On the Job Search and the Wage Distribution*

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Abstract

Estimates of the structural parameters of a job separation model derived from the theory of on-the-job search are reported in this paper. Given that each employer pays the same wage to observably equivalent workers but wages are dispersed across employers, the theory implies that an employer's separation flow is the sum of an exogenous outflow unrelated to the wage paid and a job-to-job flow that decreases with the employer's wage. The specification estimated allows worker search effort to depend on the wage currently earned. The results imply that search effort declines with the wage paid across employers, as the theory predicts, in our sample of matched employer-employee data based on the Danish Integrated Database for Labour Market Research (IDA) for the year 1994-1995. Furthermore, the estimates for the full sample and four occupation sub-samples explain the employment effect, defined as the horizontal difference between the distribution of wages earned and the distribution of wages offered.

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1 Introduction

Ample evidence suggests that employers pay observably similar workers different wages.[1] Two explanations are offered in the literature: Either employers pursue different wage policies and/or high wage firms attract more able workers.[2] Recent empirical studies by Abowd and Kramerz (2000a, 2000b), based on the analysis of matched employer-worker data for both the U.S. and France, conclude that the two are equally important as explanations of inter-industry differentials and that wage policy differences explain 70% of the size differentials.

It is surprising that so little is known about actual firm wage policies, other than that wage differences for observationally equivalent workers exist. Human resources textbooks, such as Milkovitch and Newman's *Compensation,* discuss many aspects of wages but provide no suggestions about what wage policy should be. Even the personnel economics literature, for example Eddie Lazear's *Personnel Economics for Managers*, has omitted discussion of optimal wage policy. This omission is surprising because the essential elements of a theory of wage policy have appeared in Samuelson's principles of economics textbook since 1951. Samuelson writes:

> **Wage policy of firms.** The fact that a firm of any size must have a wage policy is additional evidence of labor market imperfections....
>
> But just because competition is not 100 per cent perfect does not mean that it must be zero. The world is a blend of (1) competition and (2) some degree of monopoly power over the wage to be paid. A firm that tries to set its wage too low will soon learn this. At first nothing much need happen; but eventually it will find its workers quitting a little more rapidly than would otherwise be the case. Recruitment of new people of the same quality will get harder and harder...
>
> Availability of labor supply does, therefore, affect the wage you set under realistic conditions of imperfect competition. If you are a very small firm you may even bargain and haggle with prospective workers so as to not pay more than you

[1] Papers that provide empirical documentation include Krueger and Summers (1988), Katz and Summers (1989), Davis and Haltiwanger (1991), Doms, Dunne and Troske (1997), Abowd, Kramarz and Margolis (1999) and Oi and Idson (1999).

[2] Krueger and Summers (1987, 1988) emphasized the former explanation, while Murphy and Topel (1987) argued that unmeasured differences in individual ability are the principal explanation. Although work by Dickens and Katz (1987) and Gibbons and Katz (1992) attempted to resolve the debate, their efforts and those of others were hampered by lack of appropriate matched worker-employer data.

> have to. But if you are of any size at all, you will name a wage for each type of job; then decide how many of the applicants will be taken on;... [p. 554][3]

To the extent that wage policies differ, the typical worker has an incentive to seek out higher paying firms as suggested in Samuelson's comments. Indeed, on-the-job search motivated by wage dispersion provides an explanation for the commonly observed negative association between wages paid and separation flows in a cross section of firm.[4] The theory also implies that the wage earned increases in the stochastic sense with the elapsed duration since the worker's last non-employment spell as a consequence of job-to-job movement. This implied employment duration effect on the wage earned provides another interpretation of positive tenure and experience coefficients in empirical wage equations. Determining whether an employment effect exists and documenting that its quantitative size can be explained by a simple on-the-job search model is a major contribution of the paper.

The principal task of this paper is to estimate a structural model of worker separations based on the theory of on-the-job search using cross-firm observations on separation flows and to test the associated implications of the theory for the differences between the distribution wages offered and the distribution of wages earned. Burdett (1978) provides the original formal treatment of search on-the-job given wage dispersion across employers. In his model, employers pursue a stationary wage policy by assumption, an unemployed worker accepts the first offer received above some reservation wage, and an employed worker moves to a higher paying job when the opportunity arises. Mortensen (1990) demonstrates that the process by which workers move from one job to another will generate a distribution of wages earned over employed workers which stochastically dominates the distribution of wages offered applicants. The location difference between the two distributions, here called the employment effect, is a consequence of the fact that employed workers move up the "job ladder" by flowing from lower to higher paying jobs without intervening spells of non-employment. The formal model used in the estimation is a generalization of Burdett's theory that allows for an endogenously chosen search intensity. The data strongly supports the need for incorporating the choice of search effort into the model.

The data used in the estimation are based on the Danish Integrated Database for Labour Market Research (IDA). This matched employer-employee data source, a product of Statis-

[3] Samuelson's text adds and deletes information in each version. The material quoted here is not in the 1948 edition, appearing first in 1951 and remaining intact through the 1989 edition.

[4] For a review of this literature, see Farber (1999).

tics Denmark, includes employment and wages paid on an annual basis as well as employee characteristics including employment status in the previous year in all workplaces in Denmark since 1980. The data of interest for this paper includes cross section information on the total number of workers employed in each firm in November of 1994, the number of these who are still employed one year later, and the hourly wage paid each employee during the survey year, November 1994 to November 1995. Information on the occupation membership of each employee is also available in the data set and is used in this paper to create the sub-samples studied. The occupations include managers, salaried workers, skilled workers and unskilled workers. To focus on the cross-firm distribution of wages we define an employer's wage as the average hourly wage paid to its employees. Our focus on average firm wages is uncommon; it is based on three observations. First, given any search theory of job-to-job movements based on firm wage differentials it is only the firm component that matters: differences in personal ability simply confuses the issue. And job-to-job movements are quantitatively important. Peter Matilla (1974) was the first to note that between 50-60% of job transitions did not involve a spell of unemployment; Bowlus et al (2001). report that 44% of the job-transitions of younger males in the NLSY79 data are direct job-to-job moves.Second, under the identifying assumption that worker and firm components of the wage are independent, firm averages allow us to abstract from irrelevant differences in ability. In other words, under this assumption differences in average wages equal differences in firm components plus noise. Third, indepence in worker- firm components holds in other data sets (see Abowd, Kramarz and Margolis (1999) for the case of France)and could be tested using the Danish data, a task we leave for future work. We note that In these data the cross -firm variance in (log) wages accounts for up to 50% of the total variation.

The distribution of wages earned is the employment size weighted distribution of employer wages while the distribution of wages offered is weighted by the relative number of workers hired by each firm from non-employment. Because the data source matches employment and earnings histories of individual workers with their employing firms, both distributions are observed in these data. The employer separation function is estimated under the maintained assumption that all workers in the specified sub-sample under study are equally productive in every firm. In other words, the maintained hypothesis is that cross firm differences in the average hourly wage paid represent pure wage dispersion attributable to heterogeneity in wage policies. The results are reported for sub-samples defined by worker occupation as well as for the total sample.

