Worker flows and matching efficiency

Marcelo Veracierto

Introduction and summary

One of the best known facts about labor market dynamics in the U.S. economy is that unemployment and vacancies are strongly negatively correlated, an empirical relationship called the "Beveridge curve."[1] In recent times, however, large deviations from the Beveridge curve have been observed. In particular, vacancies have increased quite significantly since mid-2009, but this phenomenon has not been accompanied by a substantial decrease in the unemployment rate (see figure 1). This failure of the Beveridge curve has surprised many economists and has been interpreted as evidence of mismatch, that is, of increased frictions in the process through which workers meet job opportunities (for example, Kocherlakota, 2010). The purpose of this article is to provide a measure of mismatch in U.S. labor markets and to assess its importance in determining the behavior of the unemployment rate and other labor market outcomes since the start of the latest recession. The framework that I use is a simplified version of the Mortensen and Pissarides (1994) model. Since my purpose is to use it as a tool for organizing and interpreting data, I will abstract from any explicit decision making and focus on the essential structure of the model.

The basic structure of the Mortensen and Pissarides model has three main components. First, it has an aggregate matching function that summarizes the process through which unemployed workers and employers with open vacancies search for each other and meet. It functions very much like a standard production function, with unemployed workers and vacancies entering as inputs of production and the number of matches formed appearing as output. The second element is a free-entry condition for the creation of vacancies. In particular, it is assumed that there is a fixed cost to post a vacancy and that employers create vacancies up to the point at which the expected discounted value of a filled job equals this fixed cost. The expected value of a job is given by the probability of filling the job, which is determined by the aggregate matching function, and by the value of a job. In a full-blown version of the model, the value of a job is endogenously determined by the expected revenues that the job will generate and by the bargaining power of the worker. However, in the simplified version considered in this article, I am silent about the explicit process through which the value of a job is determined. The third main component is a simple accounting relationship that states that the total flows in and out of each labor market state must be equal. A standard approach in the literature is to allow only for two labor market states (employment and unemployment) and to assume that the model is always at its steady state (that is, its long-run equilibrium). However, I consider more flexible specifications in this article.

I use this simple version of the Mortensen and Pissarides model to measure mismatch and evaluate its consequences during the post-2007 recession period. This is not the first article to do this. Two closely related papers are Barlevy (2011) and Barnichon and Figura (2010). Barlevy follows the standard approach by postulating two labor market states, assuming a constant separation rate (that is, the rate at which workers transit from employment into unemployment), and by assuming that the model is always at its long-run steady state. On the contrary, Barnichon and Figura incorporate a third labor market state (nonparticipation) and allow the transition rates between the three labor market states to vary over time. However, similar to Barlevy, Barnichon and Figura assume that the model is always at its steady state and that only unemployed workers enter the matching function.[2]

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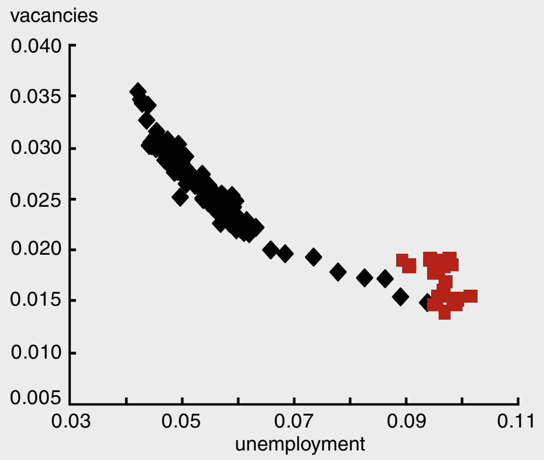
Given the different assumptions made in the literature, I use my model to evaluate how sensitive the results are to the different specifications. I consider the following dimensions. First, I assess the importance of allowing the separation rate to vary over time instead of assuming it to be constant. Second, I evaluate the consequences of specifying three labor market states instead of two. Third, I assess the consequences of assuming that the model is always at its steady state instead of allowing for transitionary dynamics. Fourth, I evaluate the consequences of allowing nonparticipants to enter the matching function instead of assuming that the matching function solely applies to unemployed workers.

I find that the results are extremely sensitive to the alternative specifications. However, in the preferred scenario (which has three labor market states, variable transition rates, transitionary dynamics, and nonparticipants entering the matching function), I obtain the following findings.[3] First, the matching efficiency has been quite volatile throughout the whole sample period (2001:1[January]–2011:2[February]). Second, the matching efficiency has been drifting down since the start of the last recession. Third, the value of filled jobs plummeted between 2007:12 (the start of the latest recession) and 2009:6, but it has recovered quite significantly since then. Fourth, conditional on the observed paths for the value of a job and all transition rates, the drop in matching efficiency since the start of the recession has had only a moderate impact on the unemployment rate: The current unemployment rate would be 1 percentage point lower if the matching efficiency had stayed unchanged. Fifth, the bulk of the increase in the unemployment rate since the start of the recession is accounted for by changes in the transition rates across labor market states. Sixth, the matching efficiency, the value of a job, the transition rates, and the search intensity of nonparticipants all have significant effects on the dynamics of nonparticipation. Since they deemphasize the importance of matching inefficiencies in explaining the large increase in the unemployment rate since the start of the last recession, the results in this paper are consistent with a greater role for policy in achieving improvements in labor market conditions.

In the next section, I consider the case of two labor market states. In the following section, I consider the case of three labor market states and a matching function with only unemployed workers. Then, I consider the case of three labor market states but allow for nonparticipants to enter the matching function. Readers solely interested in learning about the relative contributions to unemployment dynamics should jump to the last section of the paper, which uses the preferred scenario. The first two sections report results using alternative but less satisfactory methodologies.

FIGURE 1

Unemployment rate vs. vacancies



Note: Vacancies and unemployment are normalized by total labor force.
Sources: Author's calculations based on data from the Bureau of Labor Statistics' *Current Population Survey* and *Job Openings and Labor Turnover Survey*.

The case of two labor market states

There are two types of agents: firms and workers. Each firm has one job available, which can either be filled or vacant. The expected discounted value of profits generated by a filled job is equal to J_t units of the numeraire. Posting a vacant job requires k units of the numeraire. There is an infinite number of potential firms. Workers can be in either of two states: employed or unemployed. Employed workers get separated from their current jobs with probability λ_t. Unemployed workers and posted vacancies determine the total number of new matches that are formed according to the following matching function:

$$1)\quad M_t = A_t U_t^{\alpha} V_t^{1-\alpha},$$

where M_t is the total number of new matches, U_t is the total number of unemployed workers, V_t is the total number of posted vacancies, A_t is the productivity of the matching function, and $0 < \alpha < 1$.

Normalizing to one the total number of workers in the economy, the evolution of unemployment over time can be described by the following equation:

2) $U_{t+1} = U_t - M_t + (1 - U_t)\lambda_t$.

That is, the total number of workers that will be unemployed tomorrow U_{t+1} is equal to the total number of currently unemployed workers that do not find a match $U_t - M_t$, plus the total number of currently employed workers that get separated from their jobs $(1 - U_t)\lambda_t$.

Since firms are profit maximizers, the following free-entry condition must be satisfied:

3) $$k = \left(\frac{M_t}{V_t}\right) J_t.$$

That is, the cost of posting a vacancy k must be equal to the probability of filling a vacancy M_t/V_t times the expected discounted value of profits generated by a filled job J_t. If this condition was not satisfied, the total number of vacancies created would be either zero or infinity, depending on the direction of the resulting inequality.

Observe that the productivity of the matching function A_t, the separation rate λ_t, and the expected discounted profits generated by a filled job J_t are exogenous to the model. Given the total number of workers unemployed at date zero U_0, the model generates an endogenous path for $\{M_t, V_t, U_{t+1}\}_{t=0}^{\infty}$.

Steady state

Assuming a constant matching productivity A, a constant separation rate λ, and constant expected discounted profits generated by a filled job J, a steady state of the model economy can be defined as an initial unemployment level $U_0 = U$, such that the endogenous path for $\{M_t, V_t, U_{t+1}\}_{t=0}^{\infty}$ that the model generates is constant over time. That is, that $M_t = M$, $V_t = V$, and $U_t = U$ for every $t \geq 0$. A steady state (M, V, U) can be interpreted as the total matches, vacancies, and unemployment that the economy will converge to in the long run.

From equations 1–3, we have that the conditions a steady state must satisfy are the following:

4) $M = AU^{\alpha}V^{1-\alpha}$,

5) $M = (1 - U)\lambda$,

6) $$k = \left(\frac{M}{V}\right) J.$$

Substituting equation 5 in equations 4 and 6 gives the following simplified steady-state conditions:

7) $$U = \frac{\lambda}{\lambda + A\left(\frac{V}{U}\right)^{1-\alpha}},$$

8) $$k = A\left(\frac{U}{V}\right)^{\alpha} J.$$

Equation 7 defines a negative relationship between unemployment and vacancies and, for this reason, is called the "Beveridge" curve. Equation 8 defines a positive linear relationship between unemployment and vacancies and, since it is defined by a free-entry condition to the posting of vacancies, it is called the "job creation" curve. The Beveridge and job creation curves are depicted in figure 2. The intersection of these curves determines the steady state (U^*, V^*).

It is particularly important to determine what causes shifts in each of these two curves. It is possible to show that an increase in the separation rate λ shifts the Beveridge curve up, an increase in the expected discounted profits from a filled job J does not affect the Beveridge curve, and an increase in the matching efficiency parameter A shifts the Beveridge curve down. In turn, the separation rate λ has no effect on the job creation curve, but an increase in either J or A rotates the job creation curve clockwise. Given these shifts in the Beveridge and job creation curves, we can now determine how changes in λ, J, and A affect the steady-state pair (U^*, V^*). In particular, we can conclude that that an increase in λ increases both vacancies V and unemployment U, that an increase in J increases V and reduces U, and that an increase in A reduces V. The effects of an increase in A on U are unclear from the figure, but substituting equation 8 in equation 7 gives that

$$U = \frac{\lambda}{\lambda + A^{\frac{1}{\alpha}}\left(\frac{J}{k}\right)^{\frac{1-\alpha}{\alpha}}}.$$

Thus, we can safely conclude that an increase in A reduces U.

To the extent that the transitionary dynamics in response to a change in either λ, A, or J are fast, business cycle fluctuations in unemployment and vacancies can be studied by performing the steady-state analysis described in the previous paragraph. Assuming that this is the case, we can make the following tentative hypothesis. First, since there is a strong negative empirical relationship between vacancies and unemployment between 2001:1 and 2007:12, fluctuations in the value of a filled job J, together with a relatively constant separation rate λ and a relatively constant matching productivity A, are the most likely scenario for explaining this period. Second, significant changes in A and/or λ are necessary for explaining the substantial deviations from the Beveridge curve observed after 2007:12, especially after 2009:6 (see figure 1). A key issue will be to determine the behavior of the matching efficiency parameter A during this later period. Another key issue will be to evaluate the contribution of changes in A, λ, and J to the unemployment and vacancy dynamics observed during this later period. Addressing these issues will be the focus of the next two subsections.

Before proceeding, it will be convenient to rewrite equations 7–8 as follows:

$$9)\quad U_t = \frac{\lambda_t}{\lambda_t + A_t\left(\frac{V_t}{U_t}\right)^{1-\alpha}},$$

$$10)\quad k = A_t\left(\frac{U_t}{V_t}\right)^{\alpha} J_t.$$

This makes explicit the assumption that the economy at any month t can be safely described by the steady-state equations 7–8, an assumption that will be maintained throughout the rest of this section.

