Employment Changes, the Structure of Adjustment Costs, and Firms' Size†

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Abstract

In this paper we analyze the pattern of employment adjustment at the plant level using a rich data set for Norway. We first document the stylized facts about employment changes in small and large plants. The data reveals important differences across size classes. In particular, episodes of zero net employment changes are more frequent for smaller plants. A simple "q" model of labor demand is then developed, allowing for the presence of fixed, linear and convex components in adjustment costs. Econometric estimation supports the importance of departing from traditional models of labor demand based solely on symmetric convex adjustment costs. Fixed (or linear) components of adjustment costs are important. There is, moreover, evidence that fixed costs contain a component that are unrelated to size, in addition to a components proportional to size. As a result, the range of inaction is wider for smaller plants. Finally, the quadratic components of costs are asymmetric and, although some ambiguities exist about the nature of the asymmetry, the more general models indicate that it is more costly at the margin to contract employment than to expand it.

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1. Introduction

In the last few years there has been an heightened awareness of the shortcomings of traditional models of factor demand based on convex and symmetric adjustment costs and of the need to consider more general adjustment cost functions (see Hamermesh and Pfann (1996) for a critical review). The increased availability of firm and plant level panel data made it easier to provide empirical evidence on these issues and has lead to a blossoming of empirical studies, particularly on investment.[1] Recent contributions on labor demand are scarcer, although by no mean absent.[2]

In this paper we intend to advance our understanding of both net and gross employment changes, using a rich data set on Norwegian plants that can also be matched with administrative records on workers. Although labor protection is known to be strict in a Scandinavian type of welfare state as Norway, its rank is about average among OECD countries on the strictness of dismissal regulations for firms (OECD, 1999). Evidence on the flexibility of the Norwegian economy from job and worker flows data suggests that it is about average for OECD countries, although worker flows are a bit below average.[3]

Two are the distinguishing features of our paper. First, we specify a simple optimizing model of labor demand that allows for a fairly general structure of adjustment costs. In the basic specification, such costs are function of net employment changes and include fixed, linear and quadratic components. The model can be thought of as a *q* model for employment, and like other models in this area, generates a region in which labor demand does not respond to changes in fundamentals, because the gains from increasing or decreasing employment by one unit is not large enough to compensate the incurring of adjustment costs. Moreover, the response to fundamentals may differ for net employment increases versus decreases, reflecting asymmetries in the quadratic component of adjustment costs.

Secondly, the adjustment costs are allowed to differ for small and large plants. One way to model this is to allow for a truly fixed component in adjustment costs that makes the range

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[1] Among the most recent papers that analyze the importance of non convexities and irreversibility in generating non smooth investment patterns see Doms and Dunne (1998), Goolsbee and Gross (1997), Barnett and Sakellaris (1998), Abel and Eberly (1999), Cooper, Haltiwanger and Power (1999), Nilsen and Schiantarelli (2000), Letterie and Pfann (2000)

[2] See, the seminal contributions by Hamermesh (1989a, 1989b, 1992), and the more recent ones by Rota (1995), Abowd and Kramarz (1997), Campbell and Fisher (2000a,b), and Goux, Maurin and Pauchet (2001).

[3] See Salvanes (1997) and Salvanes and Førre (2001).

of inaction wider for smaller plants (firms). Indeed larger plants are more likely to have personal and planning departments that are set up for with dealing with employment changes and they may experience less disruption to production when such changes occur. As a result, the range of the value of fundamentals for which there are no employment changes is wider for smaller plants (firms). [4]

Although in this version of the paper we specify adjustment costs as a function of net employment changes, the model can be extended to allow for adjustment costs that are a function of gross hiring or firing. Moreover, since the plant level data can be linked to individual records, we can reconstruct gross hiring. Unfortunately gross separation cannot be distinguished according to their cause. In future work, we will therefore be able to estimate models for gross hiring, based on the assumption that adjustment costs depend upon gross and not net flows. Finally, we plan to use more extensively the possibility of matching individual and plant level data in order to break down employment according to workers' characteristics, such as education and length of tenure, that are likely to affect adjustment patterns. [5]

The structure of the paper is as follows. We start by presenting in Section 2 some descriptive evidence on employment adjustment patterns and gross hiring. The data reveals interesting differences across plants of different size. In Section 3 we describe in details the Norwegian institutions regulating the adjustment of the labor factor. Section 4 contains the theoretical model that underpins our econometric estimation. In Section 5 we present econometric estimates of various versions of the model for plants in the metal product and machinery sector (excluding large-construction and ship-building industry) over the period 1986-1995. This sector contains a large number of plants of different size and with different employment histories. Concentrating on a single industry keeps the problem of matching plant and individual level observations manageable and reduces heterogeneity problems in estimation. Section 6 concludes the paper.

