**VERY PRELIMINARY AND INCOMPLETE**

# Labor Market Flows and Vacancies in the Cross Section and Over Time

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by

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**Abstract**
Many theoretical models of labor market search imply a tight link between worker flows (hires and separations), vacancies, and job flows (employer-level employment growth) at the employer level. Using establishment data from multiple sources for the U.S., we show that hiring, quit, layoff, and vacancy rates exhibit strong, highly nonlinear relationships to establishment growth in the cross section. These relationships, notably for vacancy and quit rates, vary with aggregate conditions. We also develop a framework for evaluating how well the implications of various models fit the data. Aggregate variations in hires and layoffs are well captured by models with tight links between worker and job flows. Aggregate variations in quits and vacancies are not. Specifications that allow the micro-level quit relationship to vary with aggregate conditions (consistent with models of endogenous quits) perform remarkably better. Finally, our framework provides methodology for producing a backcasted series of worker flow and vacancy rates, which we estimate over the 1990-2008 period.

Keywords: worker flows, job flows, vacancies, search and matching models, cyclical employment fluctuations
JEL Codes:

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## I. Introduction

Theoretical models of search and matching carry implications for how worker flows and vacancies vary in the cross section and over time. Many of these models postulate a tight link between hiring and job creation (employer-level expansion) and between separations and job destruction (employer-level contraction). Others, through processes like on-the-job search, postulate more complex relationships.

We study the behavior of vacancies, hires, layoffs, and quits in the cross section of employer growth rates and over time. We provide several contributions. First, we document a new set of facts about labor market dynamics. As we show, vacancies and worker flows exhibit powerful, highly nonlinear relationships to employer growth rates in the cross section. These cross-sectional relationships vary with aggregate conditions in interesting ways. Second, we assess how closely the implications of several classes search models fit the data. We begin with models in the spirit of the seminal Mortensen and Pissarides (1994, hereafter MP) formulation, then move on to models allow for on-the-job search, and models that incorporate learning about match quality. Third, using the implications of these models as guidance, we develop parsimonious statistical models that characterize how worker flows and vacancies vary in the cross section of employer growth rates, including how the cross-sectional relationships vary with aggregate conditions. We then evaluate how well these statistical models fit both the establishment-level evidence at the micro level as well as their ability to generate the observed aggregate movements in aggregate worker flow and vacancy rates. A novel feature of our statistical models is that they provide a methodology to produce a backcasted series of these aggregate rates.

Our study exploits three major establishment-level data sources. We obtain establishment-level data on worker flows and vacancies from the Job Openings and Labor Turnover Survey (JOLTS) of the Bureau of Labor Statistics (BLS). These are monthly data that begin in December 2000, though we cumulate the monthly data to the quarterly frequency to conform to our other data sources. These data provide us with our evidence on the cross-sectional relationships between vacancies, worker flows, and establishment-level growth. We rely on the Business Employment Dynamics (BED) data, also from the BLS, for quarterly data on establishment-level employment growth. These data are longitudinal, which allow the calculation of growth rates, include all private establishments covered by a state unemployment program (about 98 percent of all U.S. establishments), and are available from beginning of 1990 through the end of 2008. We use the BED data to generate the cross-sectional distribution of establishment-level growth rates for each quarter it covers. In future work, we plan to use the Longitudinal Research Datafile (LRD) of the Census Bureau to generate the same cross-sectional distributions for manufacturing back to 1972.

Figures 1 and 2 plot the quarterly, seasonally adjusted aggregate time series for worker flows and vacancies from the JOLTS and aggregate job creation and destruction rates from the BED.[1] All rates are cover the private sector and are expressed as a percent of employment. We define job creation as the sum of employment gains at new and expanding establishments as in Davis, Haltiwanger and Schuh (1996). We define job

[1] We derive our JOLTS series from interacting the cross-sectional relationships between vacancies, worker flows and establishment-level growth with the densities of employment growth derived from the BED. This approach follows the methodology of Davis et al. (2010) closely and is described in more detail in our empirical section.

destruction analogously. Figure 1 shows that job destruction and layoffs tend to move together, while quits move counter to both. Figure 2 shows that job creation and hires rates have declined markedly since early 2006. Vacancies rose until mid-2007 and then fell sharply. Our study seeks to explore the micro level sources of these aggregate movements.

We show that, in the cross-section at the micro level, hiring and separation rate exhibit powerful elements of the iron-link behavior implied by MP-style search models. In particular, when plotted as a function of the establishment-level growth rate, hires and separation rates exhibit “hockey stick” patterns. The hires relation is flat to the left of zero growth (contracting employers) and nearly proportional to employment growth to the right of zero (expanding employers), with a definite kink at zero. The separations relation is roughly a mirror image of the hires relation. The components of the separation rate, however, i.e., the layoff rate and the quit rate, exhibit starkly different patterns. The relation of the layoff rate to growth closely follows the behavior of the separation rate relation. It is flat to the left of zero growth, rises nearly one-for-one with the size of an establishment contraction to the right of zero, and has a clear kink at zero. The quit relationship is also flat to the left of zero growth and has a kink at zero, but only rises with the size of a contraction for relatively small employment changes. For larger contractions, the quit rate is essentially constant with respect to establishment growth. The relation of the vacancy rate to establishment growth essentially mirrors the relation of the hiring rate with one important departure: the vacancy rate rises with the size of an establishment expansion much less than one-for-one. In fact, compared to the hiring relationship, the vacancy relation to growth appears almost flat.

The more important metric for evaluating the relationship between the cross-sectional evidence and the implications of a canonical search model is whether these relationships vary over time. In short, we find that, consistent with standard models, the relations of hiring and layoffs to growth generally maintain their iron-link behavior over time. In other words, these relations are generally time-invariant. We find that the relations of quits and vacancies to growth, however, vary considerably over time. Both relationships shift downward when aggregate conditions are weak. The time-varying behavior of the quit relation is a notable departure from the implications of a standard search model.

As we discuss below, models that extend the standard MP provide guidance for why we may observe such departures from the implied iron link relationships over time. Faberman and Nagypál (2009) consider a model of on-the-job search that delivers an "abandon-ship" effect. Firms vary in their idiosyncratic profitability and workers search while employed. Since wages are increasing in firm profitability, the workers most likely to take an outside offer are those who are currently at low-profitability firms. Consequently, quit rates (weakly) decline in the value of the firm's idiosyncratic profitability, and the employment growth rate rises. Barlevy (2002) considers a model with on-the-job search where there exists some match-specific productivity between workers and firms. Workers will move away from bad matches, but their propensity to do so will depend on aggregate conditions. When aggregate conditions are weak, workers will tend to remain in poor matches, which Barlevy refers to as the "sullying" effect of recessions. For our purposes, the Barlevy model suggests that shifts in the cross-sectional quit-growth relationship over time will disproportionately affect contracting establishments, to the extent that shrinking establishments represent poorly-matched workers. In Jovanovic (1979, 1985) and Moscarini (2005), gradual learning about match quality leads to a separations rate that declines with match tenure. Because more rapid growth involves a higher share of young matches, these learning models imply that separations rise with growth at expanding employers. Pries and Rogerson (2005) integrate elements of Jovanovic-style learning into an MP model. Separations occur because of job destruction, as in the MP model, and because of learning effects. Thus, the model of Pries and Rogerson generates elements of iron-link behavior in hires and separations while rationalizing a positive relationship between separations and growth at expanding employers.

We also develop parsimonious statistical models for how worker flows and vacancies vary in the cross section. These statistical models serve three objectives. First, they provide useful guidance in evaluating existing models as well as developing new theoretical models of labor market flows and in calibrating these models to the data. Second, they allow us to investigate whether tracking the cross-sectional distributions adds much to our understanding of aggregate movements in labor market flows and vacancies. Third, they provide a methodology for backcasting an aggregate time series for vacancies, hires, quits and layoffs.

Our work in this paper has many antecedents. There is a large body of previous research on job flows and worker flows. We review research in this area in Davis and Haltiwanger (1999) and Davis, Faberman and Haltiwanger (2006). Labor market flows and job vacancies play central roles in modern theories of unemployment based on search and matching models. See Pissarides (2000), Rogerson, Shimer and Wright (2005) and

Yashiv (2007) for reviews of work in this area. Models that treat hires as the outcome of a matching function carry implications for the relationship between hires and vacancies in the cross section and over time. We explore some of those implications in Davis, Faberman and Haltiwanger (2009).

The paper proceeds as follows. Section 2 discusses the conceptual underpinnings that guide our empirical work. We start with the model of Cooper, Haltiwanger and Willis (2006), which extends the basic MP model to multi-worker firms, move next to models that endogenize the worker's quit decision, such as Faberman and Nagypal (2008) and Barlevy (2002), and conclude with models of learning about match quality, such as Jovanovic (1979). Section 3 describes our data and empirical measures. Section 4 presents our statistical models and the analysis of how well they can account for the aggregate movements in vacancies and worker flows. Section 5 presents the backcasted series of vacancies and worker flows that results from this statistical modeling. Section 6 concludes.

## II. Conceptual Underpinnings

In linking worker and job flows at the micro level, it is instructive to start with the identity for the evolution of establishment-level employment:

$$e_{it} = e_{it-1} + h_{it} - l_{it} - q_{it}\,, \tag{1}$$

where $e_{it}$ is employment at firm *i* at time *t*, $h_{it}$ represents hiring, $l_{it}$ represents layoffs, and $q_{it}$ represents quits. Total separations are the sum of quits and layoffs. Theory provides guidance on the margins establishments use to accommodate changes in employment and the factors that can yield turnover in excess of these changes. In what follows, we explore what guidance we can gain from alternative theoretical models about these relationships. We start with simple search and matching models where there is an iron link between hires and job creation on the one hand and separations and job destruction on the other. We then consider alternative specifications that relax these iron link implications.

*II.A. Models with an Iron Link Relationship between Worker and Job Flows*

The standard Mortensen and Pissarides (1994) search and matching model assumes an iron link relationship between hires and job creation and between separations and job destruction. The standard model has no quits (and in turn no on-the-job search) or other factors that could alter these tight relationships. In addition, the standard model has no notion of a multiple-worker firm, so its ability to produce testable implications for these iron-link relationships is limited. Several subsequent, models, however, have extended the Mortensen-Pissarides framework to permit multiple-worker firms.[2] To help fix ideas, we use the structure and notation of the Cooper, Haltiwanger and Willis (2007) model (hereafter CHW) model to illustrate the implications of an iron link relationship between worker and job flows. In the CHW model, establishments are subject to both aggregate and idiosyncratic productivity shocks and the production function is assumed to be a strictly concave function of employment. Establishments face fixed and variable costs for posting vacancies as well as for making layoffs. Quits are assumed to be exogenous and a constant fraction of establishment-level employment, while hiring and

[2] These include Bertola and Caballero (1994), Bertola and Garibaldi (2001), Acemoglu and Hawkins (2006), and Rotemberg (2006). Cooper, Haltiwanger, and Willis (2007), Elsby and Michaels (2008), and Fujita and Nakajima (2010) present models where both the hiring and firing decision of the firm is endogenized. Barlevy (2002) and Faberman and Nagypál (2008) present models with endogenous quit behavior.

firing are the result of endogenous decisions by the establishment. Establishments and workers are matched using a standard matching function that depends on aggregate labor market tightness (aggregate unemployment and vacancies). There is no on-the-job search so the pool of searching workers is those that have exogenously quit or have endogenously been laid off.[3]

The relationship between employment changes and worker flows in the CHW model is given by[4]

$$e_{it} = (1-\overline{q})e_{it-1} + \eta(U_t, V_t)v_{it} - l_{it}, \tag{2}$$

where $\overline{q}$ is the exogenous and constant quit rate, $\eta(U_t, V_t)$ is the job-filling rate, which is derived from a standard matching function and depends on aggregate unemployment and vacancies, and $v_{it}$ are vacancies posted at the beginning of the current period by the establishment. This equation exploits the relationship between hires and vacancies given by

$$h_{it} = \eta(U_t, V_t)v_{it}. \tag{3}$$

In the CHW model, the establishment is in one of three regimes each period: (i) positive vacancies and zero layoffs; (ii) positive layoffs and zero vacancies; or (iii) an inaction region with zero vacancies and layoffs. The realization of its profit shocks (from either aggregate or idiosyncratic shocks) determines in which region the establishment operates. Higher realizations lead to vacancy posting, lower realizations lead to layoffs,

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[3] In the CHW model, all bargaining power is given to the establishments although the reservation value of a worker's time is assumed to be a function of the aggregate state. The wage determination process impacts the magnitude of the fluctuations but for our purposes this is not directly relevant – we are interested primarily in the implied cross sectional relationship between worker and job flows in this type of model.

[4] Throughout the paper we apply the convention of using capital letters to denote aggregate variables and lowercase letters to denote micro-level variables.

and the presence of fixed costs creates the inaction region, where the only employment changes are exogenous quits.

The CHW model generates a cross-sectional distribution of establishment-level growth rates that depends in complex ways on the interaction of the driving forces (the aggregate and idiosyncratic shocks) and the key parameters of the revenue, cost and matching functions in the model. Aggregate shocks induce shifts the distribution, while parameters such as fixed adjustment costs determine its shape. At the same time, the model has an iron-link mapping between establishment-level employment growth and hiring, layoffs, and quits.