Constant separation rate

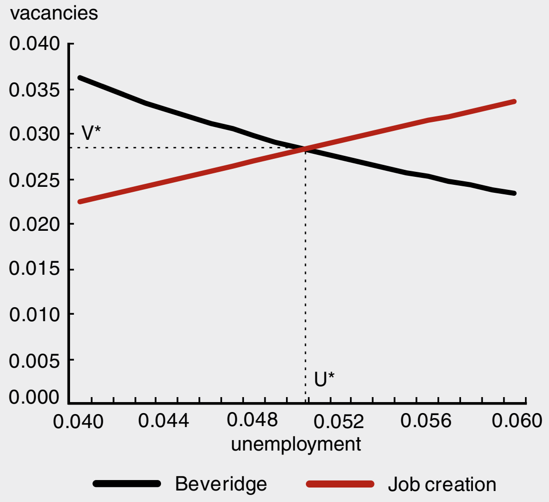
Shimer (2005) has argued that the separation rate λ does not play an important role in generating unemployment fluctuations. For this reason, I follow Barlevy (2011) and consider in this section that the separation rate λ is constant over time. Under this assumption, I use the model described by equations 9–10 to measure the time paths for the efficiency parameter A_t and the value of a job J_t.

In what follows, I set the separation rate λ to 0.042, which is equal to the average employment-to-unemployment transition rate plus the average employment-to-nonparticipation transition rate between 2001:1 and 2007:12. From equation 9, we have, for any two months i and j, that

$$11)\quad 1-\alpha_{j,i} = \left\{\ln\left[\frac{\lambda}{U_j} - \lambda\right] - \ln\left[\frac{\lambda}{U_i} - \lambda\right]\right\} \Big/ \left\{\ln\left(\frac{U_i}{V_i}\right) - \ln\left(\frac{U_j}{V_j}\right)\right\}.$$

FIGURE 2

Beveridge and job creation curves



Within the period 2001:1–2007:12 (which is a period with relatively constant matching productivity A), we can thus select the month i with the largest U/V ratio and the month j with the smallest U/V ratio and use them to get an estimate for α from equation 11.[4] These months happen to be $i = 2003{:}6$ and $j = 2001{:}1$. The estimated value of α turns out to be 0.4915.[5]

Equation 9 can also be used to measure the matching efficiency at month t as follows:

$$12)\quad A_t = \left[\frac{\lambda}{U_t} - \lambda\right]\left(\frac{U_t}{V_t}\right)^{1-\alpha}.$$

Using the above value of α and averaging the values of A_t between 2001:1 and 2007:12 obtained from equation 12 gives an estimate of $A = 1.06$.

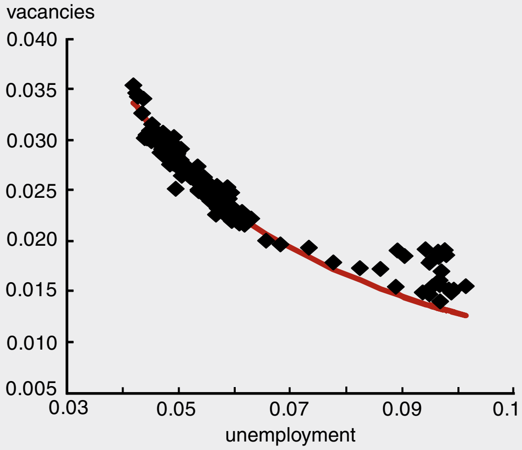
Using this constant value for A, we can then use equation 9 to construct the vacancies predicted by the model economy (conditional on the observed unemployment rate) as follows:

$$13)\quad V_t = \left\{\left[\frac{\lambda}{U_t} - \lambda\right]\frac{1}{A}\right\}^{\frac{1}{1-\alpha}} U_t.$$

The predicted vacancies are shown by the red line in figure 3. We see that under a constant matching efficiency parameter A, the model does a good job at reproducing the behavior of vacancies between 2001:1 and 2007:12. However, beginning in 2009, the model

FIGURE 3

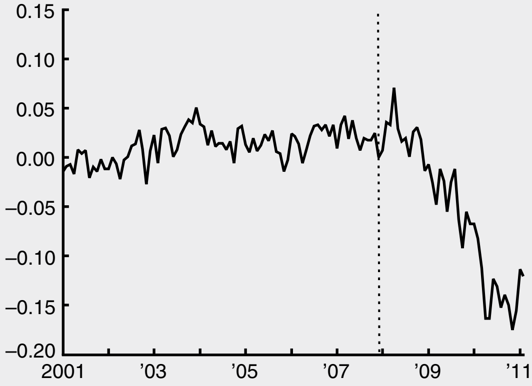
Predicted Beveridge curve



Note: Vacancies and unemployment are normalized by total labor force.
Sources: Author's calculations based on data from the Bureau of Labor Statistics' *Current Population Survey* and *Job Openings and Labor Turnover Survey*.

FIGURE 4

Matching efficiency
(2 states, constant separation rate)



Note: The log of A_t is normalized to zero at the start of the past recession.
Sources: Author's calculations based on data from the Bureau of Labor Statistics' *Current Population Survey* and *Job Openings and Labor Turnover Survey*.

fails to keep track of the data using a constant A. This suggests that the matching efficiency parameter A may have experienced substantial changes in this later period. To show that this could be the case, figure 4 reports the values for A_t (in logs) measured from equation 12 for the whole sample period (the vertical line corresponds to 2007:12, that is, to the start of the past recession). We see that the matching efficiency was relatively stable before 2008:1. However, starting in 2008:1, the matching efficiency has fluctuated quite substantially. In particular, we see that after an initial increase, the matching efficiency has been decreasing continuously, reaching a cumulative drop of 17.5 percent by 2010:11.

Normalizing the cost of posting a vacancy k to one and using the path for A_t already found, equation 10 can be used to construct a time series for the value of a job J_t. In particular, we have that

$$14)\quad J_t = \frac{k}{A_t}\left(\frac{V_t}{U_t}\right)^{\alpha}.$$

Figure 5 reports the evolution of the value of a job between 2001:1 and 2011:2 (in logs). We see that J_t dropped quite substantially during the recession: Between 2007:12 and 2009:8, the value of a job declined by 68 percent.[6]

I now turn to evaluate the contributions of changes in A_t and J_t to the dynamics of unemployment and vacancies since the beginning of the recession. In order to do this, I compute adjusted unemployment U_t^* and adjusted vacancies V_t^* using equations 9–10 under the assumption that $A_t = A_{2007:12}$, for every month t. That is, I let the value of a job J_t evolve as in figure 5 (that is, as in the data) but fix the matching productivity to the value that it had at the start of the recession. For this reason, U_t^* and V_t^* measure the unemployment rates and vacancies that would have been obtained had the matching productivity remained constant at its December 2007 level but the path for the value of a job J_t had remained the same. Observe that in a full-blown model (in which J_t is endogenously determined), a change in the path for A_t would generally affect the path for J_t. As a consequence, comparing (U_t^*, V_t^*) with (U_t, V_t) cannot be strictly interpreted as describing the total effects of variations in A_t; it should be interpreted as describing the *conditional* effects of A_t (that is, conditional on the observed path for J_t). In a full-blown model, the variations in A_t would have to be accompanied by variations in other variables (for example, in the bargaining power of workers) in order to obtain an unchanged path for J_t.[7]

Figure 6 shows the path for U_t^* (labeled "constant A") and for U_t (labeled "variable A"). We see that through 2009:1, the productivity of the matching function did not play an important role in the unemployment dynamics observed (both paths are quite similar). However, starting in mid-2009, we see that the decline in matching productivity reported in figure 4 played a significant role in generating a significantly larger unemployment

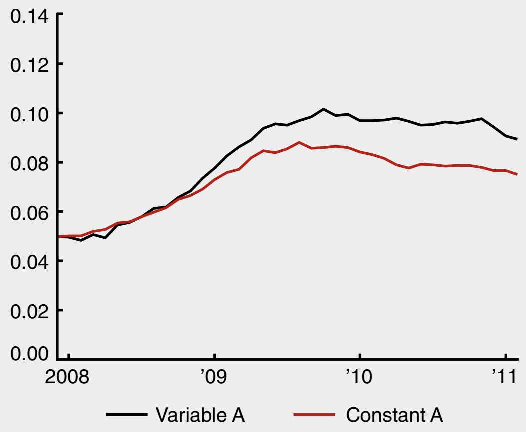
FIGURE 5

Value of a job
(2 states, constant separation rate)

Note: The log of J_t is normalized to zero at the start of the past recession.
Sources: Author's calculations based on data from the Bureau of Labor Statistics' *Current Population Survey* and *Job Openings and Labor Turnover Survey*.

FIGURE 6

Effects on unemployment rate
(2 states, constant separation rate)



Sources: Author's calculations based on data from the Bureau of Labor Statistics' *Current Population Survey* and *Job Openings and Labor Turnover Survey*.

rate. In particular, we see that by February 2011 the unemployment rate would have been 7.5 percent instead of 8.9 percent had the matching productivity remained constant at its beginning-of-recession level.

Figure 7 reports the paths for V_t^* (labeled "constant A") and for V_t (labeled "variable A"). We also see that through 2009:1, changes in the productivity of the matching function had negligible effects on vacancies. However, by mid-2009 both paths start to diverge, and we see that by February 2011 vacancies would have been 1.6 percent instead of 1.9 percent had the matching productivity remained constant at its 2007:12 level.

Variable separation rate

In this section, I allow the separation rate to vary over time. Figure 8 reports the separation rate between 2001:1 and 2011:2 that is obtained from the Bureau of Labor Statistics' *Current Population Survey* (CPS) data (once again, the vertical line depicts the beginning of the last recession). We see that early on in the recession the separation rate increased quite significantly, reaching 4.9 percent by 2009:1, but that it subsequently trended down toward its pre-recession level.

Given the data on U_t and V_t and the separation rate λ_t reported in figure 8, I compute the matching efficiency A_t from the following equation:

$$15)\quad A_t = \left[\frac{\lambda_t}{U_t} - \lambda_t\right]\left(\frac{U_t}{V_t}\right)^{1-\alpha},$$

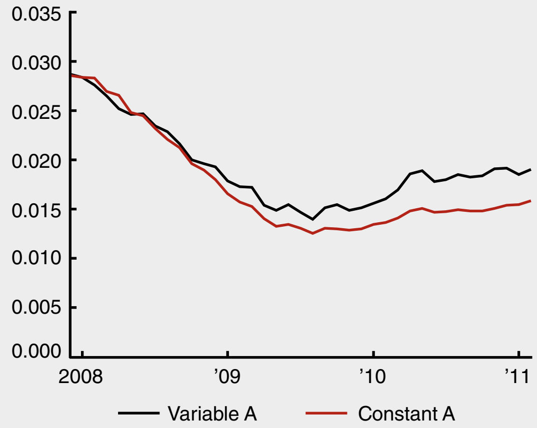
which is analogous to equation 12, except that λ_t is allowed to vary over time. The resulting path for the matching productivity A_t is reported in figure 9. We see that contrary to figure 4, we now observe large fluctuations in A_t previous to the start of the recession. Another difference is that there is a sharp increase in matching productivity early on in the recession that compensates for the 2009:1 spike in the separation rate. Also, we see that starting in 2009:2, the matching productivity trends down much more sharply than in figure 4.

The value of filled jobs J_t is computed from equation 14 using the A_t values obtained from equation 15. The resulting path is reported in figure 10. We see that this path is not very different from that in figure 5.

