Economics*, 55(5), 2008.

[45] Thomas, C. and F. Zanetti. "Labor market reform and price stability: an application to the Euro Area," Working Paper, 2008.

[46] Trigari, A. "The Role of Search Frictions and Bargaining for Inflation Dynamics," *IGIER Working Paper*, 2006.

[47] Trigari, A. "Equilibrium Unemployment, Job Flows and Inflation Dynamics," *Journal of Money, Credit and Banking*, 2009.

[48] Walsh, C. "Labor Market Search and Monetary Shocks," in *Elements of Dynamic Macroeconomic Analysis*, S. Altug, J. Chadha, and C. Nolan, Cambridge University Press, 2004, 451-486.

[49] Woodford, M. "Inflation and Output Dynamics with Firm-Specific Investment," Working Paper, 2004.

Table 1: Skewness, Monthly data

	du	*dy*
1951-2007	0.65** (0.19)	0.26 (0.36)
1985-2007	0.09 (0.08)	0.17 (0.12)

Notes: Monthly unemployment u is constructed by the BLS from the CPS, and y is logged real GDP. Both series are seasonally adjusted and detrended with an HP-filter (λ=10,000). Newey-West standard errors are reported in parentheses. ** indicates significance at the 5% level.

Table 2: Skewness and Kurtosis, JS and JF

	US data		*Model*	
	JS	*JF*	*JS*	*JF*
Skewness	1.10** (0.42)	0.25 (0.22)	1.67** (0.51)	0.75 (0.49)
Kurtosis	4.40 (3.58)	2.49 (0.90)	5.58 (3.14)	3.22 (1.28)

Notes: Empirical *jf* and *js* are the quarterly unemployment exit rate and unemployment inflow rate series constructed by Shimer (2007). All variables are reported in logs as deviations from an HP trend with smoothing parameter $\lambda=10^5$. For US data, Newey-West standard errors are reported in parentheses. For model data, standard deviations across 500 model simulations over 600 months are reported in parentheses. ** indicates significance at the 5% level.

Table 3: US Data, 1951-2006

		u	*v*	*θ*	*jf*	*js*	*h*	*y*
Standard deviation		0.187	0.198	0.378	0.116	0.065	0.007	0.021
Quarterly autocorrelation		0.938	0.948	0.946	0.912	0.648	0.83	0.84
Correlation matrix	*u*	1	-0.90	-0.97	-0.95	0.61	-0.50	-0.69
	v	-	1	0.98	0.92	-0.55	0.63	0.78
	θ	-	-	1	0.96	-0.62	0.60	0.76
	jf	-	-	-	1	-0.48	0.51	0.69
	js	-	-	-	-	1	-0.55	-0.56
	h	-	-	-	-	-	1	0.81
	y	-	-	-	-	-	-	1

Notes: Seasonally adjusted unemployment *u* is constructed by the BLS from the Current Population Survey (CPS). The seasonally adjusted help-wanted advertising index *v* is constructed by the Conference Board. Labor market tightness is the vacancy-unemployment ratio. *jf* and *js* are the quarterly unemployment exit rate and unemployment inflow rate series constructed by Shimer (2007). Hours per worker *h* only covers 1956-2006 and is the sum of the quarterly average of weekly manufacturing overtime of production workers and the average over 1956-2006 of weekly regular manufacturing hours of production workers from the Current Employment Statistics from the BLS, and *y* is real GDP. All variables are reported in logs as deviations from an HP trend with smoothing parameter $\lambda=10^5$.

Table 4: Mortensen-Pissarides (1994) model with productivity shocks

		u	v	θ	jf	js	y
Standard deviation		0.084 (0.01)	0.044 (0.004)	0.044 (0.003)	0.012 (0.001)	0.096 (0.009)	0.021 (0.002)
Quarterly autocorrelation		0.88 (0.02)	0.91 (0.02)	0.76 (0.04)	0.76 (0.05)	0.76 (0.05)	0.84 (0.03)
Correlation matrix	u	1	0.96	-0.96	-0.97	0.97	-0.99
	v	-	1	-0.87	0.86	0.86	-0.93
	θ	-	-	1	0.99	-0.99	0.99
	jf	-	-	-	1	-0.99	-0.99
	js	-	-	-	-	1	-0.96
	y	-	-	-	-	-	1

Notes: Standard errors -the standard deviation across 500 model simulations over 600 months- are reported in parentheses.