We depict this mapping in Figure 3. Figure 3(a) shows the behavior of the hiring, layoff, and quit rates as a function of the establishment-level growth rate. Establishments in the inaction range are at a mass point of net growth equal to $-\bar{q}$. No hiring or layoffs occur for these establishments. Establishments in the hiring/vacancy posting range have growth rates greater than $-\bar{q}$, choose to hire. Establishments in this range have zero layoffs and hiring rises monotonically with increases in the establishment-level growth rate. Establishments in the layoff range have growth rates less than $-\bar{q}$. In this range, the hiring rate is zero and layoffs rise monotonically with decreases in the establishment-level growth rate.[5]

This iron link mapping of the CHW model also provides strong predictions for the relationship between vacancies and establishment-level employment growth. Equation (3) implies that $v_{it} = h_{it} / \eta(U_t, V_t)$. Therefore, the vacancy rate pattern will mimic the

[5] A special case of the specification in Figure 3 is one where $\bar{q}$ = 0, in which case the hiring and layoff rates would be 45 degree lines from the origin. In this case, hiring would exactly equal job creation and layoffs would exactly equal job destruction. The model of Elsby and Michaels (2008) has such a characterization.

hiring rate pattern but with a slope of $1/\eta(U_t, V_t)$. That is, vacancies will rise monotonically with establishment-level growth to the right of $-\bar{q}$. This relationship is depicted in Figure 3(b) for the case where $\eta < 1$. Unlike hires, layoffs, or quits, the vacancy rate curve will be time varying as the slope of the relationship will change with changes in aggregate labor market tightness (i.e., a higher ratio of $V_t$ to $U_t$). In expansions, there is greater labor market tightness. This decreases the job-filling rate and increases the slope of the vacancy-growth relationship, as depicted in the figure.

*II.B. Relaxing the Iron Link Relationship*

The iron link implications of the CHW model can be relaxed in a number of ways. One obvious way is to relax the assumption of a constant quit rate. For example, suppose that the quit rate varies exogenously but procyclically, which would be consistent with the empirical evidence. This has straightforward implications for the relationship between worker and job flows. We illustrate these in Figure 4. Figure 4(a) shows that as the quit rate shifts, and the hires and layoff curves adjust accordingly. A decrease in the quit rate from $q(G_0)$ to $q(G_1)$, associated with a more slack labor market, causes the hiring rate and the layoff rate curves to shift to the right. This creates an environment where establishments will need fewer hires when expanding and more layoffs when contracting to achieve a given growth rate. Consequently, as Figure 4(b) shows, establishments looking to hire will need fewer vacancies, causing the vacancy rate curve to shift to the right. Since the job-filling rate increases in the slack labor market, the slope of the vacancy curve also becomes flatter. The general insight from Figure 4 is that, not surprisingly, as the pattern of quits changes so will the accompanying patterns of hires, layoffs, and vacancies. This will also apply to more complex models of quits.

Even larger departures will emerge if quits are permitted to be endogenous. Faberman and Nagypál (2008) develop an on-the-job search model with endogenous quits. In their model (hereafter FN), workers that search while employed have a positive probability of getting an offer that dominates their current job that is decreasing in the idiosyncratic profit shock on the current job. Moreover, workers employed at establishments with a very low idiosyncratic shock will accept any offer received. Thus, the FN model yields the prediction of a nonlinearly decreasing relationship between quits and the establishment-level growth rate that exhibits a backward S-shape. This shape emerges endogenously because establishments with sufficiently low (negative) growth rates are in the range where all outside offers are accepted and establishments with sufficiently high (positive) growth rates are in the range where few outside offers are accepted. Workers at contracting establishments act like "rats leaving a sinking ship," since they are the ones most likely to accept an outside offer.

The key insight from the FN model for the relationships in Figures 3 and 4 is that any nonlinear relation between the quit rate and establishment-level growth will generate a nonlinear relationship between the hiring rate and growth, and potentially between the layoff rate and growth.

The FN model only discusses its steady-state implications. Barlevy (2002), however, develops a model of endogenous quits where the quit rate varies procyclically over time. In this model, poorly-matched workers are more likely to remain on the job in recessions because their outside options are relatively weak. His findings help motivate the procyclical patterns depicted in Figure 4 but they also open up additional dimensions of worker flow-job flow relationship. Namely, to the extent that poorly-matched workers are in low (negative) growth establishments, the Barlevy model implies that quit rates in contracting establishments should be more cyclically sensitive than quit rates at expanding establishments.

Heterogeneity in match quality is a rich area of inquiry (see, e.g., Jovanovic (1979, 1985), Moscarini (2005) and Kiyotaki and Lagos (2007)) that also yields further departures from the iron link and relaxed iron link implications of Figures 3 and 4. Heterogeneity in match quality helps account for why there may be hires and layoffs over all ranges of net employment growth rates. That is, even for growing establishments, some recent hires may be poor matches and subsequently let go, and even for shrinking businesses there may be hires to replace poor-quality matches in excess of a desired employment contraction. In addition, as Hall (1995), Pries (2004), and Pries and Rogerson (2005) point out, heterogeneity in match quality has the implication that worker flows beget further worker flows. That is, establishments with many recent hires are more likely to have poor matches and therefore end up with greater quits.

The lesson of this discussion is that the iron link patterns of Figure 3 and even the relaxed iron link patterns of Figure 4 are likely too simple to capture all of the relevant patterns in the data. Nevertheless, we think Figures 3 and 4 are useful starting points for two reasons. First, they provide a straightforward exposition of the links between worker flows, vacancies, and establishment-level growth that provides a framework for quantifying their contributions to the micro and macro variation in worker flow rates.

Second, they provide a flexible framework for incorporating departures from the iron link specification and quantifying their contributions to variations in worker flow rates.

*II.C. Aggregate Implications of the Iron Link and Relaxed Iron Link Relationships*

The iron link specification of the worker flow-job flow relationship and its departures provide differing implications for the sources and nature of cyclical movements in aggregate worker flow and vacancy rates. To see this, consider the micro-level behavior of worker flows and vacancies as a function of establishment growth, *g*. In any period *t*, the aggregate worker flow or vacancy rate will be a weighted average of its micro-level relationship with establishment growth, with the weights equal to the density of employment at establishments with a growth rate equal to *g*. Consider the aggregate hiring rate. It can be expressed as

$$H_t = \sum_g f_t(g) h_t(g)\,, \qquad (4)$$

where $h_t(g)$ is the mean hiring rate for establishments with a growth rate equal to *g* at time *t*, and $f_t(g)$ is the share of employment at establishments with growth *g* at time *t*. The key insight from this equation is that movements in the aggregate hiring rate can come from one of two sources: shifts in the micro-relationship between the hiring rate and establishment growth or changes in densities of employment across establishment growth rates. By definition, the latter are equivalent to shifts in the cross-sectional distribution of establishment-level growth rates.

It is important to emphasize that equation (4) is simply an accounting identity. That is, aggregate hires rate at time *t* can always be measured by taking the weighted average of establishment-level hires across the full range of growth rates. This will hold for all worker flow rates and the vacancy rate. Moving away from the accounting identity requires behavioral models of the micro level relationships between vacancies, worker flows and growth.

Consider the CHW model where there exist iron link relationships between worker flows and establishment growth. Based on the identify in equation (4), the relationships in Figure 3(a) will be given by

$$\overline{H}_t = \sum_g f_t(g)\overline{h}(g),$$

$$\overline{L}_t = \sum_g f_t(g)\overline{l}(g), \text{ and} \tag{5}$$

$$\overline{Q}_t = \sum_g f_t(g)\overline{q} = \overline{q} \quad \forall t .$$

The iron link relationships of the CHW model have the stark implication that all movements in aggregate worker flows should come entirely from movements in the cross-sectional distribution of establishment growth. They also have the counterfactual implication that the aggregate quit rate is constant over time at $\overline{q}$ .

In the CHW model, aggregate vacancy will be

$$\overline{V}_t = \sum_g f_t(g)\frac{\overline{h}(g)}{\eta(U_t,V_t)} = \frac{\overline{H}_t}{\eta(U_t,V_t)} . \tag{6}$$

Since the job-filling rate varies with aggregate conditions, movements in the aggregate vacancy rate will be a function of the joint movements in the cross-sectional growth rate distribution and aggregate job-filling rate.

As we relax the iron link relationships of the CHW model, Figure 4 illustrates that micro level relationships in equations (5) and (6) are no longer time-invariant. Denote the micro level relationships depicted in Figure 4 for hires and layoffs as $\tilde{h}_t(n)$ and $\tilde{l}_t(n)$, respectively. The aggregate rates are defined as

$$\tilde{H}_t = \sum_g f_t(g)\tilde{h}_t(g),$$

$$\tilde{L}_t = \sum_g f_t(g)\tilde{l}_t(g), \tag{7}$$

$$\tilde{Q}_t = \sum_g f_t(g)\tilde{q}_t(g) = \tilde{q}_t, \text{ and}$$

$$\tilde{V}_t = \sum_g f_t(g)\frac{\tilde{h}_t(g)}{\eta(U_t,V_t)} = \frac{\tilde{H}_t}{\eta(U_t,V_t)}.$$

The equations in (7) show that the cross sectional distribution of establishment-level growth rates will no longer be a sufficient statistic for movements in the aggregate hiring and layoff rates. So long as $\tilde{h}_t(n)$ and $\tilde{l}_t(n)$ are known, however, one will be able to account for the micro level sources of these movements. This general property will hold for any model where the empirical relationship of hiring, layoffs, quits and vacancies is known (i.e., can be derived from observable conditions).

As we move to further departures from the iron link specification, the aggregation from the micro level to the aggregate flow rates does not change but the interactions of the micro level growth relationships and the cross-sectional distribution become richer. For example, endogenizing the quit rate as in Faberman and Nagypál (2008) or Barlevy (2002) will introduce a nonlinear relationship between the quit rate and establishment growth (so that $q_t(g)$ will now depend on $g$) and consequently introduce additional nonlinearities in the relationships between hiring and establishment growth and layoffs and establishment growth. Introducing learning about match quality as in Jovanovic (1979) will enrich the micro-level relationships further.

## III. Data and Measurement

For our analysis, we appeal to two data sources, the Job Openings and Labor Turnover Survey (JOLTS) and the Business Employment Dynamics (BED) data, both produced by the BLS. The JOLTS is a survey of roughly 16,000 establishments who each month report their employment, total hires during the month, total separations during the month, and number of vacancies open at the end of the month. Establishments report separations separately by quits, layoffs, and other separations (i.e., retirements, intra-firm transfers). The survey begins in December 2000 and is representative of all nonfarm employment.[6]

The BED data include longitudinally linked administrative records for all businesses covered under a state unemployment insurance system. As such, it is a virtual census of all establishments. The data are quarterly and include information on the employment and payroll of each establishment, as well as information on various establishment characteristics (e.g., industry, location, whether it is part of a multi- or single-unit firm.) The BLS uses the BED to publish quarterly statistics on private sector gross job creation and gross job destruction that date back to 1992, though microdata exists back to 1990.[7]

We use a sample of JOLTS data that cover January 2000 through June 2009 and a sample of BED data that cover 1990Q2 through 2008Q4. Both cover all private sector employment. Due to data access restrictions, our BED sample excludes several U.S.

[6] For more details on the JOLTS, see Clark and Hyson (2001) and Faberman (2008a). Davis et al. (2010) address several measurement issues inherent in an earlier version of the JOLTS data. In this study, we use an updated version of the JOLTS data whose revisions the BLS details at http://www.bls.gov/jlt/methodologyimprovement.htm.

[7] For more details on the BED data, see Spletzer et al. (2004). The BLS does not publish job flow statistics for the earlier years because of issues related to administrative changes during the 1990-92 period. We employ methods identical to those used by Faberman (2008b) to address these issues.

states.[8] A key feature of our analysis is the interaction of the micro-level relationships of worker flows and establishment growth derived from the JOLTS data with the employment growth rate distributions derived from the BED. Consequently, we need to construct quarterly worker flow and vacancy rates from the JOLTS data. In doing so, we require that establishments are observed in the JOLTS data for all three months of a quarter. This restriction reduces our sample by about 12 percent and produces slightly lower aggregate worker flow estimates than one would derive from the published JOLTS statistics, but it does not alter the cyclicality of the aggregate estimates.

We face some complications in creating our quarterly measures. First, the JOLTS sample weights are monthly, and due to sample nonresponse and benchmark revisions, the weight for a given establishment can change considerably. To deal with this, we measure each quarterly worker flow, $w_{et}$, for establishment *e* in quarter *t* as

$$w_{et} = [\theta_{et,3} w_{et,3} + \theta_{et,2} w_{et,2} + \theta_{et,1} w_{et,1}] / \theta_{et,3}$$

where $w_{et,m}$ is the worker flow level reported for month *m* of quarter *t* by establishment *e* and $\theta_{et,m}$ is the JOLTS sample weight for establishment *e* during month *m* of quarter *t*. Therefore, when we weight any given establishment's data by its third-month sample weight, $\theta_{et,m}$, we recover the correctly weighted data for each month of the quarter. We measure vacancies as the number of job openings reported at the end of the third month of the quarter. Since this is a stock measure, it does not face the aggregation issue that confronts the worker flow measures.

