

## **Labor Market Flows 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) and job gains and losses at the employer level. Partly motivated by these theories, we exploit establishment-level data from U.S. sources to study the relationship between worker flows and job flows in the cross section and over time. The data exhibit strong, highly nonlinear relationships of hiring, quit and layoff rates to employer growth in the cross section.

We also develop a framework for evaluating how well various models and views fit the patterns in the data. Aggregate fluctuations in hires and layoffs are well captured by empirical specifications that impose a tight cross-sectional link between worker flows and job flows. Aggregate fluctuations in quits are not. Allowing the cross-sectional quit relationship to vary with aggregate conditions leads to remarkable improvement in fit, consistent with models of labor market dynamics that assign a major role to endogenous quit behavior.

Keywords: worker flows, job flows, search and matching models, employment fluctuations, cyclicalities of quits

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## **I. Introduction**

Many theoretical models of labor market search imply a tight link between worker flows (hires and separations) and job gains and losses at the employer level. Partly, motivated by these theories, we exploit establishment-level data from U.S. sources to study the relationship between worker flows and job flows in the cross section and over time. At the economy-wide level, we know that hires, quits and job creation are procyclical, while layoffs and job destruction are countercyclical. Total separations are nearly acyclical, reflecting roughly offsetting movements in quits and layoffs.<sup>1</sup>

Previous work has not produced a thorough and convincing explanation of these cyclical patterns. Part of the reason is that the measurement of worker flows and job flows typically proceeds from different data sources, so the respective measures are comparable only at a high level of aggregation.<sup>2</sup> In this paper, we overcome this problem by using data from the relatively new Job Openings and Labor Turnover Survey (JOLTS) at both the micro and aggregate levels. The JOLTS data permit internally consistent measurement and analysis of hires, separations, quits, layoffs, job creation and job destruction at the establishment and aggregate level.

We combine the JOLTS data with comprehensive administrative data from the Business Employment Dynamics (BED) to document a new set of facts about the relationship between job flows and worker flows in the cross section and over time. We show that worker flows exhibit powerful, highly nonlinear relationships to employer

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<sup>1</sup> See Davis and Haltiwanger (1999) and Davis, Faberman and Haltiwanger (2006) for evidence and discussion. The empirical regularities discussed in this first paragraph are present in Figures 1 and 2 using the JOLTS and BED data covering the U.S. private sector.

<sup>2</sup> Even at high levels of aggregation, standard sources of data on worker flows and job flows also differ in scope, sampling frequency and other respects that hinder direct comparisons.

growth rates in the cross section. That is, in the cross section there are tight links between job flows and worker flows. In addition, we show that these cross-sectional relationships vary systematically with the cycle in a manner that helps understand the aggregate behavior of job and worker flows.

To put structure on the empirical analysis, we begin with models in the spirit of the seminal work of Mortensen and Pissarides (1994) (hereafter MP) that imply a tight link between job flows and worker flows in the cross section and over time. We develop an empirical approach that permits assessing how closely models with tight links fit the data. Using this as a starting point, we consider alternative empirical specifications that are motivated by models that imply departures from tight links between worker and job flows (e.g., models that emphasize the role of on-the-job search). We evaluate how well these alternative empirical specifications fit both the establishment-level evidence at the micro level as well as their ability to generate the observed aggregate movements in worker flow rates.

As noted, our study exploits two major establishment-level data sources. The JOLTS data provides monthly, establishment-level data on worker flows, vacancies and employment changes starting in December 2000. We cumulate the monthly data to the quarterly frequency to conform to our other data source. We rely on the BED to obtain the cross-sectional distribution of establishment-level employment growth rates. The BED data contain observations on all private sector establishments covered by state unemployment insurance programs. They are currently available from 1990 through the middle of 2009. We use the BED data to generate the cross-sectional distribution of establishment-level growth rates for each quarter it covers.

Figures 1 and 2 plot quarterly, seasonally adjusted aggregate time series for worker flows and vacancies from the JOLTS and aggregate job creation and destruction rates from the BED.<sup>3,4</sup> All rates 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 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.<sup>5</sup> Vacancies rose until mid-2007 and then fell sharply. In addition, both hiring and vacancy rates appear more volatile than the job creation rate. Our study explores the micro level sources of these aggregate movements.

We show that, in the cross-section at the micro level, hiring and separation rates exhibit powerful elements of the “iron-link” behavior implied by MP-style search models. That is, the behavior of hiring is tightly linked to that of job creation, and the behavior of separations is tightly linked to that of job destruction. When plotted as a function of the establishment-level growth rate, hires and separation rates exhibit nonlinear, “hockey stick” shapes. The hires relation is flat to the left of zero growth

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<sup>3</sup> We derive our “JOLTS” series by combining the cross-sectional relationships of worker flows to establishment-level growth in JOLTS with the employment growth densities in the BED. Combining the two data sources in this way exploits the comprehensive nature of the BED to overcome certain weaknesses in the JOLTS sample design. Our approach follows the methodology of Davis, Faberman, Haltiwanger and Rucker (2010) closely and is described in more detail in our empirical section.

<sup>4</sup> While our study focuses on worker flows, we include the aggregate vacancy rate series for comparison. In future work, we hope to extend our analysis to include vacancies. Our recent work studying hiring and vacancy patterns (see, Davis, Faberman and Haltiwanger (2010)) highlights the need to address stock-flow issues in exploring the relationship between vacancy stocks and worker and job flows.

<sup>5</sup> It is apparent in Figures 1 and 2 that there is a downward trend in job creation and destruction. The causes and consequences of this downward trend are of independent interest (see, Davis, Faberman, Haltiwanger, Jarmin and Miranda (2010) for further discussion). Note, further that Figures 1 and 2 are consistent with the cyclical patterns discussed in the opening paragraph. The standard deviations of the linear detrended job creation and destruction series from the BED are 0.30 and 0.46 respectively (similar relative volatility patterns hold using HP filtered series). Also, note that over the JOLTS sample period the standard deviation of hires and job creation are 1.18 and 0.44, respectively (linear detrended hires and job creation series have standard deviations of 0.84 and 0.30 respectively).

(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.

Turning to the components of separations, quits are higher at contracting than expanding businesses with the lowest quit rate at businesses with no change in employment. Layoffs are also substantially higher at contracting businesses than expanding businesses with again the lowest layoff rate at businesses with no change in employment. Much of the variation across businesses for both quits and layoffs is for contracting businesses. Both quits and layoffs rise with job destruction at establishments that contract moderately, while layoffs dominate the adjustment margin among rapidly contracting establishments.

The cross-sectional relationship of layoffs to employment growth is rather stable over time. In contrast, the cross-sectional quit relationship varies markedly with aggregate conditions. The quit relation shifts downward when aggregate conditions are weak, especially at contracting establishments. The time-varying behavior of the cross-sectional quit relation is a notable departure from the implications of the standard MP search models.

As we discuss below, several theoretical models provide guidance for why we observe departures from the iron-link relationships between worker flows and job flows in standard MP models. 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 move away from bad matches with a propensity that depends on aggregate conditions. When aggregate conditions are weak, workers tend to remain in poor matches, which Barlevy refers to as the “sully” effect of recessions. To the extent that poor matches are more prevalent at shrinking establishments, these arguments suggest that shifts over time in the cross-sectional quit-growth relationship disproportionately affect contracting establishments.

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 about match quality. 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. The data support this hybrid view of the cross-sectional relationship between hires and employer growth.

