Firm Entry and Labor Market Dynamics*

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Abstract

We present a model of fluctuations in which firms face sunk costs to enter the production process and labor markets are characterized by search and matching frictions. Sunk costs give rise to an endogenously time-varying value of vacancy creation; it is always zero in models where entry is costless. This result amplifies and propagates technology shocks into labor market variables, resulting in higher volatility of unemployment and a relationship between vacancies and unemployment that replicates that observed in the data. The model achieves this without resorting to either wage rigidity or a large outside option for employed workers. Effects are largest when the value of vacancy creation is countercyclical.

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The views expressed here are the authors’ and not necessarily those of the Federal Reserve Bank of Atlanta or the Federal Reserve System.
1 Introduction

Plant births and deaths play a prominent role in explaining the dynamics of creation and destruction of jobs. According to Davis, Haltiwanger and Schuh (1996) at the annual frequency startups are responsible for a 15.5 % of job creation (8.4% at the quarterly frequency) and shutdowns contribute 22.9 % to job destruction (11.6 % at the quarterly frequency).

This paper analyzes the role of firm entry and exit and product creation in an equilibrium model of fluctuations with labor market matching. Specifically, we want to assess how those features affect the response of labor market variables to a technology shock. A novel mechanism in our analysis is an endogenously time-varying value of creating a vacancy. In equilibrium, as firms need to expend resources to enter the market, vacancy creation has positive value; its value is zero if entry is costless. We show how the cyclical properties of the value of vacancy creation are related to the ability of the model to match the labor market business cycle facts. We first use a simple motivating example in which the value of creating a vacancy exogenously moves over the cycle. We use this example to highlight the intuition behind our results. We then proceed to construct economies in which the value of creating a vacancy is endogenous and changes with aggregate conditions. We show that this improves relative to existing models when compared to the data.

We relate our results to a large literature that has followed Shimer (2005). This literature has tried to find ingredients so that the standard Mortensen and Pissarides (1994) model augmented with aggregate shocks would match the labor market business cycle facts. So far, it has focused on two ingredients. On the one hand, a large outside option for the worker, in other words, a large value of being unemployed even close to that of being employed. Hagedorn and Manovskii (2007) propose this solution. On the other hand, rigidity in real wages as advocated primarily by Hall (2005). The first mechanism matches well the business cycle moments. However, it has implausible implications for
the response of the unemployment rate to changes in the unemployment benefit. For example, using Hagedorn and Manovskii’s (2007) calibration, Hornstein, Krusell, and Violante (2005) calculate that a 15% increase in the unemployment benefit would double the unemployment rate. Hall’s calibration also delivers, for instance, the correct response of market tightness to a technology shock. However, it has two counterfactual implications. First, the volatility of wages is zero; second, the correlation between labor’s share in output and labor productivity is minus one. Pissarides (2007) and Haefke and Van Rhens (2007) are skeptical about wage rigidity as a solution. Evidence points to wages of new hires being quite volatile and those are the ones that are relevant in Shimer’s (2005) study.

Notably, in our framework the outside option for workers is nowhere close to the value of being employed and wages are volatile (relative to a model similar to Shimer (2005)). We match the correlation between vacancies and unemployment and much of the volatility of market tightness relative to productivity. We obtain these results in economies with monopolistic firms, sunk costs, and search and matching in labor markets. Our point of departure is the model by Bilbiie, Ghironi and Melitz (2007) to which we embed the Mortensen and Pissarides (1994) structure. In our model economies, business cycle fluctuations are the result of technology shocks only. We begin with an economy that uses labor as the only factor of production. We show how the improvement of the Mortensen-Pissarides framework is small, as the value of vacancy creation is procyclical. We later introduce capital as a factor of production, which reverses the cyclicality of the value of creating a vacancy and bringing the model’s implications much closer to the data.

2 Motivation

Let’s first consider a steady state version of Mortensen-Pissarides model to see how changes in the firm’s outside option can break the simple link between productivity shock and the v-u ratio. We adopt a discrete-time search and matching model. All payments
are made at the end of the time period so that results in the discrete-time version are similar to the continuous-time model as in Shimer (2005). There is a unit measure of risk-neutral workers, and a continuum of risk-neutral firms. All agents discount future payoffs at rate \( r = 1/\beta - 1 \).

Workers can either be unemployed or employed. An unemployed worker gets flow utility \( b \) from non-market activity and searches for a job. An employed worker earns wage \( w \) but may not search. A firm hires one worker to produce output with productivity \( Z \). In order to hire a worker, a firm must undertake the recruiting expense \( \omega \). A worker and a firm separate according to a fix separation rate \( s \) such that both worker and firm have to search again. Let \( \theta \) be the vacancy-unemployment ratio. Under the assumption of constant returns-to-scale matching technology, the job finding probability for unemployed workers is a function of \( \theta \), denoted by \( f(\theta) \); and the vacancy filling probability is \( q(\theta) = f(\theta)/\theta \).