The estimates of the separation model parameters imply a strong negative relationship between search effort and wage for all occupations. In other words, search intensity is high for workers employed in low wage jobs but drops off, typically quite dramatically, as the wage earned by an employed worker increases and tends to zero as the wage earned tends to the highest paid. Because workers who currently earn less have more to gain by searching more intensively, these results support the theory of optimal on-the-job search effort. An estimate of the curvature parameter of the cost of search function is identified, in spite of the fact that search effort is not itself directly observed. Although the parameter estimates vary across occupations, the result for the full sample suggests that a quadratic cost of search effort is a good first order approximation.

Given the model's implications for employment and wage mobility, the distribution of wages earned by employed workers obeys a law of motion that depends only on the wage offer distribution and the separation function. Hence, the estimated separation function and observed offer distribution can be used to solve for a theoretical steady state distribution of wages earned by employed workers. The implied theoretical distribution can be compared with the actual distribution of earned wages found in the data. Indeed, doing so provides an independent test of the theory since the observed distribution of wages earned is not used to estimate the model. As predicted by the theory, the actual distribution of wages earned in each of our data sets always lies to the right of the distribution of wages offered. Furthermore, the observed distribution of wages earned and that predicted by the estimated model are remarkably close for both the full sample and the four occupational sub-samples studied in the paper. Hence, the model passes this rather stringent 'out of sample' test. It may be noted that other theories of wage formation, e.g., firm-specific human capital, predict a difference between the offer and earnings distributions. However, these theories do not imply the rates of turnover seen in the data. For example, total separations average 30% of employment over the years 1981 to 1996. Workers with less than 1 year of tenure turned over at the rate of 50%, while workers with 5 years of tenure separated at a rate of 18%. Indeed, the tenure-specific turnover rate in these data never goes below 12% per year. Turnover rates of this magnitude clearly indicate the importance of on the job search.

Closely related papers are few. Other than work that document the fact that job-to-job flows are relatively large, we are aware of only a few attempts to estimate a structural model of these flows at the micro level. Among recent examples, Bontemps et. al (2000) and Rosholm and Svarer (1999) estimate an empirical competing hazard job separation model using panel data on worker job histories. Although a new job is one of the destination states in their analyses, they implicitly assume that search effort is independent of the worker's current wage. Yashiv (2000) estimates the parameters of a search effort cost function, as we do, but his workers search only when not employed. Furthermore, his estimates are based on aggregate time-series data. Still, his preferred specification is a quadratic cost function like that estimated here for the complete sample.

The rest of the paper is laid out as follows. Section 2 presents the fundamental model of job separation estimated in the paper and derives the steady state wage distribution implied by it and the offer distribution. Section 3 introduces the maximum likelihood estimation procedure and the data set. Section 4 discusses the results for both the full sample and for the occupation sub-samples. Section 5 concludes.

2 Job Search and Wage Dispersion

2.1 A Model of Job Separation

The model is in the spirit of Burdett (1978). All workers are identical labor market participants. Each acts to maximize expected wealth and lives forever. Let w represent an employed worker's current wage and let $F(w)$ represent the probability that a randomly selected wage offer is no greater than w, where each employer's weight implicitly reflects relative recruiting effort. In other words, $F(w)$ is the fraction of "vacancies" that offer wage w or less. To simplify the derivations below, the wage offer distribution is regarded as continuous.

Each worker receives outside offers at a Poisson frequency λs where s is a measure of the worker's search effort.[5] Each worker chooses search effort subject to a twice differentiable increasing convex cost function $c(s)$ such that total and marginal cost are zero at the origin, i.e., $c(0) = c'(0) = 0$. Finally, any existing job-worker match ends for exogenous reasons at the exponential job destruction rate δ. Then, under the assumption that each worker acts to maximize expected wealth, the current wage contingent value of employment, $W(w)$,

[5] There is no loss of generality in the linearity of the relationship. However, the implicit assumption that workers who do not make an effort receive no offers does have content.

solves the continuous time Bellman equation

$$
\begin{aligned}
rW(w) \quad &= \quad \max_{s\geq 0}\left\{w - c(s) + \lambda s \int \left[\max\left\langle W(x), W(w)\right\rangle - W(w)\right] dF(x) + \right. \\
&\left. \delta[U - W(w)]\right\}, \qquad (1)
\end{aligned}
$$

where U is the value of non-employed search.

The difference between wage and search cost on the right side of equation (1) is the worker's net current income. The next term on the right side represents the expected capital gain associated with the possible arrival of an outside offer, given that the worker acts optimally by accepting job offered with higher value. The last term reflects the expected capital loss attributable to job destruction, the difference between the value of unemployment and the value of employment in the worker's current job. Hence, the equation is an arbitrage condition which defines the asset value of being employed to be that which equates the riskless return on the asset value of the search while employed option to current net income plus expected capital gains and losses associated with the option. This relationship is a continuous time equivalent of the well known Bellman equation of dynamic programming. Indeed, because equation (1) can rewritten as

$$W(w) = \max_{s\geq 0}\left\{\frac{w - c(s) + \delta U + \lambda s \int \max\left\langle W(x), W(w)\right\rangle dF(x)}{r + \delta + \lambda s}\right\}$$

and because the right hand side satisfies Blackwell's sufficient conditions for a contraction on the space of differentiable and increasing real valued functions, the value function is the unique fixed point of the contraction map on that space (see Lucas and Stokey (1989)).

Because the solution $W(w)$ to (1) is increasing in w, an employed worker accepts any offer greater than her current wage. Indeed,

$$W'(w) = \frac{1}{r + \delta + \lambda s(w)[1 - F(w)]} > 0$$

by the envelope theorem, where $s(w)$ is the optimal search effort choice. >From the first order condition for an interior solution, integration by parts, and the appropriate substitution for $W'(w)$, it follows that

$$
\begin{aligned}
c'(s(w)) \quad &= \quad \lambda \int_{w}^{\overline{w}} \left[W(x) - W(w)\right] dF(x) = \lambda \int_{w}^{\overline{w}} W'(x)[1 - F(x)]dx \qquad (2) \\
&= \quad \lambda \int_{w}^{\overline{w}} \frac{[1 - F(x)]dx}{r + \delta + \lambda s(x)[1 - F(x)]}
\end{aligned}
$$

where $\overline{w}$ is the upper support of the wage offer distribution. In other words, the optimal search effort function is the unique particular solution to this integral equation. Optimal search effort, $s(w)$, is strictly decreasing and continuous in the wage earned by convexity of the cost of search function.

Consider the same worker when not employed. The value of non-employment solves the analogous asset pricing equation

$$rU = \max_{s \geq 0} \left\{ b - c(s) + \lambda s \int \left[\max \langle W(x), U \rangle - U \right] dF(x) \right\}, \tag{3}$$

where b represents income forgone when employed, e.g., the unemployment benefit. The worker's reservation wage, R, is the solution to

$$W(R) = U.$$

Under the assumption that the cost of search effort is the same whether employed or not, a comparison of equations (1), (2) and (3) imply that optimal search effort when unemployed, denoted as s_0, equals search effort when employed at the worker's reservation wage and, consequently, the worker's reservation wage is simply the unemployment compensation, i.e.,

$$s_0 = s(R) \tag{4}$$

and

$$R = b. \tag{5}$$

In sum, the overall job duration hazard for any worker employed by an employer paying wage w is

$$d(w) = \delta + \lambda s(w)[1 - F(w)], \tag{6}$$

where $s'(w) < 0$ and $s(\overline{w}) = 0$. Under the assumption that an employer pays all workers the same wage and the cost of search is the same for all workers, the function $d(w)$ also represents the employer's separation rate.