Motivated by theoretical ideas, we develop parsimonious statistical models for how worker flows vary in the cross section. These statistical models serve three objectives. First, they provide useful guidance in evaluating and developing theoretical models of labor market flows. As a related point, the statistical models deliver useful

inputs for calibrating theoretical models. Second, they allow us to investigate whether tracking the cross-sectional distributions adds much to our understanding of aggregate movements in labor market flows. Third, they provide a framework for obtaining out-of-sample (i.e., historical) predictions for the aggregate time series of hires, quits and layoffs.

Our statistical models underscore the importance of accounting for changes over time in the relationships of the quit rate to employer-level growth in the cross-section. When we impose time-invariant relations of worker flows to employment growth rates in the cross section, the statistical model performs reasonably well in tracking the aggregate movements of the hires rate and the layoff rate, but it fails miserably in tracking the aggregate behavior of the quit rate. Consequently, it also does poorly in predicting the aggregate separations rate, so much so that the model predicts a counterfactually increasing separation rate during the most recent downturn. When we move to a specification that allows the worker flow-employer growth relationships to vary with aggregate conditions, our ability to track aggregate quits and separations improves dramatically.

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 (2010).

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. We then consider models that endogenize the worker's quit decision, as in Faberman and Nagypál (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 investigates how well they account for worker flows in the cross section and over time. Section 5 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:

$$e_{it} = e_{it-1} + h_{it} - l_{it} - q_{it}, \quad (1)$$

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 a tight, “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 relationships is limited. Several subsequent, models, however, have extended the Mortensen-Pissarides framework to permit multiple-worker firms.<sup>6</sup> 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 firing are the result of endogenous decisions by the establishment.<sup>7</sup> Establishments and

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<sup>6</sup> 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.

<sup>7</sup> The labeling of the endogenous separations as layoffs and the exogenous separations as quits in this setting is consistent with the long tradition of denoting employer-initiated separations as layoffs and worker-initiated separations as quits (see, e.g., McLaughlin (1990,1991)). McLaughlin (1990,1991) shows how the separations induced by idiosyncratic profit shocks will be employer-initiated separations and separations induced by shocks to workers outside opportunities will be worker-initiated separations under

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.<sup>8</sup>

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

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

where  $\bar{q}$  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.<sup>9</sup> This equation exploits the relationship between hires and vacancies given by

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

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

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reasonable assumptions about information without necessarily inducing any inefficient separations. In the CHW setting, the quits are exogenous so the formal link between outside opportunities and quits is not present but our later characterization of the baseline model with procyclical quits is consistent with this approach. We note, however, that many models (e.g., FN) with on-the-job search have the feature that quits become a function of idiosyncratic profit shocks. As we discuss below, the distinction between quits and layoffs in terms of the sources of the shocks becomes more ambiguous in such models.

<sup>8</sup> 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.

<sup>9</sup> Throughout the paper we apply the convention of using capital letters to denote aggregate variables and lowercase letters to denote micro-level variables.

operates. Higher realizations lead to vacancy posting, lower realizations lead to layoffs, 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 in the distribution, while parameters such as fixed adjustment costs determine its shape. At the same time, the model exhibits the iron-link mapping between establishment-level employment growth and hiring, layoffs, and quits that is characteristic of the standard MP model.

We depict this mapping in Figure 3. The Figure 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.<sup>10</sup>

In this model, the cross-sectional distribution of employment growth rates at the establishment-level fully determines the aggregate fluctuations of hires and layoffs with

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<sup>10</sup> 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. We also note that with stochastic quits the inflection point will vary across establishments.

some straightforward but interesting implications. For example, modest recessions characterized by leftward shifts of the cross sectional distribution from a mode to the right of zero to a mode around zero will exhibit more volatility in hires than layoffs. In contrast, sharp recessions characterized by a more pronounced leftward shift in the cross sectional distribution (so that the mode becomes negative in the downturn, with substantial mass of contracting establishments) will exhibit a sharper rise in layoffs. The point is that the highly nonlinear micro relationships depicted in Figure 3 imply a nonlinear relationship between the cross sectional distribution and aggregate worker flows. Below, we more formally develop the aggregate implications of the relationship between aggregate worker flows and the cross sectional distribution for this and subsequent models.

## *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, which shows that as the quit rate shifts, 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. The general insight from Figure 4 is that, not surprisingly, as the

pattern of quits changes so will the accompanying patterns of hires and layoffs. 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, these arguments imply 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 implications of Figure 3 and relaxed iron link implications of Figure 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 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 model 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 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

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

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. Moving away from the accounting identity requires behavioral models of the micro level relationships between worker flows and growth.

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

$$\begin{aligned}\bar{H}_t &= \sum_g f_t(g) \bar{h}(g), \\ \bar{L}_t &= \sum_g f_t(g) \bar{l}(g), \text{ and} \\ \bar{Q}_t &= \sum_g f_t(g) \bar{q} = \bar{q} \quad \forall t.\end{aligned}\tag{5}$$

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  $\bar{q}$ .

As we relax the iron link relationships of the CHW model, Figure 4 illustrates that micro level relationships in equation (5) 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

$$\begin{aligned}\tilde{H}_t &= \sum_g f_t(g) \tilde{h}_t(g), \\ \tilde{L}_t &= \sum_g f_t(g) \tilde{l}_t(g), \\ \tilde{Q}_t &= \sum_g f_t(g) \tilde{q}_t(g) = \tilde{q}_t, \text{ and}\end{aligned}\tag{6}$$

The equations in (6) 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, and quits 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). For layoffs, the establishments are asked to identify involuntary separations

initiated by the employer.<sup>11</sup> For quits, the establishments are asked to identify employees who left voluntarily (excluding retirements which are captured in the other separations category). The survey begins in December 2000 and is representative of all nonfarm employment.<sup>12</sup>

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.<sup>13</sup>

We use a sample of JOLTS data that cover January 2000 through June 2009 and a sample of BED data that cover 1990Q2 through 2009Q2. Both cover all private sector employment. Due to data access restrictions, our BED sample excludes several U.S. states.<sup>14</sup> 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

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<sup>11</sup> The JOLTS survey instructions for layoffs and discharges includes the following examples: layoffs with no intent to rehire, layoffs lasting more than 7 days, discharges resulting from mergers, downsizing, or closings, firings or other discharges for cause, terminations of permanent or short-term employees, terminations of seasonal employees (whether or not they are expected to return next season)

<sup>12</sup> 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>.

<sup>13</sup> 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.

<sup>14</sup> These states are Connecticut, Florida, Massachusetts, Michigan, Mississippi, New Hampshire, New York, Pennsylvania, and Wyoming. The patterns of job creation and destruction at the aggregate level from the BED that excludes these states closely mimics the analogous patterns from the published statistics that include these states.

employment growth rate distributions derived from the BED. Consequently, we need to construct quarterly worker flow 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 cyclical nature 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,  $\theta_{et,3}$ , we recover the correctly weighted data for each month of the quarter.

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 includes the 12<sup>th</sup> 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  $n_{e,t-1} = n_{et} - h_{et} + s_{et}$ , where  $h_{et}$  denotes total quarterly hires and  $s_{et}$  denotes total quarterly separations. We express our worker flow measures as

rates by dividing them by  $(1/2)[n_{et} + n_{e,t-1}]$ , which is the average employment measure of Davis, Haltiwanger, and Schuh (1996).

Another issue is that the JOLTS data do not include 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, Faberman, Haltiwanger and Rucker (2010). Their approach takes the employment density at opening and closing establishments from the BED as given and assumes the following values for their worker flow rates:

	<i>Hiring Rate</i>	<i>Quit Rate</i>	<i>Layoff Rate</i>	<i>Other Seps. Rate</i>
Entrants	200.0	0.0	0.0	0.0
Exits	0.0	12.4	180.2	7.4

We use the BED data to calculate the cross-sectional distribution of establishment-level growth rates for each quarter. 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 during the third month of the previous quarter. This measure is consistent with the net change implied by the  $n_{e,t-1}$  and  $n_{e,t-1}$  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, or growth rates across groups of establishments.