The only state variable in this simple example is \( Z \), and all other endogenous variables depend on it. Let \( Q \) be the present value of a vacant job which capture the outside option of the firm. In Shimer (2005) and others, this value is set to equal zero due to costless entry of firms. However, to investigate the effect of changes in the firm’s outside option, we assume that \( Q \) is exogenous and depends on \( Z \). Let \( J, F \) and \( H \) be the present value of a filled job, unemployed worker, and employed worker, respectively. All these present values must satisfy the following recursive relationship:

\[
\begin{align*}
    rQ &= -\omega + q(\theta) (J - Q), \\
    rJ &= Z - w - s (J - Q), \\
    rF &= b + f(\theta) (H - F), \\
    rH &= w - s (H - F).
\end{align*}
\]

When a worker and firm meet, wages are determined by Nash bargaining to split the expected surplus. The surplus is divided between the worker and firm with the worker's
bargaining power equal to $\phi \in (0, 1)$. The Nash bargaining solution gives:

$$\frac{H - F}{\phi} = \frac{J - Q}{1 - \phi}.$$ 

Then, v-u ratio can be pinned down by solving above system of equations, which is given by:

$$\frac{r + s}{q(\theta)} + \phi \theta = (1 - \phi) \frac{Z - b - rQ(Z)}{\omega + rQ(Z)}.$$ 

When the firm’s outside option is zero, the elasticity of the v-u ratio $\theta$ with respect to “net labor productivity” $Z - b$ is:

$$\frac{r + s + \phi f(\theta)}{(r + s)(1 - \eta(\theta)) + \phi f(\theta)}$$

where $\eta(\theta) \in [0, 1]$ is the elasticity of $f(\theta)$ with respect to $\theta$. Shimer (2005) argues that the elasticity of $\theta$ cannot exceed 2 with reasonable parameter values. Therefore, unless the value of leisure $b$ is close to productivity $Z$, the v-u ratio is likely to be unresponsive to changes in the productivity shock.

However, if $Q$ is fluctuating along with $Z$, the above simple relationship between average productivity and the v-u ratio is distorted. The elasticity of the v-u ratio with respect to $Z$ becomes far more complicated:

$$\frac{(r + s + \beta f(\theta)) \Psi + \Gamma}{(r + s)(1 - \eta(\theta)) + \beta f(\theta)}$$

where $\Psi = 1 - (z - b - \omega) rQ_z/(\omega + rQ)$ and $\Gamma = \Psi (1 - \beta) rQ/(\omega + rQ)$.

Table (1) shows the case when $Q$ follows an exogenous process in the labor market search and matching model. The process is assumed to be

$$\ln(Q) = a \ln(Z),$$

$$\ln(Z') = \rho z \ln(Z) + \varepsilon.$$
### Table 1: Volatility of V-U Ratio

<table>
<thead>
<tr>
<th></th>
<th>std(θ)</th>
<th>std(Z)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$a = 10$</td>
<td>0.082</td>
<td>0.02</td>
</tr>
<tr>
<td>$a = -10$</td>
<td>0.144</td>
<td>0.02</td>
</tr>
<tr>
<td>$Q = 0$</td>
<td>0.039</td>
<td>0.02</td>
</tr>
</tbody>
</table>

We can see that the fluctuation in the firm’s outside option can significantly improve the volatility of v-u ratio than standard model. In particular, when the outside option is negatively correlated with the shock, the standard deviation rises by factor of 4. The remainder of the paper will present a model that endogenizes $Q$. We build an entry and exit model in which the vacancy value is always positive and varies over time.

### 3 The Model Economies

We start with an economy in which labor is the only factor of production and it is used to both set up a firm and to produce the consumption good. To facilitate the mapping between the model and the business cycle statistics form the data, we add capital to our model economies in a subsection below. Firms demand capital to pay the sunk cost and be allowed in the market and as an input to produce a consumption good.

#### 3.1 An Economy without Capital

##### 3.1.1 Environment

Our economy is populated by a large extended household comprised of a continuum of members of total mass equal to $\bar{N}$ and an infinite mass of firms.

Members in the household can either be employed or unemployed. Unemployed agents receive an unemployment benefit while they search for jobs with the hope of finding a job opportunity. This opportunity will allow them to enter into a relationship with a firm, to negotiate a contract that stipulates the retribution for their services, and to produce
output during the following period. A fraction \( \tilde{N}_t \) of employed agents works and gets paid the negotiated wage. Members of the household have preferences over a sequence of a composite of goods over time, \( \{C_t\}_{t=1}^{\infty} \). The per-period utility function is of the relative risk aversion class. The household’s (expected) discounted lifetime utility as of time 0 is given by,

\[
E_0 \sum_{t=0}^{\infty} \beta^t \left[ \frac{(C_t)^{1-\sigma}}{1-\sigma} \right],
\]