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[4] The structure of adjustment costs has important implications for the way in which productivity gains are achieved in an economy. For instance, Haltiwanger, Krizan and Foster (1999) find that reallocation of labor between heterogeneous firms within narrowly defined sectors are very important in explaining productivity gains in the US economy. The size distribution of establishments and their respective adjustment costs will have important implications on how economies respond to shocks.

[5] So far very little is known about the relative importance of gross versus net flows. One important exception is Hamermesh (1995), using a small data set for US firms. For empirical models based on adjustment costs defined on gross flows see Abowd and Kramarz (1997) who use 1992 data for French establishments.

2. Data and Descriptive Evidence

2.1. The Data

Our empirical work is based on yearly plant level information for the period 1986-1995 contained in Manufacturing Statistics including production, sales, employment, production costs, the age of the plant, whether the plant belongs to a multi-plant or single plant firm. Investment and capital stock information is also is available (see Halvorsen, Jensen and Foyn (1991)). Total sales are calculated by adding sales of produced goods and traded goods, income from repairs and contracted works, income from leasing and deliveries to other plants in same firm. We restrict our attention to plants with an average size of at least five employees, since plant or firm specific information is not available for plants below five employees. We have excluded all auxiliary units which do not take part of the production directly (separate storage and office units). Plants in which the central or local governments own more than 50 percent of the equity have been excluded from the sample, as well as observations that are reported as "copied from previous year". This actually means missing data. In this paper we focus on plants in the metal products and machinery industries (ISIC 38), excluding large-construction and ship-building industry. Concentrating on a single industry reduces the heterogeneity problem in estimation and keeps the problem of matching plant and individual level observations manageable. Moreover, sector 38 is important and rather large, accounting for 35% of manufacturing employment in 1990.

The remaining data set was trimmed to remove outliers. To avoid measurement errors in the employment changes, observations where the total employment level was 3 times larger than, or less than 1/3 of the employment level for the previous year were dropped. Finally, we included only series with at least four consecutive observations implying also that exits and new entries of plants were excluded. The final unbalanced panel contains 1414 production plants with a total of 10681 observations (an unbalanced panel).

The plant level data can be matched with administrative individual information. In the administrative registers, individuals are identified by their social security number. In the second quarter each year every worker is matched to the individual's main employer. The starting and terminal dates of each matched employer-employee contract are given. Up to now we have used such information to reconstruct gross job flows. However in the future we plan to use also individual information on education, age, tenure etc. to analyze how adjustment patterns differ across heterogeneous workers.

2.2 Descriptive Statistics

What are the basic patterns of employment changes for our sample of Norwegian plants? We summarize the basic characteristics of the distribution of net employment changes in Table 1 and in Figure 1. Over the period 1986-1995, there is a large degree of heterogeneity in the patterns of employment changes. Employment increases and decreases occur equally frequently: approximately 40% of the observations represent positive employment changes while 40% correspond to employment decreases. Interestingly in 20% of cases we observe no employment changes. This may be suggestive of the fact that changing the number of jobs even by a small amount may imply sizeable adjustment costs that deter firms from adjusting. This would be the case for instance, in the presence of fixed or linear components of adjustment costs. If the firm increases the work force the more frequent changes occur in the interval (0, +20%). This occurs 65% of the times (conditionally on the firm expanding) and represents a 49% share of total employment increases. Similarly, if the firm contracts, decreases in the interval (-20%, 0) occur most frequently (65% of the times) and they represent a share of 51% of total employment changes. However plants experience frequently also changes in excess of 20%, particularly for employment increases.