Figure 5 shows the cross-sectional distribution of establishment-level growth rates averaged across two periods in the sample: 2006Q1-2006Q4 and 2008Q3-2009Q2. Table 1 summarizes the density of employment at expanding, contracting and stable establishments pooled over selected periods that are chosen to roughly coincide with the recession and expansion periods of our sample. Figure 5 shows that roughly 15 percent of employment was at establishments with no employment change during 2006, and this fraction rose slightly during the 2008-09 period. The majority of employment in both periods is at establishments either expanding or contracting by 5 percent or less, with most employment (90 percent) at establishments with growth between -30 and 30 percent. Within this range, however, there is a clear leftward shift of the growth rate distribution from 2006 to the 2008-09 period. This shift is most apparent at establishments either expanding or contracting by 5 percent or less. The fraction of employment at establishments expanding by 5 percent or less falls from 24.1 percent to 21.8 percent, while the fraction of establishments contracting by 5 percent or less rises from 22.0 percent to 24.0 percent. Table 1 shows that such movements are characteristic throughout our sample period. 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**

##### *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 II. We then assess how well these derived aggregate series fit the actual time-series of aggregate worker flow rates.

Our framework rests on estimating relationships between worker flows 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 aggregate worker flows.

We begin by estimating the mean worker flow rates for all establishments whose growth rate falls within some interval.<sup>15</sup> 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, or quits 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 rates by interacting the  $w_t(g)$  from the JOLTS with the quarterly growth rate distributions derived from the BED data.<sup>16</sup> Let  $f_t(g)$  denote the share of employment within growth rate interval  $g$  during quarter  $t$ . The aggregate estimate of each worker flow rate is then

$$W_t = \sum_g f_t(g) w_t(g). \quad (7)$$

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<sup>15</sup> 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 rates for entrants and exits when we aggregate the micro-level relationships to the macro level.

<sup>16</sup> 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, Haltiwanger and Rucker (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.

We next turn to out statistical models of the micro level relations between 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,

$$w_t(g) = \alpha(g) + \varepsilon_t^D(g). \quad (8)$$

Since they only depend on  $\hat{\alpha}(g)$ , the predicted values from this regression,  $\hat{w}^D(g)$ , will be constant across all quarters. 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. Allowing 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

$$\hat{W}_t^D = \sum_g f_t(g) \hat{w}^D(g). \quad (9)$$

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

$$w_t(g) = \alpha(g) + \beta_1 G_t^+ + \beta_2 G_t^- + \beta_3 \Delta G_t + \beta_4 JF_t + \varepsilon_t^B(g), \quad (10)$$

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,  $\Delta G_t$  is an accelerator term that measures the change aggregate net employment growth rate, and  $JF_t$  is the aggregate job-finding rate of the unemployed.<sup>17</sup> 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.

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

$$\hat{W}_t^B = \sum_g f_t(g) \hat{w}_t^B(g). \quad (11)$$

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 aggregate net employment growth rate and job-finding rate and a set of class variables,  $D(\tilde{g})$ , that categorize the growth rate intervals into several groups,<sup>18</sup>

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<sup>17</sup> 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. We measure the job-finding rate as the fraction of unemployed who become employed from one month to the next, as measured in the Current Population Survey.

<sup>18</sup> The class variables aggregate the  $g$  growth rate intervals into five groups, with two dummy variables representing expansions or contractions of up to 10 percent of employment, respectively, two dummy



$$w_t(g) = \alpha(g) + \beta_1 G_t^+ + \beta_2 G_t^- + \beta_3 \Delta G_t + \beta_4 JF_t + \delta_1 D(\tilde{g})G_t + \delta_2 D(\tilde{g})JF_t + \varepsilon_t^F(g) \quad (12)$$

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

$$\hat{W}_t^F = \sum_g f_t(g) \hat{w}_t^F(g). \quad (13)$$

#### *IV.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 a straightforward comparison to Figure 3. Figure 6 presents the fixed cross-section estimates for hiring, total separation, layoff, and quit 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).

Figure 6 shows that the hiring rate exhibits a strong, nonlinearly increasing relationship with growth at the establishment level. When interpreting the figure, 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. Separation rates exhibit strong, nonlinearly decreasing relationships with growth, though there are notable differences between the relationships

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variables representing  $g < -10$  percent and  $g > 10$  percent, respectively, and one dummy variable representing zero-growth.

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. The quit rate is, however, higher for contracting establishments relative to expanding establishments. 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 predictions of an iron link relation between worker flows and employer growth of the CHW and MP-style models are broadly supported by these fixed effect estimates for hires and layoffs. 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 is not

centered at the average quit rate but at zero. As discussed in Section II, 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.

Table 2 shows how well our statistical models fit the micro-level worker flow rates. The first column reports the R-squared value for the fixed-cross section regression specified in (8). Movements in the cross-sectional growth rate density alone provide a very good fit of the micro-level hiring and separation rates, with R-squared values over 0.98. The latter is driven by a tight fit of the micro-level layoff rate (R-squared of 0.96). The quit rate has a considerably weaker fit than the other worker flows (R-squared of 0.86.)

While the estimates and fit of the fixed cross-sectional specification 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 (7)) to the aggregate flows implied from the fixed cross-section specification (from equation (9)).

The results of this exercise are plotted in Figure 7 for hires, total separations, layoffs, and quits.<sup>19</sup> 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.. The implied hiring rate from the cross sectional distribution alone exhibits a much more modest decline in hires than actual hires in the 2008-2009 period. The layoff rate implied by the cross sectional distribution alone more closely captures the actual rise in the layoff rate in this downturn.

The quit rate implied by the cross sectional distribution alone tracks the actual quit rate poorly. Consequently, the fit of the aggregate separation rate is also poor. In fact, the quit rate series implied by changes in the distribution alone is essentially a flat line for most of the period, and the specification predicts a counterfactual rise in the quit rate (and in the separation rate) during the 2008-09 downturn.

The first column of Table 3 quantifies what Figure 7 illustrates. It reports the mean squared error based on deviations from actual and predicted in the top panel and the

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<sup>19</sup> 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.

correlation between actual and predicted in the bottom panel for the fixed cross-section specification.<sup>20</sup> 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 rate. For the latter, the mean squared error is quite large and the correlation is negative. In turn, the poor fit for quits implies the overall fit for separations is relatively poor in spite of the relatively good fit of layoffs. Since quit rates exhibit considerable movement over the sample period, equation (4) suggests that it must be the case that the micro-level relationship of quits with growth vary over time. Whether these movements are simple functions of aggregate conditions is an open empirical question. If they do, our baseline and flexible specifications will capture such fluctuations.

#### *IV.C. Changes in the Cross-Sectional Relations Over Time*

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 over all quarters as in Figure 6, 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 8. 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.

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<sup>20</sup> The results are quite similar for the mean absolute error.

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 relationship, and to a lesser extent, the separation-growth relationship, over time are considerably more pronounced. The quit rate is lowest during the 2008-09 recession and highest during 2006. In addition, the differences are more pronounced for contracting establishments. Among expanding establishments, the difference in quit rates between 2006 and 2008-09 ranges between 1.5 and 2 percentage points.<sup>21</sup> 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 large differences are not present in comparing 2006 to the 2001-2003 period suggesting that the severity of the 2008-2009 downturn is important for the cyclical patterns of quits. These patterns reinforce the finding that 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.

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<sup>21</sup> In the next draft we will include statistical tests of the differences depicted in Figure 8.

#### *IV.D. 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. That is, we first estimate each model at the micro level (using (10) and (12), respectively) and then generate the aggregate flows using equations (11) and (13), respectively.