Second, there is a timing issue in that worker flows are reported for the first through the last day of the month while employment is reported for the pay period that

[8] These states are California, Connecticut, Florida, Massachusetts, Michigan, Mississippi, New Hampshire, New York, Oregon, Pennsylvania, Washington, and Wyoming.

includes the 12th of the month. To ensure that our employment and growth rate measures are consistent with the growth rate implied by the our hires and separations measures, we measure end-of-quarter employment as $n_{et} = n_{et,3}$ (using the notation from above) and beginning-of-quarter employment as $n_{e,t\text{-}1} = n_{et} - h_{et} + s_{et}$, where $h_{et}$ denotes total quarterly hires and $s_{et}$ denotes total quarterly separations. We express our worker flow and vacancy measures as rates by dividing them by (1/2)[ $n_{et} + n_{e,t\text{-}1}$], which is the average employment measure of Davis, Haltiwanger, and Schuh (1996).

Another issue is that the JOLTS data do account for establishment entry and exit. These establishments, however, are captured in the BED data. Since entrants and exits account for a sizable fraction of employment changes, we incorporate them into our analysis using the approach of Davis et al. (2010). The latter takes the employment density at opening and closing establishments from the BED as given and assumes the following values for their worker flow rates:

| | *Hiring Rate* | *Quit Rate* | *Layoff Rate* | *Other Seps. Rate* | *Vacancy Rate* |
|---|---|---|---|---|---|
| Entrants | 200.0 | 0.0 | 0.0 | 0.0 | 38.2 |
| Exits | 0.0 | 12.4 | 180.2 | 7.4 | 0.0 |

We use the BED data to calculate the cross-sectional distribution of establishment-level growth rates for each quarter.[9] Since the BED data are the universe of all establishments, we do not have to deal with issues related to sample weighting, and since the data are quarterly we do not have to deal with aggregating to the quarterly frequency. We measure the net employment change for a quarter as the difference between employment during the third month of the current quarter and employment

[9] In future work, we plan to incorporate an analysis of the JOLTS estimates interacted with growth rate distributions derived from the Longitudinal Research Database of the Census Bureau, which will provide a longer time series of distributions for manufacturing.

during the third month of the previous quarter. This measure is consistent with the net change implied by the $n_{e,t\text{-}1}$ and $n_{e,t\text{-}1}$ measures used with the JOLTS data. We measure the employment growth rate as the net change divided by the same average employment measure as above. We also use the average employment measure when employment weighting worker flow, vacancy, or growth rates across groups of establishments.

Figure 5 shows the cross-sectional distribution of establishment-level growth rates averaged across all quarters in the sample (1990Q2 – 2008Q4), and Table 1 summarizes the density of employment at expanding, contracting and stable establishments pooled over select years. The years are chosen to roughly coincide with the recession and boom periods of our sample. Figure 5 shows that about 14 percent of employment is at establishments with no employment change, on average, while the majority of employment is at establishments either expanding or contracting by 5 percent or less. Most employment (90 percent) is at establishments with growth between -30 and 30 percent. Table 1 shows that there is considerable variation in the fraction of employment at expanding, contracting, or stable establishments. In particular, recessions are generally periods where the fraction at expansions declines and the fractions at contractions or stable establishments increase.

## IV. Accounting for Labor Market Flows and Vacancies

### *IV.A. Methodological Framework*

One goal of our analysis is to assess how well the implications of standard models of labor market search and matching fit the data. To this end, we develop an empirical framework for estimating aggregate time-series derived from the worker-job flow relationships implied by the models discussed in Section 2. We then assess how well these derived aggregate series fit the actual time-series of aggregate worker flow and vacancy rates.

Our framework rests on estimating relationships between worker flows and vacancy rates and establishment growth using regression specifications motivated by our theoretical models. We then interact these estimated relationships with the growth rate distributions derived from the BED data to produce an aggregate time series that we compare to the actual time series of worker flows and vacancies.

We begin by estimating the mean worker flow and vacancy rates for all establishments whose growth rate falls within some interval.[10] Note that this follows the identity relationship in equation (4). We use our quarterly JOLTS sample to estimate the employment-weighted mean rate for either hiring, layoffs, quits, or vacancies by growth rate interval and quarter. Let $w_t(g)$ denote one of these rates for growth rate interval $g$ during quarter $t$.

We estimate what we consider to be the "actual" estimate of aggregate worker flow and vacancy rates by interacting the $w_t(g)$ from the JOLTS with the quarterly growth rate distributions derived from the BED data.[11] Let $f_t(g)$ denote the share of employment within growth rate interval $g$ during quarter $t$. The aggregate estimate of each worker flow or vacancy rate is then

[10] We use 37 growth rate intervals that range from -200 percent to 200 percent and increase in size as the absolute value of the growth rate increases. These intervals include separate designations for establishments with growth rates of zero, -200 percent (exits) and 200 percent (entrants). We use intervals of varying length because of the sparse number of observations of establishments with extreme growth rates. Note that our JOLTS sample only includes continuous establishments, but we incorporate assumed worker flow and vacancy rates for entrants and exits when we aggregate the micro-level relationships to the macro level.

[11] We regard the estimates of the "actual" flows using (8) as more reliable than the published estimates from JOLTS for the reasons discussed in detail in Davis, Faberman and Haltiwanger (2010). Roughly speaking, equation (8) yields an *estimate* of the actual flow that accounts for entry and exit as well as for other sampling issues in JOLTS. It also provides a natural benchmark for our statistical models that follow, since all use the BED densities as weights in their aggregation.

$$W_t = \sum_g f_t(g) w_t(g) . \qquad (8)$$

We next turn to out statistical models of the micro level relations between vacancies, worker flows and establishment growth. Our first specification is motivated by the iron link relationship of the CHW model (and related MP-style search models). It postulates that the micro-level relationships for hires, layoffs and quits are constant over time. We denote this as the fixed cross-sectional specification as we regress each micro flow rate on a set of dummy variables representing one of the growth rate intervals, $\alpha(g)$, that are fixed over time,

$$w_t(g) = \alpha(g) + \varepsilon_t^D(g) . \qquad (9)$$

Since they only depend on $\hat{\alpha}(g)$, the predicted values from this regression, $\hat{w}^D(g)$, will be constant across all quarters. Although, as Figure 3(b) illustrates, it is inconsistent with the CHW model, we also estimate equation (9) for the vacancy-growth relation for completeness but note that such a specification is not motivated by any model. We also depart somewhat from the CHW model in that it has the stark implication that $\hat{\alpha}(g) = \hat{\alpha}, \forall g$ but we allow these effects to vary by growth rate interval. Allow such flexibility will permit this specification to capture nonlinearities such as the backward S-shape relationship implied by the FN model. It will not, however, allow for changes in the quit-growth relationship over time implied by the Barlevy (2002) model.

We produce the aggregate time series implied from this model by interacting the predicted $\hat{w}^D(g)$ with the quarterly growth rate distributions derived from the BED. The aggregate rates are

$$\hat{W}_t^D = \sum_g f_t(g)\hat{w}^D(g). \qquad (10)$$

Our second specification is motivated by the models in Section 2 that relax the iron link relationships by allowing for cyclical variation in the quit-growth relationship, and subsequently in the hires-growth and layoffs-growth relationships. To account for such movements, we specify a regression of the form

$$w_t(g) = \alpha(g) + \beta_1 G_t^+ + \beta_2 G_t^- + \beta_3 \Delta G_t + \varepsilon_t^B(g), \qquad (11)$$

where $G_t^+$ is the aggregate net employment growth rate conditional on a positive rate, $G_t^-$ is the aggregate net employment growth rate conditional on a negative rate, and $\Delta G_t$ is an accelerator term that measures the change aggregate net employment growth rate.[12] We refer to this as our baseline specification since it allows for changes in the micro-level relationships over the business cycle in the most parsimonious way. It is flexible enough to capture the movements in hires, quits and layoffs depicted in Figure 4(a), as well as some aspects of the vacancy rate relationship in Figure 4(b); it will not be able to capture changes in the slope of the vacancy-growth relationship over time.

Denote the predicted values from the baseline specification as $\hat{w}_t^B(g)$. The aggregate rates implied from the baseline specification are

$$\hat{W}_t^B = \sum_g f_t(g)\hat{w}_t^B(g). \qquad (12)$$

Finally, further relaxations of the iron link relationship could include disproportionate shifts in the flow-growth relationships over time, as in Barlevy (2002). Therefore, we extend the baseline specification to include an interaction term between the

[12] We obtain the aggregate growth rate measures from the published Current Employment Statistics (CES) estimates of the BLS. The JOLTS survey is designed so that the difference between its aggregate hiring and separation rates is roughly equal to the CES aggregate net growth rate.

aggregate net employment growth rate and a set of class variables, $D(\tilde{g})$, that categorize the growth rate intervals into several groups,[13]

$$w_t(g) = \alpha(g) + \beta_1 G_t^+ + \beta_2 G_t^- + \beta_3 \Delta G_t + \delta D(\tilde{g}) G_t + \varepsilon_t^F(g) . \qquad (13)$$

The interaction terms have the added benefit of being able to capture potential movements in the slope of the vacancy-growth relationship, as depicted in Figure 3(b).[14]

Denote the predicted values from the flexible specification as $\hat{w}_t^F(g)$. The aggregate rates implied from this specification are

$$\hat{W}_t^F = \sum_g f_t(g) \hat{w}_t^F(g) . \qquad (14)$$

*V.B. Accounting for Changes with Fixed Cross-Sectional Relationships*

We begin by reporting results of our fixed cross-sectional specification. Graphical illustrations of the results allow an straightforward comparison to Figure 3. Figure 6 presents the fixed cross-section estimates for hiring and vacancy rates and Figure 7 presents fixed cross-section estimates for separations, layoffs, quits, and other separation rates. We estimate our specification for total separations and its components (layoffs, quits and other separations) for completeness. The reported estimates use JOLTS establishments pooled across all quarters in our sample (2001Q1 – 2009Q2).[15]

Figure 6 shows that hiring and vacancy rates exhibit strong, nonlinearly increasing relationships with growth at the establishment level. When interpreting the

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[13] The class variables allow the *g* growth rate intervals to represent their original ranges within $g \in [-10, 10]$ percent, so that the interactions can capture the rich nonlinear behavior observed for the flow rates in Figures 5 an 6 within this range. The remaining intervals are grouped into two dummy variables representing $g < -10$ percent and $g > 10$ percent.

[14] It may be that even richer aggregate growth rate terms are required to capture the changing slope patterns of the vacancy-growth relationship over the cycle since the relationship between aggregate net employment growth and labor market tightness may be quite complex. We plan to explore richer specifications in future drafts.

[15] In the next draft of the paper, we will report summary statistics from the micro regressions.

figures, keep in mind that the negative growth to the left of zero along the horizontal axis represents establishment-level job destruction and the positive growth to the right of zero represents establishment-level job creation. The hiring rate is positive but essentially constant for contracting establishments. The hiring rate is lowest for establishments for no employment change. It then increases nearly one-for-one with the job creation rate for expanding establishments. The vacancy rate increases as a function of growth throughout most of the growth rate range. The notable exception is at zero growth, where the vacancy rate exhibits a discrete drop. The vacancy rate rises much less than one-for-one with the growth rate, never rising above 10 percent even for the fastest growing establishments.

Figure 7 shows that separation rates exhibit strong, nonlinearly decreasing relationships with growth, though there are notable differences between the relationships of its components (layoffs, quits, other separations). Both the layoff rate and the total separation rate exhibit a relationship to establishment growth that is a mirror-image of the hiring-growth relation. They increase nearly one-for-one with the job destruction rate for contracting establishments and are essentially constant for expanding establishments. Establishments with zero growth have the lowest layoff and total separation rates. The quit rate is highest for contracting establishments, but rises with the job destruction rate only for establishments with relatively small contractions and then remains constant for establishments with larger contractions. The quit rate is also constant with respect to the job creation rate, albeit at a lower level. As with the other worker flows, the quit rate is lowest for establishments with zero growth. Other separations (i.e., retirements, intra-firm transfers) increase somewhat with large contractions, but otherwise exhibit a constant rate with respect to growth. We include this group for completeness but given their relatively small contribution to total separations, we focus the remainder of our study on only quits and layoffs.

The iron link predictions of the CHW and MP-style models for hires and layoffs are broadly supported by these fixed effect estimates in that layoffs rise sharply with the size of a contraction and hires sharply with the size of an expansion. The positive hiring rates for contracting establishments and the positive layoff rates for expanding establishments are not strictly consistent with the iron link model, but the rates over these ranges are small and relatively constant, and the latter feature is consistent with these models. Also, unlike Figure 3, the point of inflection of the "hockey sticks" for hires and layoffs (as well as for vacancies) is not centered at the average quit rate but at zero. As discussed in section 2, this pattern is consistent with the iron link models that allow for stochastic behavior and/or heterogeneity in quits.

The quit-growth rate relationship is generally flat relative to the layoff-growth relationship, consistent with the CHW model, but there are clear and systematic departures from the strict prediction of a flat quit-growth relationship. Indeed, the relationship roughly has the backward S-shape predicted by the FN model. The rising portion of the backward S-shape for establishments with modest employment contractions is consistent with the "rats leaving a sinking ship" implication of the FN model. The backward S-shape relationship for quits also affects hiring and layoff behavior at establishments with small contractions. Hires rise with contractions just to the left of zero and layoffs don't rise as steeply as quits for mild net contractions. Consistent with the standard model's predictions, vacancies rise steadily with job creation, but the slope of the vacancy-growth relationship is less than the hiring-growth relationship.[16]

While the estimates of the fixed cross-sectional relationships provide critical insights, our primary means of evaluating the success of any given specification is to consider how well it accounts for the observed aggregate fluctuations in the flow rates. Therefore, we compare the actual flows (from equation (8)) to the aggregate flows implied from the fixed cross-section specification (from equation (10)).

