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The Establishment-Level Behavior of Vacancies and Hiring

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Abstract

We study vacancies, hires, and vacancy yields (success rate in generating hires) in the Job Openings and Labor Turnover Survey, a large representative sample of U.S. employers. We also develop a simple framework that identifies the monthly flow of new vacancies and the job-filling rate for vacant positions, the employer counterpart to the job-finding rate for unemployed workers. The job-filling rate moves counter to employment at the aggregate level but rises steeply with employer growth rates in the cross section. It falls with employer size, rises with the worker turnover rate, and varies by a factor of four across major industry groups. Our analysis also indicates that more than 1 in 6 hires occur without benefit of a vacancy, as defined by JOLTS. These findings provide useful inputs for assessing, developing, and calibrating theoretical models of search, matching, and hiring in the labor market.

Keywords: vacancies, job openings, job-filling rate, vacancy duration, hiring, labor market search, matching, establishment data

JEL Codes: D21, E24, J60

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1. Introduction

In many models of search, matching, and hiring in the labor market, employers post costly vacancies to attract job seekers.¹ These models often feature a matching function that requires job seekers and job vacancies to produce new hires. The concept of a job vacancy also plays an important role in mismatch and stock-flow matching models of the labor market.² Despite a key role in theoretical models, few empirical studies consider vacancies and their connection to hiring at the establishment level. Even at more aggregated levels, our knowledge of vacancy behavior is quite thin compared to our knowledge of unemployment. As a result, much theorizing about vacancies takes place in a relative vacuum. In this paper, we seek to enrich our understanding of establishment-level and aggregate vacancy behavior and to develop new evidence for assessing, developing, and calibrating theoretical models of search, matching, and hiring in the labor market.

We study vacancy rates, the rate of new hires and vacancy *yields* at the establishment level, using the Job Openings and Labor Turnover Survey (JOLTS), a large stratified sample of U.S. employers. The vacancy yield is the flow of realized hires during the month per reported job opening at the end of the previous month. Using JOLTS data, we investigate how the hires rate, the vacancy rate, and the vacancy yield vary with employer growth in the cross section, how they differ by employer size, worker turnover, and industry, and how they move over time. To obtain a longer sample for time-

¹ This description fits random search models such as Pissarides (1985) and Mortensen and Pissarides (1994), directed search models such as Moen (1997), wage-posting models such as Acemoglu and Shimer (2000), and on-the-job search models such as Burdett and Mortensen (1998) and Nagypal (2007). The precise role of vacancies differs among these classes of models. See Mortensen and Pissarides (1999), Rogerson, Shimer and Wright (2006) and Yashiv (2006) for reviews of research in this area.

² See, for example, Hansen (1970) and Shimer (2007) for mismatch models and Coles and Smith (1998) and Ebrahimi and Shimer (2008) for stock-flow matching models.

series analysis, we supplement the JOLTS data with the Conference Board's Help Wanted Index and data on hires from the Current Population Survey.

We first document some basic patterns in the behavior of hires and vacancies. The aggregate vacancy yield moves counter-cyclically, as predicted by standard matching function specifications. In the cross section, the vacancy yield falls with establishment size, rises with worker turnover, and varies by a factor of four across major industry groups. We also document striking, nonlinear relationships of the hires rate, the vacancy rate, and the vacancy yield to the growth rate of employment in the cross section of establishments. Among shrinking establishments, the relationship of all three measures to employer growth is nearly flat. Among expanding establishments, all three measures rise steeply with employer growth. Stable establishments with no employment change have the lowest values of all three measures. The predominantly positive relationship between vacancy yields and employer growth in the cross section contrasts sharply to their negative relationship in the time series.

Another set of basic facts pertains to the distribution of vacancies and hires across establishments. Employers with no recorded vacancies at month's end account for 45% of aggregate employment, and those with exactly one vacancy account for another 7%. Nevertheless, many establishments with zero vacancies at the end of the previous month record new hires during the month. In fact, these establishments account for 42% of hires during the month. This percentage appears to move in a pro-cyclical manner, and it is much higher in establishments and industries with high worker turnover rates.

The large percentage of hires by employers with no reported vacancy stock partly reflects an unmeasured flow of new vacancies during the month. The unmeasured flow

of new vacancies also inflates the vacancy yield. In other words, the observed values for these two measures are partly an artifact of time aggregation and the distinction between point-in-time stocks (vacancies) and monthly flows (hires). To address this matter, we develop a simple framework that treats JOLTS data on the monthly flow of new hires and the stock of vacancies at month's end as observed outcomes of daily processes for new vacancies and new hires. By cumulating the daily processes to the monthly level, we can deal with the stock-flow distinction and uncover several interesting quantities not directly observed in JOLTS: the flow of new vacancies during the month, the daily job-filling rate, and the mean number of days required to fill an open job position.

The job-filling rate is the employer counterpart to the much studied job-finding rate for unemployed workers.³ Although theoretical models of search and matching carry implications for both job-finding and job-filling rates, the latter have received comparatively little attention. Applying our framework, we find that the job-filling rate moves counter-cyclically at the aggregate level. In the cross section, the job-filling rate exhibits the same strong patterns as the vacancy yield. Perhaps most striking, the job-filling rate rises very steeply with employer growth – from about 1-2 percent per day at establishments with stable employment levels to more than 10 percent per day for establishments that expand by 7% or more during the month. Jobs take longer to fill at larger employers, averaging 15-17 days at establishments with fewer than 250 workers and about 38 days at those with 1000 or more. The job-filling rate for employers in the highest worker turnover quintile is ten times greater than in the lowest turnover quintile.

³ Recent studies include Hall (2005a), Shimer (2007b), Yashiv (2007), Petrongolo and Pissarides (2008), Elsby, Michaels, and Solon (2009) and Fujita and Ramey (forthcoming).

In Section 2 we discuss several reasons that hires can occur without benefit of a vacancy, as defined and recorded in JOLTS. An obvious reason is that JOLTS records the stock of vacancies once per month and the flow of hires during the month. Recognizing this fact, we apply our framework to estimate the fraction of hires that occur without benefit of a prior vacancy, adjusting for the stock-flow distinction. Specifically, a steady-state version of our framework predicts that establishments with no recorded vacancies account for 20% of hires during the month. The actual figure in the data is 42%. We interpret this discrepancy to mean that 22% of hires occur without a prior vacancy as defined in JOLTS. We also carry out a more sophisticated exercise that treats daily vacancy flows and daily job filling as stochastic processes at the establishment level, and that accounts for the size distribution of employment and the uneven distribution of vacancies over establishments. When we fit this model to the data, we estimate that 16% of hires occur without benefit of a prior vacancy.

One can interpret our exercises to estimate the fraction of hires without vacancies as an effort to partly unpack the “black box” nature of the matching function (Petrongolo and Pissarides, 2001) and to uncover evidence of how hiring practices and the role of vacancies vary across employers and over time. Thus, we estimate that only 12% of hires occur without benefit of a prior vacancy in the government sector, where formal hiring processes are most prevalent. An estimated 30% of hires take place without benefit of a vacancy at establishments with 0-9 employees, compared to only 5% at establishments with 1,000 or more employees. There is some evidence that hires without benefit of a vacancy are a smaller percentage of all hires during downturns.

Our evidence of hiring without a prior vacancy raises several issues. First, it highlights the value of models that incorporate multiple recruiting channels, not all of which involve formal vacancies. Second, cyclical variation in the relative importance of different recruiting channels can lead to biased estimates of matching function parameters, as analyzed by Sunde (2007). Third, models that ignore cross-sectional and time variation in the mix of recruiting methods may yield misleading inferences in other respects when fit to data on employment, wages, vacancies, and unemployment. Fourth, it is also possible that our evidence of hiring without a vacancy reflects systematic underreporting of vacancies by JOLTS respondents. Under this interpretation, the evidence says that underreporting of job vacancies varies over time and differs greatly by industry and employer size.

Our study is related to several previous empirical studies of vacancy behavior. The pioneering work of Abraham (1983, 1987), and Blanchard and Diamond (1989) uses the Help Wanted Index (HWI) to proxy for vacancies, and many other studies follow the same approach. The Help Wanted Index yields sensible patterns at the aggregate level (Abraham, 1987; Blanchard and Diamond, 1989; and Shimer, 2005), but it cannot accommodate a firm-level or establishment-level analysis. Several recent studies exploit aggregate and industry-level JOLTS data on hires, separations, and vacancies (e.g., Hall, 2005a; Shimer, 2005, 2007a; Valetta, 2005). Earlier studies by Holzer (1994), Burdett and Cunningham (1998) and Barron, Berger, and Black (1999) consider vacancy behavior in small samples of U.S. employers. Van Ours and Ridder (1991) investigate the cyclical behavior of vacancy flows and vacancy durations using periodic surveys of Dutch employers. Coles and Smith (1996), Berman (1997), Yashiv (2000), Dickerson

(2003), Andrews et al. (2007) and Sunde (2007) exploit vacancy data from centralized registers of job openings in various countries.

The paper proceeds as follows. The next section discusses our data sources. Section 3 documents several patterns in the time-series and cross-sectional behavior of vacancies and hires. Section 4 introduces our framework for treating the stock-flow distinction and fits it to the data. We show how to recover monthly estimates for the unobserved flow of new vacancies, the daily job-filling rate, and the mean vacancy duration. Section 5 considers a steady-state approximation to the framework and estimates the fraction of hires that take place without benefit of a prior vacancy. Section 6 fits a stochastic version of our framework to JOLTS micro data using a simulated method of moments approach. Section 7 concludes with a summary of our main contributions and some remarks about directions for future research.

2. Data Sources

The Job Openings and Labor Turnover Survey (JOLTS) samples about 16,000 establishments per month. Respondents report hires and separations during the month, employment in the pay period covering the 12th of the month, and job openings at month's end. They also report quits, layoffs and discharges, and other separations (e.g., retirements). The JOLTS commences in December 2000, and our establishment-level sample continues through December 2006. We drop observations that are not part of a sequence of at least two consecutive observations for the same establishment. This restriction enables a comparison of hires in the current month to vacancies at the end of the previous month, an essential element of our analysis. The resulting sample contains 577,268 observations, about 93% of the full sample that the BLS uses for published

JOLTS statistics. We have verified that this sample restriction has little effect on aggregate estimates of vacancies, hires, and separations.⁴

For our purposes, it is important to consider exactly how job openings (vacancies) are defined and measured in JOLTS. The survey form instructs the respondent to report a vacancy when “a specific position exists, work could start within 30 days, and [the establishment is] actively seeking workers from outside this location to fill the position.” The respondent is then asked to report the number of such vacancies existing on “the last business day of the month.” Further instructions define “active recruiting” as “taking steps to fill a position. It may include advertising in newspapers, on television, or on radio; posting Internet notices; posting ‘help wanted’ signs; networking or making ‘word of mouth’ announcements; accepting applications; interviewing candidates; contacting employment agencies; or soliciting employees at job fairs, state or local employment offices, or similar sources.” Vacancies are not to include positions open only to internal transfers, promotions, recalls from temporary layoffs, jobs that commence more than 30 days hence, or positions to be filled by temporary help agencies, outside contractors, or consultants.

Given the survey instructions, there are several ways in which a hire can occur without benefit of a reported vacancy. First, the new job starts more than 30 days after the recruitment period, as in the market for economics professors. Second, the employer hires someone it previously engaged as an independent contractor, consultant, or temp worker

⁴ There is a broader selection issue in that the JOLTS is not designed to capture most establishment births and deaths, which may be why our sample restriction has little impact on aggregate estimates. Another issue is the potential impact of JOLTS imputations for item nonresponse, on which we rely. See Clark and Hyson (2001), Clark (2004) and Faberman (2008a) for detailed discussions of JOLTS. See Davis, Faberman, Haltiwanger, and Rucker (2008) for an analysis of how the JOLTS sample design affects the published JOLTS statistics.

(leased from a temporary help agency) while forgoing any active recruiting as defined by JOLTS. Third, the hire otherwise occurs without benefit of active recruiting efforts. For example, an employer might create a new position to hire an attractive candidate who suddenly becomes available or known. This hiring outcome is analogous to a discouraged worker who is not “actively seeking work,” but who accepts a job if a suitable one becomes available. Fourth, the hire stems from a vacancy posted and filled within the month, an issue we address below. Finally, hires can occur without benefit of a reported vacancy because respondents fail to comply with the survey instructions.