Table 5: Calibration, monthly frequency

Discount rate	β=0.99$^{1/3}$	
Matching function elasticity	σ=0.72	Shimer (2005)
Bargaining weight	γ=0.5	
Probability vacancy is filled	$q(\theta)$=0.35	den Haan, Ramey and Watson (2000)
Job finding probability	$\theta q(\theta)$=0.3	u=10%
Exogenous separation rate	$\bar{\rho}$ =0.0.32	
Income replacement ratio	b=0.28	Shimer (2005)
Vacancy posting cost	c=0.01	Andolfatto (1996)
Returns to hours	α=0.65	
Disutility of hours	σ_h=10	Trigari (Forthcoming)
AR(1) process for output	ρ_m=0.93	
Standard-deviation of AD shock	σ_m=0.0079	

Table 6: Search model with demand constraints, Aggregate Demand shocks

		u	v	θ	jf	js	h	y
Standard deviation		0.174 (0.021)	0.470 (0.046)	0.623 (0.069)	0.173 (0.019)	0.061 (0.006)	0.007 (0.001)	0.020 (0.002)
Quarterly autocorrelation		0.86 (0.03)	0.65 (0.06)	0.75 (0.05)	0.75 (0.05)	0.15 (0.08)	0.14 (0.08)	0.84 (0.04)
Correlation matrix	u	1	-0.83	-0.90	-0.91	0.47	-0.30	-0.97
	v	-	1	0.98	0.98	-0.60	0.76	0.92
	θ	-	-	1	0.99	-0.58	0.66	0.97
	jf	-	-	-	1	-0.59	0.65	0.97
	js	-	-	-	-	1	-0.50	-0.60
	h	-	-	-	-	-	1	0.48
	y	-	-	-	-	-	-	1

Notes: Standard errors -the standard deviation across 500 model simulations over 600 months- are reported in parentheses.

Table 7: Contribution of JF/JS and Skewness, model data

Size of AD shocks	σ	½ σ
Contribution of *JS*	22 % (0.03)	13 % (0.02)
Contribution of *JF*	78 % (0.03)	87 % (0.02)
Skewness(dU)	0.53** (0.16))	0.14 (0.17))

Notes: *u*, *y* and *JS* are monthly model unemployment, output and job separation rate. The contributions of JF and JS are calculated using the method from Shimer (2007) and Fujita and Ramey (2007). Standard errors -the standard deviation across 500 model simulations over 600 months (50 years)- are reported in parentheses.

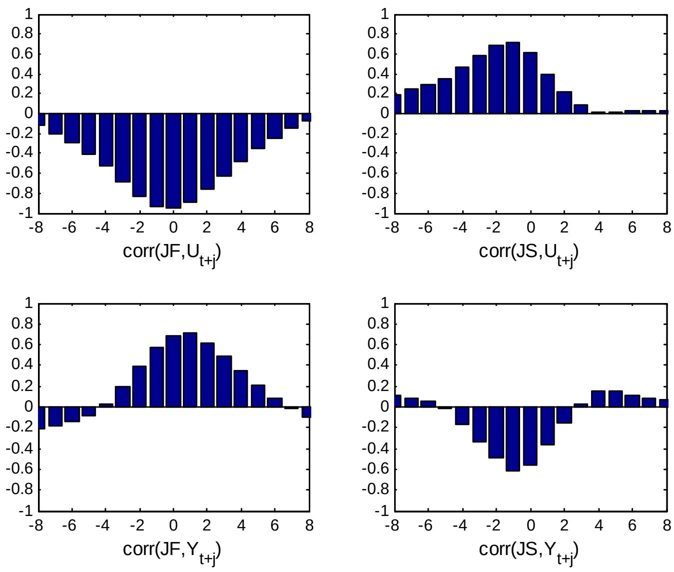

Figure 1: Empirical Cross-Correlograms of the Job Finding rate and the Job Separation rate with Unemployment and Output over 1951-2006.

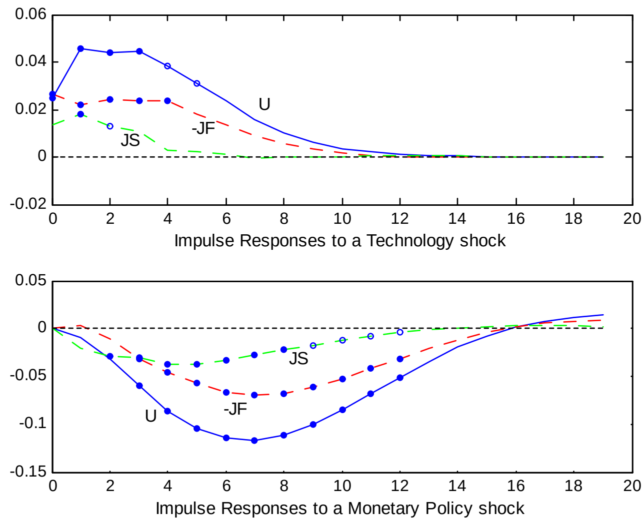

Figure 2: Impulse response functions of Unemployment, the (minus) Job Finding probability and the Job Separation probability to monetary and technology shocks. Solid circles indicate that the response is significant at the 5% level and open circles at the 10% level.