The results of this exercise are plotted in Figure 8 for hires, vacancies, layoffs, and quits.[17] Each panel shows the actual aggregate rate ($W_t$) and the rate from the fixed cross-section specification ($\hat{W}_t^D$). The latter are labeled "implied by the growth rate distribution," since only changes in the establishment growth rate distribution account for aggregate fluctuations in the flow rates in this specification. The Figure suggests that movements in the cross-sectional growth rate distribution alone do a fairly good job of predicting the aggregate movements in the hiring and layoff rates, but a poor job of predicting movements in the aggregate vacancy and quit rates. In fact, the vacancy and quit rate series implied by changes in the distribution alone are essentially flat lines.

The first column of Table 2 quantifies what Figure 8 illustrates. It reports the R-squared values from the univariate regression of $W_t$ on $\hat{W}_t^D$. While we do not show the

[16] As discussed in detail in Davis, Faberman and Haltiwanger (2009) the magnitude of the fill rate being larger than one reflects time aggregation and stock-flow issues (i.e., the implied fill rate reflects the cumulative flows of hires over the course of the month while the vacancies reflect the stock of vacancies at a point in time at the beginning of the month).

[17] We perform all of our exercises on seasonally unadjusted data and then seasonally adjust the aggregate time series of each exercise using the Census X-11 methodology. In addition, in this and subsequent exercises, we omit the first two quarters of the JOLTS sample (2001Q1-2001Q2) from the analysis. The JOLTS data have substantially fewer observations during these early quarters relative to the rest of the sample (2700 per quarter on average, compared to 6344 for the rest of the period), These quarters have relatively sparsely populated growth rate intervals, and consequently less precise estimates of the micro-level flow-growth relationships.

time series, we also report the R-squared values for the exercise using only manufacturing data. For the private sector, our fixed cross-section specification can account for 62 percent of the variation in the aggregate hiring rate and 80 percent of the variation in the aggregate layoff rate, but can only account for 1 percent of that variation in the vacancy rate and 0.1 percent of the variation in the quit rate. For manufacturing, movements in the growth rate distribution account for 52 percent of the variation in the aggregate hiring rate, 88 percent of the variation in the aggregate layoff rate, 21 percent of that variation in the vacancy rate, and 9 percent of the variation in the quit rate.

The results imply that an iron link specification can describe the micro-level hiring-growth and layoff-growth relationships fairly well, but it cannot predict aggregate movements in aggregate quit or vacancy rates. Since both rates exhibit considerable movement over the sample period, equation (4) suggests that it must be the case that their micro-level relationships with growth vary over time. Whether these movements track the business cycle is an open empirical question. If they do, our baseline and flexible specifications will capture such fluctuations.

Before proceeding to the analysis of the baseline and flexible specifications, we explore how the fixed cross sectional specification results vary over sub-periods. That is, instead of pooling for all quarters as in Figures 6 and 7, we estimate the fixed cross sectional specification separately for three selected periods: 2001Q2 – 2003Q1 (a relatively mild recession followed by a prolonged “jobless recovery”), 2006Q1 – 2006Q4 (an expansion period), and 2008Q3 – 2009Q2 (a deep recession). Note that the sub-periods are defined over full years to account for any seasonal movements in the micro-level relationships. The results from this exercise are in Figure 9. We focus on differences between growth rates of -30 and 30 percent, which constitutes the bulk of the employment (about 90 percent of the distribution) at the quarterly frequency.

As one might expect from our results thus far, we observe relatively little change in the relationships between the hiring rate and growth and between the layoff rate and growth. There are some notable differences over time, the hiring rate is lower and the layoff rate is slightly higher during the 2008-09 recession, particularly at contracting establishments, but these changes are relatively small. These relatively modest shifts are broadly consistent with iron link specification in Figure 3.

The shifts in the quit-growth and vacancy-growth relationships over time are considerably more pronounced. Both the vacancy rate and the quit rate are lowest during the 2008-09 recession and highest during 2006. In addition, the differences are more pronounced for contracting establishments. This is especially true for the quit rate. Among expanding establishments, the difference in quit rates between 2006 and 2008-09 ranges between 1.5 and 2 percentage points. In comparison, establishments who contract by 10 percent have a difference of 2.3 percentage points and those who contract by 30 percent have a difference of over 10 percentage points. These patterns, especially for quits, reinforce the fact models with an iron link relation between worker flows and job flows cannot fully account for the observed movements aggregate worker flow rates. The systematic movements in these relations, however, suggest that our baseline and flexible form specifications should provide a better approximation of these aggregate fluctuations.

*V.C. Relaxing the Iron Link Specification*

To evaluate the results from the baseline and flexible functional form specifications, we focus on the implied aggregate worker flows from each model.[18] That is, we first estimate each model at the micro level (using (11) and (13) respectively) and then generate the aggregate flows using equations (12) and (14), respectively.

The second and third columns of Table 2 report the R-squared values from regressing the actual aggregate rates ($W_t$) on the baseline specification ($\hat{W}_t^B$) and flexible specification ($\hat{W}_t^F$), respectively. Again, we report the results for total private employment and manufacturing. Introducing variation in the micro-level relations with the aggregate growth rate improves the predictive power of our implied aggregate series considerably for all aggregate rates. Using our baseline specification, we can now account for 88 percent of the variations in the hiring rate (up from 62 percent) and 83 percent of the variations in the layoff rate (up from 80 percent). The improvements in fit for quits and vacancies is particularly striking. We can now account for 47 percent of the variation in the vacancy rate (up from 1 percent) and 69 percent of the variation in the quit rate (up from 0.1 percent). We obtain similar improvements for our manufacturing estimates for the hiring rate (83 percent versus 52 percent), the layoff rate (90 percent versus 88 percent), the vacancy rate (50 percent versus 21 percent), and the quit rate (72 percent versus 9 percent). Interestingly, our flexible specification adds almost no predictive power over the baseline specification and in most cases produces a slightly worse fit of the actual aggregate estimates.

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[18] In the next draft of the paper we will report more direct evidence on the patterns of the micro estimates of the baseline and flexible functional forms.

Figure 10 plots the time-series behavior of the worker flow and vacancy rates implied by the baseline specification along with the series implied by the fixed cross-section specification and the actual aggregate series. Since it is practically identical to the baseline series, we exclude the results for our flexible specification. One can clearly see the improvement in fit for the hiring rate, as the baseline series now accurately captures that large drop in hiring observed in the actual series during 2008. There is little difference between the baseline specification and the fixed cross-section specification for the layoff rate, in part because shifts in the establishment growth rate distribution already accounted for a large fraction of the movements in the layoff rate. Movements in the aggregate vacancy and quit rates implied by the baseline specification exhibit movements much more in line with the procyclical patterns observed for the actual estimates, though there remain notable departures. For one, the implied vacancy and quit rates appear to recover from the 2001 recession too quickly relative to the actual series. In addition, the implied series appears to under-predict the rise in the vacancy rate during 2006-07 and the fall in the quit rate during 2008.

The results for the baseline model, in particular, provide support for the view that relaxing the iron link relationships to account for aggregate conditions, as depicted in Figure 4, provides a reasonably accurate accounting of aggregate hires and layoffs. Put differently, the results suggest that knowing the shape of the micro level relations between hires and layoffs and establishment growth and how they shift over the cycle, along with the cross-sectional distribution of establishment growth, accounts for almost all of the variation in aggregate hiring and layoff rates. The findings for quits and are less supportive. The weaker explanatory power of their baseline and flexible functional form specifications imply that these specifications are missing some key elements of the quit-growth and vacancy-growth relationships.

As overall assessment of the importance of accounting for the micro-level relationships for aggregate worker flow fluctuations, we can quantify the additional explanatory power they add to a regression of the aggregate $W_t$ on measures of aggregate conditions. Table 3 presents these results. Column 1 of Table 3 shows the R-squared from regressing the aggregate flows on the aggregate net growth rate terms that are included in the baseline specification. Column 2 of Table 2 shows the R-squared from adding as a regressor $\hat{W}_t^B$.[19] We also report in parentheses the p-value for the additional regressor. The difference in the R-squared between the two columns provides a metric of the additional explanatory power obtained from incorporating the micro-level relationships to establishment growth.

Column 1 shows that a large fraction of the variation in the aggregate worker flows is accounted for by the aggregate growth rate terms. This is not surprising since all of the worker flows have pronounced cyclical patterns. Column 2 shows the additional explanatory power from including $\hat{W}_t^B$ as an additional regressor. For hires, separations, quits and layoffs there is substantial explanatory power gained by accounting for the micro-level relationships. The increase in explanatory power is substantial. For hires, separations, quits, and layoffs it is at least an additional 10 percentage point increase in

[19] We recognize that $\hat{W}_t^B$ includes the contribution of the aggregate growth terms from the micro regression. However, if $\hat{W}_t^B$ only captured the variation that derives from the aggregate growth terms directly then adding this regressor would add no explanatory power as they are already included as regressors in column (1). Note that we have also considered a version of Table 2 where we use $\hat{W}_t^D$ and obtain virtually the same results.

the R-squared and as much as 30 percentage point increase for separations. For vacancies, there is much less of increase.

## V. A Backcasted Series of Worker Flows and Vacancies

A byproduct of our analysis is the ability to use our framework to generate estimates of aggregate worker flow and vacancy rates out of sample. Specifically, given data on quarterly growth rate densities, $f_t(g)$, and aggregate employment growth, $G_t$, one can use the estimates derived from our framework to create a backcasted series of the aggregate rates. The approach is clear once one refers back to our baseline specification. Once we obtain the coefficient estimates from the regression in (6), we can generate the predicted values, $\hat{w}_t^B(g)$, for a time series as far back as we have data on $G_t$. Then, given the aggregation specified in (7), we can generate an aggregate time series of worker flow and vacancy rates for as far back as we have data on $f_t(g)$.

We employ exactly this approach in generating a backcasted series of aggregate worker flows and vacancies. We employ our baseline specification, since it provided the best fit of the actual estimates in the previous section. We use the employment growth rate from the published Current Employment Statistics (CES) data of the BLS for our estimate of $G_t$ and the quarterly growth rate distributions from the BED for $f_t(g)$. The latter only go back to 1990Q2, so this is the start date for our backcasted series. We perform the exercise for both the private sector and manufacturing.

The results for the private sector are in Figure 11. The top panel shows the behavior of the backcasted series for the hiring rate and vacancy rate overlaid with the aggregate job creation rate from the BED data. Hiring and job creation track each other closely. Both exhibit a mild decline during the 1990-91 recession, a moderate decline during the 2001-03 downturn, and a precipitous drop during the 2008 recession. Of the two, the hiring rate appears more cyclically volatile. Interestingly, even though the baseline specification provided a relatively weak within-sample fit of the aggregate vacancy rate, its backcasted vacancy rate is still able exhibit plausible procyclical patterns in the data. For example, the vacancy rate exhibits a considerable decline during the 1990-91 recession and remains relatively high during the 1990s expansion.

The second panel of Figure 11 presents the backcasted series of the quit rate and layoff rate overlaid with the BED job destruction rate. The most striking pattern is the degree to which the layoff rate and job destruction rate track each other. Both spike sharply during the 1990-91 recession, exhibit a moderate but prolonged rise during the 2001 recession, and rise sharply in 2008. Again, while the within-sample fit of the quit rate was less than ideal, its backcasted series is still able to generate plausible procyclical patterns. Namely, it exhibits sharp declines at the onset of all three recessions.

Figure 12 shows the results of this exercise for manufacturing. Again, hiring and job creation track each other closely, though, in manufacturing, it appears that hiring and job creation are equally volatile over the business cycle. As before, despite its weak within-sample fit, the backcasted series of the baseline specification is able to produce plausible procyclical movements in the vacancy rate. Layoffs and job destruction again track each other closely, even more so in manufacturing than in the total private sector. The implied quit rate appears to be procyclical, but there are notable departures in 1995 and 1998 that may be the result of its relatively weak within-sample fit.

## VI. Conclusions

[TO BE COMPLETED]

**References**

Acemoglu, Daron and William Hawkins, 2006. "Unemployment in a Generalized Search Model," University of Rochester, mimeo.

Barlevy, Gadi, 2002. "The Sullying Effect of Recessions," *Review of Economic Studies*, 69(1): 65-96.

Bertola, Giuseppe and Ricardo Caballero, 1994. "Cross-Sectional Efficiency and Labour Hoarding in a Matching Model of Unemployment," *Review of Economic Studies* 61(3): 435-56.

Bertola, Giuseppe and Pietro Garibaldi, 2001. "Wages and the Sizes of Firms in Dynamic Matching Models," *Review of Economic Dynamics* 4(2): 335-368.

Clark, Kelly A., and Hyson, Rosemary, 2001. "New Tools for Labor Market Analysis: JOLTS," *Monthly Labor Review*, 124(12): 32-37.

Cooper, Russell, John Haltiwanger and Jonathan Willis, 2007, "Search Frictions: Matching Aggregate and Establishment Observations," *Journal of Monetary Economics*, 54, 56-78.

Davis, Steven J., 2005. "Job Loss, Job Finding, and Unemployment in the U.S. Economy over the Past Fifty Years: Comment," *2005 NBER Macroeconomics Annual*, Cambridge, MA: MIT Press.