2.2 The Steady State Wage Distribution

Given the wage offer distribution, $F(w)$, and the model of worker flows reviewed above, the distribution of wages across employed workers, denoted as $G(w)$, converges over time to a unique steady state distribution in a stationary environment. The separation theory above predicts that the wages of employed workers generally exceed the wages offered workers by employers in the sense that $G(w)$ stochastically dominates $F(w)$. The purpose of this section is to derive the formal relationship between the two distributions. Both distributions are observable in our data, and the resulting relationship is an important testable model implication.

Workers flow from unemployment to employment at rate $\lambda s_0[1 - F(R)]$, equal to the product of the offer arrival rate and the probability that a randomly generated offer exceeds the reservation wage R. Workers flow from employment to unemployment at the exogenous rate δ. Hence, if the total number of participants is fixed, then the steady state fraction not employed, u, balances these two flows, i.e., u solves

$$\frac{u}{1-u} = \frac{\delta}{\lambda s_0[1-F(R)]} = \frac{\delta}{\lambda s_0} \tag{7}$$

since $F(R) = 0$ in any equilibrium.

By analogous reasoning, the flow of non-employed workers who obtain a job paying w or less is $s_0\lambda[F(w) - F(R)]u$. Because employed workers only flow from lower to higher paying jobs, this is the total flow into the set of employed worker paid wage w or less. The flow out of this subset of employed workers, which has measure $(1-u)G(w)$, is the flow of those who lose their jobs, equal to $\delta G(w)(1-u)$, plus the flow of those who find jobs paying more than w. Since the rate at which workers search depends the current wage, the flow that finds a wage higher than w is

$$\lambda \int_{\underline{w}}^{w} s(x)[1-F(w)](1-u)dG(x),$$

where $x \in [\underline{w}, w]$ represents a wage in the interval of interest and $(1-u)dG(z)$ is the measure of workers earning that wage. Hence, the steady state solution for the distribution function $G(w)$ solves the integral equation

$$\begin{aligned} & \delta G(w) + \lambda[1-F(w)] \int_{\underline{w}}^{w} s(x)dG(x) \\ = \quad & \frac{\lambda s_0[F(w)-F(R)]u}{(1-u)} = \delta F(w), \end{aligned} \tag{8}$$

where the last equality is implied by $F(R) = 0$ and equation (7).

Equation (8) has qualitative implications of considerable interest for the predicted relationship between the distribution of wages offered to new employees and the distributions of wages paid to workers who are already employed. Namely,

$$\frac{F(w)-G(w)}{1-F(w)}=\frac{\lambda}{\delta}\int_{\underline{w}}^{w}s(x)dG(x)>0,\ \text{for all } w\in(\underline{w},\overline{w}) \tag{9}$$

implies that the wages paid employed workers are higher than those offered to new hires in the sense that $G(w)$ stochastically dominates $F(w)$. The horizontal difference between the two distribution functions can be interpreted as an employment premium or *employment effect* on the wage. It arises because some employed workers flow from lower to higher paying jobs without intervening periods of non-employment. Note that the premium declines with the job destruction rate but increases with the offer arrival parameter because workers return to unemployment more frequently as δ increases but move to higher paying jobs more rapidly as λ increases.

3 Estimating the Separation Function

3.1 Estimation Procedure

The purpose of this section is to formulate the procedure for estimating the separation process, equation (6), using cross employer wage offer and separation data and the observed wage offer distribution. The search intensity function is the unique solution of the functional equation

$$s(w)=\phi\left(\int_{w}^{\overline{w}}\frac{\lambda[1-F(x)]dx}{r+\delta+\lambda s(x)[1-F(x)]}\right)$$

by virtue of equation (2), where $\phi(\cdot)$ is the inverse of the marginal cost function $c'(\cdot)$. The estimates that follow assume a cost function of the form

$$c(s)=\frac{c_0 s^{1+\frac{1}{\gamma}}}{1+\frac{1}{\gamma}},$$

where $c_0>0$ is a scale parameter and $1+1/\gamma$ with $\gamma>0$ (for strict convexity) is the elasticity of search cost with respect to effort. Thus, the search effort function is the solution to the functional equation

$$s(w)=\left(\frac{1}{c_0}\int_{w}^{\overline{w}}\frac{\lambda[1-F(x)]dx}{r+\delta+\lambda s(x)[1-F(x)]}\right)^{\gamma}. \tag{10}$$

Equivalently, we assume that current search effort is an iso-elastic function of the expected marginal return to search effort, with elasticity $\gamma>0$.

As search effort is not directly observed, the two factors of the offer arrival rate $\lambda s(w)$ cannot be separately identified. As a consequence, the scale parameter c_0 in the cost function is not identified. Equation (10) can be expressed as

$$\lambda(w) = \alpha \left(\int_w^{\overline{w}} \frac{[1 - F(x)]dx}{r + \delta + \lambda(x)[1 - F(x)]} \right)^{\gamma}, \tag{11}$$

with the definitions

$$\lambda(w) \equiv \lambda s(w), \qquad \alpha \equiv \frac{\lambda^{1+\gamma}}{c_0^{\gamma}}. \tag{12}$$

Thus, the endogenous wage contingent arrival rate $\lambda(\cdot)$ solves a functional equation, and one parameter can be recovered by combining λ and c_0 into α, for identification purposes. The structural parameters actually estimated are the elements of the triple (δ, γ, α). For the sake of interpretation, we report the transformed triple $(\delta, \gamma, \lambda)$, with λ the value of the arrival rate given employment at the lowest wage, i.e., $\lambda = \lambda(\underline{w})$, and we represent the search intensity function as the arrival rate relative to that of the lowest paid workers, $s(w) = \lambda(w)/\lambda(\underline{w})$. This representation corresponds to an appropriate choice of units of search effort, or equivalently to an appropriate choice of the scale parameter c_0.

The IDA contains cross firm observations on the number of workers employed in November, 1994, their earnings during the subsequent year until November 1995, the number of original employees who remain employed during the year, and the number of non-employed workers hired during the year. Let w_i represent the average hourly wage paid by employer $i \in \{1, 2, ...N\}$, let n_i denote the number of employees and x_i represent the number of "stayers", defined as those who were initially employed and stayed on the whole year until the following November. The implications of the theory for the probability distribution of stayers in each firm conditional on the firm's wage and size are used to form the likelihood function for these firm level data conditionally on the model's unknown parameter vector (δ, γ, α) and "market prices" represented by the interest rate r and the offer distribution $F(w)$, which are observed.