Figures 11 and 12 explore the conditional contribution to unemployment and vacancies dynamics of the matching productivity A_t, the separation rate λ_t, and the value of a job J_t. In particular, I compute adjusted unemployment U_t^* and adjusted vacancies V_t^* using equations 9–10 under the assumption that $A_t = A_{2007:12}$ and $\lambda_t = \lambda_{2007:12}$, for every month t. That is, I let the value of a job J_t evolve as in figure 10 (that is, as in the data), but I fix the matching productivity to the value that it had at the beginning of the recession $A_{2007:12}$ and fix the separation rate to the value that it had at the beginning of the recession $\lambda_{2007:12}$. In other words, U_t^* and V_t^* measure the unemployment rates and vacancies that would have been obtained had the matching productivity and the separation rate remained constant at their December 2007 levels.

FIGURE 7

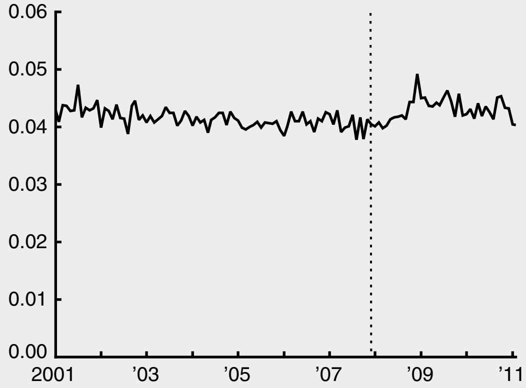
Effects on vacancies (2 states, constant separation rate)



Sources: Author's calculations based on data from the Bureau of Labor Statistics' *Current Population Survey* and *Job Openings and Labor Turnover Survey*.

FIGURE 8

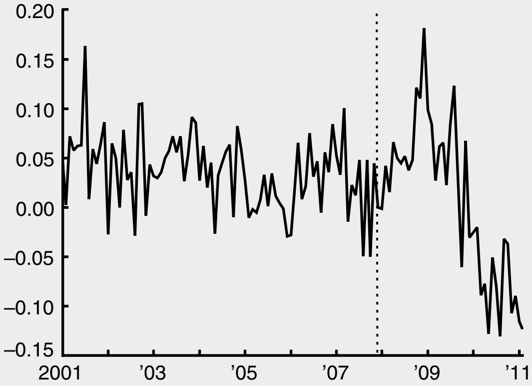
Separation rate



Note: The separation rate is equal to the sum of the employment-to-unemployment and employment-to-nonparticipation transition rates.
Sources: Author's calculations based on data from the Bureau of Labor Statistics' *Current Population Survey*.

FIGURE 9

Matching efficiency (2 states, variable separation rate)



Note: The log of A_t is normalized to zero at the start of the past recession.
Sources: Author's calculations based on data from the Bureau of Labor Statistics' *Current Population Survey* and *Job Openings and Labor Turnover Survey*.

FIGURE 10

Value of a job (2 states, variable separation rate)

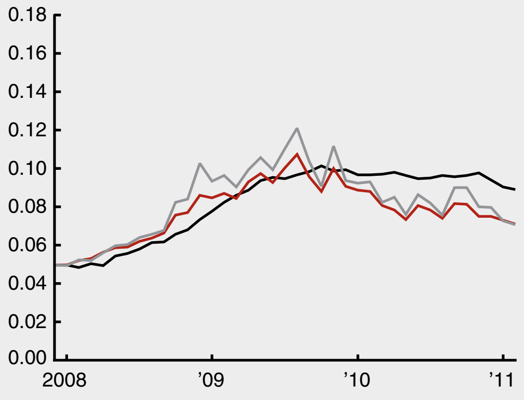
Note: The log of J_t is normalized to zero at the start of the past recession.
Sources: Author's calculations based on data from the Bureau of Labor Statistics' *Current Population Survey* and *Job Openings and Labor Turnover Survey*.

I also compute adjusted unemployment U_t^{**} and adjusted vacancies V_t^{**} using equations 9–10 under the assumption that $A_t = A_{2007:12}$, for every month t (but I let the separation rate λ_t vary as in the data). That is, I let the value of a job J_t evolve as in figure 10 and the separation rate λ_t evolve as in figure 8 but fix the matching productivity to the value that it had at the beginning of the recession $A_{2007:12}$. In other words, U_t^{**} and V_t^{**} measure the unemployment rates and vacancies that would have been obtained had the matching productivity remained constant at its December 2007 level.

In figure 11, U_t^{*} is labeled "constant A, constant λ," U_t^{**} is labeled "constant A, variable λ," and U_t

FIGURE 11

Effects on unemployment rate
(2 states, variable separation rate)



Sources: Author's calculations based on data from the Bureau of Labor Statistics' *Current Population Survey* and *Job Openings and Labor Turnover Survey*.

FIGURE 12

Effects on vacancies
(2 states, variable separation rate)

Sources: Author's calculations based on data from the Bureau of Labor Statistics' *Current Population Survey* and *Job Openings and Labor Turnover Survey*.

is labeled "variable A, variable λ." We see that U_t^* increases in the early part of the period and decreases during the second part, mirroring the evolution of the value of a job J_t described in figure 10. In turn, U_t^{**} increases much more than U_t^* early on in the recession because of the early increase in the separation rate λ_t depicted in figure 8, but as the separation rate reverts toward its beginning-of-recession level, U_t^{**} starts to behave very much like U_t^*. Finally, since the difference between U_t^{**} and U_t is solely due to changes in the matching productivity, we see that the large increase in matching productivity early on in the recession (reported in figure 9) played an important role in keeping unemployment relatively low. However, the large drop in matching productivity since early 2009 significantly contributed to maintaining an unemployment rate of more than 9 percent.

In turn, figure 12 shows that the matching productivity doesn't play a crucial role in vacancy dynamics. However, the large increase in the separation rate in the early part of the recession played a noticeable role in keeping vacancies relatively high early on in the recession.

The case of three labor market states

The model used in the previous section had two labor market states: employment and unemployment. In this section, I allow workers to be in a third labor market state: nonparticipation (that is, out of the labor force). A main reason for doing this is that in the CPS data between 2001:1 and 2007:12, the total number of people transitioning from nonparticipation to employment is almost twice as large as the total number of people transitioning from unemployment to employment (see figure 13), although the differences have become much smaller since the start of the past recession. By considering only two market states, the analysis in the previous section completely missed these transitions. Another reason for introducing three labor market states into the model is that with two labor market states, it is not clear what separation rates to consider: separations into unemployment or separations into both unemployment and nonparticipation? Explicitly introducing three labor markets states avoids this type of issue. More generally, introducing three labor market states allows me to address worker flows data in a more satisfactory way.

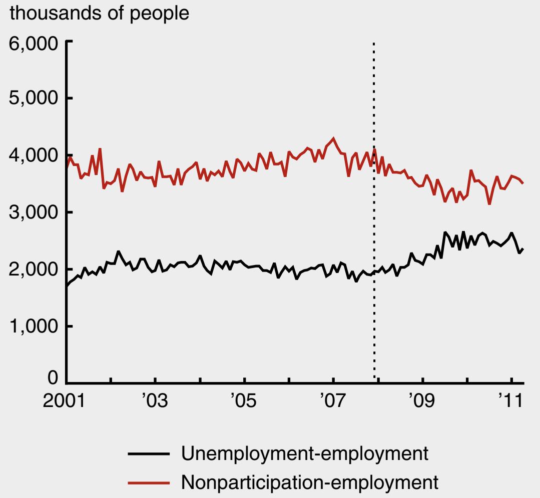
In this section, I follow Barnichon and Figura (2010) and assume that the matching function solely describes transitions from unemployment into employment. In particular, I assume that the matching function is given by

$$16)\ M_t = A_t U_t^{\alpha} V_t^{1-\alpha},$$

where M_t are the total flows from unemployment into employment, U_t is unemployment, V_t are vacancies, and $0 < \alpha < 1$.

FIGURE 13

Flows into employment



Source: Bureau of Labor Statistics' *Current Population Survey*.

The transition rate from employment to unemployment λ_t^{EU}, the transition rate from employment to nonparticipation λ_t^{EN}, the transition rate from unemployment to nonparticipation λ_t^{UN}, the transition rate from nonparticipation to unemployment λ_t^{NU}, and the transition rate from nonparticipation to employment λ_t^{NE} are assumed to be exogenous to the model.

The evolution of workers across labor market states is then given by the following equations:

$$17)\quad E_{t+1} = E_t + A_t U_t^{\alpha} V_t^{1-\alpha} + \lambda_t^{NE} N_t - (\lambda_t^{EU} + \lambda_t^{EN}) E_t,$$

$$18)\quad U_{t+1} = U_t + \lambda_t^{EU} E_t + \lambda_t^{NU} N_t - \lambda_t^{UN} U_t^{\alpha} - A_t U_t^{\alpha} V_t^{1-\alpha},$$

$$19)\quad N_{t+1} = N_t + \lambda_t^{EN} E_t + \lambda_t^{UN} U_t - (\lambda_t^{NE} + \lambda_t^{NU}) N_t.$$

Equation 17 states that next-period employment is equal to current employment, plus all transitions into employment (either from unemployment or nonparticipation), minus total separations (either to unemployment or nonparticipation). Equation 18 states that next-period unemployment is equal to current unemployment, plus all transitions into unemployment (either from employment or nonparticipation), minus all transitions out of unemployment (either to employment or nonparticipation). Equation 19 states that next-period nonparticipation is equal to current nonparticipation, plus all transitions into nonparticipation (either from employment or unemployment), minus all transitions out of nonparticipation (either to employment or unemployment).

In what follows, total population will be normalized to one, that is,

$$20)\quad E_t + U_t + N_t = 1,$$

for every period t.

Similar to the previous section, the following free-entry condition must be satisfied:

$$21)\quad k = \left(\frac{A_t U_t^{\alpha} V_t^{1-\alpha} + \lambda_t^{NE} N_t}{V_t} \right) J_t .$$

Observe that from the point of view of a firm, the probability of filling a vacancy is equal to $(M_t + \lambda_t^{NE} N_t) / V_t$, because matches can be formed with workers either coming from unemployment or from nonparticipation.

Given the total number of workers unemployed at date zero U_0 and the total number of workers that are nonparticipants at date zero N_0, the model generates an endogenous path for $\{M_t, V_t, U_{t+1}, N_{t+1}\}_{t=0}^{\infty}$.

Steady state

Assuming a constant matching productivity A, a constant value of a job J, and constant transition rates λ, a steady state of the model economy can be defined as an initial unemployment level $U_0 = U$ and an initial nonparticipation level N_0, such that the endogenous path for $\{M_t, V_t, U_{t+1}, N_{t+1}\}_{t=0}^{\infty}$ that the model generates is constant over time.

From equations 17–19, we have that the conditions that a steady state (U, N, V) must satisfy are the following:

$$22)\quad (\lambda^{EU} + \lambda^{EN})(1 - U - N) = AU^{\alpha} V^{1-\alpha} + \lambda^{NE} N,$$

$$23)\quad (\lambda^{NE} + \lambda^{NU} + \lambda^{EN})\ N = \lambda^{EN}(1 - U) + \lambda^{UN} U,$$

$$24)\quad k = \left(\frac{AU^{\alpha} V^{1-\alpha} + \lambda^{NE} N}{V} \right) J.$$

Similar to the previous section, it will be convenient to rewrite these equations as:

$$25)\quad (\lambda_t^{EU} + \lambda_t^{EN})(1 - U_t - N_t) = A_t U_t^{\alpha} V_t^{1-\alpha} + \lambda_t^{NE} N_t,$$

$$26)\quad N_t = \frac{\lambda_t^{EN}(1-U_t) + \lambda_t^{UN}U_t}{\left(\lambda_t^{NE} + \lambda_t^{NU} + \lambda_t^{EN}\right)},$$

$$27)\quad \frac{kV_t}{J_t} = A_t U_t^{\alpha} V_t^{1-\alpha} + \lambda_t^{NE} N_t.$$

This makes explicit the assumption that the economy at any month t can be safely described by the steady-state equations 22–24, an assumption that will be maintained throughout the following two subsections.