Davis, Steven J. and Haltiwanger, John, 1999. "Gross Job Flows." *Handbook of Labor Economics*, Volume 3B, Orley Ashenfelter and David Card, editors. Amsterdam: North-Holland.

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., Faberman, R. Jason, and Haltiwanger, John, 2009. "The Establishment-Level Behavior of Hiring and Vacancies," Federal Reserve Bank of Philadelphia Working Paper No. 09-14.

Davis, Steven J., Faberman, R. Jason, and Haltiwanger, John C., and Rucker, Ian, 2010. "Adjusted Estimates of Worker Flows and Job Openings in JOLTS," in *Labor in the New Economy*, edited by Katharine Abraham, Michael Harper, and James Spletzer, Chicago Press, forthcoming.

Davis, Steven J., John C. Haltiwanger, and Scott Schuh, 1996. *Job Creation and Destruction.* Cambridge, MA: MIT Press.

Elsby, Michael and Ryan Michaels, 2008. "Marginal Jobs, Heterogeneous Firmsand Unemployment Flows," NBER Working Paper No 13777.

Elsby, Michael, Michaels, Ryan, and Solon, Gary. 2009. "The Ins and Outs 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.

Fujita, Shigeru and Makoto Nakajima, 2010. "Worker Flows and Job Flows: A Quantitative Analysis," mimeo.

Fujita, Shigeru, and Ramey, Garey, 2009. "The Cyclicality of Separation and Job Finding Rates," *International Economic Review*, 50(2), 415–430.

Hall, Robert E., 2005. "Job Loss, Job Finding, and Unemployment in the U.S. Economy over the Past Fifty Years," *2005 NBER Macroeconomics Annual*, Cambridge, MA: MIT Press.

Jovanovic, Boyan, 1979. "Job Matching and the Theory of Turnover," *Journal of Political Economy*, 87, no. 5, 972-990.

Jovanovic, Boyan, 1985, "Matching, Turnover, Unemployment," *Journal of Political Economy*, 92, no. 1, 108-122.

Kiyotaki, Nobuhiro and Ricardo Lagos, 2007. "A Model of Job and Worker Flows," *Journal of Political Economy*, 115(5): 770-819.

Moscarini, Giuseppe, 2005. "Job Matching and the Wage Distribution," *Econometrica*, 73, no. 2, 481-516.

Pissarides, Christopher, 2000. *Equilibrium Unemployment Theory*, second edition. Cambrdige, MA: MIT Press.

Pries, Michael, 2004. "Persistent Employment Fluctuations: A Model of Recurring Job Loss" *Review of Economic Studies* 71(1); 193-215.

Pries, Michael J. and Richard Rogerson, 2005, "Hiring Policies, Labor Market Institutions, and Labor Market Flows," *Journal of Political Economy*, 113, no. 4, 811-839.

Rogerson, Richad, Robert Shimer and Randall Wright, 2005. "Search-Theoretic Models of the Labor Market: A Survey," *Journal of Economic Literature,* 43, no. 4 (December), 959-988.

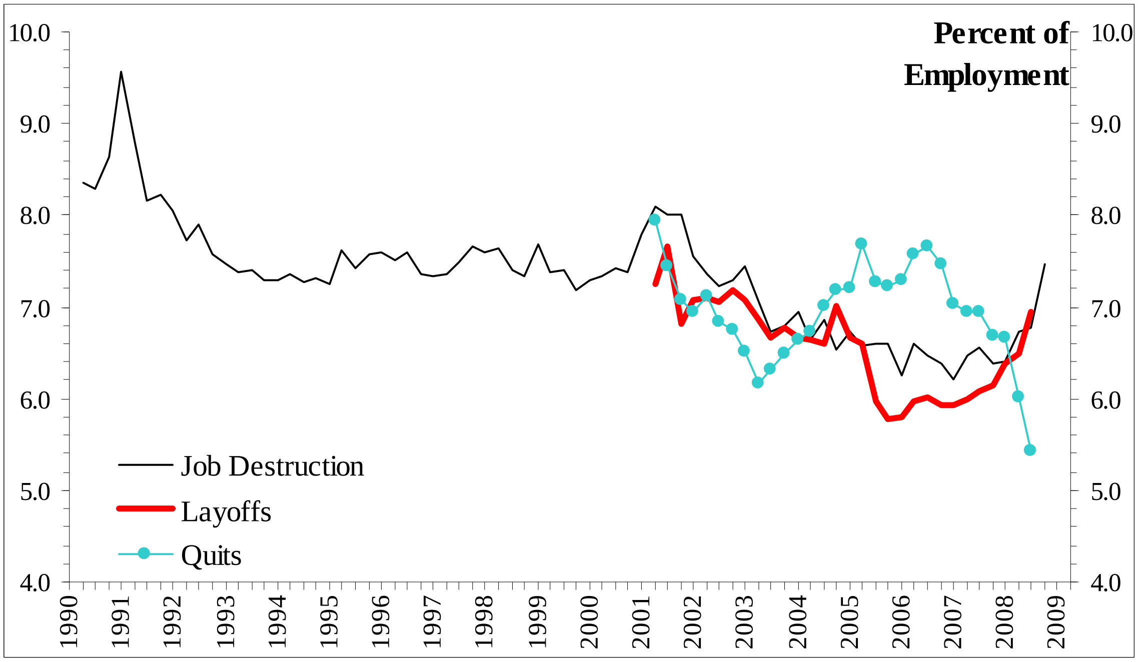
Rotemberg, Julio, 2006. "Cyclical Wages in a Search-and-Matching Model with Large Firms," NBER Working Paper No. 12415.

Shimer, Robert, 2007. "Reassessing the Ins and Outs of Unemployment." University of Chicago: mimeo.

Spletzer, James R.; Faberman, R. Jason; Sadeghi, Akbar; Talan, David M. and Clayton, Richard L. "Business Employment Dynamics: New Data on Gross Job Gains and Losses," *Monthly Labor Review* (April 2004), 127(4), pp. 29-42.

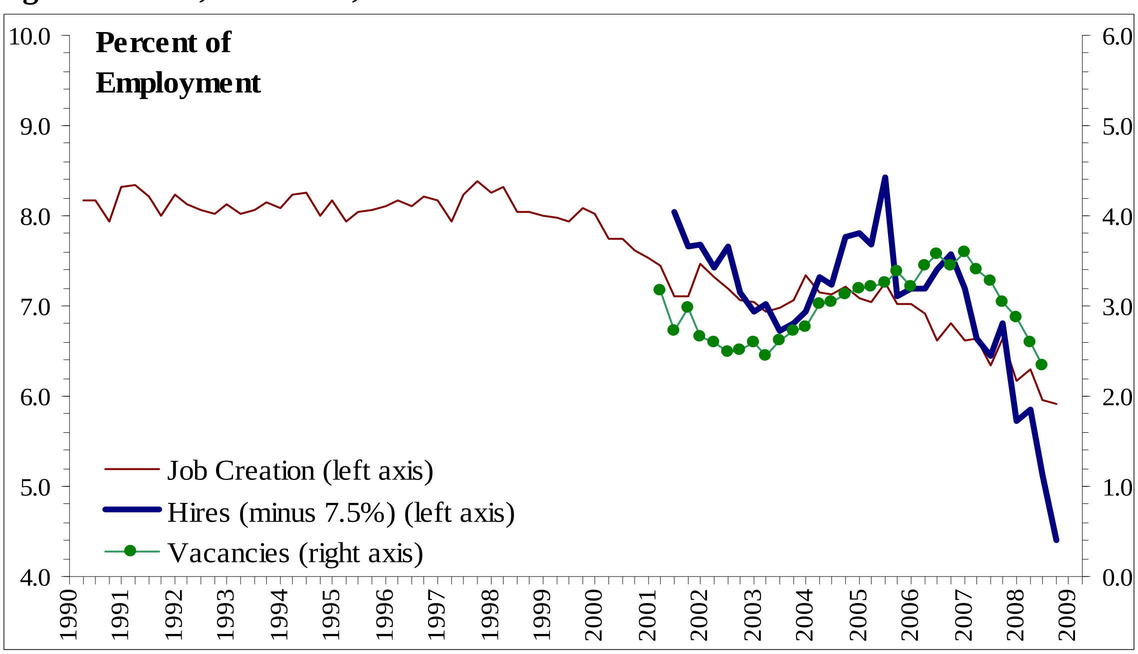
Yashiv, Eran, 2007. "Labor Search and Matching in Macroeconomics," *European Economic Review,* 1859-1895.

**Figure 1. Quits, Layoffs, and Job Destruction**




*Sources:* Quit and layoff rates (2001Q3 – 2008Q4) are authors' calculations using JOLTS establishment microdata weighted to an aggregate value for each quarter using growth rate densities from the BED. Job destruction rates (1990Q2 – 2008Q4) are authors' tabulations directly from the BED data. All estimates are seasonally adjusted. All rates are percentages of employment.

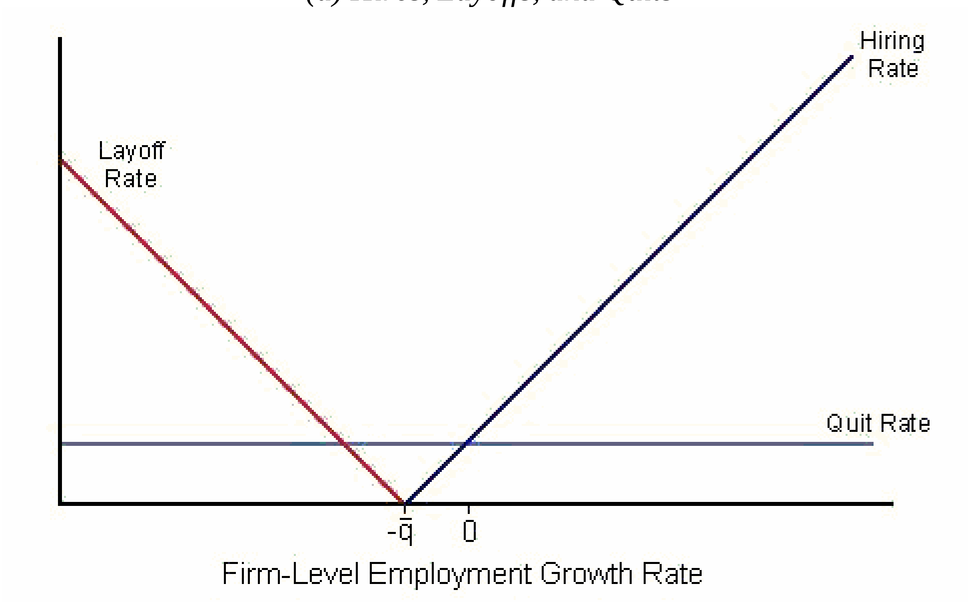
**Figure 2. Hires, Vacancies, and Job Creation**



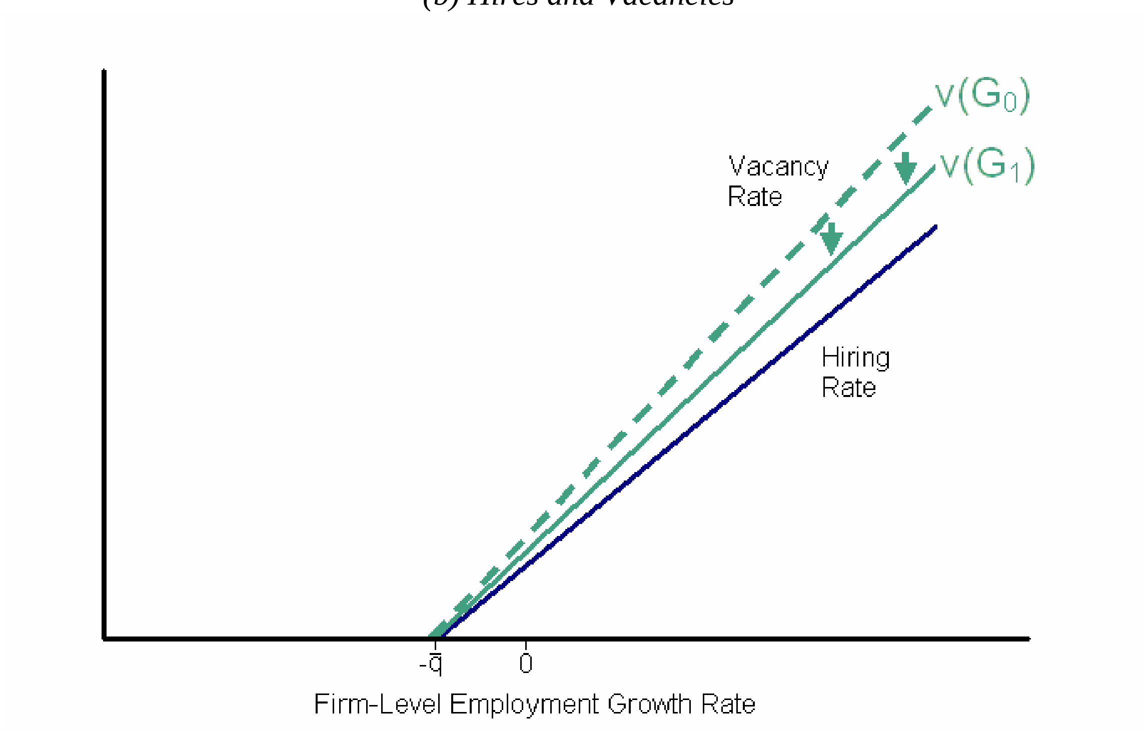

*Sources:* Hiring and vacancy rates (2001Q3 – 2008Q4) are authors' calculations using JOLTS establishment microdata weighted to an aggregate value for each quarter using growth rate densities from the BED. Job creation (1990Q2 – 2008Q4) rates are authors' tabulations directly from the BED data. All estimates are seasonally adjusted. All rates are percentages of employment. To account for scale differences, the hiring rate is shifted down by 7.5 percent.