As the duration of employment at firm i is exponential with hazard rate d_i for any worker under the assumption that all are identical, the probability that an initially unemployed worker does not leave during the year is $p_i = e^{-d_i}$. As x_i is the realized number of stayers out of the total possible, x_i is binomial with probability of "success" p_i and "sample size" n_i, i.e.,

$$\Pr(x_i = x | n_i, d_i) = \binom{n_i}{x} (e^{-d_i x})(1 - e^{-d_i})^{n_i - x}. \tag{13}$$

Conditionally on r and F, estimates of the parameters (δ, γ, α) are obtained by maximizing

$$\ln L(\delta, \gamma, \alpha) = \sum_{i=1}^{N} \left[\ln \binom{n_i}{x_i} - d_i x_i + (n_i - x_i) \ln(1 - e^{-d_i}) \right], \tag{14}$$

where for each firm d_i is given by the following rewrite of equation (6)

$$d_i = \delta + \lambda(w_i)[1 - F(w_i)] \tag{15}$$

and where the function $\lambda(w)$, which depends on α, γ, and δ, is the solution to equation (11). It is useful to note that the function $\lambda(w)$ is non-parametrically identified in 15 and hence in principle the solution for λ obtained from 11 can be compared as long as $[1 - F(w)]$ is observable.

There are three complications in the actual procedure used to obtain the estimates reported below. First, wages, new hires, and employment are observed for the firms in our sample. We use these data to form a sample analogue of the market offer distribution function $F(w)$ by weighting each firm's wage by the relative number of workers hired by that firm from non-employment. Only the non-employed are included in forming the weights because the theory implies a sample selection problem for the employed. Namely, according to the theory, no employed worker who is offered a wage less than or equal to the one earned will be observed among the new hires. Hence, if all new hires were included, those coming from employment would contribute only relatively high wages, and the resulting distribution would be biased upward in the sense that it would stochastically dominate the true sample distribution. Because the non-employed all accept any offer above the common reservation wage and because all wages offered in the market by participating employers must be no less than this minimum, there is no selection problem for these workers.

Second, the interest rate r could be regarded as a parameter to be estimated. This is known to be difficult to do (Hall (1978), Campbell, Lo, and MacKinley (1997, Chapter 8)). We set the discount rate to 4.9% per year[6]. Variation in this number between zero and 10% per year has no appreciable effect on the resulting estimates of the other parameters.

[6] We experimented with varying the (fixed) rate at levels up to 10% and found that the estimates were not sensitive to this variation. We also experimented with attempting to estimate r and found, as is common in the macro and finance literature, that it is difficult to obtain an precise and apriori sensible estimate.

Finally, the functional equation (11) does not yield a closed form solution for the search effort function $\lambda(w) = \lambda s(w)$. Hence, at any likelihood function evaluation, $\lambda(w)$ is solved for numerically as a function of the underlying set of structural parameters by iterating on the mapping in (11) until an approximate fixed point is found. We evaluated the cdf $F(w)$ at all integers between the minimum wage (69DKK) and the maximum wage, a range typically of about 300 points depending upon the sub-sample used, and we solved for $s(w)$ at each of the points. Convergence at iteration t was defined to occur when $\max_w |s_t(w) - s_{t-1}(w)| \leq 1.0e - 15$.

3.2 Data Description

The employers included in the IDA data are all of the privately owned Danish firms. Hence, the full sample is referred to as the private sector. Sub-samples are also constructed by stratifying the private sector sample by worker occupation. There are four exhaustive and mutually exclusive occupational categories: Skilled and unskilled workers, managers, and salaried workers. The firm observations are the average wage paid, the total number of employees in November 1994, and the number of these who with the firm through to the following year. A summary of the sample statistics is represented in Table 1.

In constructing the firm wage rates and the person counts on which these statistics are based, only workers between the ages of 16 and 65 years of age are included. Because there are good reasons to believe that the hourly wages for some individuals were abnormally low and for others abnormally high due to measurement error, the firm average hourly wage was constructed after excluding the wages rates for certain individuals as follows: The wage of any worker for whom reported wage rates were less than 69 DKK per hour were excluded. This figure is regarded as an estimate of the effective legal minimum wage. The wage rate of any individual in the top one percent of the observed distribution was also excluded. Although these wage rates were excluded for the purpose of computing the firm wage average, the estimate of the firm's wage policy, all workers were included in the employment and stayer number person counts.

The wage offer distribution, F, and the wage earned distribution, G, are constructed separately for each sub-sample. Specifically, for each firm, first an hourly wage paid is constructed by averaging the Statistics Denmark estimate of the hourly wage earned by each worker of the occupational type employed by the firm during the November 1994 to

Table 1: Sample Statistics

Sample	Private	Managers	Salaried	Skilled	Unskilled
Sample Size (# of firms)	113,325	49,667	57,513	44,527	70,886
Min Wage	69	69	69	69	69
Max Wage	435	626	323	310	331
Median Offer	132	188	124	138	115
Mean Wage Offer	138	188	128	141	121
Std of Wage Offer	32	50	25	26	26
Median Wage Earned	142	198	131	141	121
Mean Wage Earned	146	198	133	144	126
Std of Wage Earned	32	48	25	26	28
Min Size	1	1	1	1	1
Max Size	15,870	4,069	7,163	1,708	8,856
Mean Size	13.36	6.20	6.22	5.94	7.81
Std of Size	125.84	45.19	70.25	28.09	64.50
Mean Stayers	9.26	4.83	4.59	4.31	4.78
Std of Stayers	96.90	39.43	58.04	23.01	41.26

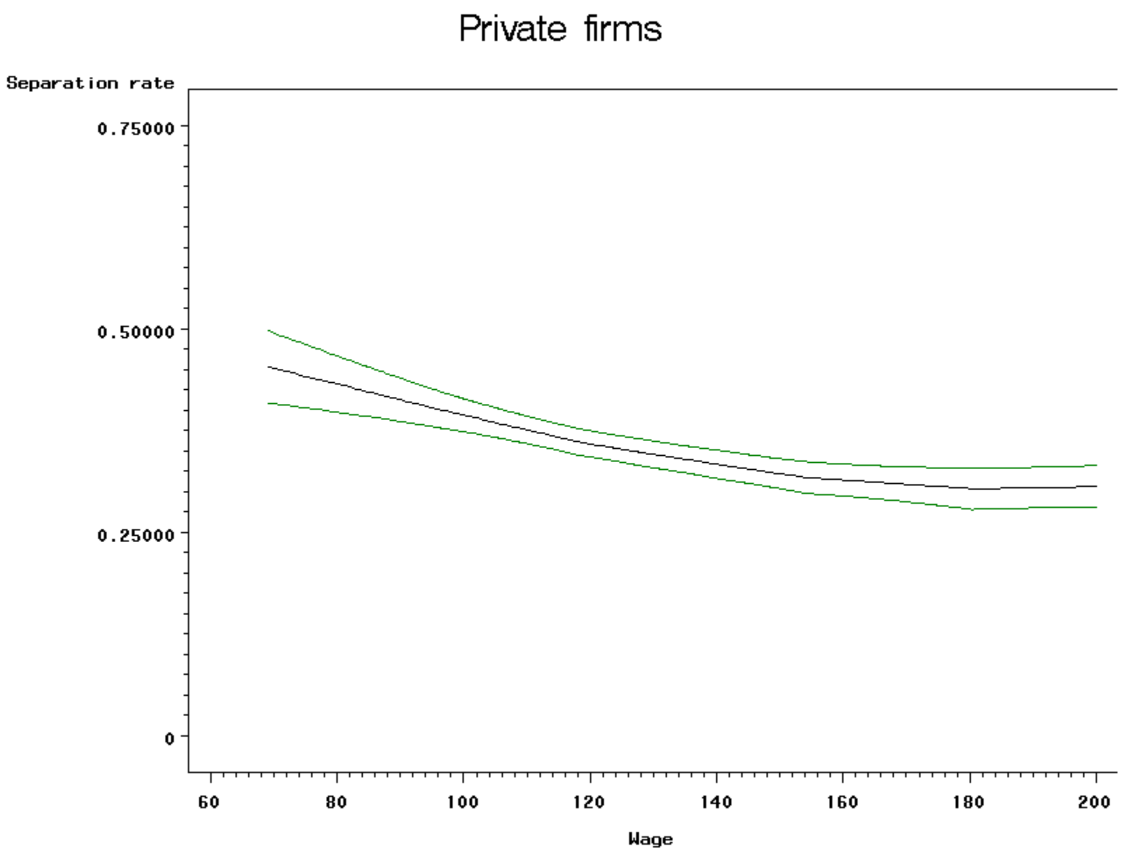
November 1995 year. Given this number, denoted w_i in the case of firm i, F is constructed by weighting these by the fraction of all non-employed worker hired by firm i during the year. The wage earned distribution, G, uses the same firm wages but weights them by each firm's relative employment size in November 1994.