where \( \beta \in (0, 1) \) is the discount factor and \( \sigma > 0 \) is the coefficient of relative risk aversion. We assume that each firm produces a differentiated commodity. At each point in time, there is a subset of goods \( X_t \subseteq X \) available to consumers and the composite good is made up of commodities from that subset. The available set is time-varying as not all firms will produce every period. To aggregate over the different commodities, we use a Dixit and Stiglitz (1977) aggregator:

\[
C_t = \left( \int_{x \in X_t} [c_t(x)]^{\frac{1}{\gamma-1}} dx \right)^{\frac{\gamma}{\gamma-1}},
\]

where \( \gamma > 1 \) is the symmetric elasticity of substitution between commodities. If \( p_t(x) \) is the price of product \( x \), then the level of \( c_t(x) \) chosen to minimize the cost of acquiring \( C_t \) given prices \( \{p_t(x)\} \) for all \( x \) is:

\[
c_t(x) = \left( \frac{p_t(x)}{P_t} \right)^{-\gamma} C_t,
\]

This price is written in terms of “money”, which in our economy is only used as a convenient unit of account and not valued for facilitating trades or for any other purpose.
where \( P_t \) is the cost of acquiring one unit of the composite good, or the price index\(^2\):

\[
P_t = \left( \int_{x \in X_t} [p_t(x)]^{1-\gamma} \, dx \right)^{\frac{1}{1-\gamma}}.
\]

Each firm uses one unit of labor to produce its commodity. The job market in our economy is characterized by the existence of search and matching frictions (see Rogerson et al. for a survey of this literature). In order to hire a worker, a firm must post a vacancy and undertake a recruiting expense of \( \omega \) per vacancy posted. Firms and potential workers match in a labor market according to a constant-returns-to-scale matching technology \( M(\bar{N} - N, V) \) given by:

\[
M(\bar{N} - N, V) = \frac{(\bar{N} - N)V}{(\bar{N} - N)^{\xi} + V^{\xi}}^{\frac{1}{\xi}}
\] (4)

This matching function takes as inputs the total number of unemployed individuals who are searching, \( \bar{N} - N \), and the total number of vacancies posted by firms, \( V \). The output is a number of matches \( M \). Denoting by \( \theta \) the vacancies to unemployment ratio \( \frac{V}{\bar{N} - N} \), the probabilities that a vacancy gets filled, \( q_t \), and that a worker finds a job, \( f_t \), are given by\(^3\),

\[
q_t = \frac{V}{M(\bar{N} - N, V)} = \frac{1}{(1 + \theta_t^{\xi})^{\frac{1}{\xi}}},
\] (5)

\[
f_t = \frac{\bar{N} - N}{M(\bar{N} - N, V)} = \frac{\theta_t}{(1 + \theta_t^{\xi})^{\frac{1}{\xi}}},
\] (6)

---

\(^{2}\)\( P \) can be obtained by solving the consumer expenditure minimization problem for constructing one unit of composite good:

\[
P = \min_c \int_{x \in X_t} p(x) c(x) \, dx,
\]

s.t. \( C = \left( \int_{x \in X_t} [c(x)]^{\frac{1}{1-\gamma}} \, dx \right)^{\frac{1}{1-\gamma}} = 1.\)

\(^{3}\)We depart from the more frequent Cobb-Douglas specification for the matching function in order to bound the job-finding and vacancy-filling probabilities to be between 0 and 1. This functional form was chosen by Den Haan, Ramey, and Watson (2000).
A match between a firm and a worker results in a wage contract that specifies a wage $w_t(x)$ paid in exchange of labor services. We assume that firms and workers split the surplus from their relationship according to a Nash bargaining rule. We will be more specific about this rule below after we have fixed some notation regarding workers’ and firms’ value functions. The relationship between a firm and a worker can break either because the firm ends production or exogenously for any other reason (at rate $s$).

In order to begin production, firms need to pay a sunk cost of entry equal to $y^E$ per effective unit of labor they use or $\frac{w_t(x)y^E}{Z_t}$ units of the consumption good. Workers in this “start-up” sector get the same wage as workers in the production sector, but they do not bargain with any firm. We understand that the existence of these two separate labor markets might be confusing at this point. We ask the reader, however, to bear with us, as this problem will disappear in the economy with physical capital. To clarify things further, one should think of the workers in the setup sector as individuals who were not successfully matched in the labor market. From the pool of unsuccessfully matched individuals, “start-ups” hire the needed workers and pay them the prevailing wage, which is the result of the bargaining that occurs between firms and workers who do match. Who actually gets to work in the “start-up” sector and who joins the unemployment pool and receives the benefit is irrelevant, because our assumption about market completeness ensures that individuals’ consumption levels vary only with changes in aggregate conditions. We do not model a firm’s exit decision explicitly and we assume that with some probability $\tau$ it dies and ends production.