**Figure 3. Implied Worker Flows from a Search Model with Multi-Worker Firms, Constant Exogenous Quit Rate**

*(a) Hires, Layoffs, and Quits*

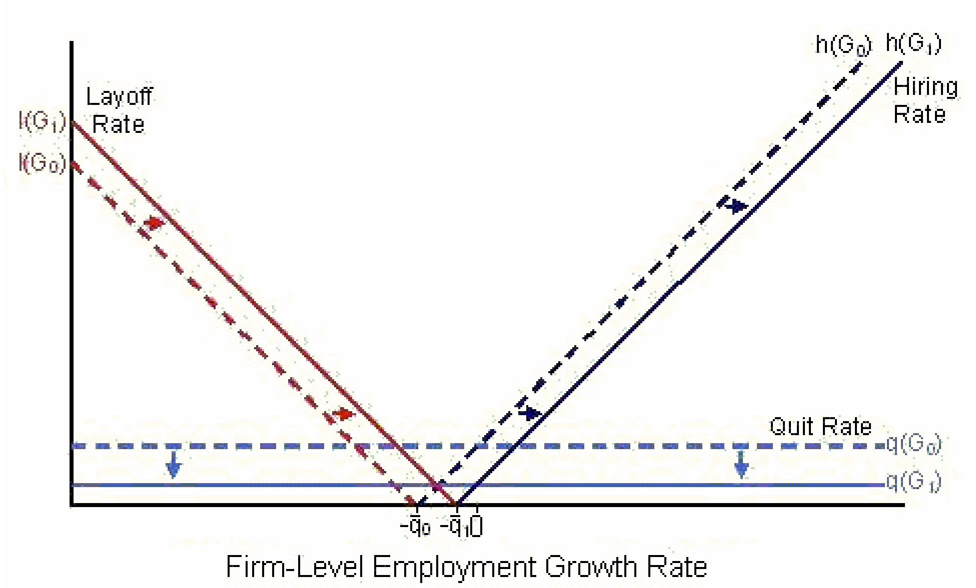



*(b) Hires and Vacancies*

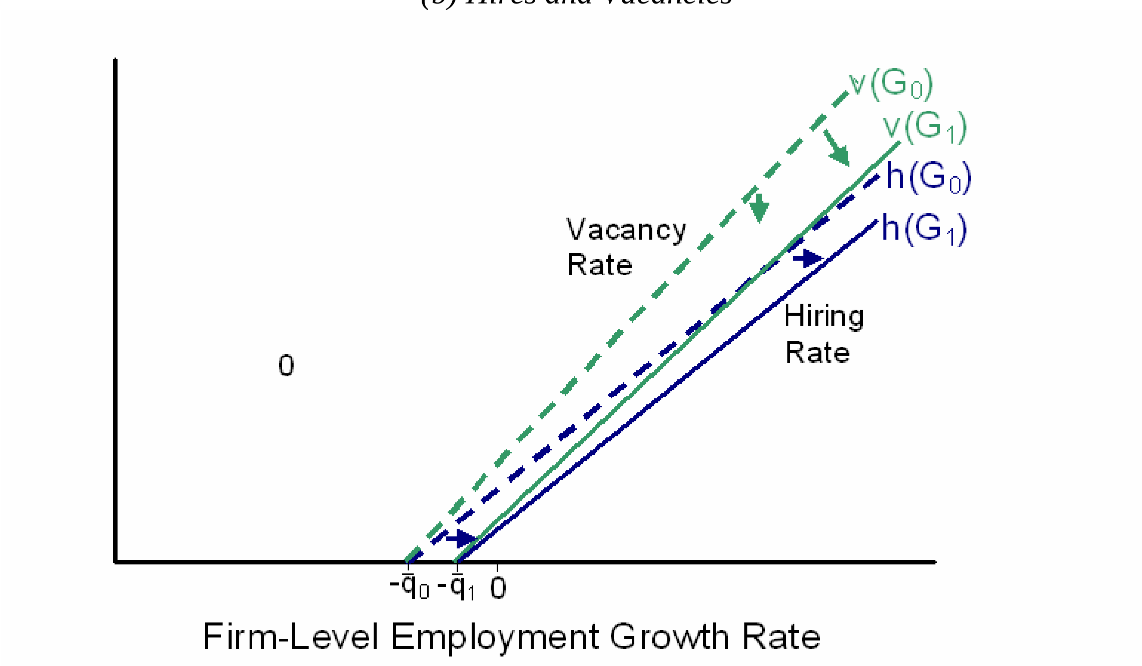



*Notes:* The figure depicts hiring, layoff, quit, and vacancy rates as a function of the firm-level quit rate for a search model with multi-worker firms and a constant, exogenous quit rate, $\overline{q}$ , faced by all firms. See text for model details.

**Figure 4. Implied Worker Flows from a Search Model with Multi-Worker Firms, Time-Varying Exogenous Quit Rate**

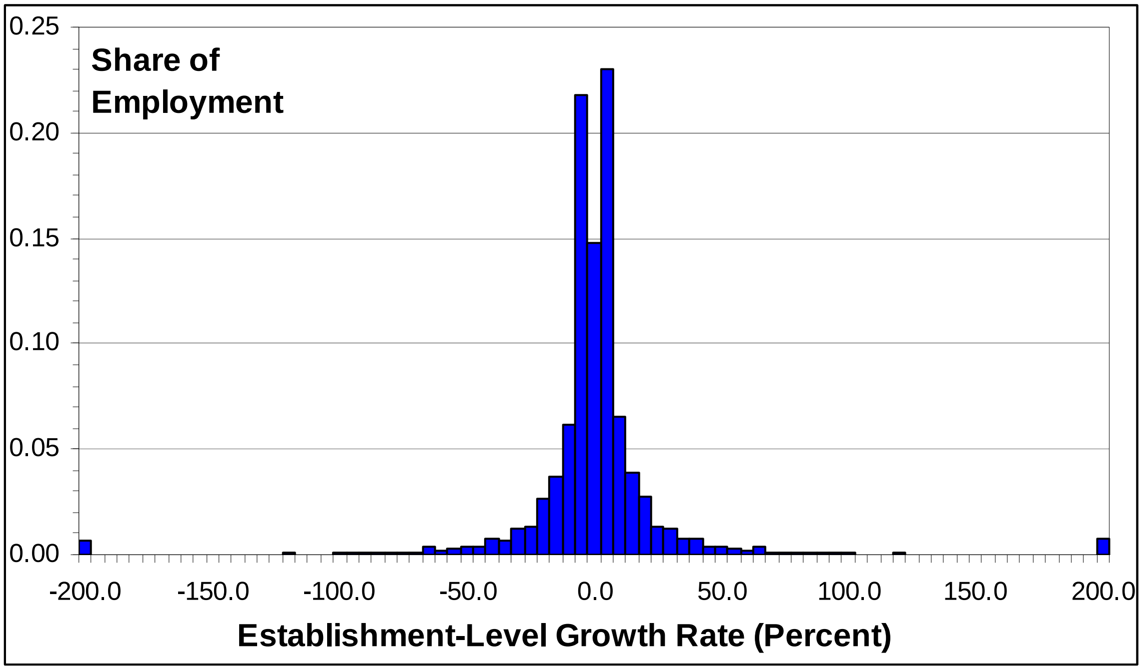



*(b) Hires and Vacancies*



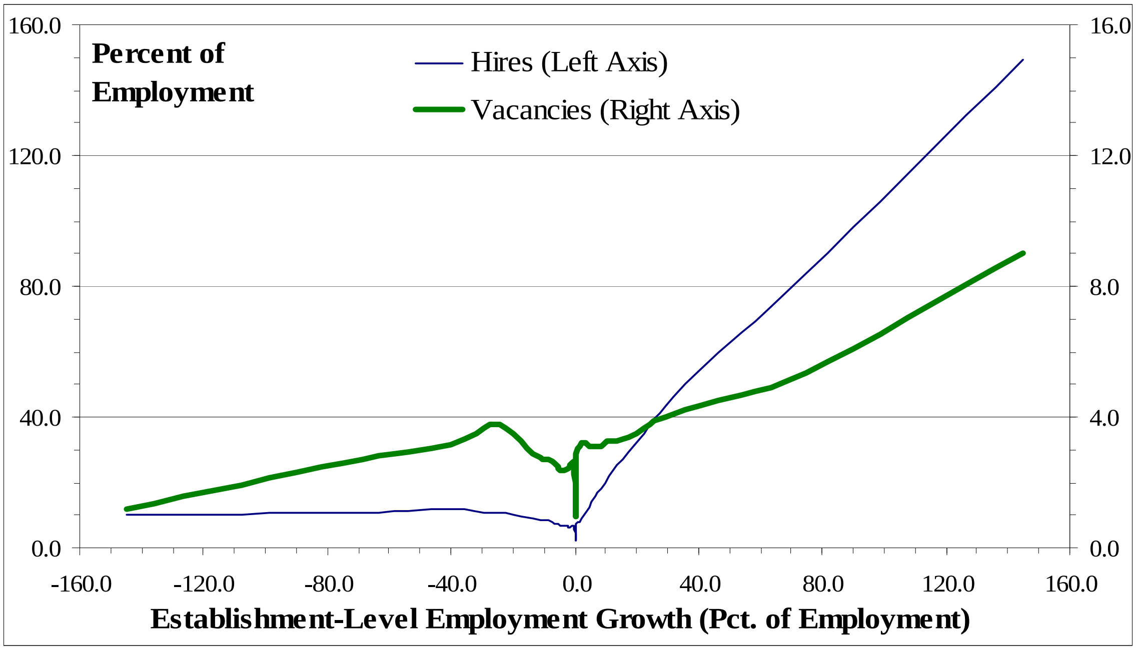

*Notes:* The figure depicts hiring, layoff, quit, and vacancy rates as a function of the firm-level quit rate for a search model with multi-worker firms and a exogenous quit rate, $\overline{q}$ , that varies with aggregate conditions, *G*, and is faced by all firms. See text for model details.

**Figure 5. The Cross-Sectional Distribution of Establishment-Level Growth Rates**



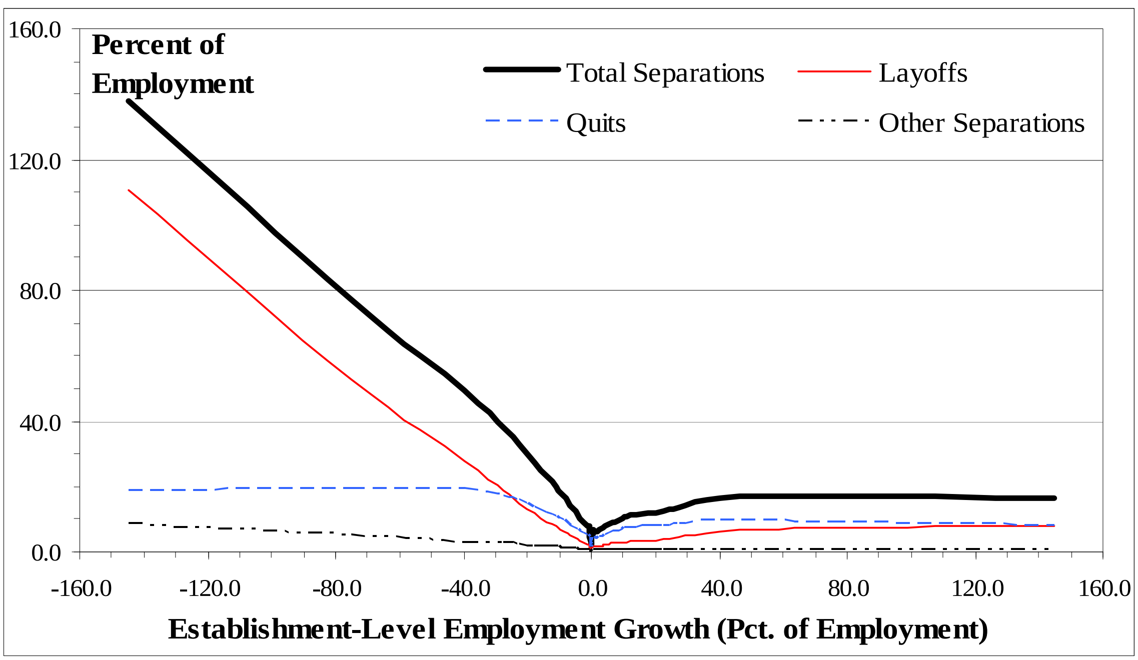

*Source:* Authors' tabulations using BED establishment data pooled over 1990Q2 – 2008Q4. Estimates are employment-weighted densities of establishment-level growth rates within fixed 5 percentage point intervals.