In Table 1, the second row indicates that there are 113,325 firms employing at least one worker. However, there are only 49,667 firms employing at least 1 manager. The occupation "manager" excludes owner-operators because the definition of wage is problematic in such cases. Denmark has a high fraction of small firms, which accounts for the difference between the two numbers.

4 Results

4.1 Private Sector

Before proceeding to the structural estimates it is useful to examine what the raw data indicate about the relation between separations and wages. Figure 1 presents a non-parametric regression of the firm separation rate on w. As expected, the separation function is decreasing in the wage rate throughout its range. The decline is greatest in the lowest part of the wage



Firm Separation Rate and Wages

distribution, namely those wages where $(1 - F(w))$ is large.

Parameter estimates for the full sample of all private sector firms are reported in Table 2. The exogenous separation rate δ and the offer arrival parameter λ are expressed as annual rates while the parameter γ is the elasticity of the search effort with respect to the expected economic payoff to search effort. Equivalently, its inverse $1/\gamma$ is the elasticity of the marginal cost function with respect to search effort. For reference, $\gamma = 1$ is the case of a quadratic search cost function.

The point estimates for the full sample are those obtained using the maximum likelihood procedure described above after substituting the constructed sample wage offer distribution for the market distribution, F. Although the reported standard errors are computed by taking the offer distribution F as given, the results obtained by computing 95% confidence intervals for each parameter using bootstrap techniques confirm that the additional sampling variance attributable to the fact that F is estimated by the empirical distribution function

Table 2: Parameter Estimates, Private Sector

	Point Estimate	Standard Errors
δ	0.2872	0.0007
γ	1.1855	0.0198
λ	0.5833	0.0055

is negligible. All parameters are highly significant. Indeed, sample sizes are such that uncertainty only affects the precision of the estimates of the third significant digit.

The job destruction rate estimate, δ, is 0.287 per year. This is roughly in accord with aggregate U. S. experience. Bleakley et al.(1999) provide monthly separation rate for the U.S. that average 1.733% for 1968-1998, implying an annual turnover rate of 21%. According to the model, the estimate suggests that jobs last somewhat less than four years, abstracting from voluntary job to job movements that are sensitive to the employer's relative wage. However, as an estimate of the flow of workers from employment to unemployment, it is almost three times higher than that obtained by Rosholm and Svarer (1999) using Danish worker panel data on transitions from employment to unemployment. Since in our estimation procedure we do not condition on the destination state of workers who leave the firm, one reasonable interpretation of the difference is that some workers move from one job to another without experiencing an intervening unemployment spell for reasons that have nothing to do with the relative wages in the two jobs. In short, $\delta = \delta_0 + \delta_1$ where δ_0 represents transitions to unemployment while δ_1 is the intercept in the job-to-job transition rate function.

Our estimate of λ for the full sample is 0.583 per year. As the sum, $\delta + \lambda = 0.87$, is the separation rate of workers employed in the lowest paying firm, the expected duration of a match paying the lowest wage in the market is only $1/0.87 = 1.149$ years. However, as the wage earned increases the separation rate decreases, both because workers search less intensively and because higher paying jobs are more difficult to find.

The parameter γ in the economic model is the elasticity of search effort with respect to the expected return to search, which declines with the wage earned, and its inverse is the elasticity of the marginal cost function with respect to search effort. The estimate $\gamma = 1.185$ suggests a cost of effort function which is approximately quadratic. Note that the data could have driven the estimate negative, in which case the economic interpretation of this parameter would be lost. Since $F(w)$ is increasing, equation (6) implies that $s(w)$ can increase even if the separation rate, $d(w)$, is decreasing. Indeed, in the received literature, search intensity while employed is assumed to be independent of the wage earned. This is equivalent to the prior specification $\gamma = 0$. This case is clearly rejected given the small standard error on our estimate of γ.

The steady state condition, equation (8), together with our estimates of the separation function parameter vector $(\delta, \gamma, \lambda)$ and the observed offer distribution F can be used to compute an implied steady state distribution of wages earned $G^*(w)$ which can be compared with the observed distribution $G(w)$. However, the following question arises: Does the steady state relation continue to hold if δ is reinterpreted as the sum of the transition rate to non-employment and the intercept of the job-to-job transition rate? The answer is yes, provided that the wage earned on the new job by a worker who changes jobs for non-wage reasons can be regarded as a random draw from the offer distribution.

To prove the assertion, let $\delta = \delta_0 + \delta_1$ where δ_0 is regarded as the rate of transition from employment to non-employment and δ_1 is the intercept of the job-to-job transition rate function. Under the assumption that workers who move between jobs for non-wage reasons earn a random offer in the destination job, the flow of workers to jobs that pay w or less is

$$s_0 \lambda F(w) u + \delta_1 F(w)(1-u),$$

where the first term is the inflow from non-employment and the second term is the inflow from employment. Equating the inflow to the outflow yields an equation equivalent to (8)

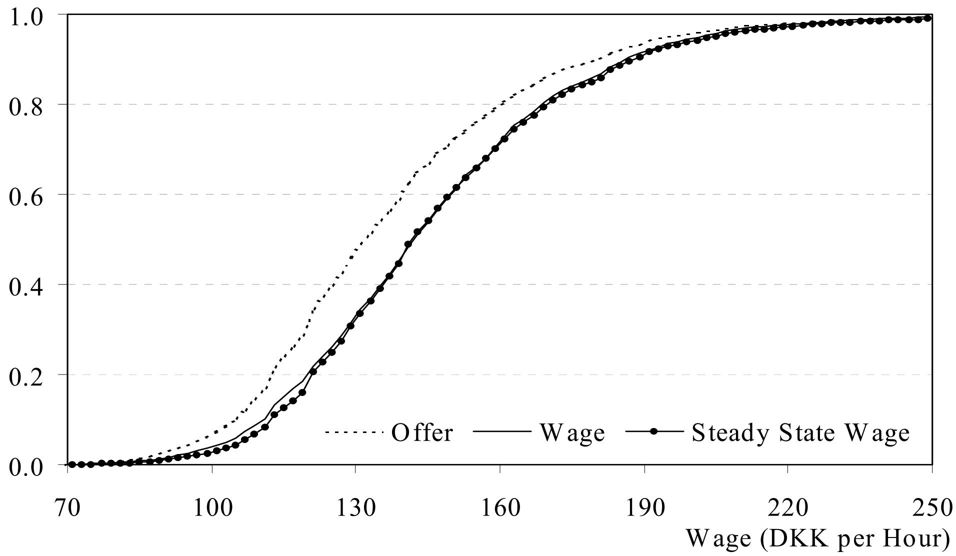
$$\begin{aligned} & \delta G(w) + \lambda[1-F(w)] \int_{\underline{w}}^{w} s(x) dG(x) \\ = & \frac{s_0 \lambda F(w) u + \delta_1 F(w)(1-u)}{1-u} \\ = & (\delta_0 + \delta_1) F(w) = \delta F(w), \end{aligned}$$