Constant transition rates

Figure 14 shows the transition rates λ_t^{UN}, λ_t^{EU}, λ_t^{EN} λ_t^{NE}, and λ_t^{NU}, in logs, normalized by their average value for the period 2001:1–2007:12. We see that these transition rates were relatively stable prior to 2007:12. However, we see that with the onset of the recession, there was a significant drop in the transition rate from nonparticipation to employment λ_t^{NE}, a drop in the transition rate from unemployment to nonparticipation λ_t^{UN}, a large increase in the transition rate from nonparticipation to unemployment λ_t^{NU}, and a large increase in the transition rate from employment to unemployment λ_t^{EU}. In turn, the transition rate from employment to nonparticipation was not significantly affected.

Based on figure 14, and similar to the previous section, here I assume that the transition rates λ_t^{UN}, λ_t^{EU}, λ_t^{EN} λ_t^{NE}, and λ_t^{NU} are constant over the period 2001:1–2007:12. Taking simple averages over this period gives the following values:

$$28)\quad \lambda^{UN} = 0.2258,$$

$$29)\quad \lambda^{EU} = 0.0132,$$

$$30)\quad \lambda^{EN} = 0.0281,$$

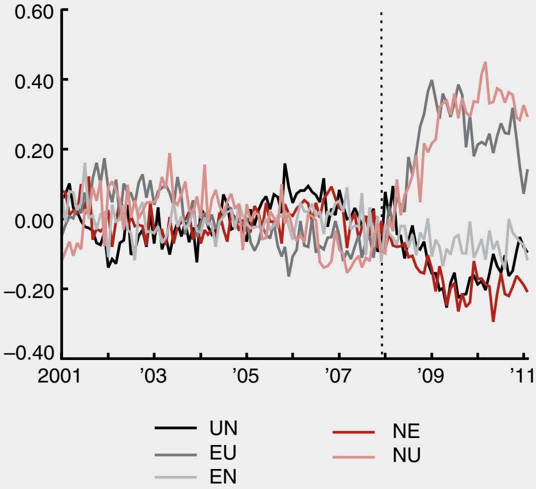
$$31)\quad \lambda^{NE} = 0.0505,$$

$$32)\quad \lambda^{NU} = 0.0253.$$

Substituting equation 26 in equation 25 under the assumption of constant λ values, we get that

FIGURE 14

Transition rates (λs)



Note: All transition rates are reported in logs and normalized to zero at the start of the last recession.
Source: Author's calculations based on data from the Bureau of Labor Statistics' *Current Population Survey*.

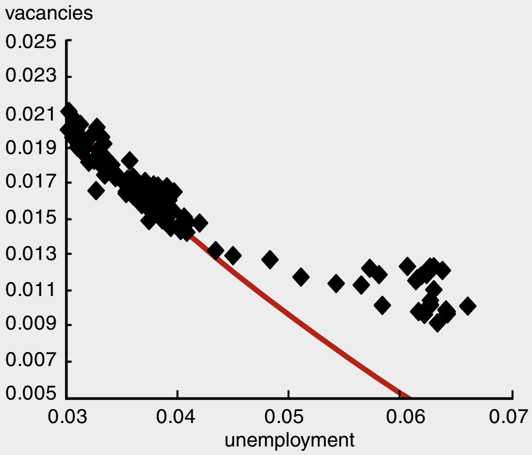
$$33)\quad A_t = \frac{1}{U_t^{\alpha}V_t^{1-\alpha}} \left\{ \begin{array}{l} \left(\lambda^{EU} + \lambda^{EN}\right)\left(1 - U_t - \left[\dfrac{\lambda^{EN}(1-U_t) + \lambda^{UN}U_t}{\left(\lambda^{NE} + \lambda^{NU} + \lambda^{EN}\right)}\right]\right) \\ -\lambda^{NE}\left[\dfrac{\lambda^{EN}(1-U_t) + \lambda^{UN}U_t}{\left(\lambda^{NE} + \lambda^{NU} + \lambda^{EN}\right)}\right] \end{array} \right\}.$$

Assuming that A is constant over the period 2001:1–2007:12, we can then use two months i and j within this period to get an estimate of α as follows:

$$34)\quad 1-\alpha_{ij} = \left[\frac{1}{\ln\left(\frac{V_i}{U_i}\right) - \ln\left(\frac{V_j}{U_j}\right)}\right] \times \{\ln \left[\begin{array}{l} \left(\lambda^{EU} + \lambda^{EN}\right) \\ \left(1 - U_i - \left[\dfrac{\lambda^{EN}(1-U_i) + \lambda^{UN}U_i}{\left(\lambda^{NE} + \lambda^{NU} + \lambda^{EN}\right)}\right]\right) \\ -\lambda^{NE}\left[\dfrac{\lambda^{EN}(1-U_i) + \lambda^{UN}U_i}{\left(\lambda^{NE} + \lambda^{NU} + \lambda^{EN}\right)}\right] \end{array} \right]$$

FIGURE 15

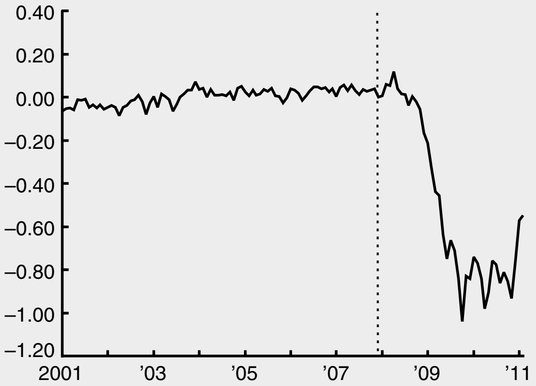
Predicted Beveridge curve



Note: Vacancies and unemployment are normalized by total civilian noninstitutional population (16 years and older).
Sources: Author's calculations based on data from the Bureau of Labor Statistics' *Current Population Survey* and *Job Openings and Labor Turnover Survey*.

FIGURE 16

Matching efficiency (3 states, steady state, constant transition rates)



Note: The log of A_t is normalized to zero at the start of the past recession.
Sources: Author's calculations based on data from the Bureau of Labor Statistics' *Current Population Survey* and *Job Openings and Labor Turnover Survey*.

$$-\ln\left[\begin{array}{l}\left(\lambda^{EU}+\lambda^{EN}\right)\left(1-U_j-\left[\dfrac{\lambda^{EN}\left(1-U_j\right)+\lambda^{UN}U_j}{\left(\lambda^{NE}+\lambda^{NU}+\lambda^{EN}\right)}\right]\right)\\ -\lambda^{NE}\left[\dfrac{\lambda^{EN}\left(1-U_j\right)+\lambda^{UN}U_j}{\left(\lambda^{NE}+\lambda^{NU}+\lambda^{EN}\right)}\right]\end{array}\right]$$

$$+\ln\left(U_j\right)-\ln\left(U_i\right)\}.$$

Picking $i = 2003{:}6$ and $j = 2001{:}1$, which are the months with the largest and smallest V/U ratio, respectively, gives an estimate of $\alpha = 0.16$.[8]

In turn, equation 33 can be used to measure the matching efficiency A_t at month t. Using the above value of α and averaging the values of A_t between 2001:1 and 2007:12 obtained from equation 33 gives an estimate of $A = 0.4533$.

Using this constant value for A, I can then use equation 33 to construct the vacancies predicted by the model economy (conditional on observed unemployment) as follows:

$$35)\quad V_t=\left(\frac{1}{AU_t^{\alpha}}\right)\times\left[\begin{array}{l}\left(\lambda^{EU}+\lambda^{EN}\right)\\ \left(1-U_t-\left[\dfrac{\lambda^{EN}\left(1-U_t\right)+\lambda^{UN}U_t}{\left(\lambda^{NE}+\lambda^{NU}+\lambda^{EN}\right)}\right]\right)\\ -\lambda^{NE}\left[\dfrac{\lambda^{EN}\left(1-U_t\right)+\lambda^{UN}U_t}{\left(\lambda^{NE}+\lambda^{NU}+\lambda^{EN}\right)}\right]\end{array}\right]^{\frac{1}{1-\alpha}}.$$

Figure 15 reports unemployment as a fraction of total population and vacancies as a fraction of total population between 2001:1 and 2011:2 (black dots), as well as the vacancies predicted by equation 35. We see that the steady state of the model with three labor market states, constant transition rates, and a constant A provides a good fit to the data through 2007:12. However, since the start of the latest recession there have been large deviations from the stable Beveridge curve predicted by the model. This indicates that the matching efficiency parameter A_t must have experienced significant changes since then. Figure 16 shows that this has been the case. It reports the matching efficiency levels obtained by equation 33 between 2001:1 and 2011:2. We see that before 2007:12, the matching efficiency had been fairly stable, but it plummeted with the onset

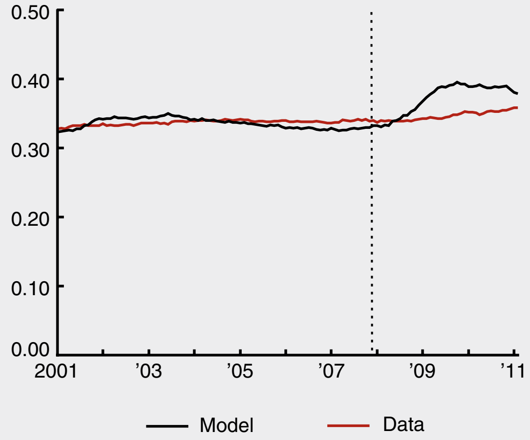
FIGURE 17

Value of a job
(3 states, steady state, constant transition rates)

Note: The log of J_t is normalized to zero at the start of the past recession.
Sources: Author's calculations based on data from the Bureau of Labor Statistics' *Current Population Survey* and *Job Openings and Labor Turnover Survey*.

FIGURE 18

Nonparticipation
(3 states, steady state, constant transition rates)



Note: Nonparticipation is normalized by total civilian noninstitutional population (16 years and older).
Sources: Author's calculations based on data from the Bureau of Labor Statistics' *Current Population Survey* and *Job Openings and Labor Turnover Survey*.

of the recession. Observe that the magnitude of the fall is much larger than in figure 4 (p. 151).

Substituting equation 26 in equation 27 we get that

$$36)\ J_t = kV_t \left(\frac{A_t U_t^{\alpha} V_t^{1-\alpha} + \lambda^{NE}}{\left[\frac{\lambda^{EN}(1-U_t) + \lambda^{UN} U_t}{(\lambda^{NE} + \lambda^{NU} + \lambda^{EN})} \right]} \right)^{-1}.$$

Figure 17 reports the path for J_t thus measured. We see that it is very similar to that in figure 5 (p. 152), indicating that having three labor market states does not significantly affect the measurement of the value of a job.

Before decomposing the effects of the matching efficiency parameter A_t and the value of a job J_t, I would like to point out that the results that follow should be taken with a grain of salt. While I selected the paths for A_t and J_t to reproduce the observed path for U_t and V_t (given the restrictions imposed by equations 33 and 36), I made no attempt to reproduce the path for nonparticipation N_t, which according to the model is given by

$$37)\ N_t = \frac{\lambda^{EN}(1-U_t) + \lambda^{UN} U_t}{(\lambda^{NE} + \lambda^{NU} + \lambda^{EN})}.$$

Figure 18 reports the path for nonparticipation in U.S. data and the path for N_t given by equation 37.