**Figure 6. Hiring and Vacancy Rates as a Function of Establishment-Level Growth**



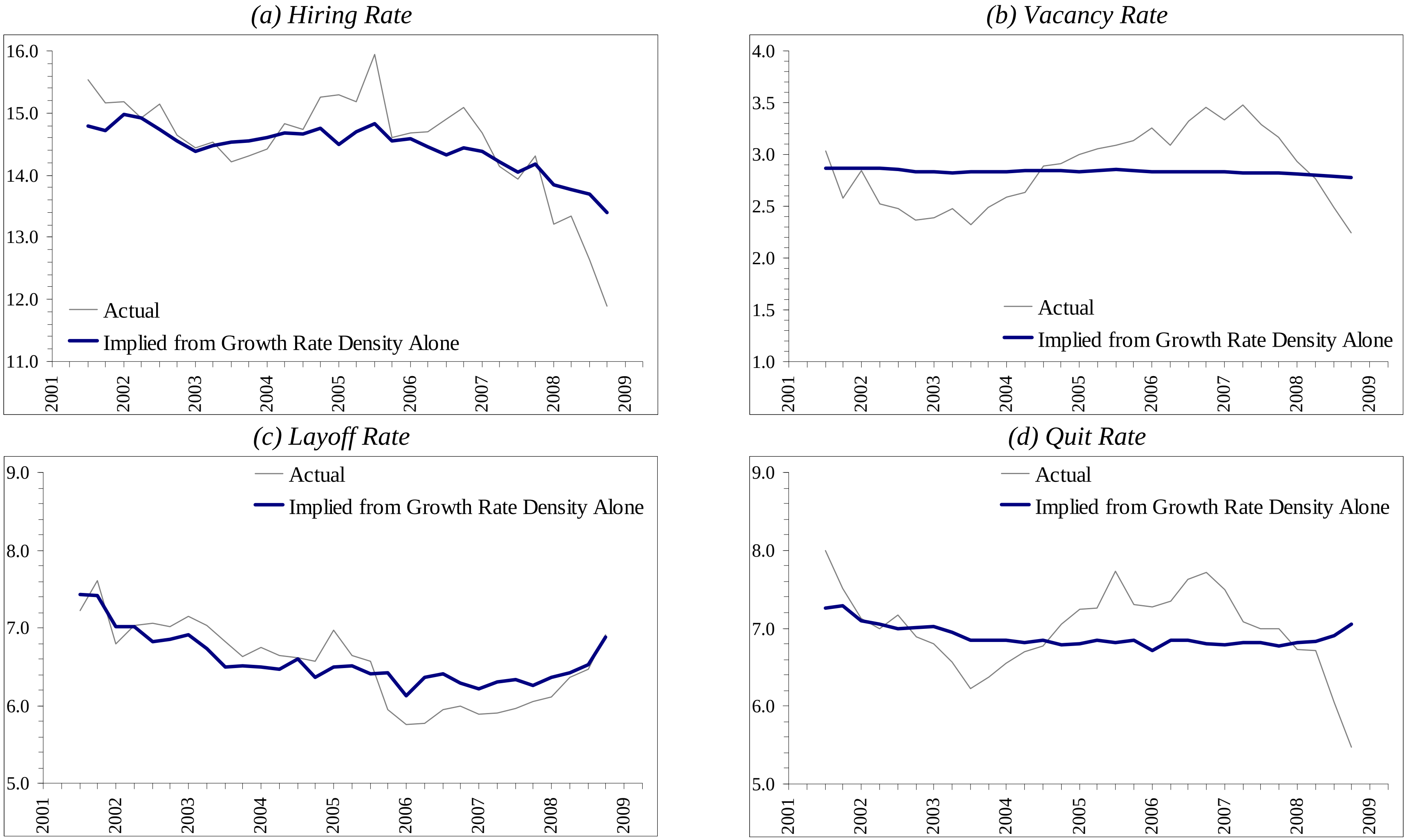

*Source:* Authors' calculations using JOLTS establishment data pooled over 2001Q1 – 2009Q2. Estimates are employment-weighted averages of the establishment-level growth rates within intervals that increase in width with the absolute value of the growth rate. Save for the endpoints and zero growth point, estimates are smoothed using a 3-bin moving average.

**Figure 7. Separation Rates as a Function of Establishment-Level Growth**



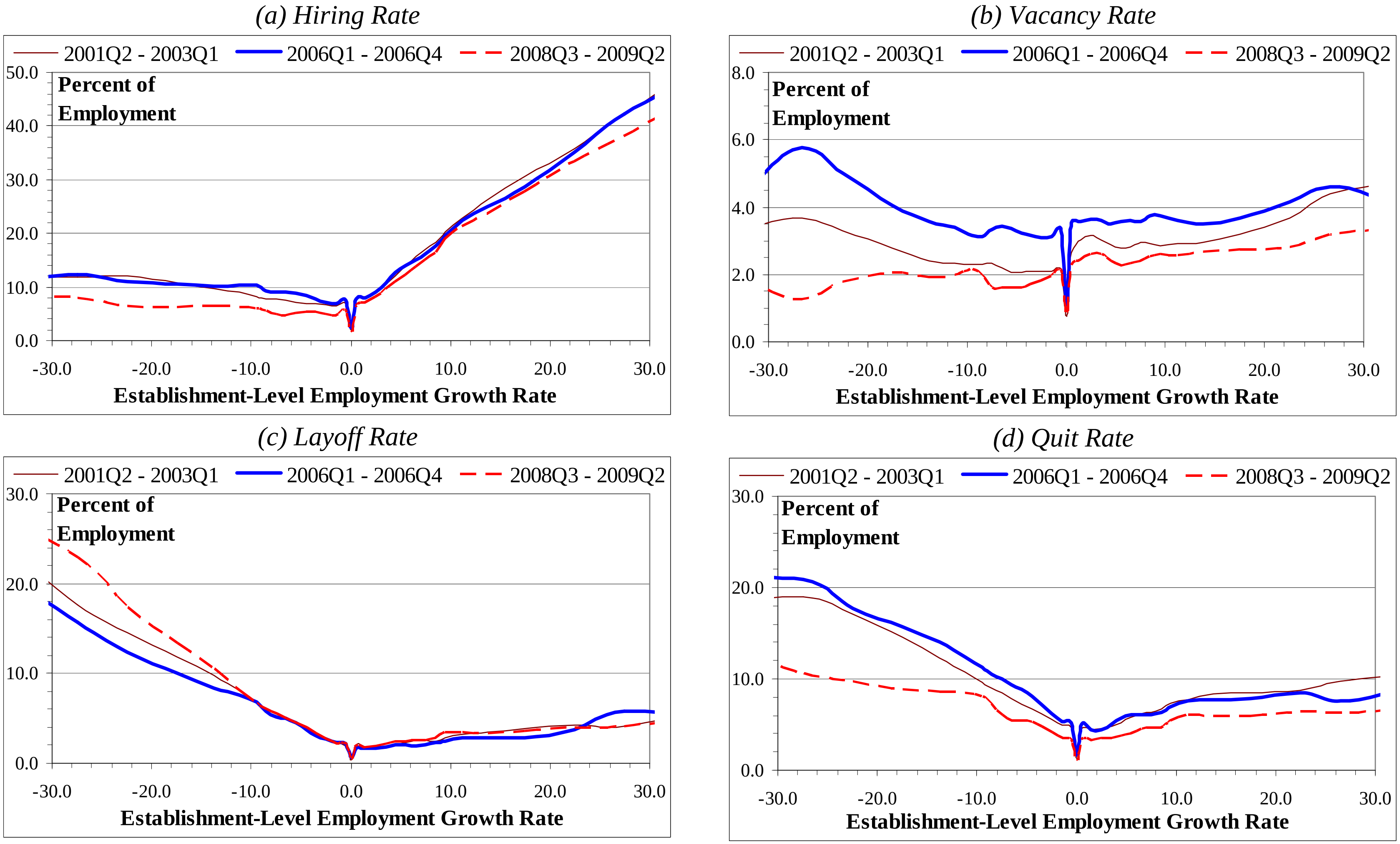

*Source:* Authors' calculations using JOLTS establishment data pooled over 2001Q1 – 2009Q2. Estimates are employment-weighted averages of the establishment-level growth rates within intervals that increase in width with the absolute value of the growth rate. Save for the endpoints and zero growth point, estimates are smoothed using a 3-bin moving average.

**Figure 8. Aggregate Worker Flows and Vacancies Implied by Changes in the Density of Establishment-Level Growth Rates**



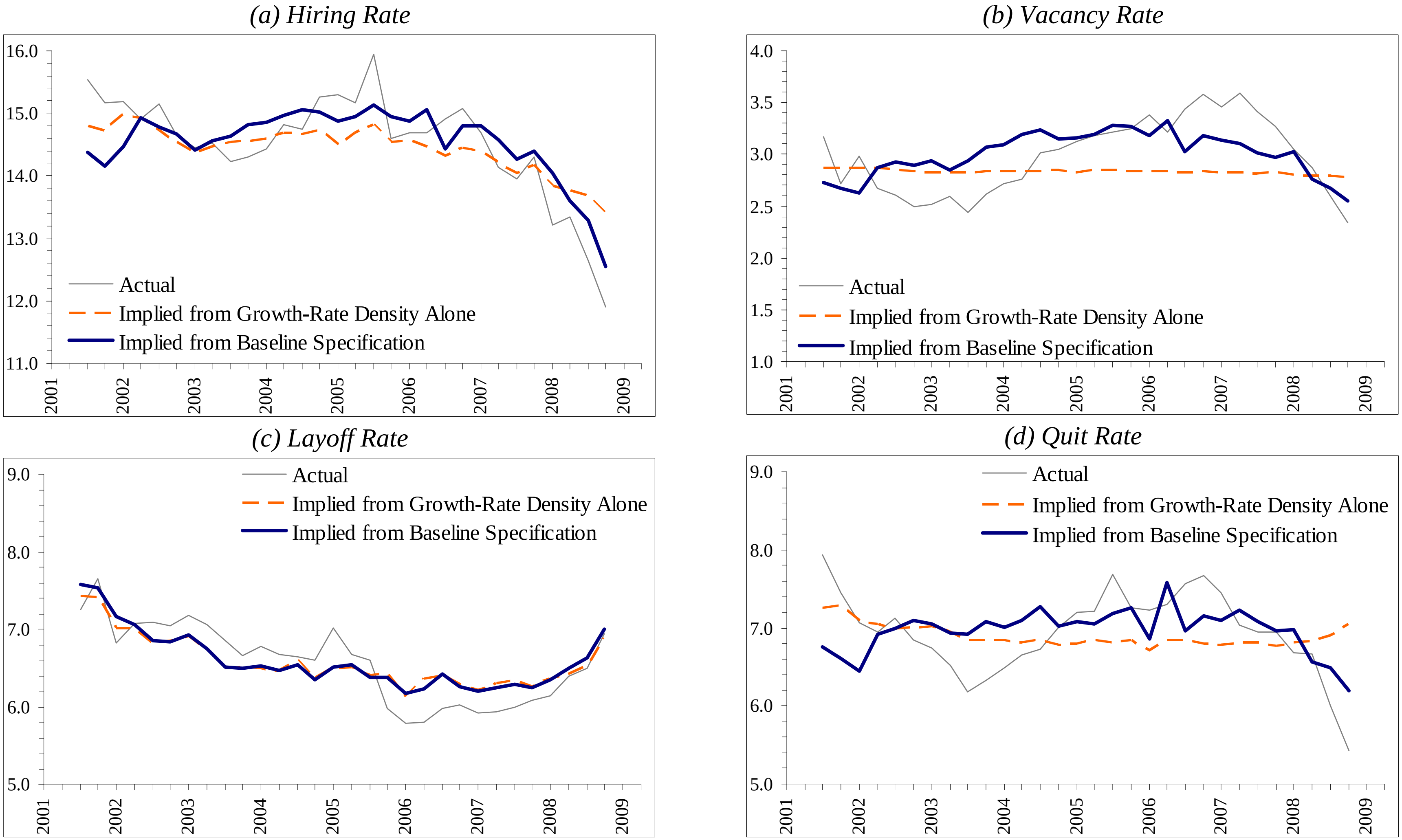

*Source:* Authors' calculations using the worker flow-growth and vacancy-growth relationships derived from JOLTS establishment data interacted with growth rate densities derived from BED data for 2001Q3 – 2008Q4. See text for details of the aggregation methodology. Estimates are seasonally adjusted.

**Figure 9. Worker Flows and Vacancies as a Function of Establishment-Level Growth, Selected Periods**




*Source:* Authors' calculations using JOLTS establishment data pooled over the listed periods. Estimates are employment-weighted averages of the establishment-level growth rates within intervals that increase in width with the absolute value of the growth rate. Save for the zero growth point, reported estimates are smoothed using a 3-bin moving average.