The pattern of adjustment differs in at least one important way across plants of different sizes: the frequency of episodes characterized by no employment changes decreases with size. The frequency of zero episodes is approximately 27% for plants of 25 workers or less, 10% for plants of 25-50 workers, 5% for plants of 51-100 workers and 3% for plants larger than 100 workers. Several reasons can be listed why there is a connection between plant size and adjustment costs. One possible explanation may be that the fixed component of adjustment costs is relatively more important for smaller plants. For instance, smaller plants are less likely to belong to a firm with a personal department used to handle expansions or contraction of the workforce. In general, reorganizations and definition of work assignments may involve fixed components of cost that are more difficult to absorb for a small plant. For the very smallest of plants there may also be an element of indivisibility, that generates consequences that are observationally equivalent to those of fixed costs. Indivisibility becomes, however, a less plausible explanation for plants of more than 25 workers, some of which continue to display significant occurrences of zero employment changes episodes.

In Table 2 we report the salient characteristics of gross hirings. Slightly more than half of the observations is accounted for hiring rates in the range (10%, 30%). Also in these cases zero hiring episodes are important and represent 22% of the observations. This frequency decreases with firm size, just as in the case of net hiring. It is interesting to note that in the majority of observations in which net employment does not change, some gross hiring take place, presumably to replace workers that have left the firm. Similar findings are described by Abowd, Corbel and Kramarz (1999). Gross hiring occurs in 56% of the cases where the employment is stable from one year to another. This suggests that there are costs specific with changing the size of the workforce that are independent from the search and training costs, and the like, that are related to the identity of the worker filling a job.

3. Institutional setting

The costs of changing both the plant size and especially the workers filling the jobs, is of course affected by the institutional setting and legislation introduced to protect workers against unfair dismissal. The institutional setting varies over countries and potentially over time. In this section, we provide some information on the Norwegian policies and institutions that affect the costs of adjusting labor demand, and make comparisons to other OECD countries.

Both the rules regarding individual and collective dismissals, and the flexibility of plants with respect to temporary hiring and the use of subcontractors, are important in explaining the costs of adjustment for plants. The different types of constraints regulating the hiring and firing of workers are not completely transparent, since, in addition to national laws, collective agreements between employer and workers organization also are very important in regulating the adjustment of the labor factor. These agreements may differ across industries industries and workers, depending upon age, tenure, etc.

One of the most important pieces of national regulation is contained in a law from 1982, “Arbeidsmiljøloven”, which includes standards for the general working conditions, overtime regulations and legal regulation for employment protection. Dismissals for personal reasons are limited to cases of disloyalty, persistent absenteeism etc., while dismissals for economic reasons are automatically unfair. In general it is possible but very difficult to replace an individual worker in a given job with another worker. The general rule for laying off a worker for economic reasons is that it can be done only when the job is "redundant" and the worker cannot be retained in another capacity. This regulation covers all workers independent of how long he/she has been hired. In general, there is a strong degree of employment protection in Norway. According to the legal regulation, employment is terminable by one month’s notice in Norway, and this one-month notice is at the lower end of the spectrum compared to many countries. This rule is basically for tenure periods up to 5 years. However, most workers have a three months' notice requirement for both parties of the contract. There is no generalized legal requirement of severance pay in Norway, but agreements in the private sector require lump-sum payments to workers who have reached the age 50-55. As an example, in the contract between LO (the largest blue collar workers organization) and NHO (the employers' association), the worker must be 50 and been working for 10 consecutive years or 20 years in the firms in order to be eligible for one to two months pay. Comparable agreements exist for the other unions. Thus, the severance payment is low in Norway compared to other countries. In comparison with other OECD countries, Norway scores generally high on employment protection together with Japan and Portugal (OECD, 1999).

Requirements for collective dismissals in Norway, basically follows the minimum rules for EU-countries. Many EU-countries actually have stronger rules than the minimum including also general compensation, a social plan for re-training or transfer to another plant within a firm for instance. Although not mandatory, some of these other requirements have been used also in Norway. For this set of dismissal restriction, Norway is ranked below average among OECD countries.