Turning to measurement mechanics, we calculate an establishment’s net employment change in month t as its reported hires in month t minus its reported separations in t . We then subtract this net change from its reported employment in t to obtain employment in $t - 1$. This procedure ensures that the hires, separations, and employment measures in the current month are consistent with our employment measure for the previous month. To express hires, separations, and employment changes at t as rates, we divide by the simple average of employment in $t - 1$ and t . The resulting growth rate measure is bounded, symmetric about zero and has other desirable properties, as discussed in Davis, Haltiwanger, and Schuh (1996). We measure the vacancy rate at t as the number of vacancies reported at the end of month t divided by the sum of vacancies and the simple average of employment in $t - 1$ and t . The vacancy yield in t is the number of hires reported in t divided by the number of vacancies reported at the end of $t - 1$.

We supplement the JOLTS data with other sources that yield longer time series for aggregate outcomes. To obtain hires and separations, we rely on two related sources of data on gross worker flows, both of which derive from the Current Population Survey

(CPS). First, using data from Shimer (2007b), we compute the aggregate hires rate at t as the gross flow of persons who transit from jobless status in $t - 1$ (unemployed or out of the labor force) to employed status in t divided by employment at t . We detrend the resulting hires rate using a Hodrick-Prescott filter with a smoothing parameter of 10^5 . This filter removes low-frequency movements in the series, including movements induced by CPS design changes, and it facilitates a comparison to the Help Wanted Index described below. Second, using data from Fallick and Fleischman (2004), we compute the aggregate hires rate as the sum of gross flows from joblessness to employment and direct job-to-job transitions. Thus, the Fallick-Fleischman data yield a more inclusive measure of the hires rate. However, their series runs from 1994 to 2007, whereas the Shimer series spans 1976 to 2007.⁵ Both series are quarterly averages of monthly values.

The Conference Board's Help Wanted Index (HWI) is a monthly measure of help-wanted advertising volume in a sample of U.S. newspapers. The HWI has significant shortcomings as a proxy for vacancies, but it is the only vacancy-related measure for the U.S. economy that provides a long, high-frequency time series. We detrend the HWI using the same HP filter as before, then rescale the deviations to match the mean JOLTS vacancy rate in the overlapping period.⁶ We use the detrended rescaled HWI in the first month of each quarter as a proxy for vacancies and match it to the monthly average CPS-based hires rates in the same quarter.

⁵ Direct job-to-job transitions by workers cannot be identified under the pre-1994 CPS design.

⁶ This approach to the HWI follows Abraham (1987) and Shimer (2007b), who discuss the measurement issues in detail. See also Kroft and Pope (2008).

3. Aggregate, Cross-Sectional, and Establishment-Level Patterns

3.A. Aggregate Patterns

Figure 1 draws on JOLTS, CPS, and HWI sources to plot time series for aggregate hires and vacancies, expressed as a percentage of employment. The HWI and the JOLTS-based measures for vacancies and hires show a strong pro-cyclical pattern.⁷ In contrast, the CPS-based measures show little cyclicity in the aggregate hires rate. The Fallick-Fleischman measure of hires is larger than the Shimer measure because the former captures job-to-job transitions.⁸ The HP filtering in the Shimer measure removes a secular decline in hiring rates observed in other research (Faberman, 2008b; Davis et al., 2006).

Figure 2 displays three time series for the aggregate vacancy yield. As discussed in Section 2, the JOLTS-based measure of the vacancy yield is calculated as the flow of hires during month t divided by the stock of vacancies at the end of month $t-1$. The plotted JOLTS-based vacancy yield is a quarterly average of monthly values. Although constructed in a very different way, the CPS-HWI vacancy yields have a similar interpretation. All three measures of the vacancy yield move counter-cyclically, but there are notable timing differences between the JOLTS-based measure of the vacancy yield and the ones based on the CPS and HWI.

A counter-cyclical vacancy yield is in line with standard specifications of the matching function in models of frictional unemployment. To see this point, let hires be

⁷ The economy was in recession from March to November 2001, according to NBER dating, but employment continued to contract until the middle of 2003.

⁸ See Davis et al. (2008) on the large gap between CPS-based and JOLTS-based measures of aggregate hires.

determined by a constant returns to scale matching function defined over job vacancies (v) and unemployed persons (u): $h = \mu v^{1-\alpha} u^\alpha$, where $\mu > 0$ and $0 < \alpha < 1$. Rearranging,

$$(1) \quad \frac{h}{v} = \mu \left(\frac{v}{u} \right)^{-\alpha}.$$

Thus, a standard matching specification implies that the vacancy yield (h/v) is a log-linear decreasing function of labor market tightness. The correlation between the log vacancy yield and log tightness is -0.85 in the detrended CPS and HWI data from 1975Q2 to 2007Q2 and -0.88 in the JOLTS data from 2001Q1 to 2008Q3. An OLS regression of the log vacancy yield on log tightness yields an estimated elasticity α of 0.41 using CPS and HWI data and 0.38 using JOLTS data, with small standard errors in both cases.⁹

3.B. Cross-Sectional Patterns

Table 1 draws on JOLTS micro data to report the hires rate, separation rate, vacancy rate, and vacancy yield by industry, employer size group, and worker turnover group. Worker turnover is measured as the sum of the monthly hires and separations rates at the establishment. All four measures show considerable cross-sectional variation, but we focus our remarks on the vacancy yield. Government, Health & Education, Information and FIRE have low vacancy yields on the order of 0.8 hires during the month per vacancy at the end of the previous month. Construction, an outlier in the other direction, has a vacancy yield of 3.1. The vacancy yield falls by more than half in moving from establishments with fewer than 50 employees to those with more than 1,000. It rises by a factor of ten in moving from the bottom to the top turnover quintile.

⁹ OLS regression is a useful way to summarize the empirical relationship between the vacancy yield and labor market tightness. See Berman (1997), Petrongolo and Pissarides (2001), and Coles and Petrongolo (2008) for efforts to treat simultaneity, time aggregation, and other issues that arise in seeking to recover a structural matching function.

What explains these strong cross-sectional patterns? One possibility is that matching is intrinsically easier or more efficient in certain types of industries, establishments, or jobs. For example, Albrecht and Vroman (2002) build a matching model with heterogeneity in worker skill levels and in the skill requirements of jobs. Jobs with greater skill requirements have longer expected vacancy durations because employers are choosier about whom to hire. Barron, Berger, and Black (1999) provide evidence that search efforts and vacancy durations depend on skill requirements. Davis (2001) identifies a different effect that leads to shorter vacancy durations in better jobs. In his model, employers with more productive jobs search more intensively because the opportunity cost of a vacancy is greater for such jobs. Thus, if all employers use the same search and matching technology, better jobs are filled at a faster rate.

Another possibility is that workers and employers sort into separate search markets, each characterized by potentially different market tightness levels, different matching technologies, or both. By inspection of (1), it is clear that this type of heterogeneity gives rise to differences in vacancy yields across labor markets that are defined by observable and relevant employer characteristics.

Another class of explanations recognizes that firms recruit, screen, and hire workers through a variety of channels, and that reliance on these channels differs across industries and employers for technological and institutional reasons. For example, construction firms may recruit workers from a hiring hall or other specialized labor pool for repeated short-term work, perhaps reducing the incidence of measured vacancies and inflating the vacancy yield. Employers in government and certain other industries operate under laws and regulations that require a formal search process for the vast

majority of new hires, ensuring that a high percentage of hires are preceded by a measured vacancy. More generally, employers rely on a mix of recruiting and hiring practices that differ in propensity to involve a measured vacancy and in vacancy duration. These methods include bulk screening of applicants who respond to help-wanted advertisements, informal recruiting through social networks, opportunistic hiring of attractive candidates, impromptu hiring of unskilled workers in spot labor markets, and the conversion of temp workers and independent contractors into permanent employees. Differences in the mix of recruiting and hiring practices are likely to lead to cross-sectional differences in the vacancy yield.

3.C. The Establishment-Level Distribution of Vacancies and Hires

We now turn to the establishment-level distribution of vacancies and hires. The JOLTS data are the first large, representative U.S. data source that allows for a micro-level examination of the frequency, intensity, and variability of job openings. We present some basic facts related to these outcome measures.

Table 2 and Figure 3 document the large percentage of employers with few or no reported vacancies. In the average month, 45% of employment is at establishments with no reported vacancies. When establishments report vacancies, it is often at very low rates and levels. The median vacancy rate is less than 1% of employment, when calculated in an employment-weighted manner, and the median number of vacancies is just one. At the 90th percentile of the employment-weighted distribution, the vacancy rate is 6% of employment and the number of vacancies is 63.¹⁰

¹⁰ Weighting all establishments equally, 88 percent report no vacancies, the vacancy rate at the 90th percentile is 3%, and the number of vacancies at the 90th percentile is just one.

Table 2 also provides some information about the establishment-level distribution of hires. Establishments with no hires during the month account for 35% of employment. This result suggests that the need for hires at the monthly frequency may not be that great for many employers. Nevertheless, this cannot be the full explanation for the prevalence of employers with no reported vacancies, because Table 2 also reports that 42% of hires take place at establishments with no reported vacancy going into the month. This fact indicates that average vacancy durations are very short or that many hires occur without benefit of a vacancy as captured by JOLTS data. The rightmost column of Table 2 shows that the establishment-level incidence of vacancies is highly persistent. In particular, only 18% of vacancies in the current month are at establishments with no recorded vacancies in the previous month.

Table 2 also documents considerable variation in the frequency of hires and vacancies across industries, employer size classes, and worker turnover groups. Establishments with zero reported vacancies account for 20% of all hires in Government, 49% in Retail Trade, and 67% in Construction. These large differences indicate that industries differ greatly in mean vacancy duration, the propensity to rely on vacancies (as defined by JOLTS) as inputs into the hiring process, or both.

Perhaps counter-intuitively, industries with the highest worker turnover rates (Table 1) have the highest employment-weighted incidence of establishments with no reported vacancies. The same pattern holds across worker turnover quintiles, setting aside establishments with no worker turnover. In addition, nearly half of all hires by employers in the top worker turnover quintile occur at establishments with no reported vacancies going into the month. Recall from Table 1 that worker turnover is 26.5% of employment

per month for establishments in this group. Given these results, it must be the case that vacancy durations are extremely short for these employers or that a large fraction of their hires take place without benefit of a vacancy as defined in JOLTS. Sections 4, 5, and 6 below develop methods to estimate mean vacancy durations and the fraction of hires without benefit of a vacancy.

3.D. Hires, Vacancies, and Establishment Growth

We next consider how hires, vacancies, and vacancy yields co-vary with employer growth rates at the establishment level. The size and direction of employment changes provide signals about the size and direction of labor demand shocks hitting the establishment. Seen in this light, the cross-sectional relationships of hires, vacancies, and vacancy yields to employer growth provide useful inputs for formulating and assessing theoretical models of how employers respond to labor demand shocks.¹¹

To estimate these relationships in a flexible non-parametric manner, we proceed as follows. We first pool the roughly 577,000 establishment-level observations over all months. Next, we partition the feasible range of growth rates, $[-2.0, 2.0]$, into a large number of non-overlapping intervals. Each establishment-level observation is then sorted into one of these intervals based on its monthly growth rate value. We use very narrow intervals with width .001 near zero and progressively wider intervals as we move away from zero in either direction.¹² We also allow for a mass point at zero employment change. Given our partition and sorting of establishments, we then calculate

¹¹ Previous research finds a wide distribution of growth rates at the establishment level at any point in time (e.g., Davis, Haltiwanger, and Schuh, 1996). Earlier research also finds highly nonlinear relationships between the hires rate and the establishment growth rate in the cross section (Abowd, Corbel, and Kramarz, 1999; Davis, Faberman, and Haltiwanger, 2006).

¹² We use wider intervals as we move into the thinner parts of the cross-sectional growth rate density to maintain precision in our estimates.

employment-weighted means for the hires rate, the vacancy rate, and the vacancy yield for each growth rate interval. An equivalent procedure is to execute an OLS regression of the outcome variables on an exhaustive set of interval dummies. The coefficients on the interval dummies recover the estimated non-parametric relationship of the outcome variables to the establishment-level growth rate of employment. Under the regression approach, we can easily introduce establishment fixed effects or other controls.

Figures 4, 5, and 6 display the non-parametric regression results.¹³ The hires relation must satisfy part of an adding-up constraint, since net growth is the difference between hires and separations. Thus, the minimum feasible value for the hires rate is the horizontal axis for non-positive growth and the 45-degree line for positive growth. Hiring lies above this minimum for all growth rates.

Figure 4 shows the highly non-linear, kinked relationship between the hires rate and the establishment growth rate first documented in Davis, Faberman and Haltiwanger (2006). The hires rate declines slightly with employment growth at shrinking establishments and reaches its minimum for establishments with no employment change. To the right of zero, the hire rate rises more than one-for-one with the growth rate of employment. This cross-sectional relationship says that hires and job creation are very tightly linked at the establishment level.¹⁴ Controlling for establishment fixed effects does little to alter the relationship. In fact, the “hockey-stick” shape of the hires-growth relation is even more pronounced when we control for establishment fixed effects.