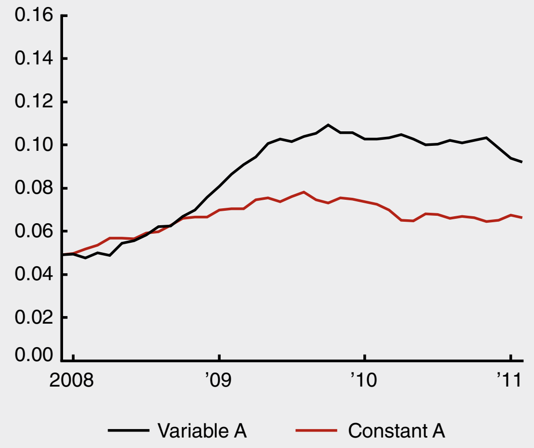
We see that the model does a reasonable job at reproducing the path for N_t before 2007:12, but that it largely overpredicts nonparticipation after that. This suggests that either the assumption of constant transition rates or the assumption that the economy is always at the steady state of the model fails. I return to this issue in the next section.

Similar to the previous section, I compute adjusted unemployment U_t^*, adjusted nonparticipation N_t^*, and adjusted vacancies V_t^* from equations 25–27 under the assumption that $A_t = A_{2007:12}$, for every month t. That is, I let the value of a job J_t evolve as in figure 17 (that is, as in the data) but fix the matching productivity to the value that it had at the start of the recession. In other words, U_t^*, N_t^*, and V_t^* measure the unemployment, nonparticipation, and vacancies that would have been obtained had the matching productivity remained constant at its December 2007 level but the value of a job had evolved as observed.

The version of the model with constant transition rates delivers the following results.[9] Similar to figure 6 (p. 152), figure 19 indicates that starting in mid-2009, the decline in matching productivity reported in figure 16 played an important role in generating a large unemployment rate. This version of the model also indicates that by February 2011, the unemployment rate would have been 6.4 percent instead of 8.9 percent had matching productivity remained constant at its beginning-of-recession level. Figure 20 shows that

FIGURE 19

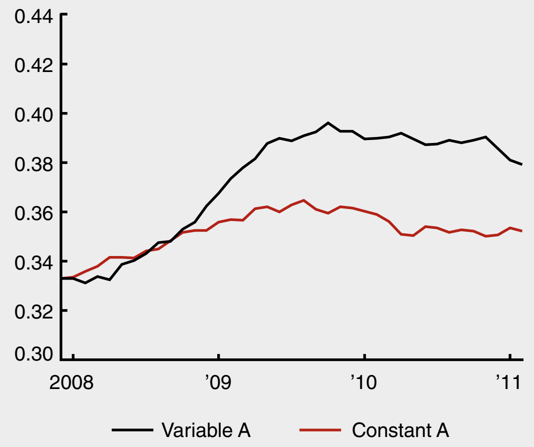
Effects on unemployment rate (3 states, steady state, constant transition rates)



Sources: Author’s calculations based on data from the Bureau of Labor Statistics’ *Current Population Survey* and *Job Openings and Labor Turnover Survey*.

FIGURE 20

Effects on nonparticipation (3 states, steady state, constant transition rates)



Sources: Author’s calculations based on data from the Bureau of Labor Statistics’ *Current Population Survey* and *Job Openings and Labor Turnover Survey*.

the effects of matching productivity on nonparticipation are very similar to those on unemployment. Finally, similar to figure 7 (p. 153), figure 21 shows that the effects of matching efficiency on vacancies are negligible.

Variable transition rates

In this section, instead of assuming that transition rates are constant, I allow them to fluctuate as in figure 14. Given data on U_t and all transition rates, I compute matching efficiency as follows:

$$38)\ A_t = \frac{1}{U_t^{\alpha} V_t^{1-\alpha}} \times \left\{ \begin{array}{l} \left(\lambda_t^{EU} + \lambda_t^{EN}\right) \\ \left(1 - U_t - \left[\dfrac{\lambda_t^{EN}\left(1-U_t\right) + \lambda_t^{UN} U_t}{\left(\lambda_t^{NE} + \lambda_t^{NU} + \lambda_t^{EN}\right)}\right]\right) \\ -\lambda_t^{NE}\left[\dfrac{\lambda_t^{EN}\left(1-U_t\right) + \lambda_t^{UN} U_t}{\left(\lambda_t^{NE} + \lambda_t^{NU} + \lambda_t^{EN}\right)}\right] \end{array} \right\},$$

an expression obtained from substituting equation 26 in equation 25. Figure 22 reports the path for A_t thus obtained. We observe huge differences from figure 16. Instead of relatively stable behavior before 2007:12 followed by a large drop, we observe significant volatility throughout the sample period and a large increase after 2007:12. These differences indicate that the predictions of the model rely critically on whether transition rates are assumed to be constant or not.

The value of a job J_t is measured as

$$39)\ J_t = kV_t\left(A_t U_t^{\alpha} V_t^{1-\alpha} + \lambda_t^{NE}\left[\frac{\lambda_t^{EN}\left(1-U_t\right) + \lambda_t^{UN} U_t}{\left(\lambda_t^{NE} + \lambda_t^{NU} + \lambda_t^{EN}\right)}\right]\right)^{-1}$$

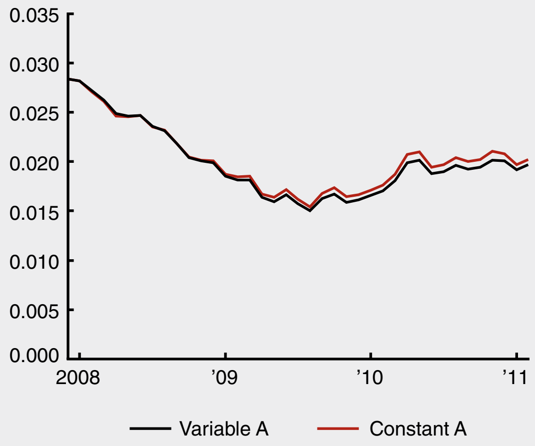
and reported in figure 23. We see that the qualitative behavior is similar to figure 17; however, the drop in J_t after the start of the past recession is now somewhat larger.

Before turning to the decomposition of the different effects, I revisit the issue of how well the model is able to reproduce the path for nonparticipation, a path that has not been targeted in the calibration. Figure 24 reports the path for nonparticipation in U.S. data and the path for N_t from equation 26. We see that contrary to figure 18, the model now does a reasonable job at reproducing the path for N_t throughout the sample period. In principle, this should be a reason for having more confidence in the results obtained in this section.

In order to decompose the different effects, I compute adjusted unemployment U_t^*, adjusted nonparticipation N_t^*, and adjusted vacancies V_t^* from equations 25–27 under the assumption that A_t=$A_{2007:12}$, $\lambda_t^{UN} = \lambda_{2007:12}^{UN}$, $\lambda_t^{EU} = \lambda_{2007:12}^{EU}$, $\lambda_t^{EN} = \lambda_{2007:12}^{EN}$, $\lambda_t^{NE} = \lambda_{2007:12}^{NE}$, and $\lambda_t^{NU} = \lambda_{2007:12}^{NU}$, for every month *t*. That is, I let the

FIGURE 21

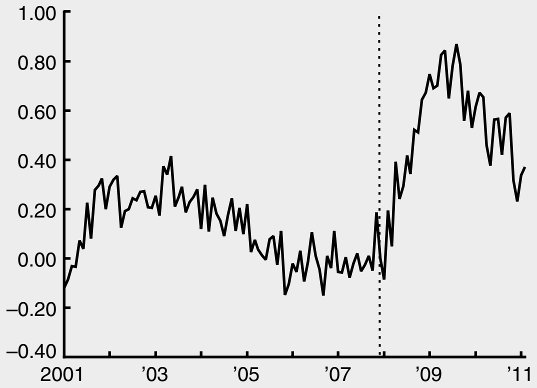
Effects on vacancies (3 states, steady state, constant transition rates)



Sources: Author's calculations based on data from the Bureau of Labor Statistics' *Current Population Survey* and *Job Openings and Labor Turnover Survey*.

FIGURE 22

Matching efficiency (3 states, steady state, variable transition rates)



Note: The log of A_t is normalized to zero at the start of the past recession.
Sources: Author's calculations based on data from the Bureau of Labor Statistics' *Current Population Survey* and *Job Openings and Labor Turnover Survey*.

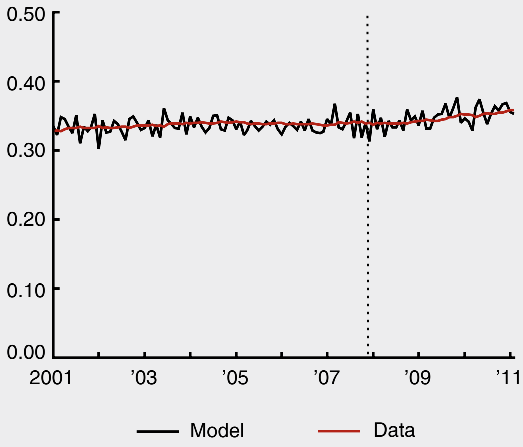
FIGURE 23

Value of a job (3 states, steady state, variable transition rates)

Note: The log of J_t is normalized to zero at the start of the past recession.
Sources: Author's calculations based on data from the Bureau of Labor Statistics' *Current Population Survey* and *Job Openings and Labor Turnover Survey*.

FIGURE 24

Nonparticipation (steady state, variable transition rates)



Note: Nonparticipation is normalized by total civilian noninstitutional population (16 years and older).
Sources: Author's calculations based on data from the Bureau of Labor Statistics' *Current Population Survey* and *Job Openings and Labor Turnover Survey*.

value of a job J_t evolve as in figure 23 (that is, as in the data) but fix the matching productivity and the transition rates to the values that they had at the beginning of the recession. In other words, U_t^*, N_t^*, and V_t^* measure the unemployment, nonparticipation, and vacancies that would have been obtained had the matching productivity and transition rates remained constant at their December 2007 levels but J_t had evolved as it did.

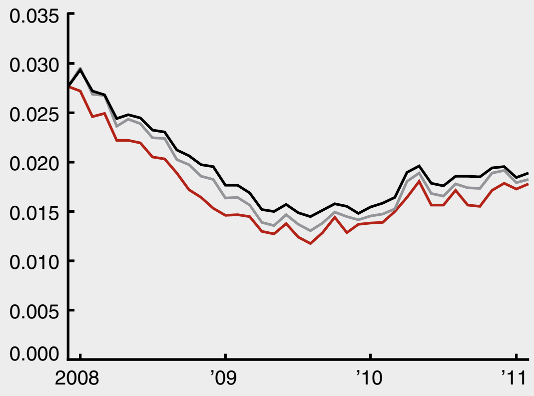
FIGURE 25

Effects on unemployment rate (3 states, steady state, variable transition rates)

Sources: Author's calculations based on data from the Bureau of Labor Statistics' *Current Population Survey* and *Job Openings and Labor Turnover Survey*.

FIGURE 26

Effects on vacancies (3 states, steady state, variable transition rates)



Sources: Author's calculations based on data from the Bureau of Labor Statistics' *Current Population Survey* and *Job Openings and Labor Turnover Survey*.