The second and third columns of Table 2 report the fit of the micro-level regressions from (10) and (12). The two specifications provide a marginal improvement in fit for hires, layoffs and total separations, but provide a notable improvement in for (by several percentage points) for quits. The second and third columns of Table 3 report the mean squared error (top panel) and correlations with the actual series (bottom panel) for the aggregate series predicted by the baseline and flexible specifications, respectively.

Introducing variation in the micro-level relations with the aggregate growth rate improves the predictive power of our implied aggregate series for all worker flows. For all predicted aggregate worker flows, the mean squared error decreases substantially. The improvement in fit for the aggregate quit and total separation rates is striking. Using our baseline specification, the mean squared error for quits declines by an order of magnitude and the correlation between the actual and predicted series goes from negative to 0.953.

The mean squared error for separations also falls substantially and the correlation between the actual and predicted series increases to 0.888. Interestingly, our flexible specification adds almost no improvement in fit over the baseline specification. There are very modest improvement in the mean squared error for quits and layoffs but no improvements in correlations for any of the series.

Figure 9 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 and quit rates, as the baseline series now accurately captures that large drop in hiring and quits observed in the actual series during 2008.

The improvement in fit for hires and quits are connected, which makes sense. The baseline model captures the procyclicality of quits and as quits decline in the recession, replacement hires also decline. This pattern helps account for the greater decline of hires relative to job creation in the 2008-2009 downturn as seen in Figure 2. That is, some of the decline in hires is associated with the decline in job creation (and captured by the shifts in the cross sectional distribution) while some of the decline in hires is associated with the decline in quits. In this respect, the procyclicality of quits drives a wedge between the iron link relationship between hires and job creation.

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. Consequently, the baseline model correctly predicts a declining and weakly procyclical total separations rate.

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 movements in the aggregate hiring, layoff, and quit rates. Put differently, the results suggest that by knowing the



shape *and cyclical movement* of the micro-level relationships between hires, layoffs, quits and establishment growth, along with movements in the cross-sectional distribution of establishment growth, one can account for almost all of the variation in aggregate worker flow rates. This is especially true for the aggregate quit rate, where movements in the cross-sectional density of growth alone account for a tiny fraction of its cyclical behavior.

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 4 presents these results. Column 1 of Table 4 shows the R-squared from regressing the aggregate flows on the aggregate net growth rate and job-finding rate terms that are included in the baseline specification. Column 2 of Table 4 shows the R-squared from adding as a regressor  $\hat{W}_t^B$ .<sup>22</sup> 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 and job-finding rate terms. This is not surprising since all of the worker flows have pronounced cyclical patterns. The highest R-squared value is for the quit rate, which is also not surprising given how much adding the aggregate variables to our statistical model improved the fit of the quit rate. Column 2

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<sup>22</sup> 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 4 where we use  $\hat{W}_t^D$  and obtain virtually the same results.

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, and layoffs it is at least an additional 13 percentage point increase in the R-squared and for separations it is as much a 27 percentage point increase. While still significant, the addition of  $\hat{W}_t^B$  in the quit rate specification only increases the R-squared by 4 percentage points.

#### *IV.D. Out-of-Sample Predictions of the Statistical Specifications*

A byproduct of our analysis is the ability to use our framework to generate estimates of aggregate worker flow rates out of sample. Specifically, given out-of-sample data on quarterly growth rate densities,  $f_t(g)$ , and aggregate employment growth,  $G_t$ , and job-finding rates,  $JF_t$ , one can use the estimates derived from our framework to create an out-of-sample 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 (10), we can generate the predicted values,  $\hat{w}_t^B(g)$ , for a time series as far back as we have data on  $G_t$  and  $JF_t$ . Then, given the aggregation specified in (11), we can generate an aggregate time series of worker flow rates for as far back as we have data on  $f_t(g)$ .

We employ exactly this approach in generating a predicted out-of-sample series of aggregate worker flows. We employ our baseline specification, since it provided the best fit of the actual estimates in the previous section. We use the same employment growth rate and job-finding rate series that we used in the baseline specification 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 predicted series.

The results for the private sector are in Figure 10. The top panel shows the behavior of the predicted series for the hiring 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 2008-09 recession. Of the two, the hiring rate is more cyclically volatile. The second panel of Figure 10 presents the predicted 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 2008-09. The predicted quit rate is strongly procyclical, exhibiting sharp declines at the onset of all three recessions.<sup>23</sup>

## **VI. Conclusions**

[TO BE COMPLETED]

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<sup>23</sup> In the next draft of the paper, we will exploit these out of sample predictions to compare to alternative estimates of layoffs and quits from the CPS.

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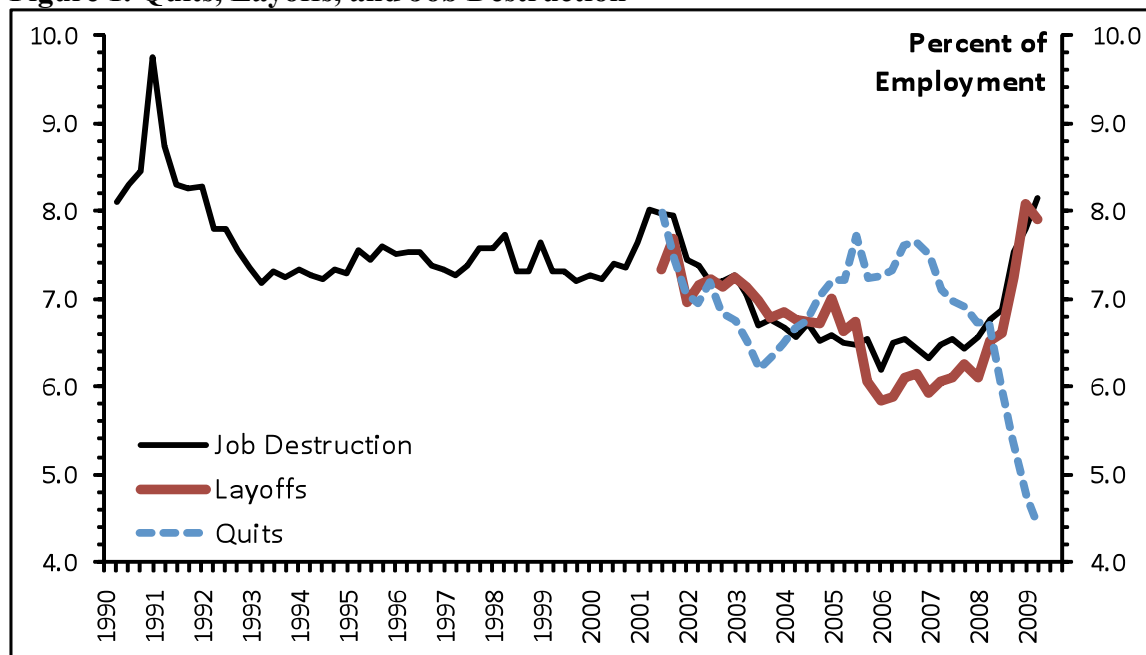
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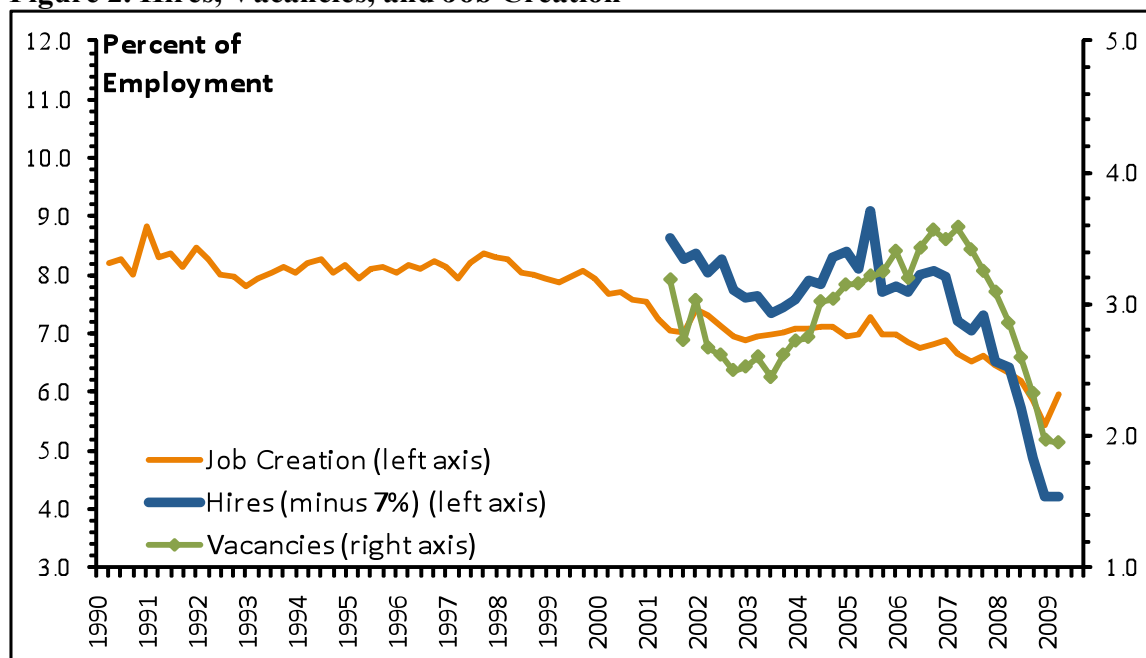
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**Figure 1. Quits, Layoffs, and Job Destruction**