¹³ We focus on monthly growth rate intervals in the -30 to 30% range because our estimates are highly precise in this range. For visual clarity, we smooth the non-parametric estimates using a centered, five-interval moving average except for intervals at and near zero, where we use no smoothing.

¹⁴ Davis, Faberman, and Haltiwanger (2006) show that a similarly tight relationship holds between worker separations and job destruction at the establishment level.

Figure 5 reveals a similar non-linear relationship for the vacancy rate. Vacancy rates average about 2% of employment at contracting establishments, dip for stable establishments with no employment change, and rise with the growth rate of employment for expanding establishments. The vacancy-growth relationship for expanding establishments is much less steep than the hires-growth relationship. For example, at a 30% monthly growth rate, the vacancy rate is just 4.8% of employment compared to 34.2% for the hires rate. Another notable contrast to the hires-growth relation is the clear discontinuity at zero in the vacancy-growth relation. The average vacancy rate is 2.2% for establishments with very small contractions (less than 1%) compared to 2.7% for those with very small expansions and 1.4% at zero growth. Controlling for establishment fixed effects eliminates the discontinuity at zero but otherwise has little effect on the vacancy-growth relationship.

Figure 6 presents the vacancy yield relationship to establishment growth. We report total hires divided by total vacancies in each growth rate interval, which is similar to dividing the hires relation in Figure 4 by the vacancy relation in Figure 5.¹⁵ Among contracting establishments, the yield is about one hire per vacancy. There is again a discontinuity at zero that disappears after controlling for establishment fixed effects. Among expanding establishments, the vacancy yield increases considerably with the growth rate. Expansions in the 25-30% range yield over five hires per vacancy. The strongly increasing relation between vacancy yields and employer growth rates survives the inclusion of establishment fixed effects.

¹⁵ It is not identical because the hires and vacancy rates have different denominators. An alternative approach is to construct the vacancy yield at the micro level and then aggregate. This alternative, which restricts the sample to establishments with vacancies, yields a pattern very similar to the one reported in Figure 6.

Since hires are a flow and vacancies are a stock in the JOLTS, one may be quick to attribute the hires-vacancy relation in Figure 6 to time aggregation—i.e., perhaps high-yield, high-growth establishments have high unobserved vacancy flows. By the same logic, differences in vacancy durations and unobserved vacancy flows during the month might explain the cross-sectional variation in vacancy yields seen in Table 2. Yet, other factors might be at work as well. For example, differences in vacancy yields might reflect differences in the propensity to attract workers without benefit of a vacancy as defined in JOLTS or as reported by JOLTS respondents. The accounting framework set forth in the next section helps to disentangle these explanations.

4. A Framework for Identifying Vacancy Flows and Job-Filling Rates

4.A. A Simple Framework

We now describe an accounting framework that identifies the flow of new vacancies during the month, the average daily job-filling rate in the month, and the mean vacancy duration. Let $h_{s,t}$ denote the number of hires on day s in month t , and let $v_{s,t}$ denote the number of vacancies. We assume a daily fill rate, f_t , and daily flow of new vacancies, θ_t , that are constant during the month but vary between months. A month contains τ workdays. Hires on day s in month t equal the fill rate times the vacancy stock:

$$(2) \quad h_{s,t} = f_t v_{s-1,t}.$$

Each day, the stock of vacancies evolves in three ways. First, an inflow of new vacancies increases the stock. Second, hires deplete the stock. Third, some vacancies close without being filled, also depleting the stock. We denote this last variable by δ_t , and assume a

constant value during the month. These assumptions imply the following daily equation of motion for the vacancy stock:

$$(3) \quad v_{s,t} = ((1 - f_t)(1 - \delta_t))v_{s-1,t} + \theta_t.$$

Next, we sum up equations (2) and (3) to obtain monthly measures that correspond to observables in the data. For vacancies, we relate the stock at the end of month $t - 1$, v_{t-1} , to the stock at the end of month t , τ days later. Cumulating (3) over τ days and recursively substituting for $v_{s-1,t}$ yields the desired equation,

$$(4) \quad v_t = (1 - f_t - \delta_t + \delta_t f_t)^\tau v_{t-1} + \theta_t \sum_{s=1}^{\tau} (1 - f_t - \delta_t + \delta_t f_t)^{s-1}.$$

The first term on the right is the initial stock, depleted by hires and closings. The second term is the flow of new vacancies during the month, similarly depleted.

Hires are reported as a monthly flow in the data. Thus, we cumulate daily hires in (2) to obtain the monthly flow, $H_t = \sum_{s=1}^{\tau} h_{s,t}$. Substituting (3) into (2), and (2) into the monthly sum, and then substituting back to the beginning of the month for $v_{s-1,t}$ yields

$$(5) \quad H_t = f_t v_{t-1} \sum_{s=1}^{\tau} (1 - f_t - \delta_t + \delta_t f_t)^{s-1} + f_t \theta_t \sum_{s=1}^{\tau} (\tau - s)(1 - f_t - \delta_t + \delta_t f_t)^{s-1}.$$

The first term on the right is hires into the initial stock of vacant job positions, and the second is hires into job positions that open during the month. Given δ_t , the system (4) and (5) identify the average daily job-filling rate, f_t , and the flow of new vacancies, θ_t .

4.B. Estimation

The unknown parameters in (4) and (5) can be estimated using publicly available JOLTS statistics for the flow of monthly hires and the end-of-month stock of vacancies. To obtain a longer time series, we also rely on HWI data and CPS data on the monthly

flow of new hires. For simplicity, we assume all months have $\tau = 26$ working days, the average number of days per month less Sundays and major holidays. We set δ_t to L_t/τ , where L_t is the observed layoff rate for month t .¹⁶ That is, we assume vacant positions close at the same rate as the daily layoff rate for filled jobs. This assumption is similar to assumptions in the search literature that set an exogenous job separation or job destruction rate to the observed layoff rate.

We solve the system (4) and (5) numerically for each month to obtain time series estimates for f_t and θ_t . We also use the pooled-sample JOLTS micro data to produce estimates by industry, size class, and turnover category. We calculate the average vacancy duration (in days) as $1/f_t$. We scale the monthly vacancy flow, $\tau \cdot \theta_t$, by employment in the month to obtain the vacancy flow rate.

4.C. Time-Series Results

Figure 7 shows monthly time series from 2001 to 2006 for the estimated flow of new vacancies, the estimated daily job-filling rate for vacant positions, and the measured vacancy stock. The monthly flow of new vacancies averages 3.4% of employment, considerably larger than the average vacancy stock of 2.4%. Vacancy stocks and vacancy flows are pro-cyclical, with stronger movements in the stock measure. The average job-filling rate is 5.0% per day. It ranges from a low of 4.0% in February 2001

¹⁶ When we use the CPS gross flow data, we set δ_t equal to the monthly employment-to-unemployment flow, as a fraction of employment, divided by τ .

to a high of 6.1% in March 2004 and moves in a roughly counter-cyclical manner. The implied average vacancy duration ranges from 16 to 25 days.¹⁷

We next apply the framework to CPS data on new hires and the detrended Help Wanted Index.¹⁸ This exercise serves as a cross check, and it provides a much longer time series for drawing inference about cyclical patterns. Figure 8 reports the quarterly time-series results, including quarterly averages of monthly JOLTS-based statistics for comparison. Estimates derived from JOLTS data show declining vacancy flows during recessions and weak labor markets. The CPS-HWI data also suggest that the flow of new vacancies diminishes in recessions, but these estimates are quite noisy and do not support strong inferences about the cyclical behavior of vacancy flows.

Turning to the top panel in Figure 8, the longer time series show pronounced counter-cyclical variation in the job-filling rate, with sharp increases during recessions. All three sources show increasing job-filling rates during the recession of 2001, but the increase is less abrupt in the JOLTS data, and it extends for an additional two years beyond the NBER-dated end to the recession. (As we remarked previously, aggregate employment continued to contract through the middle of 2003.) In short, the available evidence clearly points to a strong counter-cyclical pattern of movement in job-filling rates. This evidence supports the view that employers find it much easier to recruit suitable workers in weak labor markets.

¹⁷ Our vacancy duration estimates are similar to those obtained by Burdett and Cunningham (1998) and Barron, Berger, and Black (1999) in small samples of U.S establishments but considerably shorter than those obtained by van Ours and Ridder (1991) for the Netherlands and Andrews et al. (2007) for the U.K.

¹⁸ Greater caution is warranted for the results based on CPS and HWI data, given the nature of the HWI and that the CPS and HWI data fit our accounting framework less well than the JOLTS data.

Nevertheless, the JOLTS and CPS-HWI series for the job-filling rate are rather imperfectly correlated during the period of overlap. Figure 2 shows a similar result for the vacancy yield, which is a simple transformation of the tightness ratio under a standard specification of the matching function, as we have seen. These discrepancies between JOLTS and CPS-HWI measures are a concern, because quantitative analyses of search and matching models have relied heavily on CPS-HWI data. One potential explanation is cyclical variation in the recruiting channels used by employers to hire workers. Recall that the Help Wanted Index is based on help-wanted advertising volume in a sample of U.S. newspapers. In contrast, the JOLTS questionnaire is clearly designed to elicit information about a broader notion of vacancies and is not confined to a single recruiting channel. Russo, Gorter and Schettkat (2001) report evidence that Dutch employers alter the mix of recruitment channels as labor market tightness varies and, in particular, that they rely less heavily on paid advertisements in weak labor markets. However, this finding does not help to reconcile the discrepancies between JOLTS and HWI measures of the job-filling rate and the vacancy yield. Their results also pertain to a very different institutional environment for hiring workers and may not extend to the U.S. setting.

4.D. Cross-Sectional Results

In Section 3, we documented considerable variation in vacancy rates and vacancy yields by industry, establishment size class, and worker turnover groups. Table 3 presents cross-sectional results based on the application of our framework to the pooled-sample JOLTS micro data. Once again, there is considerable variation across industries, employer size classes, and worker turnover categories.

The average job-filling rate ranges from about 3% per day in Information, FIRE, Health & Education and Government to about 5% in Manufacturing and Transport, Wholesale & Utilities, Professional & Business Services and Other Services, to about 7% in Retail Trade and Natural Resources & Mining to 12% per day in Construction. Such large differences in the job-filling rate point to major differences in labor market tightness or in search and matching technologies across industries. Table 3 also shows that job-filling rates decline with employer size, falling by more than half in moving from the smallest to the largest establishments. The most striking pattern in the job-filling rate pertains to worker turnover categories. The job-filling rate ranges from 1.1% per day in the first turnover quintile to 11.4% per day in the fifth quintile. To the best of our knowledge, these differences have received little attention in the theoretical literature, even though they offer a natural source of inspiration for model building and a useful testing ground for theory.¹⁹

4.E. Vacancy Flows and Fill Rates Related to Establishment Growth Rates

One of the most novel aspects of studying hiring and vacancy behavior using JOLTS micro data is our ability to study patterns at the establishment level. Section 3 showed that the vacancy yield displays a strong, highly non-linear relationship to the establishment growth rate. However, it was unclear whether and how much this empirical relationship reflects time aggregation and the stock-flow distinction. We now address this issue by applying the framework developed above. The framework also allows us to identify the monthly flow of new vacancies as a function of the establishment-level growth rate. As before, we partition growth rates into many intervals

¹⁹ To be sure, there has been some theoretical work in this area, including the paper by Albrecht and Vroman (2002), which we mentioned previously.

and sort the establishment-level observations into these intervals. We then apply the framework interval by interval to obtain non-parametric estimates for the relationship of the job-filling rate and the monthly vacancy flow to the establishment growth rate.

The underlying conceptual model in this approach allows for heterogeneity in the joint distribution of f and θ at the micro level. Specifically, suppose that establishments receive draws from a joint distribution over establishment-level growth rates, job-filling rates, and vacancy flows. Applying our framework, we can recover estimates of the average f and θ draws in each growth rate interval. We are not positing a causal relationship between growth and the f and θ parameters. Rather, we seek to recover the empirical relationship that emerges from some equilibrium process. We argue below that this empirical object is helpful for discriminating among classes of theoretical models.

Figure 9 displays the estimated relationship of the daily job-filling rate and the monthly flow of new vacancies to the monthly employment growth rate with an overlay that shows the monthly layoff rate. Both the fill rate and the vacancy flow rate exhibit a pronounced kink at zero and increase very strongly with the establishment growth rate. Fill rates rise from 3% per day at establishments that expand by about 1% to 9% per day at those that expand by about 5% and more than 20% per day at those that expand by 20% or more in the month. The fill rate and flow rate of new vacancies are relatively flat to the left of zero, but they actually decline with the growth rate of employment.