Also, I compute adjusted unemployment U_t^{**}, adjusted nonparticipation N_t^{**}, and adjusted vacancies V_t^{**} from equations 25–27 under the assumption that $A_t = A_{2007:12}$, for every month t (but letting all λ_ts take their actual values). That is, I let the value of a job J_t evolve as in figure 23 and the transition rates evolve as in figure 14 (p. 156), but I fix the matching productivity to the value that it had at the beginning of the recession $A_{2007:12}$. In other words, U_t^{**}, N_t^{**}, and V_t^{**} measure the unemployment, nonparticipation, and vacancies that would have been obtained had the matching productivity remained constant at its December 2007 level but all transition rates and J_t had evolved as they did.

Figure 25 shows $U_t^{*} / (E_t^{*} + U_t^{*})$ ("constant A, constant λ"), $U_t^{**} / (E_t^{**} + U_t^{**})$ ("constant A, variable λ"), and $U_t / (E_t + U_t)$ ("variable A, variable λ"). We see that despite the large drop in the value of a job J_t described in figure 23, $U_t^{*} / (E_t^{*} + U_t^{*})$ increased only moderately. In turn, $U_t^{**}(E_t^{**} + U_t^{**})$ increases by a huge amount, indicating that the large increases in the λ_t^{EU} and λ_t^{NU} observed after 2007:12 in figure 14 had a large negative impact in the labor market. Actually, the unemployment rate turned to increase only as described by $U_t / (E_t + U_t)$ because of the large increase in matching efficiency reported by figure 12 (p. 154).

Figure 26 shows that the increase in matching productivity A_t and the changes in transition rates played a noticeable role in keeping vacancies relatively high. In turn, figure 27 shows that the increase in matching productivity A_t played a crucial role in keeping nonparticipation (N) relatively low, since the changes in transition rates would have increased it quite substantially.

Transitionary dynamics

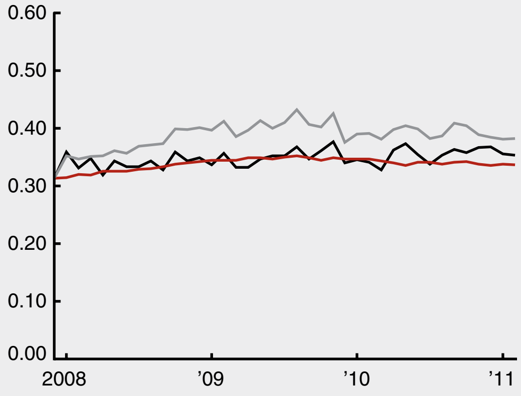
The previous section showed that introducing variable transition rates affects the results quite significantly and that it allows one to keep track of the behavior of nonparticipation much more closely. However, the analysis of the previous section suffered two drawbacks. First, while the calibration of the matching elasticity parameter α assumed constant matching efficiency and constant separation rates prior to 2007:12, we see from figures 14 (p. 156) and 22 that this is not quite the case. Second, the analysis assumed that the steady state of the model could be used to describe monthly data, while the large fluctuations in transition rates observed in figure 14 (p. 156) suggest that this may not be a good approximation. For these reasons, in this section I take a more direct approach to the calibration of the matching elasticity parameter α and perform the analysis without imposing that the model is always at its steady state. This allows me to evaluate to what extent this affects the results.

Observe from equation 16 that

$$40)\quad \ln\left(\frac{M_t}{V_t}\right) = \ln\left(A_t\right) + \alpha \ln\left(\frac{U_t}{V_t}\right).$$

FIGURE 27

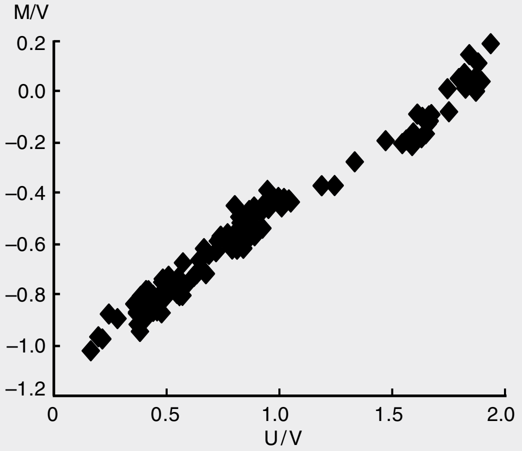
Effects on nonparticipation
(3 states, steady state, variable transition rates)



Sources: Author's calculations based on data from the Bureau of Labor Statistics' *Current Population Survey* and *Job Openings and Labor Turnover Survey*.

FIGURE 28

Matching function



Note: M/V is total matches per vacancy; U/V is the unemployment–vacancy ratio.
Sources: Author's calculations based on data from the Bureau of Labor Statistics' *Current Population Survey* and *Job Openings and Labor Turnover Survey*.

In what follows, I identify M_t with the total number of workers that transition from unemployment to employment between months t and $t + 1$, as reported by the CPS. Figure 28 plots $\ln\left(\frac{M_t}{V_t}\right)$ against $\ln\left(\frac{U_t}{V_t}\right)$ for the whole sample period. We see a strong linear relation, suggesting that equation 40 provides a good description of the data with a relatively constant A_t. Fitting equation 40 using OLS (ordinary least squares) over the period 2001:1–2007:12 gives an estimate of $\alpha = 0.69$.

Given this estimated value of α, the path for the matching efficiency parameter A_t implied by equation 40 is reported in figure 29. We see that this path is completely different from that in figure 22. The matching productivity is much less variable and contrary to figure 22, displays a large drop after the start of the last recession, reaching by the end of the sample period a value 12 percent lower than in 2007:12. There is no doubt that measuring A_t directly from the matching function in equation 16 gives a very different picture from measuring it from the steady states of the model economy.

Figure 30 reports the value of a job J_t obtained from equation 27 using the matching efficiencies A_t obtained from equation 40 and reported in figure 29. The figure is very similar to figure 23, again indicating that the path for the value of a job is robust to the different ways of measuring it.

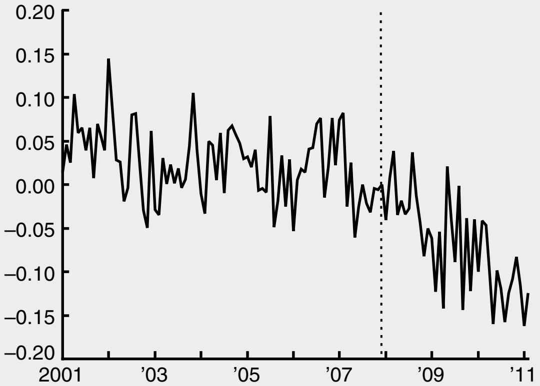
I now turn to evaluating the relative contributions of the value of filled jobs J_t, the matching efficiency parameter A_t, and the transition rates λ_t^{EU}, λ_t^{EN}, λ_t^{UN}, λ_t^{NU}, and λ_t^{NE} to unemployment dynamics since the beginning of the recession. For this purpose, I proceed as before and find a sequence E_t^*, U_t^*, N_t^*, and V_t^* that satisfies equations 17, 18, 19, and 21 under the assumption that $A_t = A_{2007:12}$, $\lambda_t^{UN} = \lambda_{2007:12}^{UN}$, $\lambda_t^{EU} = \lambda_{2007:12}^{EU}$, $\lambda_t^{EN} = \lambda_{2007:12}^{EN}$, $\lambda_t^{NE} = \lambda_{2007:12}^{NE}$, and $\lambda_t^{NU} = \lambda_{2007:12}^{NU}$, for every month t. That is, I let the value of a job J_t evolve as in figure 30 but fix the matching productivity and all transition rates to the values that they had in 2007:12 (that is, at the beginning of the recession). Similarly, as before, E_t^*, U_t^*, N_t^*, and V_t^*, describe the employment, unemployment, nonparticipation, and vacancies levels that would have obtained if the value of a job had been the only variable changing over time.

Also, I compute the $E_t^{**}, U_t^{**}, N_t^{**}$, and V_t^{**} that satisfy equations 17, 18, 19, and 21 under the assumption that $A_t = A_{2007:12}$, for every month t. That is, E_t^{**}, U_t^{**}, N_t^{**}, and V_t^{**} describe the employment, unemployment, nonparticipation, and vacancies levels that would have been obtained if the matching productivity parameter had remained constant at its December 2007 level, while all other variables (that is, J_t and all the λ values) had changed the way they did.

Figure 31 reports the paths for $U_t^* / (E_t^* + U_t^*)$ ("constant A, constant λ"), $U_t^{**} / (E_t^{**} + U_t^{**})$ ("constant A, variable λ"), and $U_t / (E_t + U_t)$ ("variable A, variable λ"). From the $U_t^* / (E_t^* + U_t^*)$ path, we see

FIGURE 29

Matching efficiency (3 states, transitionary dynamics)



Note: The log of A_t is normalized to zero at the start of the past recession.
Sources: Author's calculations based on data from the Bureau of Labor Statistics' *Current Population Survey* and *Job Openings and Labor Turnover Survey*.

FIGURE 30

Value of a job (3 states, transitionary dynamics)

Note: The log of J_t is normalized to zero at the start of the past recession.
Sources: Author's calculations based on data from the Bureau of Labor Statistics' *Current Population Survey* and *Job Openings and Labor Turnover Survey*.

that changes in the value of a job J_t played a very minor role in unemployment dynamics: The red line is roughly flat. From comparing the path for $U_t^{**}/(E_t^{**}+U_t^{**})$ with the path for $U_t^{*}/(E_t^{*}+U_t^{*})$, I conclude that changes in the transition rates λ played a crucial role in unemployment dynamics: The gray line is widely different from the red line. In fact, we see that changes in the transition rates λ accounted for most of the unemployment dynamics observed since the recession: The black line is very close to the gray line, indicating that the matching productivity played a minor role in the observed unemployment rate dynamics.

In turn, figure 32 reports the path for N_t^* ("constant A, constant λ"), N_t^{**} ("constant A, variable λ") and N_t ("variable A, variable λ"). From the N_t^* path, we see that far from accounting for the observed increase in nonparticipation, changes in the value of a job J_t would have accounted for a decrease in nonparticipation. The bulk of the increase in nonparticipation is accounted for by changes in transition rates, since changes in the matching productivity played a relatively minor role: The gray line is very close to the black line).

Finally, figure 33 shows that none of the changes in the matching efficiency parameter A_t or in the transition probabilities were important determinants of vacancies dynamics: The path for vacancies was mainly determined by J_t.

Nonparticipants compete for vacancies

This section describes and uses the most satisfactory specification of the model. Thus, it provides the main results of the paper. Observe that the model used in the previous section had three labor market states but only unemployed workers were inputs to the matching function: Nonparticipants made transitions to employment but without going through the matching function. I view this feature as a weakness of the previous specification of the model. The workers transitioning from nonparticipation to employment must be competing for the same vacancies as the workers transitioning from unemployment to employment and should therefore enter the matching function in a similar way. This section addresses this issue by modifying the matching function of the previous section accordingly. Introducing a more satisfactory specification for the matching function allows me to obtain better measurements of the matching efficiency.