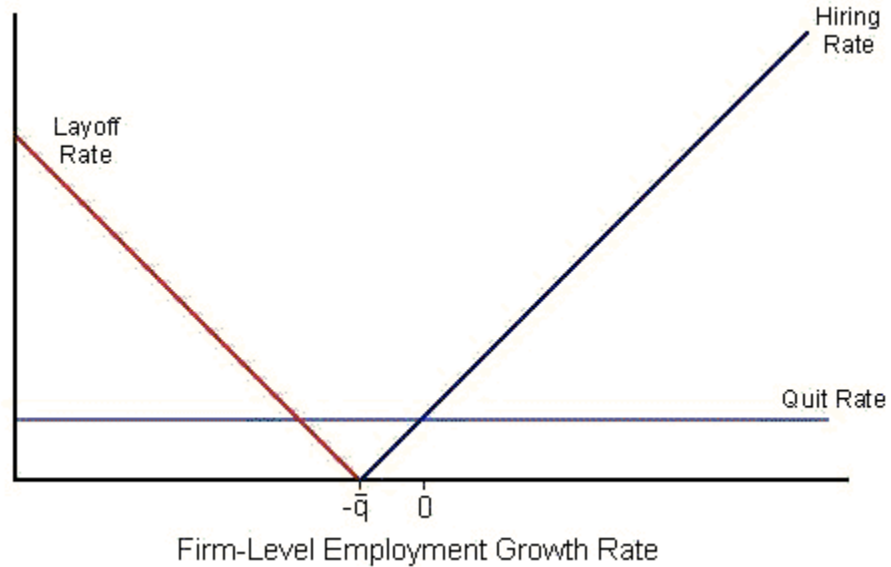
*Sources:* Quit and layoff rates (2001Q3 – 2009Q2) are authors' calculations using JOLTS establishment microdata weighted to an aggregate value for each quarter using growth rate densities from the BED. Job destruction rates (1990Q2 – 2009Q2) are authors' tabulations directly from the BED data. All estimates are seasonally adjusted. All rates are percentages of employment.

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



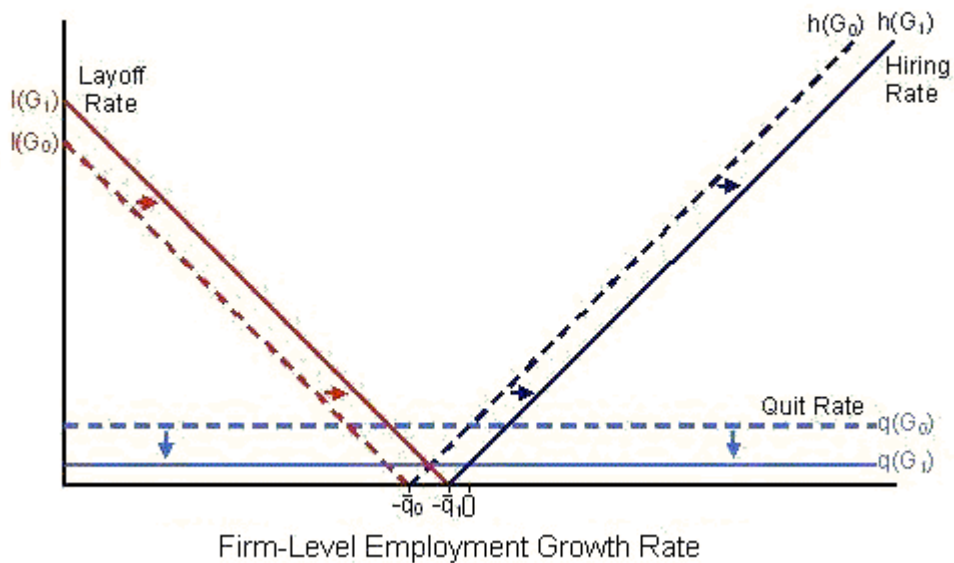
*Sources:* Hiring and vacancy rates (2001Q3 – 2009Q2) are authors' calculations using JOLTS establishment microdata weighted to an aggregate value for each quarter using growth rate densities from the BED. Job creation (1990Q2 – 2009Q2) rates are authors' tabulations directly from the BED data. All estimates 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**



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

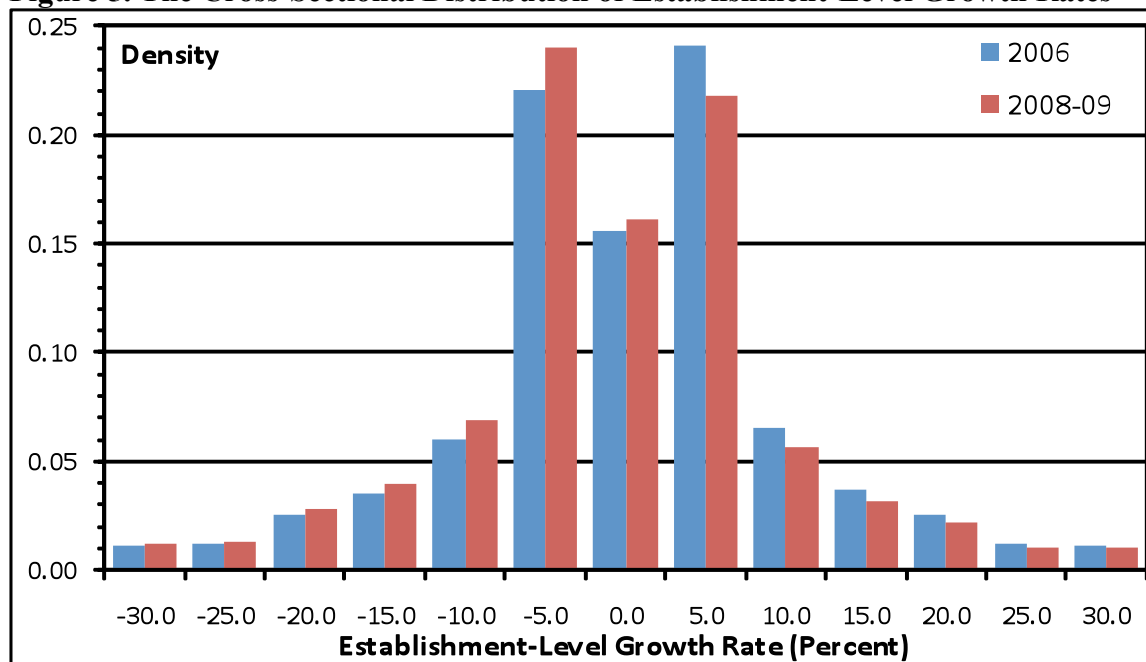
**Figure 4. Implied Worker Flows from a Search Model with Multi-Worker Firms, Time-Varying Exogenous Quit Rate**