One important conclusion is immediate from Figure 9: the strong positive relationship between the vacancy yield and the employer growth rate among expanding establishments is not simply an artifact of time aggregation. If that were the case, we would not see a positive relationship between the job-filling rate and employer growth to

the right of zero in Figure 9. In fact, we see a very strong positive relationship. The positive relationship of the vacancy yield and the job-filling rate documented in Figures 6 and 9 reflects something more fundamental about the nature of search and matching in labor markets.²⁰

We think Figure 9 strongly favors some theoretical specifications over others in frictional models of hiring. First, the estimated pattern for the job-filing rate is inconsistent with models in which vacancy posting rises one-for-one with (desired) hires. Such models imply an approximately flat relationship between the job-filling rate and the growth rate of employment.²¹ Second, Figure 9 casts doubt on models in which individual employers with monopsony power deplete the relevant local labor market when they grow rapidly in a short period of time (a month). If this were a dominant feature of the labor market environment, we would expect to see job-filling rates that decline with the growth rate. Instead, we see very much the opposite. Of course, employers can raise wages and relax hiring standards to facilitate rapid growth, which raise the job-filling rate, other things equal. However, responses on the wage and standards margins are more likely to mitigate the decline in the job-filling rate, not reverse it. Third, standard formulations of stock-flow matching models are also hard to reconcile with the fill rate relation in Figure 9, for a similar reason. These models suggest that employers are more likely to exhaust the relevant local labor market when

²⁰ This is not to say that time aggregation plays no role in the observed vacancy yield-growth relation. On the contrary, Figure 9 shows that the vacancy flow rises strongly with employment growth at expanding establishments, much more strongly than the vacancy rate in Figure 5. This pattern implies that vacancy yields are more inflated by time aggregation at rapidly growing establishments than at slowly growing ones. In other words, time aggregation is, indeed, an important part of the explanation for the vacancy yield relation observed in Figure 6.

²¹ We recognize that the stochastic nature of hires (conditional on the number of vacancies) can generate a positive relationship of the fill rate to the growth rate, but we do not think this force is strong enough to explain the observed relationship in Figure 9. Still, we need to perform some additional work to dismiss this explanation entirely.

they expand rapidly, thereby generating a negative relationship between the fill rate and the growth rate of individual employers.

On the positive side, Figure 9 points to at least three theoretical elements as potentially important features of the search and matching process. They are endogenous search intensity on the employer side, scale economies in the hiring process, and directed job creation. We briefly discuss each element in turn.

Endogenous search intensity is easily incorporated into standard search and matching models, but it is typically omitted from quantitative models taken to the data for reasons of simplicity or lack of empirical counterparts. Figure 9, however, suggests that the opportunity cost of unfilled jobs is greater for rapidly growing employers, and that they respond by searching more intensely. We are not aware of studies that investigate how employer search intensity (per vacancy) varies with the employer's actual or desired growth rate.

Scale economies in advertising or recruiting might partly account for the positive relationship between fill rates and growth rates in Figure 9. For example, it is probably less costly to achieve a given level of advertising exposure per job opening when an employer has many vacancies rather than few. Alternatively, it may be easier to attract applicants when the employer has a variety of open positions. Recruiting is easier at rapidly growing employers if prospective hires see more opportunities for promotion and wage gains and lower risks of layoff. We are aware of little evidence that speaks directly to the relevance and strength of these aspects of the hiring process, although they are not often featured in theoretical models of search and matching.

Finally, Figure 9 is highly suggestive of directed job creation in the sense of high-growth employers creating the types of jobs that fit well with the location, skills, and other characteristics of potential hires. To the extent that rapidly growing employers tailor their job openings in this way to a greater extent than slowly growing ones, they find it easier to fill their vacancies. The result is a positive relationship between the fill rate and the growth rate at the level of individual employers. The idea of directed job creation can be grafted onto a variety of different models.

5. The Framework in Steady State²²

By characterizing steady-state hires and vacancies in much the same way that Shimer (2007b) characterizes steady-state unemployment, we can obtain a simple approximate method for estimating f and θ . The steady-state versions of (2) and (3) are

$$(6) \quad f = \frac{H / \tau}{v},$$

$$(7) \quad \theta = (f + \delta - f\delta)v,$$

where $H = h \cdot \tau$. When we apply these steady-state conditions, the monthly estimates for f_t and θ_t are very similar to the ones obtained numerically by fitting (4) and (5). The mean job-filling rate from 2001 to 2006 is 5.1% under the steady-state approximation (6) compared to 5.0% using (4) and (5). The mean vacancy flow rate is 3.4% per month under both approaches.²³ We now apply the steady-state approach to estimate the fraction of hires that take place without benefit of a prior vacancy.

²² We thank Rob Shimer for suggesting the exercise conducted in this section.

²³ The steady-state approximation does not work well for some applications. For example, it performs poorly in estimating the relationship of vacancy flows and fill rates to establishment growth rates in the cross section.

Recalling equation (5), the number of hires in month t accounted for by the flow of new vacancies during t is

$$(8) \quad H_t^{NEW} \equiv f_t \theta_t \sum_{s=1}^{\tau} (\tau - s)(1 - f_t - \delta_t + f_t \delta_t)^{s-1}.$$

Thus, the framework set forth in Section 4.A implies that the number of new hires in month t by establishments with no vacancies at the beginning of the month is

$$(9) \quad H_t^{NoVac} = E_t^{NoVac} H_t^{NEW},$$

where E_t^{NoVac} is the observed employment share of establishments with no vacancies at the beginning of month t (or end of $t-1$). To calculate (9), we obtain H_t^{NEW} from (8) and calculate E_t^{NoVac} directly from the JOLTS micro data. Dividing the result by the total number of hires in month t yields the framework's implied value for the share of hires by establishments with no vacancies at the beginning of the month.

Implementing (9) from 2001-2006, our framework implies that 19.7% of hires took place at establishments that stated the month with no vacancies. Recall from Section 3 that 41.6% of hires actually took place at such establishments. Thus, our framework implies that about 22% ($41.6 - 19.7 = 21.9$) of all hires occurred without benefit of a previous vacancy. An observationally equivalent interpretation is that all hires involve a prior vacancy, but JOLTS respondents substantially underreport vacancies. Some combination of hires without a vacancy and underreporting could also account for the results. For expositional convenience, we refer to these as hires without a vacancy, but the reader should keep in mind that we require additional information to distinguish hires without a vacancy from underreporting of vacancies.

In Figure 10, we carry out the same calculations month by month. The thick line reports the observed share of hires by establishments that start the month with no vacancies, as calculated from JOLTS micro data. The thin line reports the fraction of hires that occur without benefit of a vacancy, calculated as the difference between the actual share of hires by establishments with no recorded vacancies and H_t^{NoVac} from (9). Figure 10 shows that time aggregation accounts for about half of the hires observed at establishments with no recorded vacancies. The rest reflects hires without benefit of a vacancy. The estimated fraction of hires that occur without benefit of a vacancy is smallest during the recession of 2001.

In the last column of Table 3, we report the estimated fraction of hires without a vacancy (“hires outside the framework”) by industry, employer size category, and worker turnover quintile. This fraction ranges from a low of 12% of all hires in government to over 20% in several industries. It also declines systematically with employer size – from 32% of hires at establishments with 0-9 employees to about 5% for establishments with 1,000 or more workers.

In summary, the basic framework accounts for about half of all hires by establishments with zero recorded vacancies at the beginning of the month. We suggested that the rest reflects hires without benefit of a vacancy (or underreporting of vacancies by JOLTS respondents). What else might explain the large discrepancy between observed and predicted hires by establishments with no recorded vacancies? Heterogeneity is one answer. Our framework assumes the same job-filling and vacancy flow rate for all establishments. However, as Table 3 shows, there is much heterogeneity in these quantities. Nevertheless, even when we fit the framework by industry, employer size

class, and worker turnover categories, we find evidence that many hires take place without benefit of a vacancy.

It is also worth stressing that the exercise in this section relies on a steady-state approximation and a version of our framework that fails to fully incorporate the heterogeneity we observe at the establishment level. In addition, while the basic framework equations are consistent with aggregation of micro units into the aggregate equations (4) and (5), the calculations of the results in Table 3 are not based on a stochastic process that presumably underlies (4) and (5). In the next section, we remedy these limitations by analyzing the implications of a stochastic micro version of the stock-flow framework where we can incorporate key aspects of the underlying distributions in the establishment-level data.

6. A Stochastic Micro Simulation of the Framework

The basic framework matches the aggregate hiring and vacancy rates observed in the data by construction, but in doing so, it imposes strict assumptions on the establishment dynamics that underlie these rates. For instance, the framework implicitly assumes that vacancies occur at all establishments at some constant rate and are subsequently filled at yet another constant rate throughout each period. As we have shown, this characterization is appealing because it permits estimating these rates using readily available data, but given our access to the establishment data, a richer characterization is possible. Namely, if we treat the daily flow and fill rates from the basic model as stochastic arrival rates as is standard in the search literature, we can generate a variety of the framework's simulated moments that we can then compare to what we observe in the data. That is, if we interpret the vacancy flow, θ , as the likelihood

that a vacancy will be posted on a given day, and the job-filling rate, f , as the probability that a posted vacancy will be filled on any given day, then we can generate a micro-level distribution of hires and vacancies using an establishment-based simulation of the basic framework.

The objective of this micro stochastic simulation is not simply to provide a robustness check but also to take into account key aspects of the heterogeneity at the micro level. In particular, we conduct this micro simulation in a manner that matches the size distribution of employment and the size distribution of vacancy rates. It is clear from Tables 1 and 2 that many dimensions vary by size class, including hires rates, vacancy yields, and the distribution of hires at establishments that begin the month with zero vacancies. To accomplish this in the simulation of the stochastic model, we first generate data of 30,000 establishments, each with an initial employment level and number of vacancies. To match the size distribution, we assign each establishment into one of the six size class categories listed in Tables 1-3 based on the share of total establishments each category represents in the data and assign each establishment the mean employment level for that size class. To match the vacancy rate distribution by size class, we draw an initial number of vacancies for each simulated establishment from the distribution of beginning-of-month vacancies observed in the data by size class. To keep track of an establishment's employment growth throughout the month, we assume a worker separates with probability s , which we set equal to the average separation rate observed within the data for the simulated establishment's size class. Finally, we assume an

unfilled vacancy closes with probability δ , which we set equal to the average layoff rate within the simulated establishment's size class, divided by τ days.²⁴

Given the distribution of simulated establishments and an initial guess for f and θ , we can simulate the evolution of hires and vacancies over τ days for each establishment using establishment-level versions of equations (2) and (3). From this we can generate the aggregate monthly hires rate (H_t) and the end-of-month vacancy rate (v_t) from the simulated data. We then choose the optimal \hat{f} and $\hat{\theta}$ using a Simulated Method of Moments approach that minimizes the distance between the simulated and actual hires and vacancy rates at the aggregate level. Since we have two parameters and two moments, the system is exactly identified.

We perform the SMM estimation separately on the simulated data within each size class, and we take the weighted average of these results as our aggregate estimates. While the aggregate hires and vacancy rates are the only moments we use in our SMM estimation, the micro-level nature of the simulation allows us to calculate several other establishment-level moments implied by the estimation, including the simulated versions of the moments listed in Table 2.

Our results are listed in Table 4. As one can see, even though we use an initial distribution of simulated micro data instead of aggregate estimates, the estimated job-filling and vacancy flow rates are nearly identical to those obtained from the basic framework across all size classes and for total nonfarm employment. Thus, one can conclude that our basic estimation with aggregate data approximates the micro-level job-filling and vacancy flow rates well. The fourth and fifth columns of the table list what the

²⁴ As before, we assume $\tau = 26$ days.

estimation predicts for two of the moments listed in Table 2. For comparison, we list the moments from the actual data in brackets underneath each estimate. As with the basic framework, the stochastic micro-simulation consistently under-predicts the fraction of hires that occur at establishments without a previously reported vacancy, albeit to a lesser degree. For all establishments, the model predicts that time aggregation should produce 25.6% of hires occurring at establishments with no prior vacancy. This is higher than the 19.7% observed with the basic framework estimation but is still much lower than the 41.6% observed in the data. Interestingly, the micro-simulation over-predicts the fraction of end-of-month vacancies at establishments with no beginning-of-month vacancies, or equivalently, it under-predicts the establishment-level persistence of vacancies observed in the data. Again, the pattern holds within each size category.