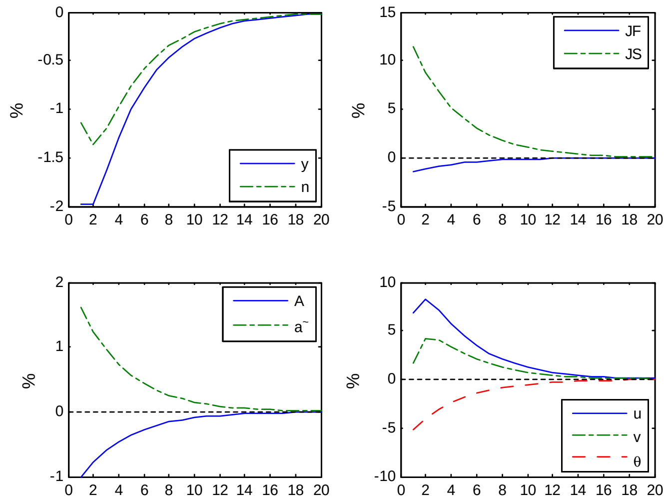

Figure 3: Mortensen-Pissarides (1994) model impulse response functions to a negative one standard-deviation productivity shock.

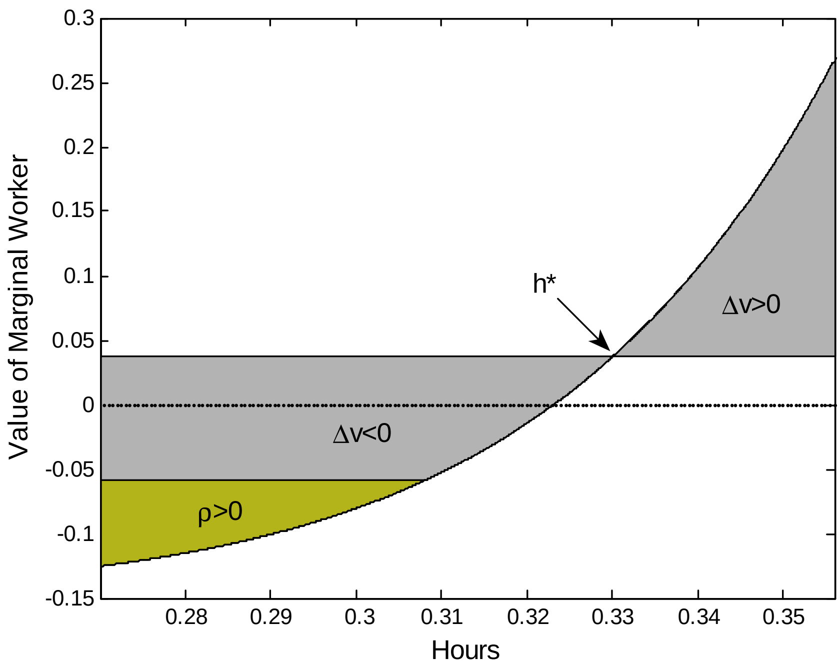

Figure 4: Aggregate Demand and the value of a marginal worker. Δv indicates changes in posted vacancies, and $\rho > 0$ indicates use of the job separation margin.

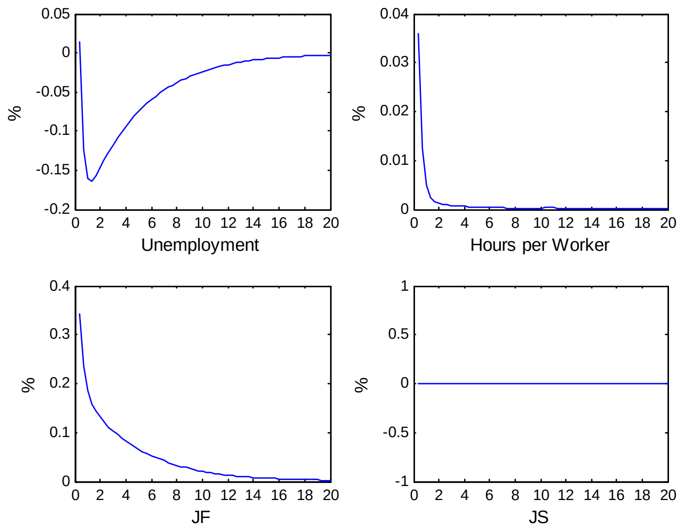

Figure 5: Model impulse response functions to a positive one standard-deviation aggregate demand shock.