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

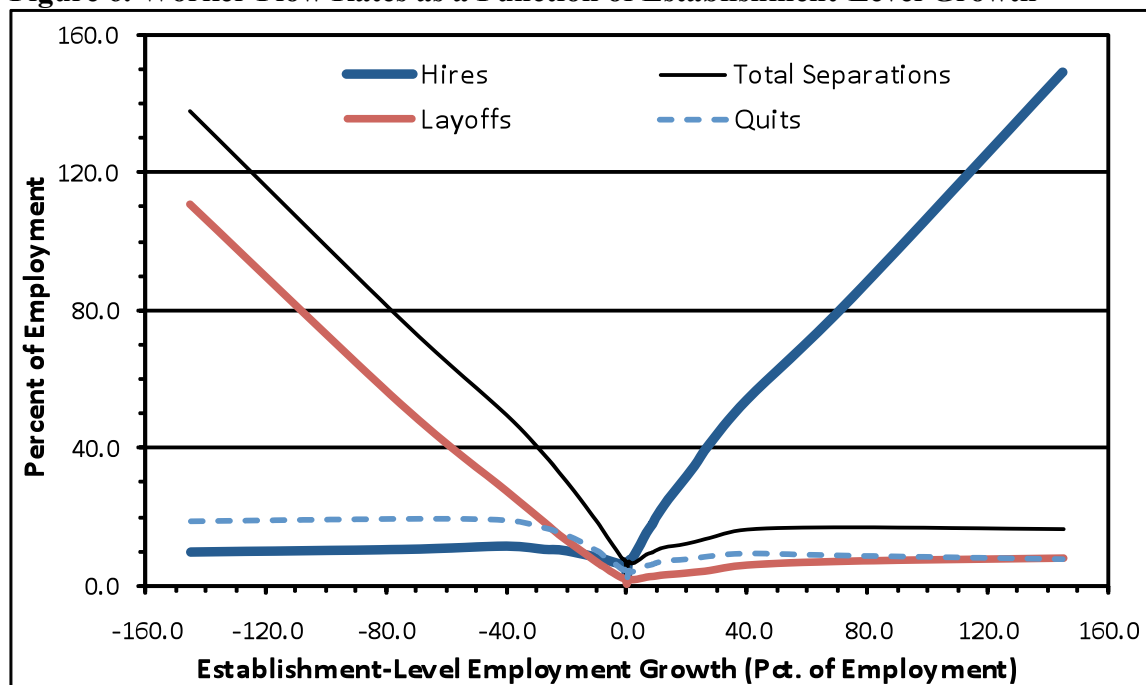


**Figure 5. The Cross-Sectional Distribution of Establishment-Level Growth Rates**



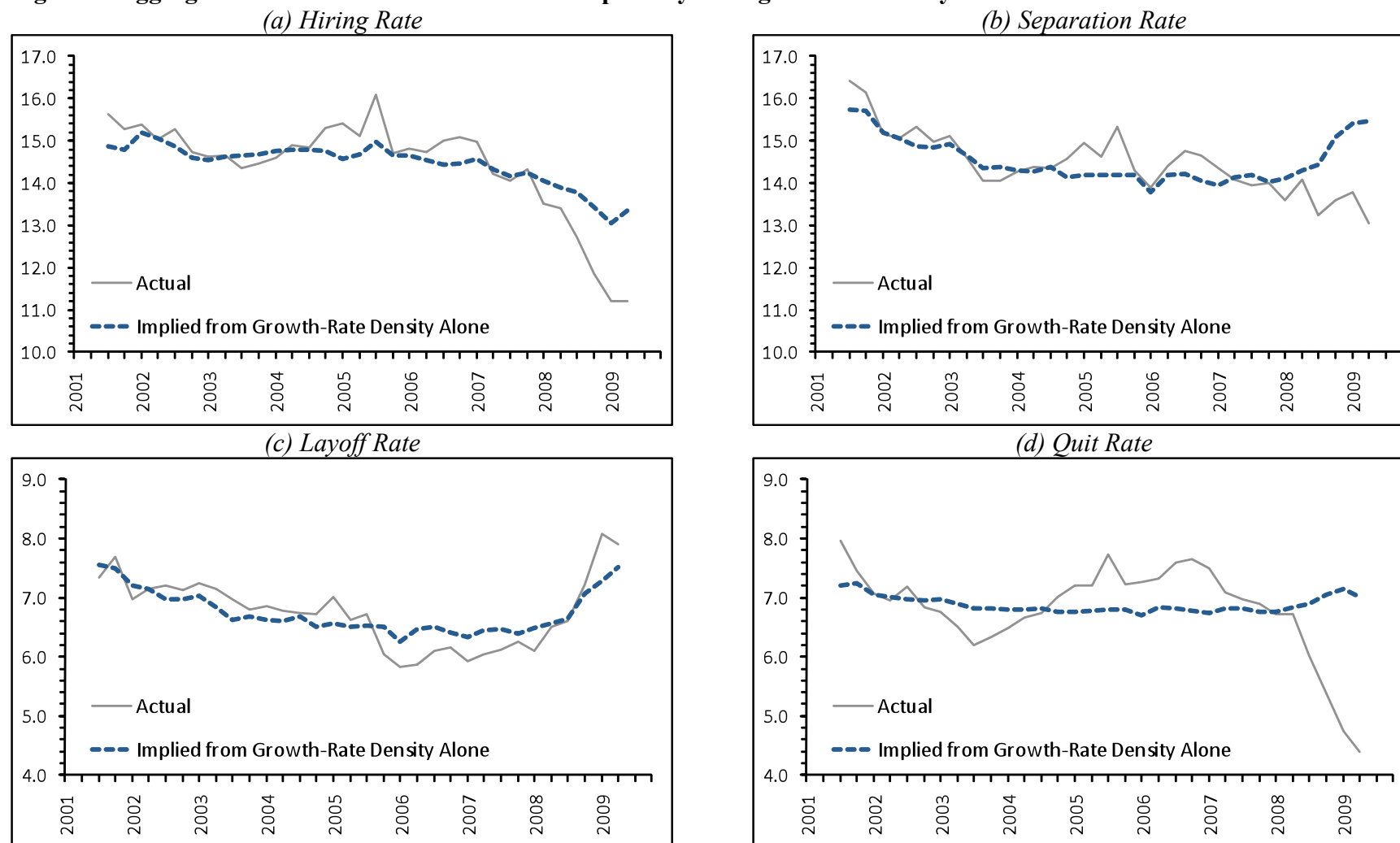
*Source:* Authors' tabulations using BED establishment data. Estimates are employment-weighted densities of establishment-level growth rates within fixed 5 percentage point intervals. The "2006" densities are pooled over 2006Q1-2006Q4 and the "2008-09" densities are pooled over 2008Q3-2009Q2.