Production of the differentiated commodity involves only labor as well. Denoting the firm’s output of the differentiated product $x$ as $y^c_t(x)$, it is obtained with the following linear technology,

$$y^c_t(x) = Z_tL_t(x)$$

\footnote{In principle, wages of firms could be different, and in that case we would have to be more explicit about how wages in the “start-up” sector are computed. Since we will restrict to a symmetric equilibrium in which all firms pay the same wage, this is irrelevant.}
where $Z_t$ is an aggregate productivity shock which follows a first-order Markov process, and $l_t(x)$ is the labor amount the firm uses, which will equal one if the firm produces and zero otherwise. The firm charges a price equal to $\rho_t(x)$ and its profits are given by $\pi_t(x) = \rho_t(x)Z_t - w_t(x)$.

Finally, the government plays a very limited role in our economy. Its task is solely to tax the household a lump-sum quantity and rebate it in the form of a benefit for the unemployed.

### 3.1.2 Optimization and Equilibrium

We restrict ourselves to a symmetric equilibrium in which all goods-producing firms charge equal prices, $\rho_t(x) = \rho_t$; demand one unit of labor which gets paid the same wage $w_t(x) = w_t$; and produce the same amount of output, $y^f_t(x) = y^c_t$. Given the CES structure of the consumption aggregate, the relative price $\rho_t$ that firms charge is given by $5 \frac{1}{N_t^{1-\gamma}}$ and the per-firm profit is given by, $\pi_t = \rho_tZ_t - w_t$. The relevant state vector for the firm is the triplet $(N_t, V_t, Z_t)'$, but to save on notation we will write down value functions without being specific about their dependence on the state vector.

Households own a diversified portfolio of firms and as a result firms discount expected future flows taking into account the household’s inter-temporal condition. Therefore, the appropriate discount factor between periods $t$ and $t + 1$ is,

$$\Delta_{t+1} = \beta \left( \frac{C_{t+1}}{C_t} \right)^{-\sigma}.$$  

(8)

Let $Q_t$ denote the capital value of a vacancy and $J_t$ denote the capital value of a filled

\[ 5\text{Given that } p_t(x) = p_t \text{ and } \rho_t = \frac{p_t}{P_t} = \frac{p_t}{\int_{x \in X} [p_t^1 - \gamma dx]^{\frac{1}{1-\gamma}}}, \text{ implies that } \rho_t = \frac{p_t}{p_t \int_{x \in X, dx} ^{\frac{1}{1-\gamma}}} \text{ and as a result, } \rho_t = \left( \int_{x \in X, dx} \right)^{\frac{1}{1-\gamma}} = N_t^{\frac{1}{1-\gamma}}, \text{ as } N_t \text{ is the both the fraction of firms producing as well as the number of workers in the goods-producing sector by our assumption of one job per firm.} \]
The following two recursive relationships must be satisfied:

\[ Q_t = -\omega + (1 - \tau) E_t \Delta_{t+1} [q_t J_{t+1} + (1 - q_t) Q_{t+1}], \quad (9) \]
\[ J_t = \pi_t + (1 - \tau) E_t \Delta_{t+1} [(1 - s) J_{t+1} + s Q_{t+1}], \quad (10) \]

Equation (9) states that the value of a vacancy (once the entry decision has been made) is the difference between two objects. First, the expected value of entering the labor market and try to match with a worker. This matching happens with probability \( q_t \), as long as the firm survives for one period, which happens with probability \( 1 - \tau \). Second, the vacancy cost \( \omega \). The difference between the two is, again, the value of a vacancy.

The interpretation of equation (10) is analogous: the value of a filled job is the profit flow \( \pi \) plus the expected continuation value of the relationship between the firm and the worker. Conditional on the firm's survival, the relationship ends with probability \( s \) and continues with probability \( 1 - s \).

In equilibrium, the entry of firms occurs until the value of vacancies is equal to the sunk cost,

\[ Q_t = \frac{y^E w_t}{Z_t}. \quad (11) \]

Due to entry costs, vacant jobs have positive value in equilibrium, which in turn, leads firms to repost vacancies following separations. The following two equations give the laws of motion for the stock of employment and vacancies:

\[ N_{t+1} = (1 - \tau) [(1 - s) N_t + f_t (\bar{N} - N_t)], \quad (12) \]
\[ V_{t+1} = (1 - \tau) [(1 - q_t) V_t + s N_t] + N^E_t. \quad (13) \]

Employment at time \( t+1 \) is the sum of matches \( (1 - s) N_t \) that were not destroyed either by the death of a firm or other form of separation, and the newly-formed matches \( f_t (\bar{N} - N_t) \) from a previous pool of unemployed people. The total number of vacancies, given by
equation (13) in the economy is equal to vacancies that did not get filled in the current period, \((1-q_t)V_t\) plus the number of separated matches \(sN_t\). Of course, we need to include the fraction of firms which continue operating for at least one more period. Finally, we need to add to that total the number of newly created firms \(N_t^E\), each of which posts a vacancy. Both employment and vacancies are predetermined variables.