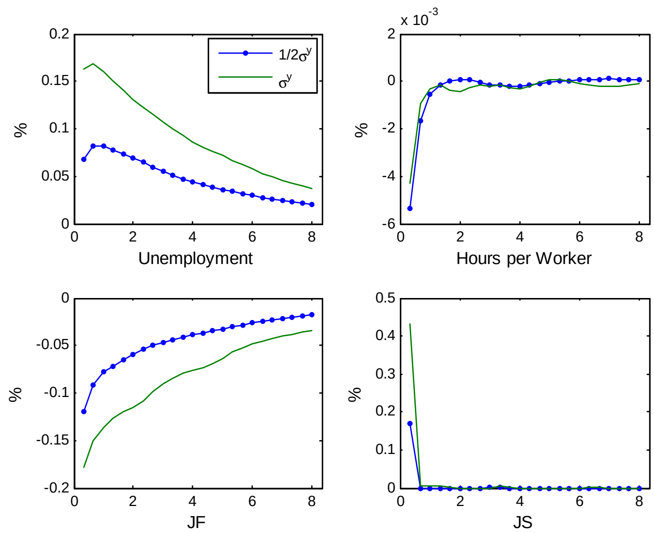

Figure 6: Model impulse response functions to negative aggregate demand shocks with respective size of one and one-half standard-deviation.

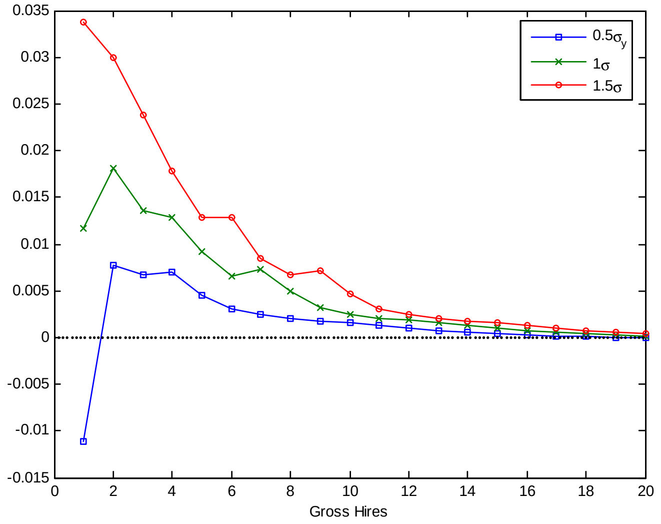

Figure 7: Model impulse response functions of gross hires to negative aggregate demand shocks of different size.

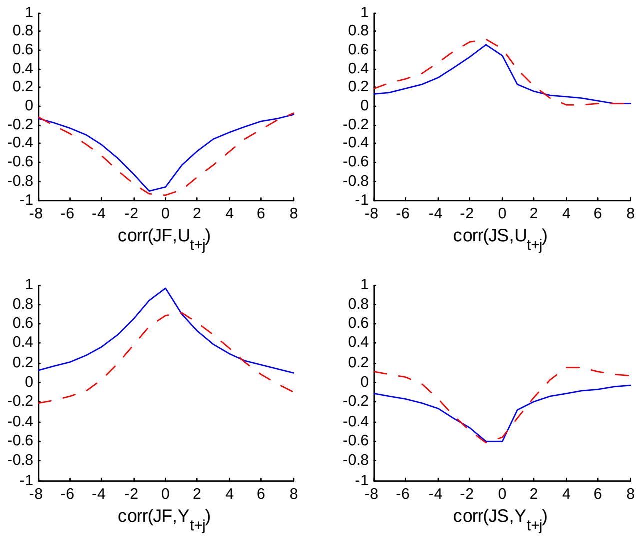

Figure 8: Model (plain line) and empirical (dotted line) cross-correlograms of the Job Finding rate and the Job Separation rate with Unemployment and Output.