The final column of Table 4 lists the percent of hires outside of the stock flow framework. It is equal to the difference between the reported estimate and the term in brackets in the fourth column and is comparable to the same statistic tabulated for the basic framework and listed in last column of Table 3. For all establishments, the stochastic micro-simulation predicts that 16% of hires lie outside the framework, a smaller estimate than the one implied by the basic framework, but nonetheless a large fraction representing nearly 1 out of every 6 hires. The main point to take away from this exercise is that even with a micro-based approach that accounts for heterogeneity in establishment size and the micro-level distribution of initial vacancies, we still get the result that a sizeable fraction of hires occur outside of a standard framework of worker recruitment.

7. Concluding Remarks

This paper examines the establishment-level behavior of vacancies and hires in a large monthly sample of U.S. employers, supplemented by aggregate data for a longer time period. We introduce the concept of the vacancy yield, a measure of success in generating hires. We show that the vacancy yield is counter-cyclical, consistent with standard search theory. We also find large differences by industry and employer size in vacancy yields, vacancy rates, and the propensity to hire without a reported vacancy, and we document strong non-linear relationships of hires, vacancies, and the vacancy yield to establishment-level growth rates in the cross-section.

To help interpret these patterns, we develop a simple framework that accounts for time aggregation and identifies other interesting quantities. The framework treats JOLTS data as the observed monthly outcomes of daily processes for new vacancies and hires. Cumulating the daily processes to the monthly level, and making use of JOLTS data, the accounting framework delivers estimated values for the unobserved monthly flow of new vacancies, the job-filling rate for reported job openings, and the mean number of days required to fill an open vacancy. The flow of new vacancies appears less cyclically volatile than the vacancy stock, according to our basic accounting framework, while the job-filling rate is counter-cyclical. It is the latter pattern that is directly relevant in terms of standard search models since it is the job-filling rate obtained after accounting for time aggregation that corresponds to the job-filling rate of standard models. Our finding that it is counter-cyclical is consistent with standard matching functions, but our finding that it is sharply increasing with establishment growth at the micro level is a novel finding that contrasts with the counter-cyclical aggregate relationship.

When we examine a steady-state approximation of our accounting framework, we estimate that 22% of hires occur outside of the framework, perhaps without benefit of a vacancy. This fraction accounts for time aggregation in the data and varies greatly by industry, employer size, and establishment turnover. When we push the data further with a stochastic micro-simulation, our estimate of hires outside of the accounting framework falls to 16 %. This estimate accounts for time aggregation as well as several sources of heterogeneity in the micro data, strengthening the argument that this residual may represent hiring that occurs without the benefit of a vacancy.

The empirical patterns we document provide a useful guide to the further development of search models. For example, Faberman and Nagypál (2008) show that a model with search on the job and productivity heterogeneity among firms can deliver a positive relationship between the job-filling rate and employer growth rates in the cross section. Other aspects of our results call for a bigger departure from received search models – in particular, the substantial fraction of hires that are outside the standard matching framework. In this respect, our evidence strongly suggests that the role of vacancies in the recruiting process varies systematically by industry, employer size, and employer growth. Similarly, the evidence suggests that at least some employers rely heavily on recruiting channels that are not captured in the JOLTS measure of job openings.

References

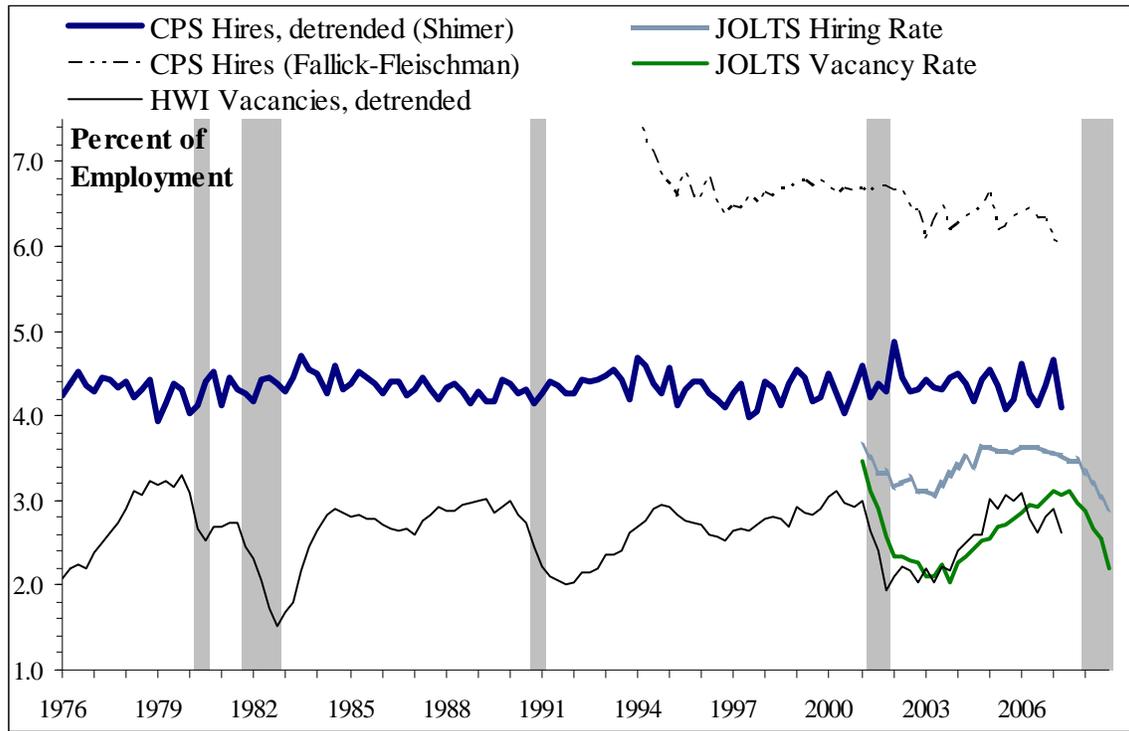
- Abowd, John, Corbel, Patrick, and Kramarz, Francis, 1999. "The Entry and Exit of Workers and the Growth of Employment: An Analysis of French Establishments," *Review of Economics and Statistics* 81(2): 170-187.
- Abraham, Katherine, 1983. "Structural/Frictional vs. Deficient Demand Unemployment: Some New Evidence," *American Economic Review* 73(4): 708-724.
- , 1987. "Help Wanted Advertising, Job Vacancies, and Unemployment," *Brookings Papers on Economic Activity*, 207-43.
- Acemoglu, Daron and Shimer, Robert, 2000. "Wage and Technology Dispersion," *Review of Economic Studies* 67(4): 585-607.
- Albrecht, James and Susan Vroman. 2002. "A Matching Model with Endogenous Skill Requirements," *International Economic Review*, 43, 1 (February), 283-305.
- Andrews, M.J., S. Bradley, D. Stott and R. Upward. 2007. "Successful Employer Search? An Empirical Analysis of Vacancy Duration Using Micro Data," *Economica*, 1-26.
- Barron, John M., Mark C. Berger and Dan A. Black. 1999. "Employer Search, Training, and Vacancy Duration," *Economic Inquiry*, 35 (January), 167-192.
- Berman, Eli. 1997. "Help Wanted, Job Needed: Estimates of a Matching Function from Employment Service Data," *Journal of Labor Economics*, 15, 1, part 2 (January), S251-S292.
- Blanchard, Oliver J., and Diamond, Peter, 1989. "The Beveridge Curve," *Brookings Papers on Economic Activity*, 2, 1-60.
- Burdett, Kenneth and Cunningham, Elizabeth, 1998. "Toward a Theory of Vacancies," *Journal of Labor Economics*, 16 (3): 445-478.
- Burdett, Kenneth, and Mortensen, Dale T., 1998. "Wage Differentials, Employer Size, and Unemployment," *International Economic Review* 39(2): 257-73.
- Clark, Kelly A., 2004. "The Job Openings and Labor Turnover Survey: What Initial Data Show," *Monthly Labor Review* 127(11): 12-23.
- Clark, Kelly A., and Hyson, Rosemary, 2001. "New Tools for Labor Market Analysis: JOLTS," *Monthly Labor Review*, 124(12): 32-37.
- Coles, Melvin G., and Smith, Eric, 1996. "Cross-Section Estimation of the Matching Function: Evidence from England and Wales," *Economica* 63(2): 589-97.

- Coles, Melvyn and Eric Smith. 1998. "Marketplaces and Matching," *International Economic Review*, 39, 239-255.
- Coles, Melvyn and Barbara Petrongolo. 2008. "A Test between Stock-Flow Matching and the Random Matching Function Approach," *International Economic Review*, 49(4): 1113-1141.
- Davis, Steven J. 2001. "The Quality Distribution of Jobs and the Structure of Wages in Search Equilibrium," NBER Working Paper 8434.
- Davis, Steven J., Faberman, R. Jason, and Haltiwanger, John, 2006. "The Flow Approach to Labor Markets: New Evidence and Micro-Macro Links," *Journal of Economic Perspectives*, 20(3): 3-24.
- Davis, Steven J., R. Jason Faberman, John Haltiwanger, and Ian Rucker. 2008. "Adjusted Estimates of Worker Flows and Job Openings in JOLTS," NBER Working Paper 14137. Forthcoming in *Labor in the New Economy*, edited by Katharine Abraham, Michael Harper and James Spletzer.
- Davis, Steven J., John C. Haltiwanger, and Scott Schuh, *Job Creation and Destruction*. (Cambridge, MA: MIT Press, 1996).
- Dickerson, Andy. 2003. "The Distribution and Determinants of Job Vacancies: Evidence from the 2001 Employer Skills Survey." Working Paper, Institute for Employment Research, University of Warwick.
- Ebrahimi, Eshan and Robert Shimer, 2008. "Stock-Flow Matching," University of Chicago, mimeo.
- Elsby, Michael, Ryan Michaels and Gary Solon. 2009. "The Ins and Out of Cyclical Unemployment," *American Economic Journal: Macroeconomics*, 1(1), 84-110.
- Faberman, R. Jason, 2008a. "Studying the Labor Market with the Job Openings and Labor Turnover Survey," in *Producer Dynamics: New Evidence from Micro Data*, Timothy Dunne, J. Bradford Jensen and Mark J. Roberts (eds.), Chicago Press, pp. 83-108.
- Faberman, R. Jason, 2008b. "Job Flows, Jobless Recoveries, and the Great Moderation," Federal Reserve Bank of Philadelphia Working Paper 08-11.
- Faberman, R. Jason, and Éva Nagypál, 2008. "Quits, Worker Recruitment, and Firm Growth: Theory and Evidence," Federal Reserve Bank of Philadelphia Working Paper 08-13.

- Fallick, Bruce and Charles A. Fleischman, 2004. "Employer-to-Employer Flows in the U.S. Labor Market: The Complete Picture of Gross Worker Flows," Federal Reserve Board of Governors, Finance and Economics Discussion Series, 2004-34.
- Fujita, Shigeru and Garey Ramey. Forthcoming. "The Cyclicalities of Separation and Job Finding Rates," *International Economic Review*.
- Hall, Robert E., 2005a. "Job Loss, Job Finding, and Unemployment in the U.S. Economy over the Past Fifty Years," in Mark Gertler and Kenneth Rogoff, eds., *2005 NBER Macroeconomics Annual*. Cambridge, MA: National Bureau for Economic Research, pp. 101-137.
- , 2005b. "Employment Fluctuations with Equilibrium Wage Stickiness," *American Economic Review*, 95(1), 50-65.
- Hansen, Bent, 1970. "Excess Demand, Unemployment, Vacancies, and Wages," *Quarterly Journal of Economics*, 84(1): 1-23.
- Holzer, Harry J., 1994. "Job Vacancy Rates in the Firm: An Empirical Analysis." *Economica* 61(1), 17-36.
- Kroft, Kory and Devin G. Pope. 2008. "Does Online Search Crowd Out Traditional Search and Improve Matching Efficiency? Evidence from Craigslist," Working Paper, Wharton School.
- Moen, Espen R., 1997. "Competitive Search Equilibrium." *Journal of Political Economy*, 105(2): 385-411.
- Mortensen, Dale T., and Pissarides, Christopher A., 1994. "Job Creation and Job Destruction and the Theory of Unemployment." *Review of Economic Studies* 61(3), 397-415.
- , 1999. "New Developments in Models of Search in the Labor Market," in Orley Ashenfelter and David Card (eds.), *Handbook of Labor Economics*, Volume 3: 2567-2628. Amsterdam: Elsevier Science.
- Nagypál, Éva, 2007. "Labor Market Fluctuations and On-the-Job Search," Northwestern University, mimeo.
- Ours, Jan van and Geert Ridder. 1991. "Cyclical Variation in Vacancy Durations and Vacancy Flows." *European Economic Review*, 35, 1143-1155.
- Petrongolo, Barbara, and Pissarides, Christopher A., 2001. "Looking into the Black Box: A Survey of the Matching Function," *Journal of Economic Literature*, 39(3): 390-431.