The household’s problem is relatively straightforward. Given its current period resources, it chooses consumption and bond holdings to maximize the expected discounted value of lifetime utility. In addition to wage income and unemployment benefits, the household gets interest from bond holdings as well as a pay-out from its diversified ownership stake in firms. The aggregate dividends firms pay out equal to \(d_t = N_t\pi_t - \omega V_t - Q_tN_t^E\). Finally, the household also gets taxed a lump-sum amount \(T_t\) which the government uses to finance the unemployment benefit program. Denoting by \(W_t\) the household’s value function at time \(t\), the optimization problem can be expressed as:

\[
W_t = \max_{C_t,B_{t+1}} \frac{C_t^{1-\sigma}}{1-\sigma} + \beta E_t W_{t+1}
\]

s.t

\[
\begin{align*}
C_t + B_{t+1} &= B_t(1+r_t) + w_t\tilde{N}_t + b(\bar{N} - \tilde{N}_t) + d_t - T_t, \\
\tilde{N}_t &= N_t + N_t^E.
\end{align*}
\]

The optimal inter-temporal condition is:

\[
\beta E_t \left( \frac{C_{t+1}}{C_t} \right)^{-\sigma} (1 + r_{t+1}) = 1
\]

As was mentioned in the previous section, wages for the employed workers are the result of Nash bargaining between each worker-firm pair. The surplus of the match for the household is captured by the change in welfare derived from having a marginal unemployed
person employed. This change is given by $\frac{\partial W}{\partial N} C^{-\sigma}$. The surplus for the firm is given by $J_t - Q_t$, the difference between the value of a filled job and the value of a vacancy. The Nash bargaining solution when the firm’s bargaining parameter is given by $\phi$ satisfies the following surplus-splitting rule:

$$\frac{J_t - Q_t}{1 - \phi} = \frac{C^\sigma \frac{\partial W}{\partial N_t}}{\phi}, \quad (18)$$

which yields the following equation for wages:

$$w_t = (1 - \phi)b + \phi(\rho_t Z_t + \omega) - \phi(1 - \theta_t)(\omega + Q_t - (1 - \tau)E_t \beta \Delta_{t+1} Q_{t+1}) \quad (19)$$

We can now define a symmetric equilibrium for our economy. It is a sequence of prices $\rho_t, w_t, r_t$; a sequence of aggregate quantities $B_t, C_t, N_t, V_t, N_t^E, \pi_t$; and a sequence of value functions $Q_t, J_t, W_t$ such that for any time period $t$, the following conditions hold:

1. **(Household Optimization)** Given prices $\rho, w, r$ the household’s optimization results in decision rules for $C_t$ and $B_t$ and the value function $W_t$.

2. **(Factor Market Clearing)** The interest rate $r_t$ is such that $B_t = 0$ for all $t$, and the wage $w$ satisfies the Nash bargaining solution given by equation (19).

3. **(Goods Market Clearing)** $C_t = w_t \tilde{N}_t + N_t \pi_t - \omega V_t - N_t^E Q_t$.

4. **(Firm’s Optimization)** Given the demand for a differentiated commodity given by equation (3), $\rho_t$ is the profit-maximizing price for the monopolist. Aggregate labor demand and vacancies posted by all firms, $N_t^E, N_t$ and $V_t$ satisfy equations (12) and (13), and the vacancy and filled position values satisfy equations (9) and (10).

5. **(Entry Condition)** $Q_t = \frac{\nu^E w_t}{Z_t}$.


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3.1.3 Calibration

We calibrate the model to the monthly frequency by assigning values to parameters, so that steady-state moments in the model match those observed in U.S. data. The risk aversion coefficient \( \sigma \) is set to 1.5 which is well within the range of values typically used in studies of aggregate fluctuations. The discount factor \( \beta \) is set to \( 0.99^{\frac{1}{4}} \) which implies a steady-state interest rate equal to 4.2%.

We assume that total factor productivity \( Z_t \) follows an AR(1) process with persistence parameter \( \rho_z \) and a zero-mean normally distributed shock with variance \( \sigma_e^2 \). We set \( \rho_z = 0.95 \) and \( \sigma_e = 0.0075 \) which are consistent with the cyclical persistence and variance in the observed Solow residual. Lacking direct evidence on a reasonable value for the workers’ bargaining parameter \( \phi \), we set it equal to 0.5 to make our results comparable to the existing literature. To pin down \( \xi \), the parameter in the matching function, we use data on job finding and vacancy filling rates. Based on his own calculations, Shimer (2005) documents that the monthly job finding rate is 0.45. Blanchard and Diamond (1989) argue that vacancy postings have an average of 3 weeks, which implies that the vacancy filling rate is \( 1 - (1 - 1/3)^4 = 0.802 \) per month. Noting that the steady state value of market tightness can be written as \( \theta = f = 0.561 \), we can recover \( \xi \) either from the expression for \( f \) or for \( q \) yielding \( \xi = 1.551 \).