**Figure 6. Worker Flow Rates as a Function of Establishment-Level Growth**



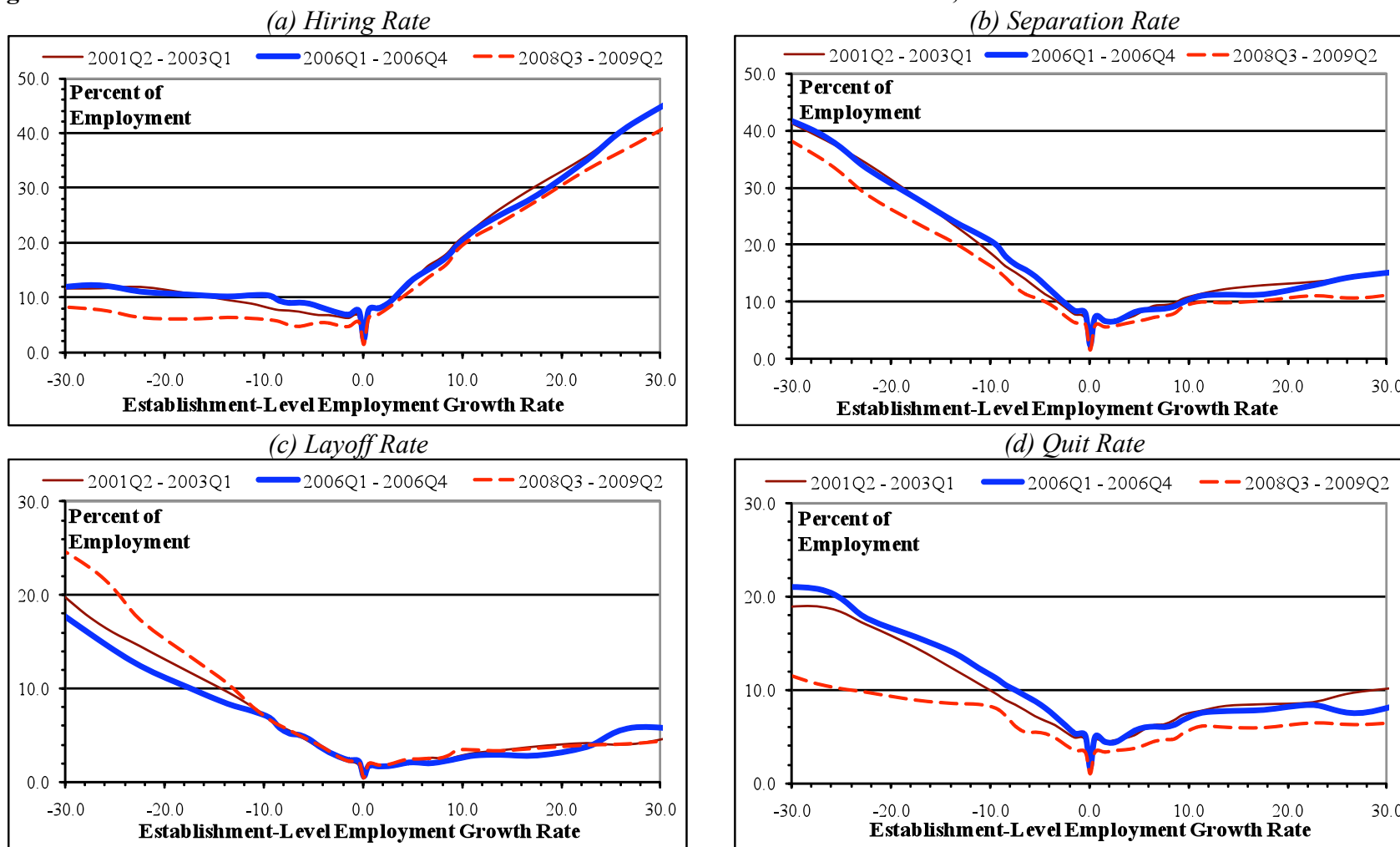
*Source:* Authors' calculations using JOLTS establishment data pooled over 2001Q1 – 2009Q2. Estimates are employment-weighted averages of the establishment-level growth rates within intervals that increase in width with the absolute value of the growth rate. Save for the endpoints and zero growth point,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

**Figure 7. Aggregate Worker Flows and Vacancies Implied by Changes in the Density of Establishment-Level Growth Rates**



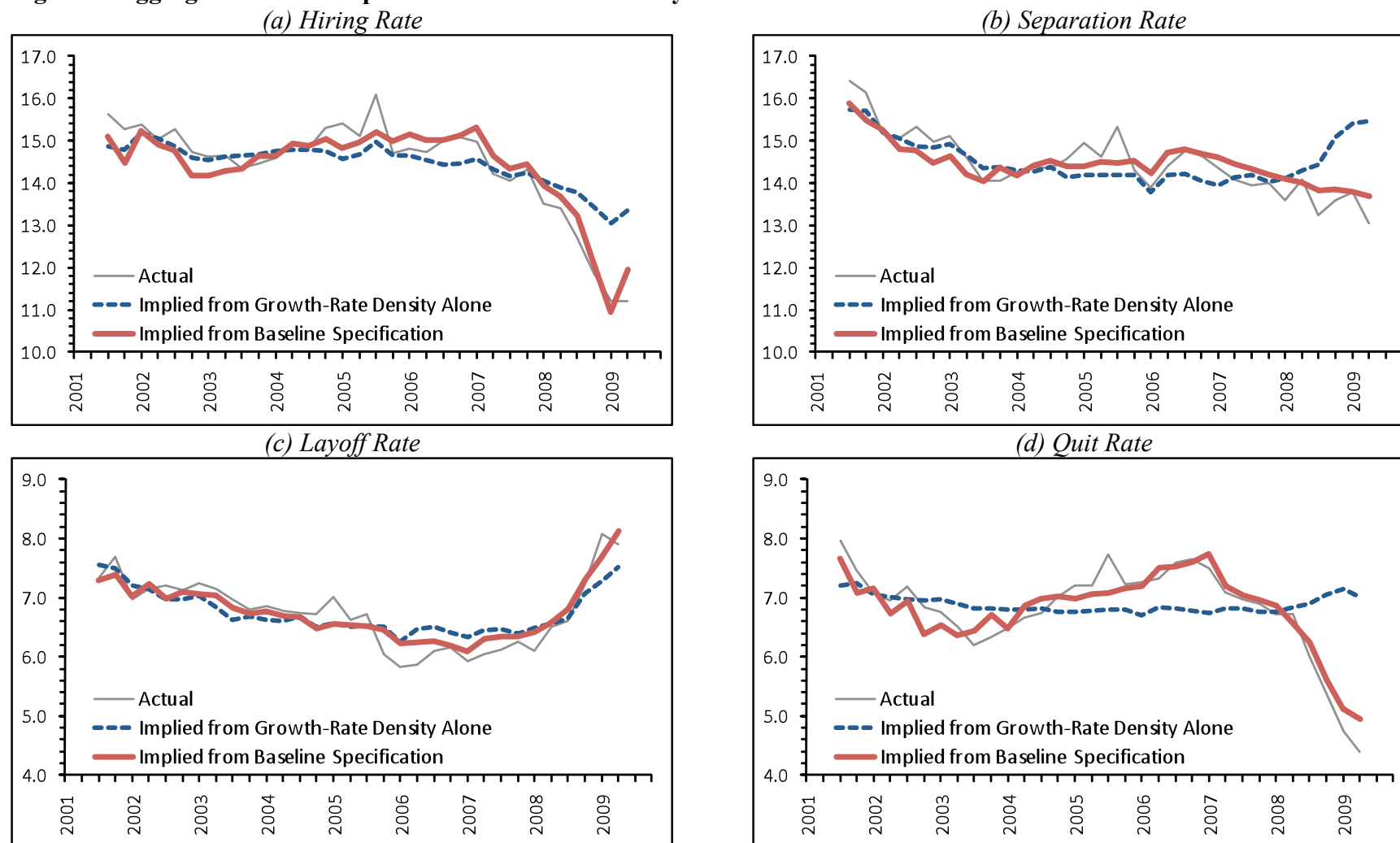
Source: Authors' calculations using the worker flow-growth and vacancy-growth relationships derived from JOLTS establishment data interacted with growth rate densities derived from BED data for 2001Q3 – 2008Q4. See text for details of the aggregation methodology. Estimates are seasonally adjusted.