because the steady state non-employment rate solves

$$\frac{s_0 \lambda u}{1-u} = \delta_0.$$

The actual wage offer distribution, $F(w)$, wage earned distribution, $G(w)$, and estimated steady state distribution, $G^*(w)$, are plotted in Figure 1. The wage offer distribution is represented by the curve that lies everywhere to the left of the other two, as the theory says it should. The estimated steady state wage distribution is represented by the curve containing the dots. It and the observed wage distribution, the remaining curve in the

Figure 1: Private Sector CDFs



panel, are virtually coincident given the resolution of the chart. In short, for the structural parameters estimated, *the model explains the entire employment effect*, as represented by the magnitude of the vertical difference between the distributions of wage earned and offered.

The estimated employment effects are substantial. Indeed, from Table 1, the difference between the median wage earned and offered is 10 DKK per hour, about 7% of the 142 DKK median wage earned per hour. It should be pointed out that the well documented experience and tenure effects on worker wages are not represented in the difference between our wage and offer distributions, at least not effects that represent accumulation of worker ability. As the firm wage rates used to construct the two distributions is an average of that paid to all workers, differences in tenure and experience characteristics across workers cancel to the extent that their distributions are the same across employers. Under this orthogonality condition, the horizontal difference between F and G is a general equilibrium effect that exists if and only if wages are dispersed and workers flow from lower to higher paying firms.

4.2 Stratification by Occupation

Estimating the model by pooling all the workers employed in the private sector obviously ignores the possible importance of worker heterogeneity. There are at least two reasons why differences in worker types should be taken into account: First, the structural parameters of interest may simply vary by type. Second, the worker composition by type may differ across firms. The second reason for stratifying the sample by type may actually be more important than the inappropriate aggregation implied by the first reason because ignoring it can induce sources of measurement error that bias the parameter estimates even if the true values were equal across types.

To illustrate the possible source of aggregation error of the second kind, consider the following specification of the wage. Let the index i represent a firm in the sample and j a worker type and assume that the wage paid by firm i can be decomposed into a fixed firm and a fixed type effect as follows:

$$w_{ij} = \mu_j + \epsilon_i$$

In other words, μ_j is the common component of the wage paid by all firms to workers of type j and ϵ_i is the firm's wage differential. Obviously, because the average wage paid by firm i is

$$\overline{w}_i = \sum_j \theta_{ij}\mu_j + \epsilon_i,$$

where θ_{ij} represents the share of firm $i's$ employees who are of type j, differences in the measured firm wage reflect true differentials if and only if the worker type composition is the same across firms. When this condition fails, an employer who disproportionately employs higher wage types will be inappropriately regarded as a high wage employer even if actual differentials in ϵ_i are distributed independently of the worker type composition across the firms. Since in this case observed differentials exceed actual, the measured wage offer distribution is more dispersed that the actual. Given the non-linear relationships in the model, the exact direction of the bias induced by this form of measurement error is not obvious. Still, its existence suggests that correcting for worker heterogeneity may be important.

The estimation results and their implications are reported for each of four occupation sub-samples. The four occupational categories, managers, salaried worker, skilled and unskilled workers, are mutually exclusive and exhaustive, as already noted. Although the

Table 3: Parameter Point Estimates (Std Errors)

Sample	Private	Managers	Salaried	Skilled	Unskilled
δ	0.2873	0.2162	0.2392	0.3007	0.3950
	(0.0007)	(0.0013)	(0.0014)	(0.0016)	(0.0018)
γ	1.1855	1.4919	1.0789	2.4390	0.7686
	(0.0198)	(0.0605)	(0.0365)	(0.1281)	(0.0319)
λ	0.5833	0.3211	0.4418	0.4585	0.4787
	(0.0055)	(0.0090)	(0.0089)	(0.0218)	(0.0080)

information available on worker characteristics found in the IDA data is much richer, an initial stratification by occupation provides a fair test of whether aggregation bias of the type suggested above is important. First, one would expect occupational composition to differ across employers for a variety of reasons. In addition, the magnitude of the wage differential offered by a given firm is also likely to depend on the occupation. Finally, potentially important occupational differences in job destruction rates as well as occupational variation in demand conditions and search costs can also be anticipated.

The structural parameter estimates (with estimated asymptotic standard errors in parentheses) are reported in Table 3 for the occupation sub-samples. For comparison, the parameter estimates derived from the full private sector sample are included in the first column.

Estimates of the exogenous separation rate parameter δ fall with the level of the occupation as ranked by the skill-education hierarchy. This observation seems to be consistent with the general fact that layoffs are higher for the less skilled and less educated. Of course, there is no particular reason to see the same relationship for job-to-job transitions not related to employer wage differentials, the other possible component included in the estimated parameter. The fact that the estimate for the full sample lies between the two highest and the two lowest sub-sample estimates suggests that the possible aggregation bias due to cross employer composition effects discussed above are not particularly important for obtaining an estimate of this parameter with the full sample. However, the negligible sampling error suggested by the standard error estimates indicates that the differences across sub-samples in the estimates are none the less real.

The estimates of the offer arrival rate parameter decrease with skill and education requirements. This result is consistent with the fact that more educated and skilled workers typically experience shorter unemployment spells. However, note that the full sample estimate of λ is substantially larger than all of the sub-sample estimates. It is possible that this fact is a consequence of composition bias in the pooled sample. If so, the estimates for the sub-samples may also be biased upward to the extent that accounting for occupation does not fully correct for worker heterogeneity.

Although the cross sample estimates of γ, the elasticity of search effort with respect to its expected return, vary considerably over the occupations, the variation is not systematically associated with differences in the skill and education requirements for occupational membership. The full sample estimate of 1.185 is similar to those of both managers and salaried workers, while search effort is far more response to expected return in the case of skilled workers and less responsive in the case of unskilled workers. Given the parametric specification, these differences are attributed to cross occupation differences in the curvature of the marginal cost of search effort function. The implication is that the marginal cost of search rises more steeply with effort in the case of unskilled workers than in any of the other occupations, and rises least for skilled workers. Considering the Danish labor market, these findings may reflect the fact that skilled workers participate in much better connected occupational networks than unskilled workers. In sum, then, search effort seems to be quite elastic with respect to its expected return in all the occupations, is highly sensitive in the case of skilled workers, and is somewhat less responsive than average in the case of unskilled workers.