We calibrate the exit probability \( \tau \) and the separation rate \( s \) following a procedure similar to that used by Den Haan et al. (2000). Let \( \Sigma \) be the total job separation rate caused either by a firm’s death or by any other cause. The rate at which firms exit the market and do not repost vacancies is \( \tau \), while \( (1 - \tau)s \) is the rate at which workers separate from firms but where firms repost vacancies immediately after. Hence, \( \Sigma = \tau + (1 - \tau)s \). The fraction of vacancies that are reposted right after separations is then \( \frac{(1-\tau)s}{\Sigma} \). Denote this quantity by \( \Omega \). Note also that \( \Sigma N \) gives the total flow out of employment, and as a result, \( \Omega q \Sigma N \) gives the total number of posted vacancies filled. If we subtract the number of posted vacancies filled from the total flow out of employment, we get the
steady-state mass of jobs that is destroyed permanently: $\Sigma N - \Sigma N\Omega q = \Sigma N(1 - \Omega q)$. In a steady state, job destruction must equal job creation. The empirical evidence described by Shimer (2005) sets $\Sigma$ equal to 0.1 at the quarterly frequency which implies $1 - (1 - 0.1)^{1/4} = 0.035$ at the monthly frequency. Therefore,

$$\Sigma = (1 - \tau)s + \tau = 0.035 \quad (20)$$

Davis et al. (1996) report that the job-creation-to-employment ratio in the manufacturing sector is 0.052 quarterly, which implies a value of 0.018 at the monthly frequency. Given a value of $q = 0.802$ per month,

$$\frac{Job \; Creation}{Employment} = \frac{\Sigma N(1 - \Omega q)}{N} = 0.018 \quad (21)$$

From equations (20) and (21) we can solve for $s = 0.021$ and $\tau = 0.014$.

Consistent with estimates reported by Basu and Fernald (1997), we set $\gamma = 11$, which implies a markup of 10 percent. We choose $y^E$ and $\omega$ to match the steady state ratio of recruiting costs to output around 3% and the consumption-output ratio equal to 75%. Changing the total mass of workers $\bar{N}$ only amounts to changing the levels, i.e., the scale of output and the mass of employment, etc., but the unit-free ratios, e.g., unemployment rate, v-u ratio, and consumption-output ratio etc., are not affected. Therefore, a choice of $\bar{N}$ does not affect any of the second moments and the impulse responses. We just pick $\bar{N} > 1$ so that the monopolist’s price is larger than the resulting price if markets are competitive, which is given by $\lim_{\gamma \to \infty} N_t^{1/\gamma} = 1$.

Finally, a controversial choice is that of the value of the unemployment benefit $b$. Much of the literature argues that the value of non work activities is far below what workers produce on the job. However, calibrations such as Hagedorn and Manovskii’s (2007)

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As it turns out, none of the results reported below are very sensitive to the exact value of $\omega$. For example, targeting the ratio of recruiting costs to output from 1% to 8% leaves the quantitative properties of the model virtually unchanged.
Table 2: Summary of Parameterization

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Target/Source</th>
</tr>
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<td>$\sigma$</td>
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<td>Prev. work</td>
</tr>
<tr>
<td>$\beta$</td>
<td>(0.99)$^{\frac{1}{2}}$</td>
<td>r=4.2%</td>
</tr>
<tr>
<td>$\phi$</td>
<td>0.500</td>
<td>Prev. work</td>
</tr>
<tr>
<td>$\xi$</td>
<td>1.551</td>
<td>$\theta = 0.561$</td>
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<td>$wV/Y = 0.03$</td>
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<td>$\gamma$</td>
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claim much success in terms of the cyclical properties of the model when the outside option for workers is very close to their productivity. Under the interpretation of $b$ as purely monetary unemployment benefits, we set $b$ so that the steady state replacement ratio $b/w$ is 0.42 as in Shimer (2005) and Gertler and Trigari (2006).

We summarize our parameterization in Table 2.

4 Results

Having assigned parameter values to the model, we solve it, simulate it, and judge its implications against U.S. data. Since the calibration is done at the quarterly frequency, we need to transform the model’s output by aggregating its “monthly” data into “quarterly” data. We do this by taking 3-period averages. We obtain a sample of data from the Bureau of Labor Statistics (BLS) and the Bureau of Economic Analysis (BEA), covering the period 1951:Q1-2004:Q4. The model’s output and U.S. data are transformed in the same way: we de-trend them by taking logs and applying a Hodrick-Prescott filter.\footnote{The HP smoothing parameter we use is $10^5$, which is larger than the standard choice of 1,600. We choose it for two reasons. First, given the large propagation in our model, much of the dynamics are in lower frequencies than those retained by a smoothing parameter equal to 1,600. And two, it was used by}
Table 3: Summary Statistics, quarterly U.S. data, 1951:1 to 2004:1

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<tr>
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<th>$V/U$</th>
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</tr>
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Table 3 shows some statistics for our sample of U.S. data for some selected quantities. We focus on unemployment ($U$), vacancies ($V$), the vacancies-to-unemployment ratio ($V/U$), GDP ($Y$), consumption ($C$) and total factor productivity ($Z$). Regarding labor market variables, the two most salient features are: the high volatility of unemployment, vacancies, and the vacancies-to-unemployment ratio; and the strong negative correlation between unemployment and vacancies. The first of the two has been the object of a large literature spawned by Shimer’s (2005) study, as the discrepancy between the data and the model is large. Other important features are the weak correlation between vacancies and productivity and the stronger correlation between vacancies and output.