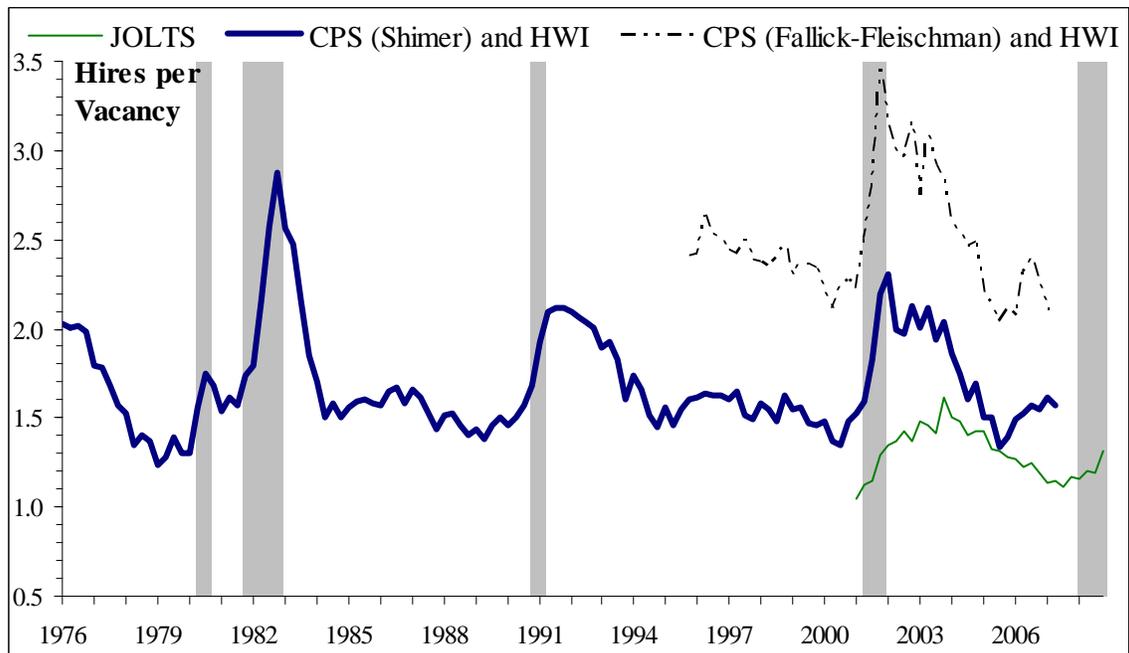
- Petrongolo, Barbara, and Pissarides, Christopher A., 2008. "The Ins and Outs of European Unemployment," *American Economic Review*, 98(2): 256-262.
- Pissarides, Christopher A., 1985. "Short-Run Equilibrium Dynamics of Unemployment, Vacancies and Real Wages," *American Economic Review*, 75(4): 676-90.
- Rogerson, Richard, Shimer, Robert, and Wright, Randall, 2006. "Search-Theoretic Models of the Labor Market: A Survey," *Journal of Economic Literature*, 43(4): 959-88.
- Russo, Giovanni, Cees Gorter and Ronald Schettkat. 2001. "Searching, Hiring and Labour Market Conditions," *Labour Economics*, 8: 553-571.
- Shimer, Robert, 2005. "The Cyclical Behavior of Equilibrium Unemployment and Vacancies," *American Economic Review* 95(1): 25-49.
- Shimer, Robert, 2007a. "Mismatch," *American Economic Review* 97(4): 1074-1101.
- , 2007b. "Reassessing the Ins and Outs of Unemployment," University of Chicago, mimeo.
- Sunde, Uwe, 2007. "Empirical Matching Functions: Searchers, Vacancies, and (Un-)biased Elasticities," *Economica*, 74(295): 537-560.
- Valetta, Robert G., 2005. "Has the U.S. Beveridge Curve Shifted Back and Why?" Federal Reserve Bank of San Francisco Working Paper 2005-25.
- Yashiv, Eran, 2000. "The Determinants of Equilibrium Unemployment," *American Economic Review*, 90(5), 1297-1322.
- , 2006. "Search and Matching in Macroeconomics," CEPR Discussion Paper Series 5459.
- Yashiv, Eran, 2007. "U.S. Labor Market Dynamics Revisited," *Scandinavian Journal of Economics*, 109(4):779-806.

Figure 1. Aggregate Rates of Hires and Vacancies



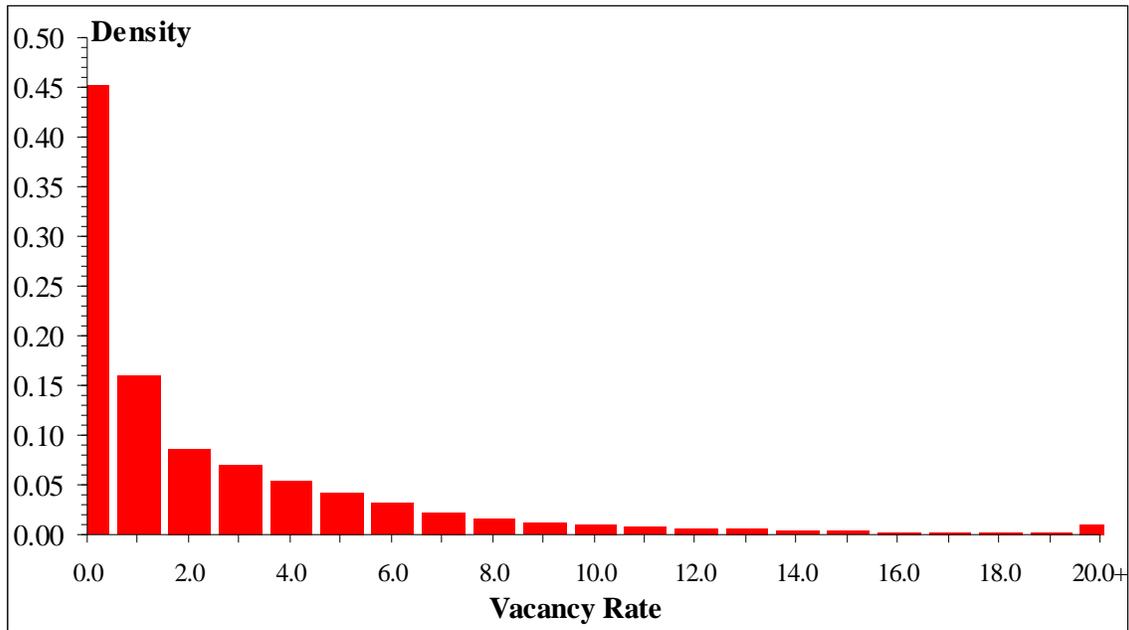
Notes: CPS Hires from Shimer (2007a) for 1976-2007 and from Fallick and Fleischman (2004, updated) for 1994-2007. Help Wanted Index from the Conference Board, and JOLTS data from the BLS. CPS (Shimer) and HWI series are detrended using an HP filter with smoothing parameter of $\lambda = 10^5$. Shaded regions depict NBER-dated recessions.

Figure 2. Aggregate Vacancy Yield

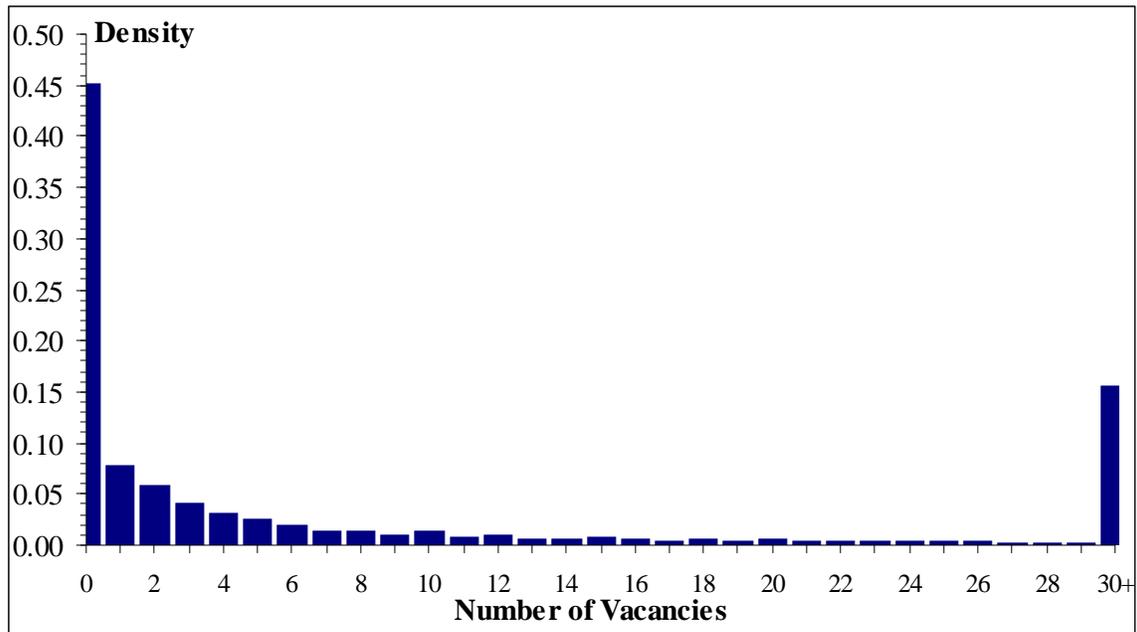


Notes: See notes to Figure 1 for data sources. See text for the vacancy yield calculations.

Figure 3. Vacancy Distributions over Establishments, Employment-Weighted
(a) Vacancy Rate as a Percent of Establishment Employment

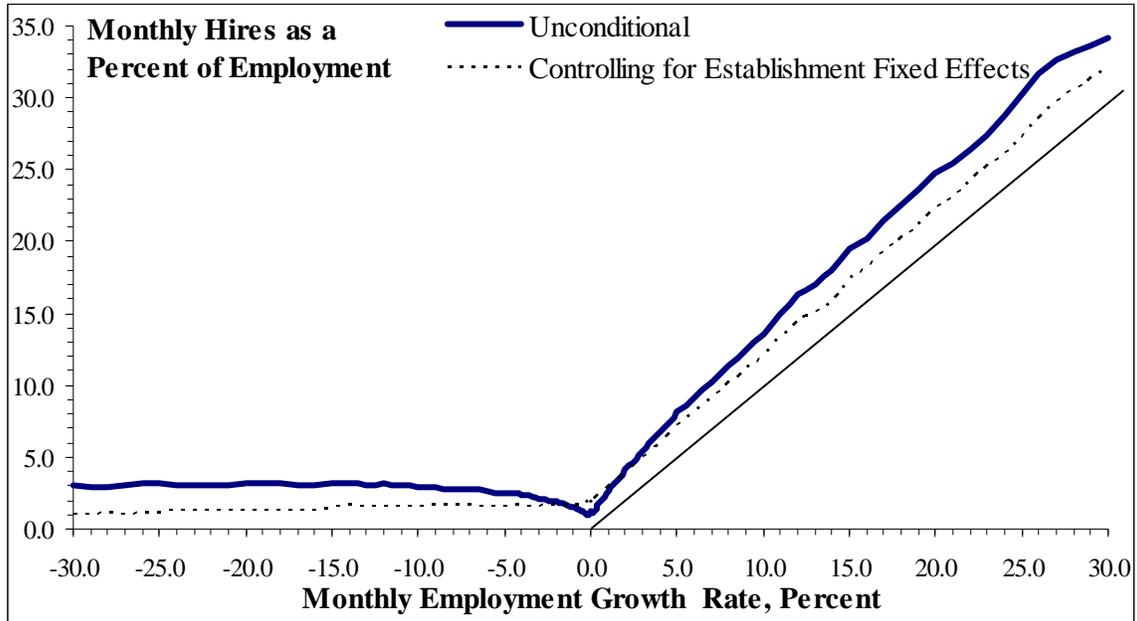


(b) Number of Vacancies at the Establishment



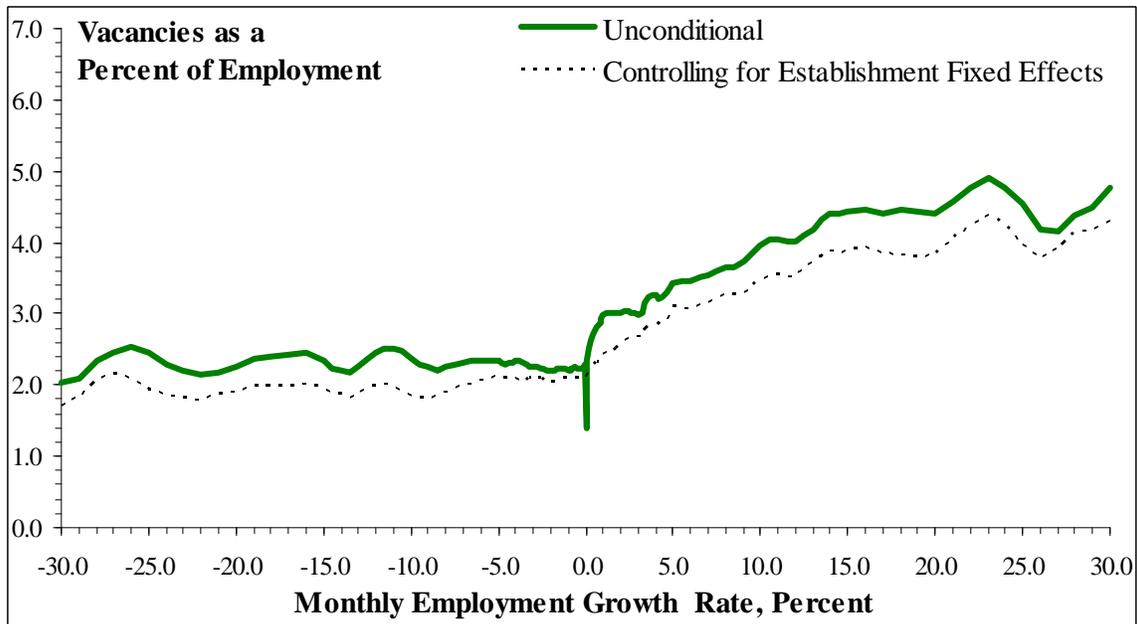
Note: JOLTS distributions calculated from approximately 577,000 monthly establishment-level observations from January 2001 to December 2006.