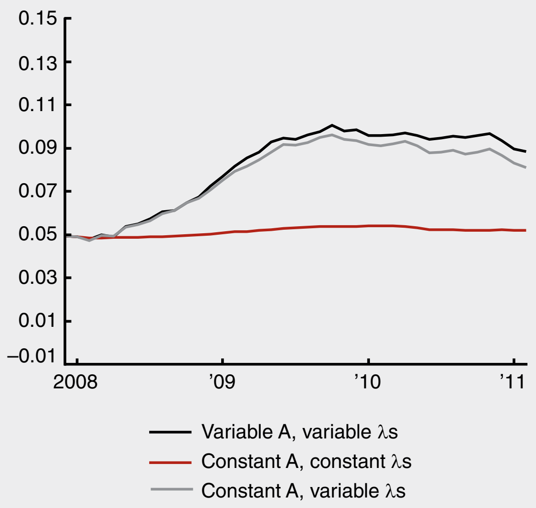
The matching function is now described as follows:

41) $$M_t = A_t\left(U_t + \psi_t N_t\right)^{\alpha} V_t^{1-\alpha},$$

where M_t is the total number of matches, U_t is unemployment, N_t is nonparticipation, V_t is vacancies, A_t is the matching efficiency, $0 \le \psi_t \le 1$, and $0 < \alpha < 1$. Observe that ψ_t can be interpreted as the fraction of the total number of workers who report they are nonparticipants but search for jobs anyway. Alternatively,

FIGURE 31

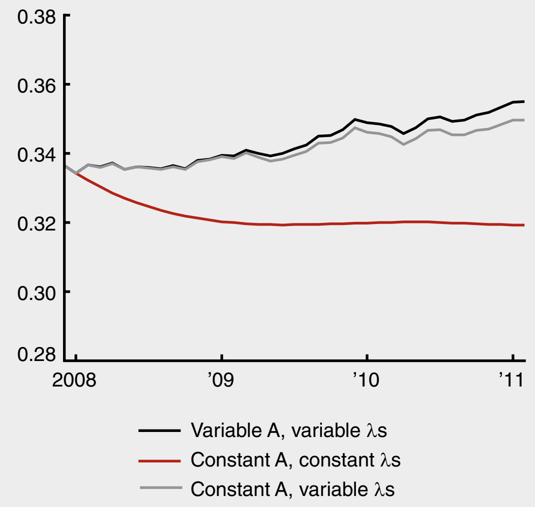
Effects on unemployment (3 states, transitionary dynamics)



Sources: Author's calculations based on data from the Bureau of Labor Statistics' *Current Population Survey* and *Job Openings and Labor Turnover Survey*.

FIGURE 32

Effects on nonparticipation (3 states, transitionary dynamics)



Sources: Author's calculations based on data from the Bureau of Labor Statistics' *Current Population Survey* and *Job Openings and Labor Turnover Survey*.

ψ_t can be interpreted as the search intensity of nonparticipant workers.

The transition rate from unemployment into employment λ_t^{UE} is given by:

$$42)\ \lambda_t^{UE} = \left(\frac{M_t}{U_t}\right)\left(\frac{U_t}{U_t+\psi_t N_t}\right) = \frac{A_t\left(U_t+\psi_t N_t\right)^{\alpha} V_t^{1-\alpha}}{U_t+\psi_t N_t},$$

since a fraction $\left(\frac{U_t}{U_t+\psi_t N_t}\right)$ of the total matches M_t is formed with unemployed workers. Similarly, the transition rate from nonparticipation into employment λ_t^{NE} is given by:

$$43)\ \lambda_t^{NE} = \left(\frac{M_t}{N_t}\right)\left(\frac{\psi_t N_t}{U_t+\psi_t N_t}\right)$$

$$= \psi_t \frac{A_t\left(U_t+\psi_t N_t\right)^{\alpha} V_t^{1-\alpha}}{U_t+\psi_t N_t},$$

since a fraction $\left(\frac{\psi_t N_t}{U_t+\psi_t N_t}\right)$ of the total matches M_t is formed with nonparticipant workers.

The transition rate from employment to unemployment λ_t^{EU}, the transition rate from employment to nonparticipation λ_t^{EN}, the transition rate from unemployment to nonparticipation λ_t^{UN}, and the transition rate from nonparticipation to unemployment λ_t^{NU} are assumed to be exogenous to the model.

The evolution of workers across labor market states is then given by the following equations:

$$44)\ E_{t+1} = E_t + M_t - \left(\lambda_t^{EU} + \lambda_t^{EN}\right) E_t,$$

$$45)\ U_{t+1} = U_t + \lambda_t^{EU} E_t + \lambda_t^{NU} N_t - \left(\lambda_t^{UE} + \lambda_t^{UN}\right) U_t,$$

$$46)\ N_{t+1} = N_t + \lambda_t^{EN} E_t + \lambda_t^{UN} U_t - \left(\lambda_t^{NE} + \lambda_t^{NU}\right) N_t.$$

Equation 44 states that next-period employment is equal to current employment, plus all new matches, minus total separations (either to unemployment or nonparticipation). Equation 45 states that next-period unemployment is equal to current unemployment, plus all transitions into unemployment (either from employment or nonparticipation), minus all transitions out of unemployment (either to employment or nonparticipation). Equation 46 states that next-period nonparticipation is equal to current nonparticipation, plus all transitions into nonparticipation (either from employment or unemployment), minus all transitions out of nonparticipation (either to employment or unemployment).

FIGURE 33

Effects on vacancies (3 states, transitionary dynamics)

Sources: Author's calculations based on data from the Bureau of Labor Statistics' *Current Population Survey* and *Job Openings and Labor Turnover Survey*.

The free-entry condition is given by

$$47)\ k = \left(\frac{M_t}{V_t}\right) J_t,$$

since from the point of view of a firm, the probability of filling a vacancy is now equal to M_t / V_t.

Observe that using equations 41, 42, and 43, we can rewrite equations 44–47 as follows:

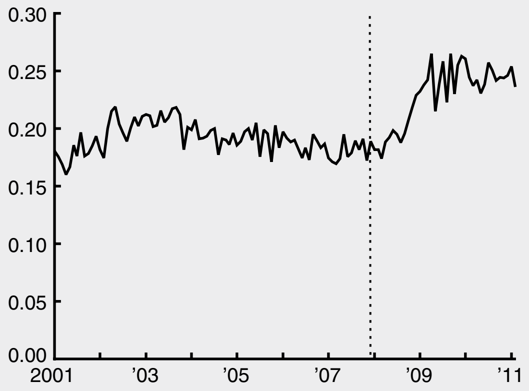
$$48)\ E_{t+1} = E_t + A_t(U_t + \psi_t N_t)^{\alpha} V_t^{1-\alpha} - (\lambda_t^{EU} + \lambda_t^{EN}) E_t,$$

$$49)\ U_{t+1} = U_t + \lambda_t^{EU} E_t + \lambda_t^{NU} N_t - \left(\frac{A_t(U_t + \psi_t N_t)^{\alpha} V_t^{1-\alpha}}{U_t + \psi_t N_t} + \lambda_t^{UN}\right) U_t,$$

$$50)\ N_{t+1} = N_t + \lambda_t^{EN} E_t + \lambda_t^{UN} U_t - \psi_t \left(\frac{A_t(U_t + \psi_t N_t)^{\alpha} V_t^{1-\alpha}}{U_t + \psi_t N_t} + \lambda_t^{NU}\right) N_t,$$

FIGURE 34

Search intensity of nonparticipants



Sources: Author's calculations based on data from the Bureau of Labor Statistics' *Current Population Survey* and *Job Openings and Labor Turnover Survey*.

$$51)\ V_t = \frac{J_t}{k} A_t(U_t + \psi_t N_t)^{\alpha} V_t^{1-\alpha}.$$

Given the total number of workers unemployed at date zero U_0 and the total number of workers that are nonparticipants at date zero N_0, the model generates an endogenous path for $\{M_t, V_t, U_{t+1}, N_{t+1}\}_{t=0}^{\infty}$.

Results

From equations 42 and 43, we have that the search intensity of nonparticipants can be measured as

$$52)\ \psi_t = \frac{\lambda_t^{NE}}{\lambda_t^{UE}}.$$

Figure 34 shows that the fraction of nonparticipants that search has increased quite substantially since the start of the latest recession.

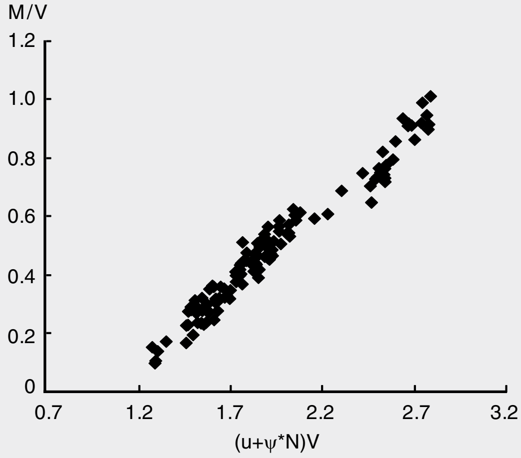
From equation 41, we have that

$$53)\ \ln\left(\frac{M_t}{V_t}\right) = \ln(A_t) + \alpha \ln\left(\frac{U_t + \psi_t N_t}{V_t}\right).$$

In what follows, I identify M_t with the total number of workers that transition from unemployment into employment between months t and $t + 1$, plus the total number of workers that transition from nonparticipation into employment between those same months,

FIGURE 35

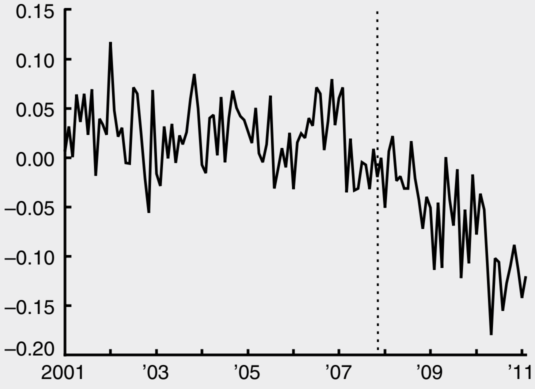
Matching function



Note: M/V is total matches per vacancy; (u+ψ*N)/V is total searchers per vacancy.
Sources: Author's calculations based on data from the Bureau of Labor Statistics' *Current Population Survey* and *Job Openings and Labor Turnover Survey*.

FIGURE 36

Matching efficiency (transitionary dynamics, N in matching function)



Note: The log of A_t is normalized to zero at the start of the past recession.
Sources: Author's calculations based on data from the Bureau of Labor Statistics' *Current Population Survey* and *Job Openings and Labor Turnover Survey*.

as reported by the CPS. Figure 35 plots $\ln\left(\frac{M_t}{V_t}\right)$ against $\ln\left(\frac{U_t+\psi_t N_t}{V_t}\right)$ for the whole sample period. We see a strong linear relation, suggesting that equation 53 provides a good description of the data with a relatively constant A_t. Fitting equation 53 using OLS between 2001:1 and 2007:12 gives an estimate of $\alpha = 0.62$.

Given this estimated value of α, the path for the matching efficiency parameter A_t implied by equation 53 is reported in figure 36. We see that the path is not very different from figure 29 (p. 163). In turn, the value of a job, which is measured as

$$54)\ J_t = k\frac{V_t}{M_t},$$

is reported in figure 37. We also see that its path is not very different from figure 30 (p. 163).

In order to decompose the effects of the different variables on labor market dynamics, I find the E_t^*, U_t^*, N_t^*, and V_t^* that satisfy equations 48–51 under the assumption that $A_t = A_{2007:12}$, $\psi_t = \psi_{2007:12}$, $\lambda_t^{UN} = \lambda_{2007:12}^{UN}$, $\lambda_t^{EU} = \lambda_{2007:12}^{EU}$, $\lambda_t^{EN} = \lambda_{2007:12}^{EN}$, and $\lambda_t^{NU} = \lambda_{2007:12}^{NU}$, for every month t. That is, E_t^*, U_t^*, N_t^*, and V_t^* describe the employment, unemployment, nonparticipation, and vacancies levels that would have been obtained if J_t had changed the way it did but all other variables had remained constant at their December 2007 levels.