**Figure 8. Worker Flows and Vacancies as a Function of Establishment-Level Growth, Selected Periods**



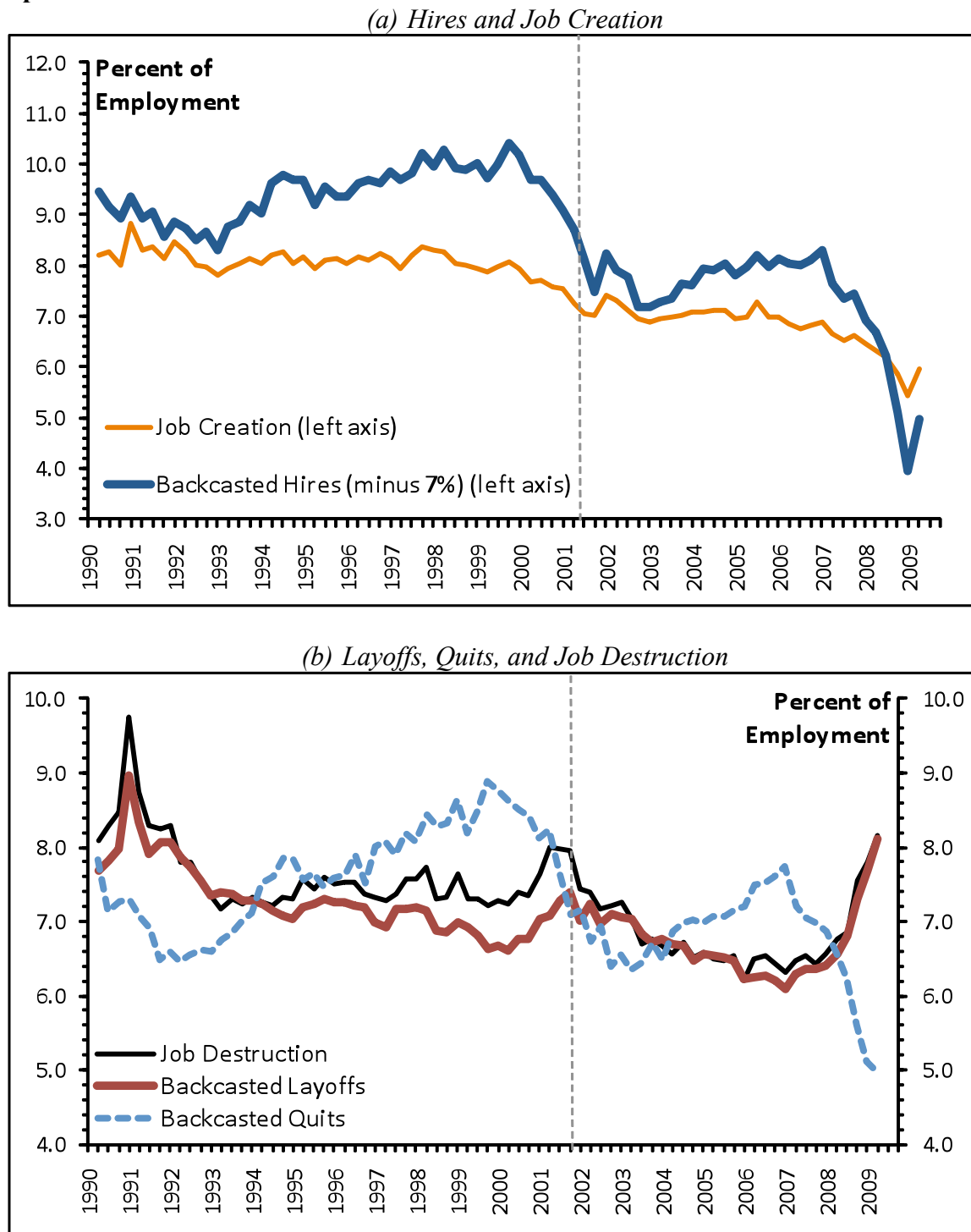
*Source:* Authors' calculations using JOLTS establishment data pooled over the listed periods. Estimates are employment-weighted averages of the establishment-level growth rates within intervals that increase in width with the absolute value of the growth rate. Save for the zero growth point, reported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

**Figure 9. 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 10. Out-of Sample Predictions of Worker Flows Implied by the Baseline Specification**



*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**

<b>Fraction of Employment at...</b>	<b>1991</b>	<b>1998-99</b>	<b>2001q2-2003q1</b>	<b>2006</b>	<b>2008q3-2009q2</b>
Contracting and Closing Establishments	43.4	40.9	43.8	40.6	44.9
Establishments with No Net Change	14.3	13.9	14.8	15.5	16.1
Expanding and Opening Establishments	42.2	45.2	41.4	43.8	39.0

*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. Micro-Level Fit of Statistical Worker Flows Models**

	<b>Implied from Growth Rate Density</b>	<b>Implied from Baseline Specification</b>	<b>Implied from Flexible Specification</b>
Hiring Rate	0.983	0.985	0.986
Separation Rate	0.980	0.983	0.984
Quit Rate	0.865	0.892	0.909
Layoff Rate	0.965	0.965	0.967

*Notes:* Table reports the R-squared values from the regression of the listed mean worker flow rate for each of 37 growth rate bins each quarter on the variables included in the listed statistical specification. Quarters cover 2001Q3-2009Q2. See text and equations (8), (10), and (12) for details of the variables included for each specification.

**Table 3. Aggregate Within-Sample Mean Squared Error and Correlations with Actual Series from Alternative Models**

	<b>Implied from Growth Rate Density</b>	<b>Implied from Baseline Specification</b>	<b>Implied from Flexible Specification</b>
<i>Mean Squared Error</i>			
Hiring Rate	0.523	0.156	0.162
Separation Rate	0.523	0.148	0.148
Quit Rate	0.680	0.065	0.058
Layoff Rate	0.103	0.049	0.044
<i>Correlation with Actual</i>			
Hiring Rate	0.944	0.945	0.940
Separation Rate	0.379	0.888	0.878
Quit Rate	-0.252	0.953	0.951
Layoff Rate	0.874	0.936	0.936

*Notes:* Table reports the mean squared (top panel) and mean absolute error (bottom panel) for each of the within sample predicted series for the alternative models. See the text for details of the estimation and aggregation methodologies.

**Table 4. Fit of Regressions of Worker Flows on Aggregate Employment Growth**

	<b>Actual Rate on Aggregate Growth Variables</b>	<b>Actual Rate on Growth Variables and Baseline Series</b>
<i>Private Employment</i>		
Hiring Rate	0.844	.972 [.000]
Separation Rate	0.655	.925 [.000]
Quit Rate	0.924	.961 [.000]
Layoff Rate	0.805	.943 [.000]

*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 text and equation (10) 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* = 32 over 2001Q3 – 2009Q2. See text for details of the estimation and aggregation methodologies.