Although the structural parameters generally differ across occupational sub-samples, the estimated model explains almost all of the employment effect measured at the median wage in all four cases. The graphical evidence for this assertion is illustrated in Figures 2-5. In the figures, the offer cdf F is at the far left in all cases, the wage distribution G is the curve on the right represented by a solid line and the steady state wage cdf G^* implied by the estimates and the offer distribution is represented by the curve with dots.

Table 4 provides a more quantitative comparison of how well the model explains the employment effect at each of the three quantiles for each of the individual occupations. The results for the pooled estimates are also reported for comparison. In the table, the employment effect is defined as the difference between the wage paid and the wage offered at each quantile. In each case, the percent explained is the ratio of the employment effect predicted by the estimates and the actual employment effect as defined above.

For the private sector as a whole, the predicted median wage paid is almost identical to the actual, but the model over predicts the difference between wages paid and offered at

Figure 2: Managers CDFs

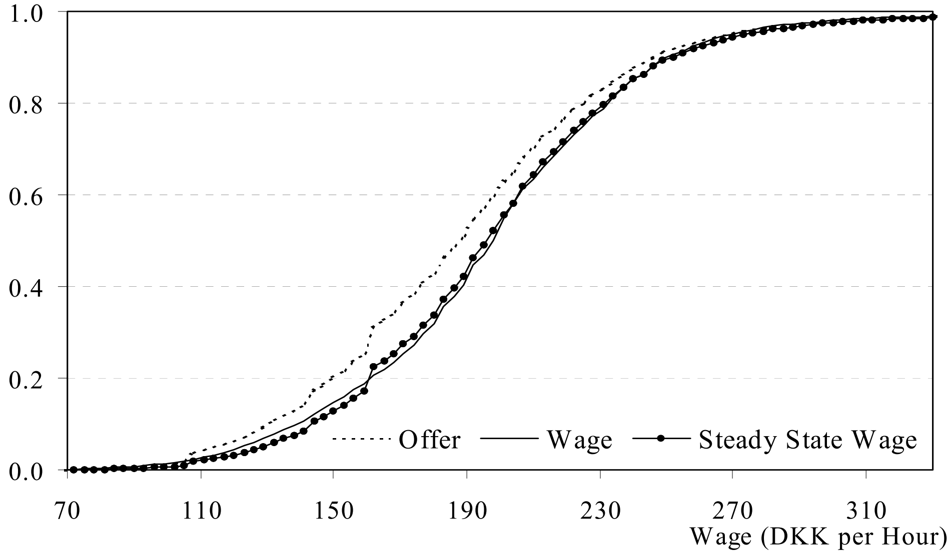


Figure 3: Salaried Workers CDFs

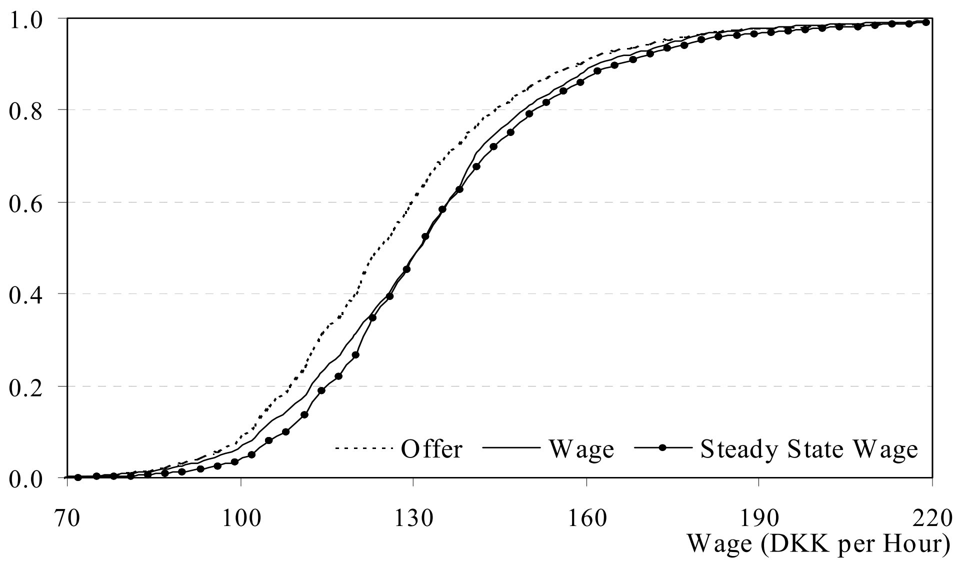


Figure 4: Skilled Workers CDFs

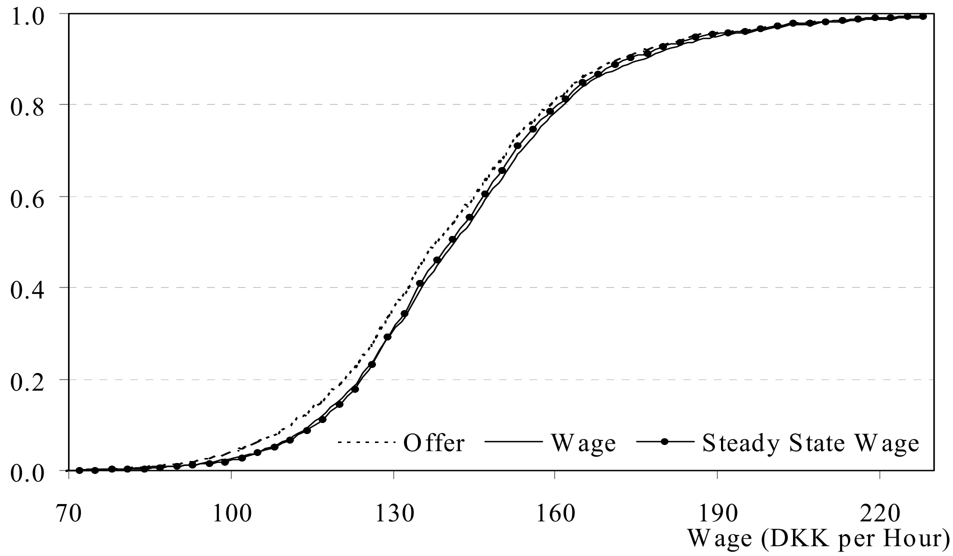


Figure 5: Unskilled Workers CDFs

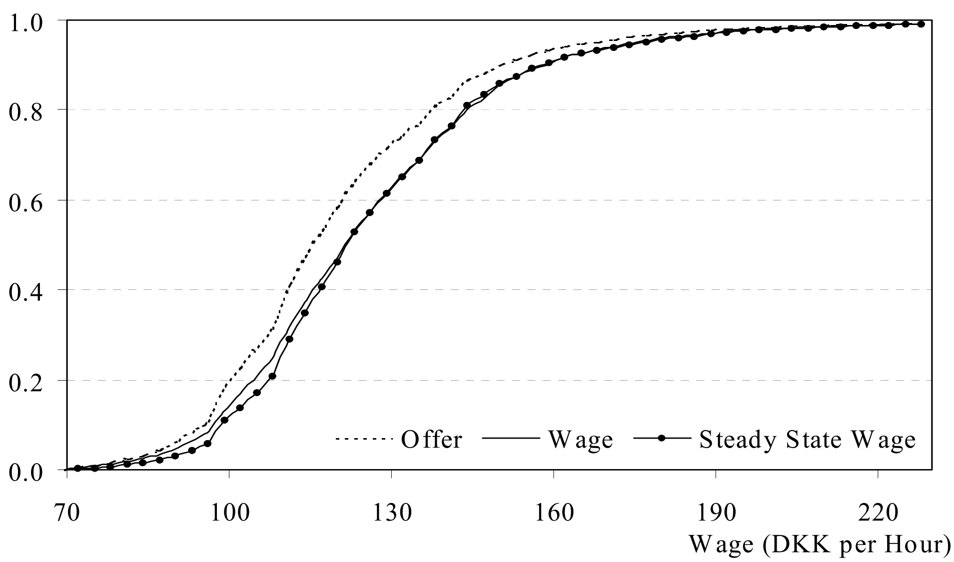


Table 4: Employment Effects; Actual and Percent Explained
(Wages in Danish Crowns per Hour)

Sample	Private	Managers	Salaried	Skilled	Unskilled
1st quantile of F	115.90	158.10	111.71	124.33	103.59
1st quantile of G	123.95	169.99	115.79	126.71	108.10
1st quantile of G^*	125.00	167.55	118.88	126.79	108.93
1st quantile effect	**8.05**	**11.90**	**4.08**	**2.38**	**4.51**
% explained	**113%**	**79%**	**176%**	**103%**	**118%**
2d quantile of F	132.00	187.86	124.18	137.85	115.05
2d quantile of G	142.18	198.04	131.29	141.47	121.11
2d quantile of G^*	141.67	196.38	131.20	140.64	121.41
2d quantile effect	**10.18**	**10.18**	**7.11**	**3.62**	**6.07**
% explained	**95%**	**84%**	**99%**	**77%**	**105%**
3d quantile of F	153.70	217.03	140.04	154.58	132.71
3d quantile of G	162.74	224.92	144.35	157.35	140.01
3d quantile of G^*	163.70	223.64	146.80	156.30	139.67
3d quantile effect	**9.04**	**7.89**	**4.30**	**2.78**	**7.30**
% explained	**111%**	**84%**	**157%**	**62%**	**95%**

both the 1st and the 3rd quantile. Across the occupational sub-samples, the model predicts the median wage paid to salaried and to unskilled workers, but under predicts the median wage paid to both managers and skilled workers. Although the model's under prediction holds at all quantiles for managers, the model over predicts at both the 1st and 3rd quantiles in the case of salaried workers, where the prediction is exact at the median. In the case of unskilled workers, the employment effect is explained at all quantiles. In the case of skilled workers, both the median and the spread are under predicted by the model. Overall, the quantitative analysis of the errors does not reveal any systematic patterns, but instead confirms the impression from the graphs.

4.2.1 Alternative Parameter Estimates

In this section we reestimate the model using the observations on the distribution of wages earned rather than wages offered. This is done by using the fact that the model and the wage distribution imply that the offer distribution is

$$F(w) = \frac{\delta G(w) + \lambda \int_{\underline{w}}^{w} s(x) dG(x)}{\delta + \lambda \int_{\underline{w}}^{w} s(x) dG(x)}. \tag{16}$$

The parameter estimates obtained by imposing this condition on F in equations (10) and (15) and using the observed distribution of wages earned, G, instead of the wage offer

Table 5: Alternative Parameter Point Estimates (Std Errors)

Sample	Private	Managers	Salaried	Skilled	Unskilled
δ	0.2872	0.2162	0.2395	0.3004	0.3932
	(0.0010)	(0.0012)	(0.0015)	(0.0016)	(0.0018)
γ	1.1225	1.5089	0.9587	2.4745	0.6986
	(0.0217)	(0.0633)	(0.0417)	(0.1243)	(0.0343)
λ	0.5899	0.3279	0.4482	0.4517	0.4892
	(0.0056)	(0.0096)	(0.0096)	(0.0197)	(0.0083)

distribution, F, are reported in Table 5.