We display the model’s results in Tables 5, 6, and 5. Table 5 displays the model’s autocorrelation for some selected labor market variables. The label “Entry w/o Capital” refers to the model presented above, while “Standard $M − P$” is the standard Mortensen-Pissarides model. Readers should think of it as the same model Shimer (2005) solved, but in discrete instead of continuous time and calibrated differently. The most important characteristic of the model is the larger autocorrelation across all variables and almost all lags. It is a consequence of the larger internal propagation mechanism of our model, and it is consistent with results in Bilbiie, Ghironi and Melitz (2007). The first-order autocorrelation in all variables are closer to those observed in the data than the standard $M − P$ model. In particular, the autocorrelation in vacancy creation rises from 0.324 to

Shimer and therefore it facilitates comparisons.
0.813, whereas in the data is 0.934. We reach a similar conclusion for the $V - U$ ratio while the model overpredicts the first-order autocorrelation for the unemployment rate.

Tables 6 and 5 show the standard deviations and the cross-correlation for a few aggregates including those shown in Table 5. The entry model without capital increases the volatilities of all variables shown. In some cases the increase is substantial, as is the case with the $V - U$ ratio or the job finding probability. The volatility of $\theta$ relative to the productivity shock increases 85% and the volatility of $f$ relative to $Z$ increases 57%. The slope of the Beveridge curve, the correlation between unemployment and vacancies, gets much closer to the empirical value of -0.90 in the model with firm entry (-0.74) than in the standard $M - P$ model (-0.56). We will soon see how these effects get amplified by introducing capital in our economy, resulting in a slope for the Beveridge curve that matches that observed in the data and a much larger volatility of market tightness relative to productivity. The propagation mechanism present in our model increases the procyclicality of labor market variables. As a result, it over-predicts the correlation between output and vacancies, unemployment and the $V - U$ ratio.

A time-varying value of vacancy creation is the most novel aspect of our analysis. It is important to relate its cyclical behavior to the higher volatility of aggregate variables and the larger correlation between unemployment and vacancies. From Table 7 we see that the correlation between $Q$, the vacancy value, and output is about 0.8. The smaller the cyclicality of $Q$, the worse the performance of the model in terms of volatilities and the correlation between vacancies and unemployment. When entry costs are very procyclical firms have a smaller incentive to create vacancies, so their volatility decreases and their relationship with the unemployment rate weakens. A negative correlation between vacancies and output reverses this result. In the economy with capital we present below, the countercyclicality of interest rates makes $Q$ negatively correlated with output, amplifying our results.

Finally, we further analyze the model using impulse response functions. These are displayed in Figures (1) and (2). The solid line corresponds to the standard $M - P$ model
Table 4: Autocorrelations

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<td>0.341</td>
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<td>0.520</td>
<td>0.386</td>
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and the dotted line to the model with firm entry. These are constructed in a standard way and they should be interpreted as describing an economy’s behavior as it reverts back to its steady-state after a one-standard-deviation shock. The larger propagation in the model with entry implies a later peak response of variables to the shock. In some cases important: output peaks at about 8 quarters in the model with entry when it peaks in the first quarter in the model without entry. The same can be said for consumption or for market tightness. The reader might be intrigued for the substantially different initial response of $J$, the capital value of a filled job, across the two models. The reason is that the law of motion for $J$ (eq. 10) includes an expectation for the value of $Q$. Although, from an unconditional point of view, $Q$ is positively related to the shock, it also initially falls as the rise in $Z$ more than offsets the rise in $w$.

4.1 Introducing Physical Capital

We now turn to an economy with capital accumulation. Firms face a sunk entry cost equal to a flow $y^E$ of effective units of capital. Households own the capital and they use it to smooth income shocks and to rent it out to firms. Aggregate capital has the same price (unity) as the composite consumption good and it depreciates at a constant rate $\delta$.

All the other aspects of the environment are identical to the economy without capital, in particular the functioning of labor markets, preferences, the definition of the composite consumption good, and the pricing behavior of firms. We will now be more specific about
how capital affects the firm’s entry decision and how it alters the household’s optimization problem. Given that we will continue using the concept of a symmetric equilibrium we will omit any reference to the particular product variety \( x \) when firms’ behavior.