Figure 4. Hires and Establishment Growth in the Cross Section, JOLTS Data



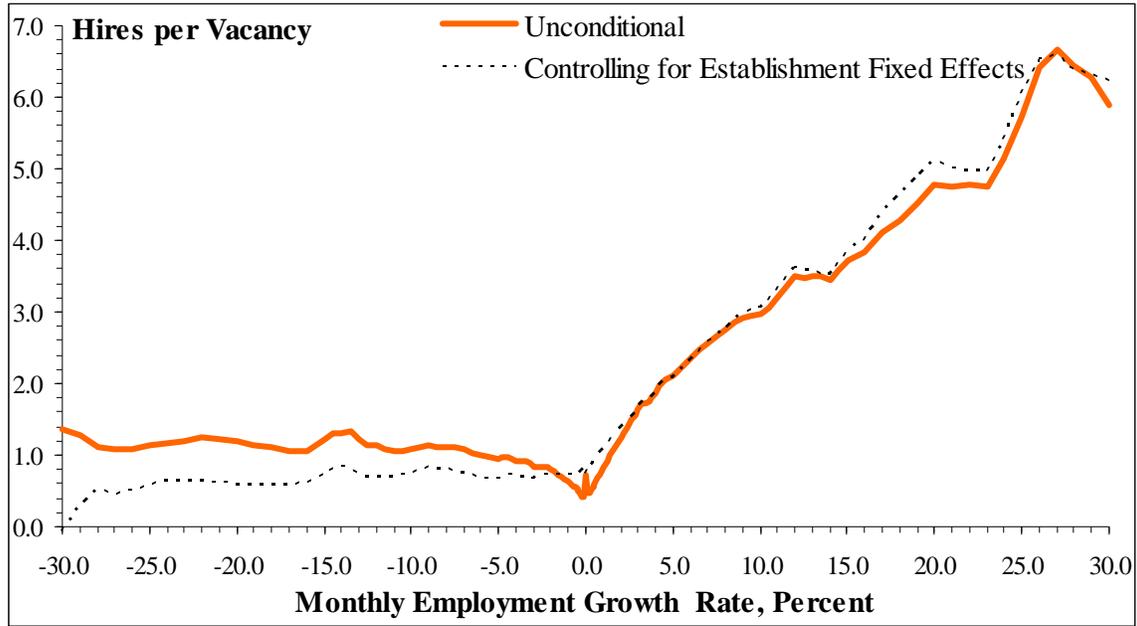
Note: The figure shows the cross-sectional relationship of the hires rate to the establishment growth rate, as fitted by non-parametric regression to approximately 577,000 monthly observations. See text for details. The straight thin line emanates from the origin at 45 degrees.

Figure 5. Vacancies and Establishment Growth in the Cross Section, JOLTS Data



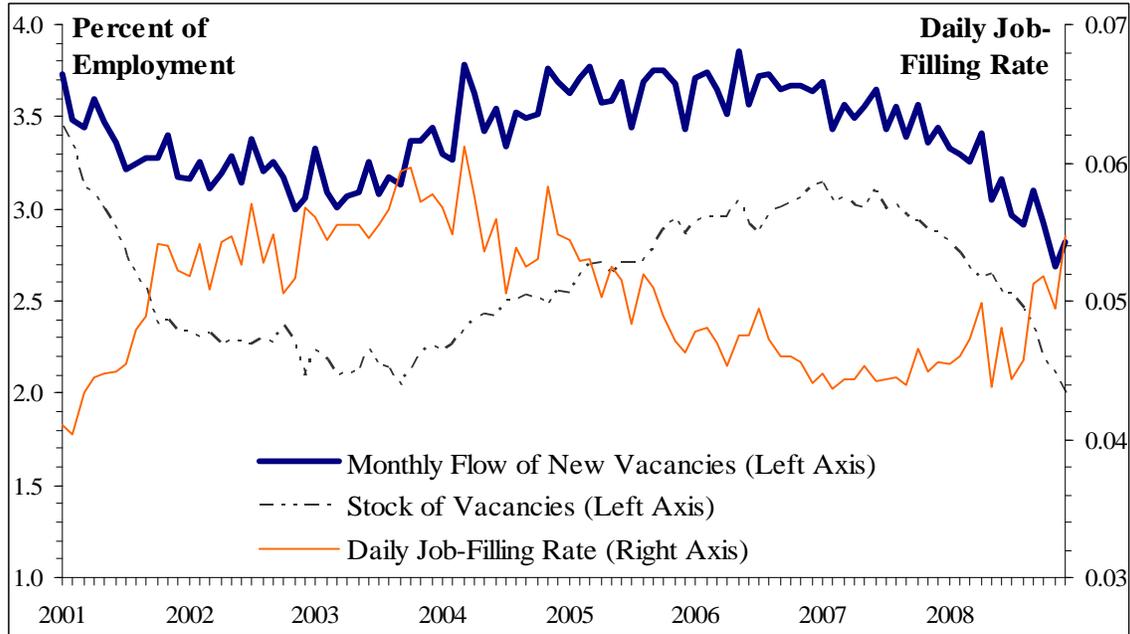
Note: The figure shows the cross-sectional relationship of the vacancy rate to the establishment growth rate, as fitted by non-parametric regression to approximately 577,000 monthly observations. See text for details.

Figure 6. Vacancy Yield and Establishment Growth in the Cross Section, JOLTS Data



Note: The figure shows the cross-sectional relationship of the vacancy yield, as fit by non-parametric regression to approximately 577,000 monthly establishment-level observations. The vacancy yield is calculated as the number of hires during month t per vacancy reported at the end of month $t-1$. See text for additional details.

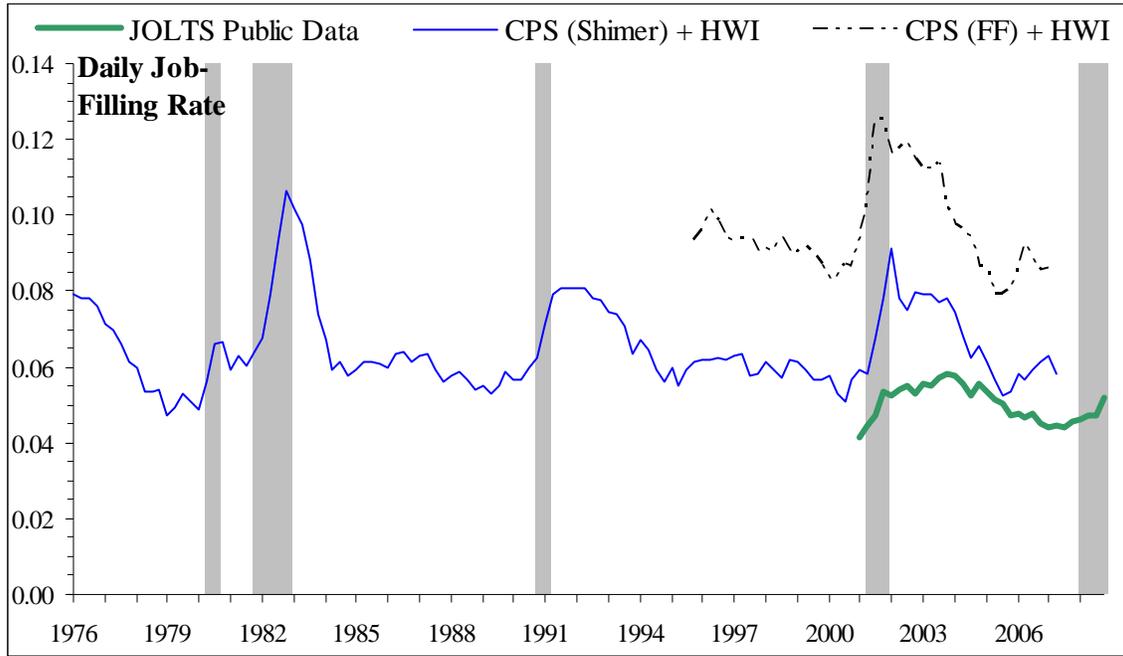
Figure 7. Basic Framework Estimates for the Monthly Flow of New Vacancies and the Daily Job-Filling Rate, Published JOLTS Data, January 2001 – December 2008



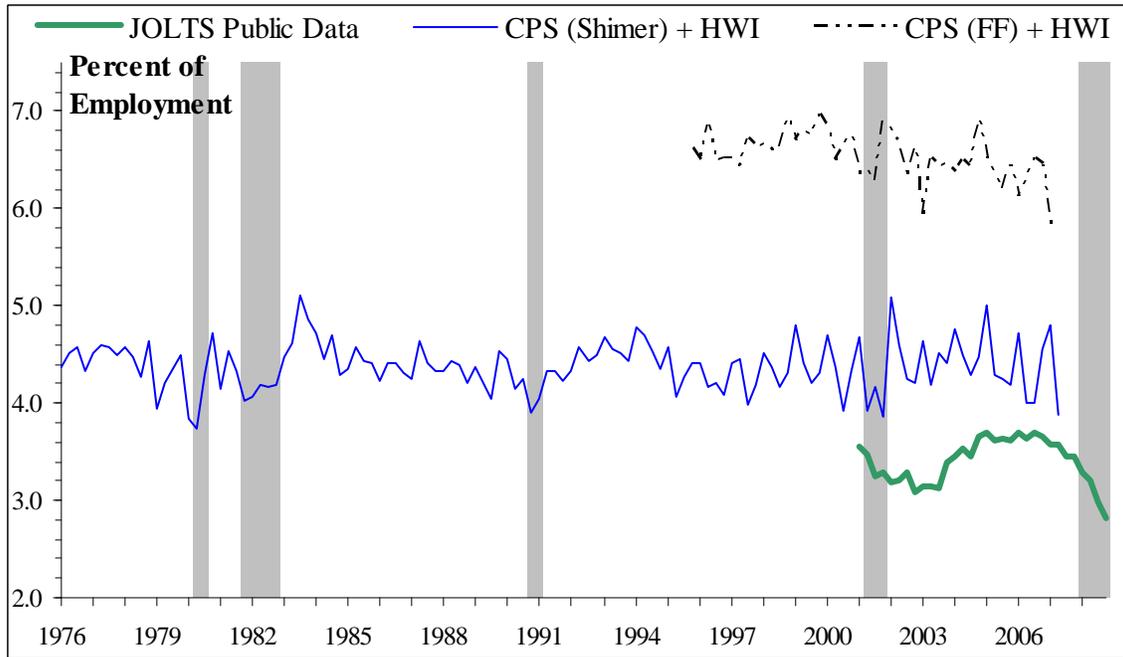
Notes: The figure shows the reported stock of vacancies and our basic framework estimates for the monthly flow of new vacancies and the daily job-filling rate, all calculated from published JOLTS data. See text for details.