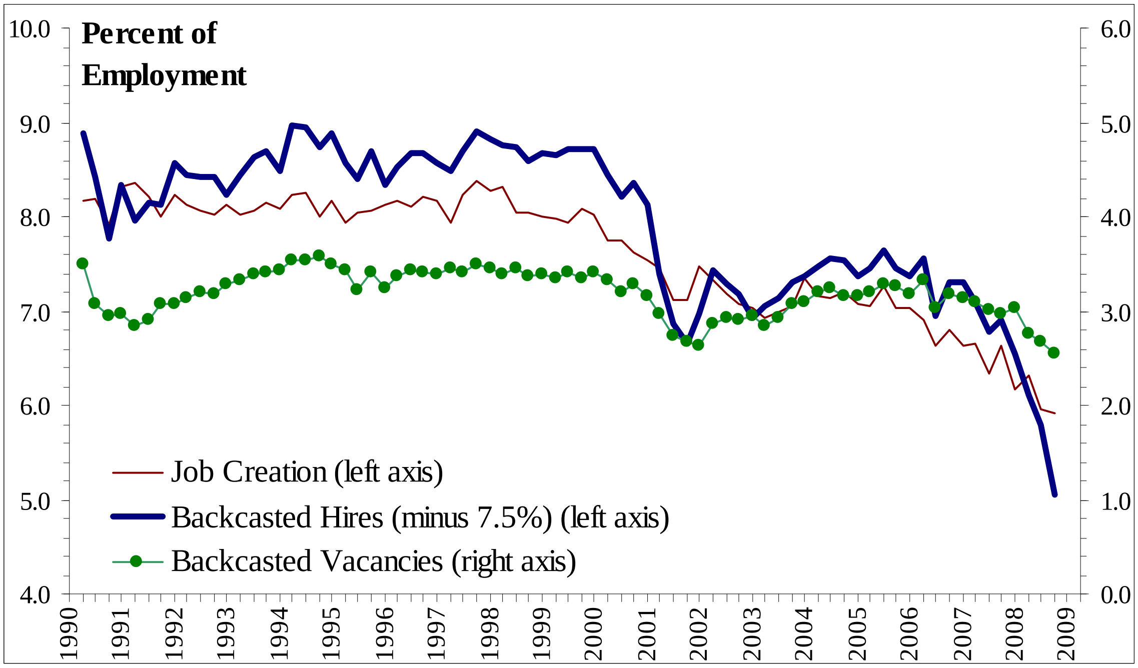
**Figure 10. Aggregate Flows Compared to Flows Generated by Alternative Statistical Models**



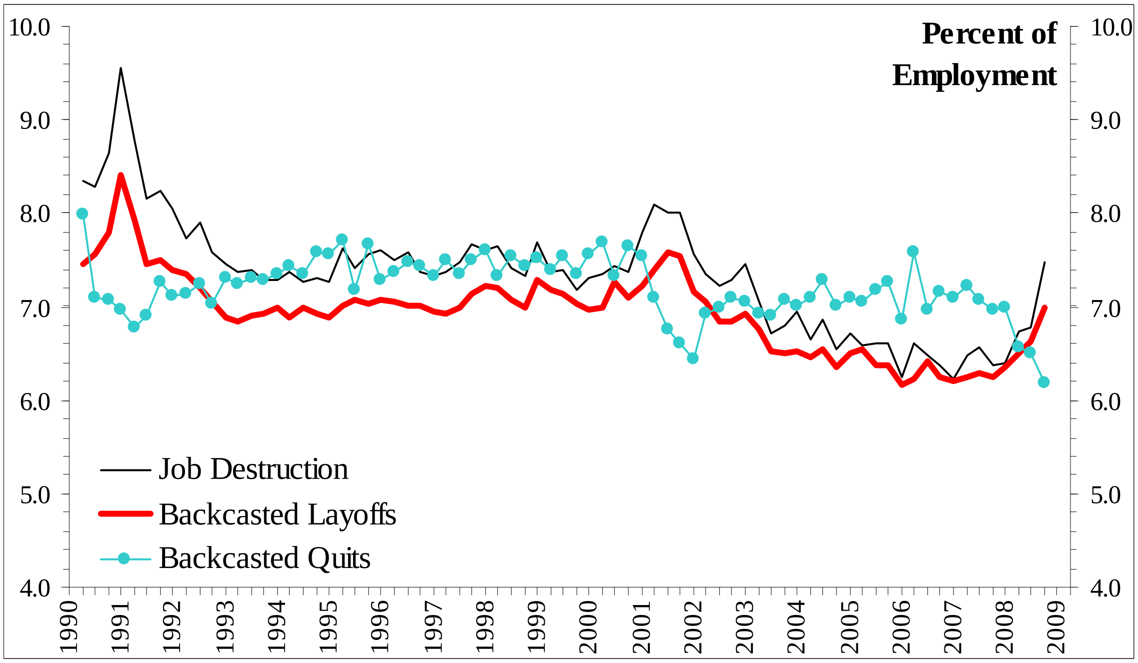

*Source:* Authors' calculations using estimates of worker flow-growth and vacancy-growth relationships derived from the JOLTS establishment data interacted with growth rate densities derived from BED data for 2001Q3 – 2008Q4. See text for details of the methodologies. Estimates are seasonally adjusted.

**Figure 11. Backcasted Worker Flows and Vacancies Implied by the Baseline Specification, Private Employment**

*(a) Hires, Vacancies, and Job Creation*



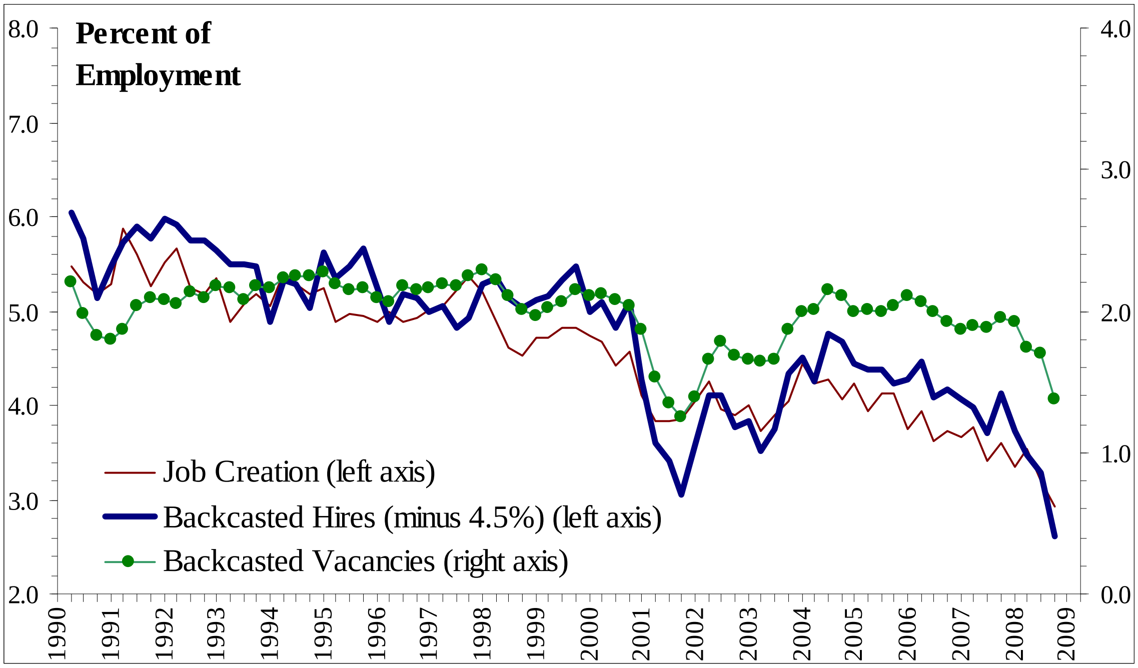

*(b) Layoffs, Quits, and Job Destruction*



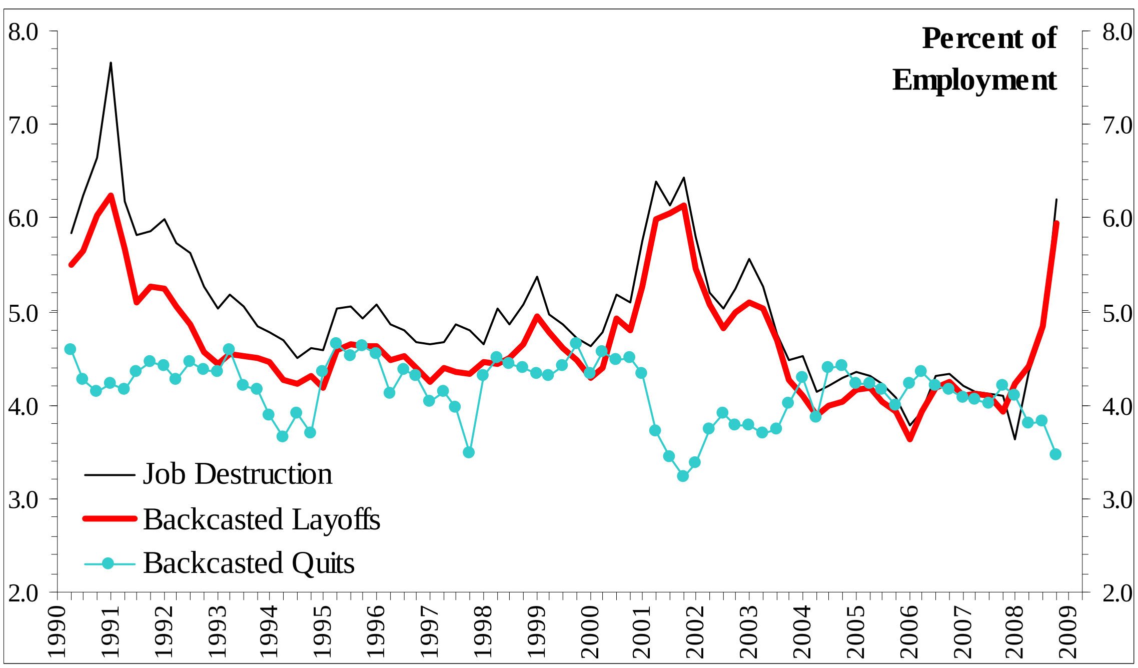

*Sources:* Worker flow and vacancy rates are authors' calculations using estimates of worker flow-growth and vacancy-growth relationships derived from the JOLTS establishment data interacted with growth rate densities derived from BED data. Job creation and destruction rates are authors' tabulations directly from the BED data. All estimates are seasonally adjusted.

**Figure 12. Backcasted Worker Flows and Vacancies Implied by the Baseline Specification, Manufacturing Employment**

*(c) Hires, Vacancies, and Job Creation*




*(d) Layoffs, Quits, and Job Destruction*




*Sources:* Worker flow and vacancy rates are authors' calculations using estimates of worker flow-growth and vacancy-growth relationships derived from the JOLTS establishment data interacted with growth rate densities derived from BED data. Job creation and destruction rates are authors' tabulations directly from the BED data. All estimates are seasonally adjusted.

**Table 1. Changes in the Cross-Sectional Distribution of Establishment-Level Growth Rates over Time, Selected Years**

| **Fraction of Employment at…** | **1991** | **1998-99** | **2001-02** | **2008** |
|---|---|---|---|---|
| Contracting and Closing Establishments | 43.1 | 41.0 | 43.7 | 43.7 |
| Establishments with No Net Change | 14.6 | 13.9 | 14.6 | 15.8 |
| Expanding and Opening Establishments | 42.3 | 45.1 | 41.7 | 40.4 |

*Source:* Authors' tabulations using BED establishment data pooled over the listed years. Estimates are the share of employment at establishments that expanded, contracted, or had no net employment change, on average, during the quarters of the listed years.

**Table 2. Within-Sample Fit of Estimated Worker Flows**

| | **Implied from Growth Rate Density** | **Implied from Baseline Specification** | **Implied from Flexible Specification** |
|---|---|---|---|
| *Private Employment* | | | |
| Hiring Rate | .622 | .880 | .877 |
| Separation Rate | .307 | .769 | .765 |
| Quit Rate | .001 | .691 | .682 |
| Layoff Rate | .803 | .831 | .832 |
| Vacancy Rate | .013 | .470 | .471 |
| | | | |
| *Manufacturing* | | | |
| Hiring Rate | .520 | .832 | .831 |
| Separation Rate | .361 | .710 | .706 |
| Quit Rate | .091 | .721 | .711 |
| Layoff Rate | .877 | .897 | .897 |
| Vacancy Rate | .206 | .503 | .499 |

*Notes:* Table reports the R-squared values from the regression of the aggregate estimate of the rate implied from the listed specification on the rate's actual aggregate estimate ($T$ = 30, 2001Q3-2008Q4). See text for details of the estimation and aggregation methodologies.

**Table 3. Fit of Regressions of Worker Flows on Aggregate Employment Growth**

| | Actual Rate on Aggregate Growth Variables | Actual Rate on Growth Variables and Baseline Series |
|---|---|---|
| *Private Employment* | | |
| Hiring Rate | .793 | .947<br>[.000] |
| Separation Rate | .556 | .886<br>[.000] |
| Quit Rate | .701 | .802<br>[.003] |
| Layoff Rate | .668 | .860<br>[.000] |
| Vacancy Rate | .483 | .493<br>[.946] |
| | | |
| *Manufacturing* | | |
| Hiring Rate | .868 | .889<br>[.052] |
| Separation Rate | .788 | .795<br>[.402] |
| Quit Rate | .756 | .756<br>[.861] |
| Layoff Rate | .869 | .901<br>[.014] |
| Vacancy Rate | .519 | .526<br>[.883] |

*Notes:* The first column of the table reports the R-squared values from the regression of the actual aggregate estimate of each rate on the three aggregate growth rate terms from our baseline specification (see equation (XX) for more details.) The second column of the table reports the R-squared values from the regression of the actual rate on the three growth rate terms and the aggregate series implied from our specification, along with the *p*-value on the coefficient on the baseline rate. For both regressions, $T$ = 30 over 2001Q3 - 2008Q4. See text for details of the estimation and aggregation methodologies.