Also, I compute the E_t^{**}, U_t^{**}, N_t^{**}, and V_t^{**} that satisfy equations 48–51 under the assumption that $A_t = A_{2007:12}$ and $\psi_t = \psi_{2007:12}$, for every month t. That is, E_t^{**}, U_t^{**}, N_t^{**}, and V_t^{**} describe the employment, unemployment, nonparticipation, and vacancies levels that would have been obtained if J_t and all λ values had changed the way they did but A_t and ψ_t had remained constant at their December 2007 levels.

Similarly, I compute the E_t^{***}, U_t^{***}, N_t^{***}, and V_t^{***} that satisfy equations 48–51 under the assumption that $\psi_t = \psi_{2007:12}$, for every month t. That is, E_t^{***}, U_t^{***}, N_t^{***}, and V_t^{***} describe the employment, unemployment, nonparticipation, and vacancies levels that would have been obtained if A_t, J_t, and all λ values had changed the way they did but ψ_t had remained constant at its December 2007 level.

Figure 38 reports the paths for $U_t^* / (E_t^* + U_t^*)$ ("constant A, λ, ψ"), $U_t^{**} / (E_t^{**} + U_t^{**})$ ("constant A, ψ"), $U_t^{***} / (E_t^{***} + U_t^{***})$ ("constant ψ"), and $U_t / (E_t + U_t)$ ("everything variable"). From the $U_t^* / (E_t^* + U_t^*)$ path, we see that changes in the value of a job J_t played a very minor role in unemployment dynamics: From an initial unemployment rate of 4.9 percent, changes in J_t are only able to generate a peak unemployment rate of 6.4 percent. From comparing the path for $U_t^{**} / (E_t^{**} + U_t^{**})$ with the path for $U_t^* / (E_t^* + U_t^*)$, we see that changes in the transition rates λ played a crucial role in generating the large and persistent

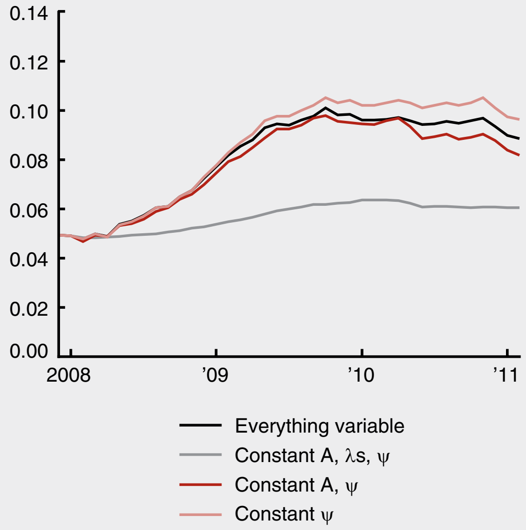
FIGURE 37

Value of a job (transitionary dynamics, N in matching function)

Note: The log of J_t is normalized to zero at the start of the past recession.
Sources: Author’s calculations based on data from the Bureau of Labor Statistics’ *Current Population Survey* and *Job Openings and Labor Turnover Survey*.

FIGURE 38

Effects on unemployment (transitionary dynamics, N in matching function)



Sources: Author’s calculations based on data from the Bureau of Labor Statistics’ *Current Population Survey* and *Job Openings and Labor Turnover Survey*.

increase in the unemployment rate. In fact, the path for $U_t^{**} / \left(E_t^{**} + U_t^{**}\right)$ is very similar to $U_t / \left(E_t + U_t\right)$. Comparing $U_t^{***} / \left(E_t^{***} + U_t^{***}\right)$ with $U_t^{**} / \left(E_t^{**} + U_t^{**}\right)$, we see that the large drop in matching efficiency shown in figure 36 had a nontrivial role in the increase in the unemployment rate: The largest difference between $U_t^{***} / \left(E_t^{***} + U_t^{***}\right)$ and $U_t^{**} / \left(E_t^{**} + U_t^{**}\right)$ is 1.5 percent. Comparing $U_t^{***} / \left(E_t^{***} + U_t^{***}\right)$ with $U_t / (E_t + U_t)$, we see that the increase in the search intensity of nonparticipants shown in figure 34 roughly offsets the effects of the fall in matching efficiency.

Figure 39 reports the paths for N_t^{*} (“constant A, λ, ψ”), N_t^{**} (“constant A, ψ”), N_t^{***} (“constant ψ”) and N_t (“everything variable”). We see that the value of a job had a significant effect on nonparticipation: The gray line first declines and then increases quite rapidly. The changes in transition rates first increased nonparticipation but then lowered it: The red line is initially above the gray line, but it crosses it in mid-2009. The drop in matching efficiency of figure 36 has the effect of increasing nonparticipation: The light red line is significantly higher than the red line. However, the large increase in the search intensity of nonparticipants shown in figure 34 had a large effect on reducing nonparticipation: The black line is much lower than the light red line.

Lastly, figure 40 shows that the only important determinant of vacancy dynamics was the value of a job J_t (all other lines are quite similar to the gray).

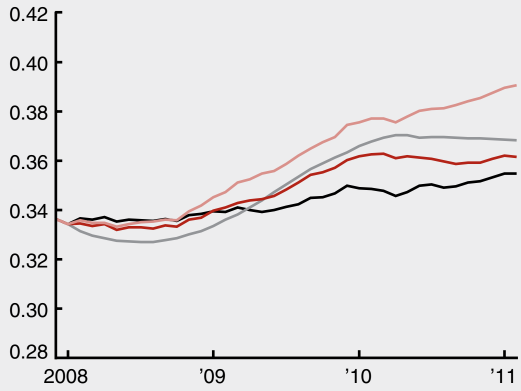
Conclusion

This article has explored different approaches to measuring matching efficiency and assessing its implications for labor market dynamics since the start of the past recession. In particular, I evaluated the importance of allowing for a third labor market state, allowing for variable transition rates, considering explicit transitionary dynamics, and allowing nonparticipants to enter the matching function. I find that the results are quite sensitive to the different specifications.

In the preferred scenario (that is, the case with three labor market states, variable transition rates, nonparticipants entering the matching function, and explicit transitionary dynamics), I obtained the following findings. First, the matching efficiency parameter is quite volatile throughout the sample period. Second, the matching efficiency has been drifting down since the start of the recession. Third, the value of filled jobs plummeted between 2007:12 and 2009:6 but has recovered quite significantly since then. Fourth, conditional on the observed paths for the value of a job and all transition rates, the drop in matching efficiency since the start of the recession has had only a moderate im-

FIGURE 39

Effects on nonparticipation (transitionary dynamics, N in matching function)

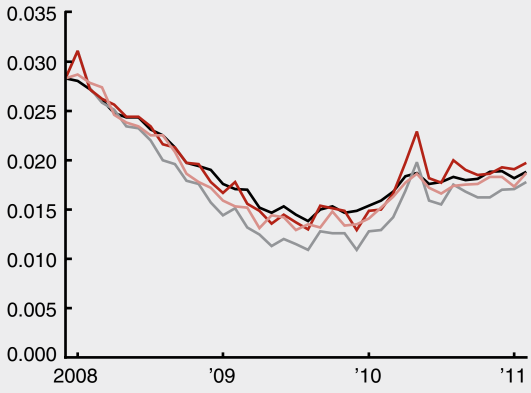


Everything variable
Constant A, λs, ψ
Constant A, ψ
Constant ψ

Sources: Author's calculations based on data from the Bureau of Labor Statistics' *Current Population Survey* and *Job Openings and Labor Turnover Survey*.

FIGURE 40

Effects on vacancies (transitionary dynamics, N in matching function)



Everything variable
Constant A, λs, ψ
Constant A, ψ
Constant ψ

Sources: Author's calculations based on data from the Bureau of Labor Statistics' *Current Population Survey* and *Job Openings and Labor Turnover Survey*.

pact on the unemployment rate. Fifth, the large effects on unemployment rate dynamics arise from changes in the transition rates. Sixth, the matching efficiency, the value of a job, the transition rates, and the search intensity of nonparticipants all have significant effects on the dynamics of nonparticipation.

The analysis performed in this article decomposed the observed growth in unemployment and nonparticipation into contributions from changes in matching efficiency, the value of a job, the search intensity of nonparticipants, and the transition rates across different labor market states. This decomposition was done very much in the spirit of standard growth accounting exercises, in which GDP growth is decomposed into growth contributions from total factor productivity, capital, and labor. Interpreted as a growth accounting exercise, the results in this paper should be considered as extremely informative. However, care should be exercised in providing a counterfactual interpretation to the results. The reason is that if the matching efficiency had stayed constant at its 2007:12 level (instead of dropping as it actually did), this would have affected the value of a job and the transition rates across labor market states, but these secondary effects have not been considered in the analysis. That is, the contributions to labor market dynamics of the value of a job, the productivity of the matching function, the different transition rates, and the search intensity of nonparticipants have been calculated as not affecting the other variables.[10] To evaluate counterfactuals such as this, the explicit economic decisions and wage determination process that this paper has abstracted from would have to be incorporated and the equilibrium of such full-blown models would have to be analyzed. Of course, the counterfactual results would depend on how those modeling choices are made.

Another caveat to the analysis is that it has not incorporated job-to-job transitions. Since the workers making these transitions are competing for the same pool of vacancies as unemployed and nonparticipant workers, their behavior may affect the measurement of matching efficiency.

NOTES

[1]The negative relation between unemployment and vacancies is not exclusive to the U.S.: It is present in a number of countries. See Petrongolo and Pissarides (2001) for an empirical survey of the Beveridge curve and the matching function.

[2]Strictly speaking, what these papers implicitly assume is that the transitionary dynamics of the model economy are extremely fast. Under this assumption, they use the steady state of the model to analyze data, even when the matching function and transition rates change over short periods.

[3]The preferred specification is the one with the least restrictive and/or most appealing assumptions.

[4]We could choose alternative approaches. For instance, we could take the average of the ratios in equation 11 for every pair of months (i, j). The problem with this approach is that measurement errors would be severely amplified for pairs of months with similar unemployment/vacancy ratios. Another approach would be to take the average of the ratios in equation 11 for pairs of months with sufficiently large differences in unemployment/vacancy ratios. This approach would lead to a similar estimate for α as the approach chosen here.

[5]For U_t, I use the unemployment rate at month t from the Bureau of Labor Statistics' (BLS) *Current Population Survey* (CPS). For V_t, I use the average vacancies reported by the BLS's *Job Openings and Labor Turnover Survey* (JOLTS) in months t and $t-1$, divided by the size of the labor force reported by the CPS in month t. I average the vacancies reported by JOLTS because they correspond to the number of vacancies at the end of the month, while the CPS data roughly correspond to observations in the middle of the month.

[6]This is a large number. However, J_t must be interpreted as the value of creating an additional job and not as the average value of all existing jobs. Obtaining such a large drop in the value of a marginal job should not be surprising, given the severity of the recession experienced by the U.S. at the time.

[7]See the conclusions for a further discussion of how to interpret the results of this article.

[8]See note 2 for a discussion of this estimation approach.

[9]These results should not be taken seriously. In what follows, I show that the large drop in matching efficiency obtained in figure 16 is an artifact of the constant transition rates.

[10]Observe that similar caution must be used in providing a counterfactual interpretation to standard GDP growth accounting exercises. If total factor productivity had stayed constant during the last 50 years (instead of growing at its actual rate), this would have affected capital accumulation and labor supply. However, these secondary effects are not taken into account when reporting the contribution to growth of total factor productivity.

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