Firms need to pay a sunk cost to begin the goods production process. Opening a firm or starting a new product variety needs a flow \( y^E \) using a linear technology that has capital as its only input, i.e. \( y^E = Z_t K_t^E \). The productivity shock follows, as before, a first-order Markov process. Denoting by \( r_t \) the rental rate of capital and noting that one unit of capital produces \( Z_t \) units of the composite good, the sunk cost of entry is \( \frac{r_t y^E}{Z_t} \) or \( r_t K_t^E \) (in units of the composite consumption good).

The amount of output produced for consumption and investment purpose (the goods-producing sector) is still the result using only labor:

\[
y_t^c = Z_t l_t, \tag{22}
\]

where again, the amount of labor demanded by the firm is either 1, if the firm produces, or zero otherwise.

It is worth noting that aggregate capital, \( K_t = N_t^E k_t^e \) is now part of the state vector for firms and households. Labor markets function in the same way as in the economy without capital, and as a result in both economies the determination of the wage rate \( w_t \) is identical. For the sake of exposition we re-write the main equations describing the equilibrium. The laws of motion for employment and vacancies are given by,

\[
N_{t+1} = (1 - \tau) [(1 - s)N_t + f_t(\bar{N} - N_t)], \tag{23}
\]

\[
V_{t+1} = (1 - \tau) [(1 - q_t)V_t + sN_t] + N_t^E. \tag{24}
\]

The values of a vacancy and a filled position are the same as for the economy without
capital,

\[ Q_t = -\omega + (1 - \tau) E_t \Delta t + [q_t J_{t+1} + (1 - q_t) Q_{t+1}], \]  
\[ J_t = \pi_t + (1 - \tau) E_t \Delta t + [(1 - s) J_{t+1} + s Q_{t+1}], \]

As before, firms enter the market until the sunk cost, given by \( r_t K^e_t \) equals the value of a vacancy,

\[ Q_t = r_t K^e_t \]  

Introducing capital modifies slightly the household’s problem. Denoting again by \( W_t \) the value function for the household, the problem can be written formally as,

\[ W_t = \max_{C_t, I_t} \frac{C_t^{1-\sigma}}{1-\sigma} + \beta E_t W_{t+1} \]

subject to

\[ C_t + I_t = b(\bar{N} - N_t) + w_t N_t + r_t K_t + d_t - T_t, \]
\[ K_{t+1} = (1 - \delta) K_t + I_t. \]

The reader should note that now the mass of agents that receive the unemployment benefit is equal to \( \bar{N} - N_t \). Given that firms do not demand labor for being set up, there is no fraction \( N_t^E \) of workers that receives wage \( w_t \). The first order condition implies:

\[ \beta E_t \left[ \left( \frac{C_{t+1}}{C_t} \right)^{-\sigma} (r_{t+1} + 1 - \delta) \right] = 1 \]

4.1.1 Results

Capital introduces one additional parameter: a depreciation rate \( \delta \). We assume a 10% annual rate of depreciation, which roughly equals 0.025 per quarter. The calibration
strategy for $b$, $\omega$, and $y^E$ is identical to the economy without capital and results in the following values: $b = 0.41$, $\omega = 0.70$ and $y^E = 900$.

Table 5 shows the autocorrelations for a few selected variables in this economy. Propagation is even stronger than before and even at four lags variables display a large degree of persistence. Despite a first-order autocorrelation of the shock equal to 0.85, market tightness, vacancies and unemployment all have values above 0.95.

The third column of Table 6 shows the standard deviations of some macroeconomic aggregates for the economy with capital and labor. The amplification effect of firm entry is notable. The volatility of market tightness is 0.11, more than five times that of the shock. Both vacancies and unemployment, and most importantly the vacancy value $Q$ are much more volatile than in the labor-only entry model. Turning to the autocorrelations displayed in Table 5, the correlation between vacancies and unemployment is -0.92, almost exactly the value observed in U.S. data. We can see now that $Q$ is highly countercyclical as its contemporaneous correlation with output is -0.643. The procyclicality of employment $N$ decreases significantly as our measure of output includes sunk costs.

## 5 Conclusions

Cyclical dynamics of labor market variables look puzzling when evaluated through standard equilibrium models of fluctuations. We have shown that a model with firm entry introduces a novel mechanism that reconciles several puzzling features without dramatically altering modeling assumptions. The novel mechanism is an endogenously time-varying
value of vacancy creation, which arises as a consequence of sunk costs. We relate the cyclical behavior of this object to the ability of the Mortensen-Pissarides search and matching framework of matching the observed slope of the Beveridge curve and producing a volatile series of vacancies and unemployment. In a model with only labor the quantitative effects are small as this value of creating a vacancy is procyclical. Introducing physical shows how our mechanism can be powerful enough to bring the model’s implications much closer to the data.
References


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Table 9: Cross Correlations: Entry with Capital and Labor

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Figure 1: Impulse responses to a technology shock
Figure 2: Impulse responses to a technology shock (continued)