Figure 8. Basic Framework Estimates, Various Data Sources

(a) Daily Job-Filling Rates

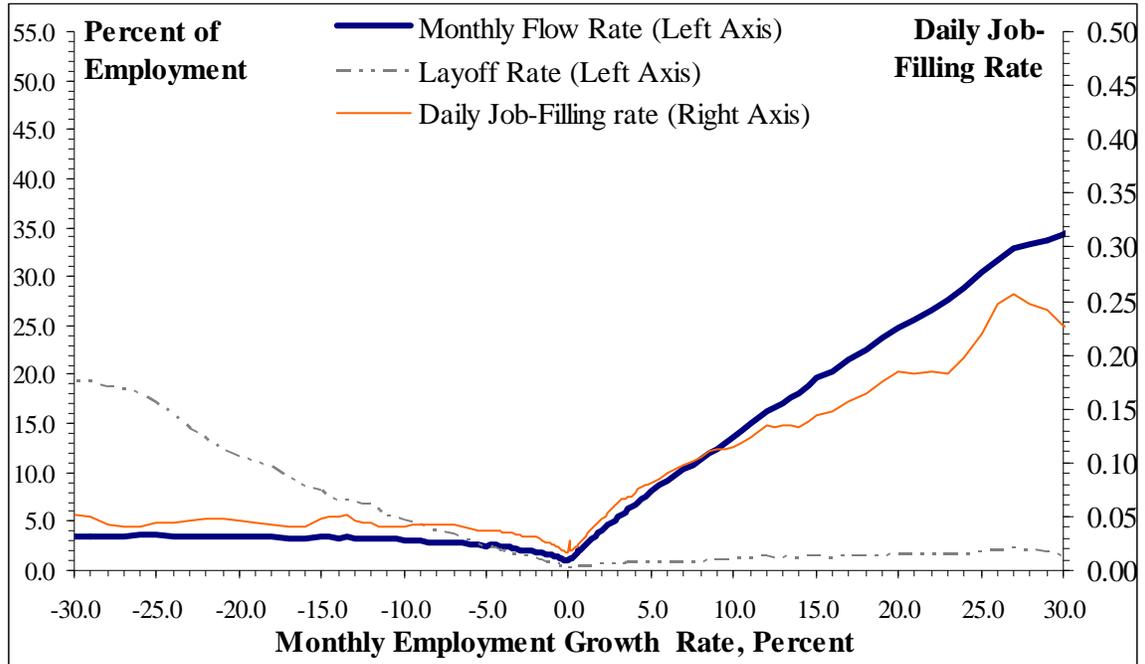


(b) Monthly Flow of New Vacancies



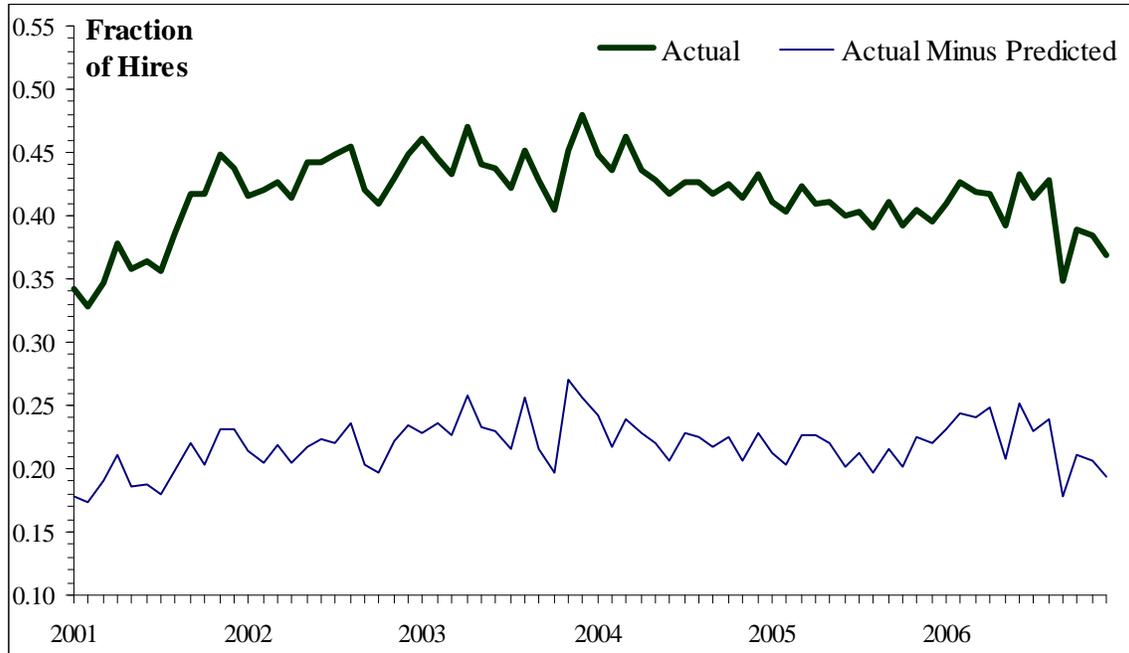
Notes: The figures show the daily job-filling rate and the monthly flow of new vacancies, as estimated from the indicated data sources using our basic framework.

Figure 9. Fill Rates, Vacancy Flows and Layoffs as Functions of Establishment Growth, 2001-1006



Notes: Layoff rate calculated directly from JOLTS micro data. See text for description of other curves.

Figure 10. Observed Fraction of Hires with No Recorded Vacancy and Estimated Fraction of Hires without Benefit of a Prior Vacancy, Monthly, 2001 to 2006



Notes: The thick curve ("Actual") shows the fraction of hires in month t at establishments with no recorded vacancy at the end of $t-1$. The thin curve shows the estimated fraction of hires without benefit of a vacancy, calculated as the difference between the actual and predicted values for the fraction of hires at establishments with no recorded vacancy. See text for details.

Table 1. Hires, Separations and Vacancies by Industry, Size, and Turnover

	h_t	s_t	v_t	h_t / v_{t-1}	Employment Share
<i>Nonfarm Employment</i>	3.4	3.2	2.5	1.3	---
<i>Major Industry</i>					
Natural Resources & Mining	3.1	3.0	1.5	2.0	0.5
Construction	5.4	5.4	1.7	3.1	5.3
Manufacturing	2.3	2.6	1.7	1.3	11.3
Transport, Wholesale & Utilities	2.7	2.7	1.9	1.4	8.0
Retail Trade	4.5	4.4	2.3	1.9	11.4
Information	2.2	2.4	2.6	0.8	2.4
Finance, Insurance & Real Estate	2.3	2.2	2.5	0.9	6.1
Professional & Business Services	4.6	4.2	3.5	1.3	12.4
Health & Education	2.7	2.3	3.5	0.7	12.7
Leisure & Hospitality	6.3	6.0	3.4	1.8	9.3
Other Services	3.3	3.2	2.3	1.4	4.1
Government	1.6	1.3	1.9	0.8	16.5
<i>Establishment Size Class</i>					
0-9 Employees	3.4	3.3	2.0	1.6	12.1
10-49 Employees	4.0	4.0	2.3	1.7	23.2
50-249 Employees	4.0	3.8	2.6	1.5	28.3
250-999 Employees	3.1	2.9	2.8	1.1	17.1
1,000-4,999 Employees	2.1	1.9	3.0	0.7	13.0
5,000+ Employees	1.7	1.5	2.4	0.7	6.4
<i>Turnover Category</i>					
No Turnover	0	0	1.1	0	24.4
First Quintile (lowest turnover)	0.5	0.6	1.7	0.3	15.1
Second Quintile	1.3	1.2	2.6	0.5	15.1
Third Quintile	2.4	2.2	2.9	0.8	15.1
Fourth Quintile	4.5	4.3	3.1	1.4	15.1
Fifth Quintile (highest turnover)	13.5	13.0	4.4	3.1	15.1

Notes: Estimates are tabulated from our sample of JOLTS micro data. Rates are as defined in the text.

Table 2. Establishment-Level Hires and Vacancy Statistics by Industry, Size, and Turnover

	Percent of Employment with $h_t = 0$	Percent of Employment with $v_{t-1} = 0$	Percent of h_t with $v_{t-1} = 0$	Percent of v_t with $v_{t-1} = 0$
<i>Nonfarm Employment</i>	34.8	45.1	41.6	17.9
<i>Major Industry</i>				
Natural Resources & Mining	40.1	59.2	57.8	22.5
Construction	46.3	73.7	67.2	36.3
Manufacturing	33.0	43.3	41.3	15.4
Transport, Wholesale & Utilities	43.2	51.2	41.5	20.2
Retail Trade	39.4	59.3	49.1	30.5
Information	32.6	34.3	29.5	13.7
Finance, Insurance & Real Estate	44.6	48.8	40.3	16.9
Professional & Business Services	34.7	41.9	31.9	14.8
Health & Education	27.5	31.6	26.0	8.3
Leisure & Hospitality	33.1	54.2	47.7	25.6
Other Services	61.6	70.6	54.5	30.9
Government	21.6	25.7	20.2	7.8
<i>Establishment Size Class</i>				
0-9 Employees	87.0	91.6	76.9	43.2
10-49 Employees	60.0	73.6	60.3	33.3
50-249 Employees	27.7	43.6	36.5	16.5
250-999 Employees	11.9	18.7	17.3	6.2
1,000-4,999 Employees	3.7	7.1	6.3	2.4
5,000+ Employees	1.1	8.8	8.0	3.0
<i>Turnover Category</i>				
No Turnover	100.0	85.2	--	27.7
First Quintile (lowest turnover)	20.7	22.5	18.2	7.6
Second Quintile	12.3	22.6	19.7	7.2
Third Quintile	11.8	28.4	25.9	10.8
Fourth Quintile	12.1	38.4	35.6	18.5
Fifth Quintile (highest turnover)	12.0	49.0	49.2	27.4

Notes: Estimates are tabulated from our sample of JOLTS micro data.

Table 3. Basic Framework Results by Industry, Size, and Turnover

	Daily Fill Rate f_t	Monthly Flow Rate $\tau\theta_t$	Duration (Days) $1/f_t$	Percent of h_t Outside Framework[#]
<i>Nonfarm Employment</i>	0.050	3.4	20.0	21.8
<i>Major Industry</i>				
Natural Resources & Mining	0.078	3.1	12.8	24.5
Construction	0.121	5.4	8.3	16.0
Manufacturing	0.052	2.3	19.3	22.0
Transport, Wholesale & Utilities	0.052	2.7	19.1	18.5
Retail Trade	0.073	4.5	13.7	16.7
Information	0.031	2.2	32.0	18.9
Finance, Insurance & Real Estate	0.034	2.3	29.0	24.1
Professional & Business Services	0.049	4.6	20.4	13.9
Health & Education	0.028	2.7	35.4	17.0
Leisure & Hospitality	0.069	6.3	14.6	19.1
Other Services	0.053	3.3	18.8	22.6
Government	0.032	1.6	31.4	12.1
<i>Establishment Size Class</i>				
0-9 Employees	0.061	3.3	16.5	32.0
10-49 Employees	0.066	4.0	15.2	22.3
50-249 Employees	0.059	4.0	17.1	15.6
250-999 Employees	0.041	3.1	24.1	10.1
1,000-4,999 Employees	0.026	2.1	37.9	4.4
5,000+ Employees	0.026	1.7	38.9	5.7
<i>Turnover Category</i>				
No Turnover	---	---	---	---
First Quintile (lowest turnover)	0.011	0.4	87.9	15.3
Second Quintile	0.019	1.3	52.8	15.1
Third Quintile	0.030	2.4	32.8	17.3
Fourth Quintile	0.054	4.6	18.4	17.8
Fifth Quintile (highest turnover)	0.114	14.0	8.7	15.3

Notes: Estimates are tabulated from our sample of JOLTS micro data.

[#]: Estimates come of the fraction of hires outside of the basic framework come from a steady-state approximation. See text for details.

Table 4. Stochastic Micro Simulation Results by Size

	Employment Share	Daily Fill Rate f_t	Monthly Flow Rate $\tau \cdot \theta_t$	Percent of h_t with $v_{t-1} = 0$	Percent of v_t with $v_{t-1} = 0$	Percent of h_t Outside Framework
<i>Establishment Size Class</i>						
0-9 Employees	0.121	0.062	3.4	46.6 [76.9]	75.7 [43.2]	30.3
10-49 Employees	0.232	0.065	4.0	39.9 [60.3]	64.1 [33.3]	20.5
50-249 Employees	0.283	0.058	4.1	22.8 [36.5]	37.8 [16.5]	13.7
250-999 Employees	0.171	0.041	3.1	7.9 [17.3]	13.8 [6.2]	9.4
1,000-4,999 Employees	0.130	0.026	2.1	2.3 [6.3]	4.3 [2.4]	4.0
5,000+ Employees	0.064	0.026	1.7	1.8 [8.0]	3.4 [3.0]	6.2
Weighted Average of Size Class Results		0.051	3.4	25.6	35.1	15.8

Notes: Estimates are tabulated from our sample of JOLTS micro data using a simulated method of moments estimation of our accounting framework. Numbers in brackets represent the listed fraction's value from the data.