There are at least two good reasons to consider these alternative estimates. First, related empirical work has generally imposed the steady state conditions simply because data limitations precluded the observation of wages offered. Second, and perhaps more importantly, checking to see if the alternative estimates differ is one way to determine whether the steady state condition is violated in any material sense. As it turns out, the alternative estimates tell exactly the same economic story as the original estimates. Specifically, the exogenous separation rate δ rises and the offer arrival rate at the smallest wage λ declines with occupation status. The point estimates of the search cost curvature parameter are essentially the same values, and are ranked across occupations in exactly the same order as were the original estimates. We conclude, therefore, that there is strong evidence for the steady state relationship implied by the model in our data set.

5 Conclusions

Establishing a structural link between two well known empirical observations, that higher paying employers have lower turnover and that workers with more experience earn higher wages, is a principal empirical contribution of the paper. Given the existence of wage policy dispersion across employers, a link is implied by the fact that workers have an incentive to seek higher paying jobs. If they do so, workers flow from low to high paying firms and, consequently, the wage earned is positively related to the time since the last unemployment spell.

The empirical exercise conducted in the paper is one of estimating the parameters of a specific structural model of turnover using firm level observation on separation flows and wages, and the distribution of alternative wage offers. The model is the standard on-the-job search formulation with endogenous search effort. The exercise is successful in that it yields well determined coefficient estimates that are consistent with the theory for both the full sample and for each of the four occupational sub-samples.

The estimates strongly support the hypothesis that workers choose search effort in response to economic incentives. Specifically, the high estimated elasticities of search effort with respect to expected return to search (γ) imply that a worker searches more when earning a relatively low wage because the return is higher. These results suggest that one should incorporate this feature in future empirical work on worker turnover.

When workers flow from lower to higher paying jobs without intervening spells of non-employment, the expected wage earned rises with experience as measured by the elapsed time since the last non-employment spell. The impact of this measure of experience on the wages of individual workers is reflected at the market level by the employment effect, defined as the horizontal difference between the distribution of wages earned by the employed and the distribution of wages offered applicants. Conditional on the wage offer distribution and the structural parameter values, the model can be used to predict the employment effect. Since the wage distribution itself was not used in the estimation of the model's parameters, these predictions provide an out of sample test of the theory.

For the full sample of all workplaces with workers not distinguished by occupation, the theory passes the test with flying colors. Indeed, the predicted difference between the median wage earned and offered is essentially identical to the actual difference. Of course, there are differences in the extent to which the model explains the employment effect, both across occupations and across the quantiles used to measure the effect within occupations. The model explains all of the difference between the median wage and offer for salaried and unskilled workers and about 80% to 85% of the difference for managers and skilled workers. Finally, the model under predicts the employment effect by about 15% at all quantiles in the case of managers.

These findings provide ample evidence that labor market imperfections have an important influence on the distribution of wage income. Separations, however, are but one part of the story. Reducing turnover lessens the need to use wages as a recruitment tool, but does not eliminate it. Indeed, firm wage policy has to balance investment decisions by workers and firms in firm-specific capital with turnover considerations. Linking the hiring and separation problems faced by workers and firms remains a challenging problem.

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