The work force flexibility of an economy can be enhanced by allowing fixed-term contracts in addition to standard contract, and the use of temporary work agencies. In many OECD countries there has been a strong trend in liberalizing the use of these two schemes. In Norway, the use of fixed term contracts is allowed only for limited situations, such as specific projects, seasonal work or the replacement of workers who are absent temporary. Some exceptions from this rule exist, for example for chief executives and researchers. However, it may not necessarily as restrictive as it appears since defining a specific project for a firm is partly open discretion. Large scale projects for a firm is often defined as a specific project and not defined as part of the standard activity of the firm. Hence, workers employed by the project work under fixed-term contracts. Successive contracts are possible with some limitations, and there is in general no rule of limiting the cumulated duration of successive contract. In general the use of temporary work agencies are prohibited, but wide exceptions exists for service sector occupations. Restrictions for the number of renewals exist, and 2 years is the maximum for cumulated contracts. Compared to other OECD countries, Norway is ranked a little bit above average for the strictness of the use of temporary employment (OECD, 1999).

Very few comparative studies of the overall degree of employment protection exist. A much-sited study by Emerson (1987), ranks Italy as having the strongest employment protection rules while the UK and partly Denmark are at the other end of the spectrum. Norway is ranked together with Sweden, France and partly Germany, when all regulations taken together as an intermediate country with a fairly high degree of protection. Obviously inter-country comparisons are difficult, however also Rogstad (1990) finds that employment protection is stronger in for instance Norway and France as compared to for instance the UK and Denmark. The most recent comparison is made by OECD in 1999, where Norway is ranked as number 12 of 19 OECD countries for the late 1980s, and as number 19 of 26 OECD countries for the late 1990s. The difference is the liberalization of the use of temporary contracts in many countries in the 1990s.

4. A simple "*q*" model for employment.

In this section we develop a model for employment demand that allows for a general structure of adjustment costs. The model is similar in spirit to q models of investment in the presence of fixed adjustment costs and irreversibilities (see Abel and Eberly (1994) and (1999)). It is also related to the model in Hamermesh (1992) that also contains fixed and quadratic components of adjustment costs.[6] We will show that when firms expand or contract, the growth rate of employment is related to the shadow value of the marginal worker, q, defined as the present discounted value of the marginal product of labor, net of wage costs. Our strategy is to use simple approximations to q and to estimate various versions of the model that differ in the precise specification of adjustment costs and of the stochastic elements of the model.

More precisely, we assume that firm i maximizes the present discounted value of cash flow, defined as:

$$V_t = E_t \sum_{j=0}^{\infty} \beta^j \left[F(L_{t+j}) - G(\Delta L_{t+j}, L_{t+j-1}) - w_{t+j} L_{t+1} \right] \tag{1}$$

where L_t denotes employment, $F(L_t)$ the gross production function, $G(\Delta L_t, L_{t-1})$ adjustment costs, assumed to be a function of net employment changes, and w_t the wage rate. We omit the index i for each firm for notational simplicity. Similarly, although capital is not introduced explicitly in the problem for ease of notation, firms should be thought as using both capital and

6 See also the other seminal contributions by Hamermesh (1989a), (1989b).

labor. However, capital is either not costly to adjust, or, if it is, its adjustment costs are additively separable from those for labor (there are no interrelated adjustment costs). Adjustment costs contain fixed, linear and quadratic components. Fixed costs, in turn, contain two elements: a_0, that is truly fixed, and $a_1 L_{t-1}$ that depends upon firm size. More specifically:

$$\begin{aligned} G(\Delta L_t, L_{t-1}) = D_t^+ & \left[a_0^+ + a_1^+ L_{t-1} + b^+ \Delta L_t + \frac{c^+}{2} (\frac{\Delta L_t}{L_{t-1}})^2 L_{t-1} \right] \\ & + D_t^- \left[a_0^- + a_1^- L_{t-1} - b^- \Delta L_t + \frac{c^-}{2} (\frac{\Delta L_t}{L_{t-1}})^2 L_{t-1} \right] \end{aligned} \tag{2}$$

D_t^+ (D_t^-) is a dummy that equals one when the firm expands (contracts) and it is zero otherwise. When firms increase employment, the proportional increase in employment satisfies:

$$\frac{\Delta L_t}{L_{t-1}} = \psi^+ \left[q_t - b^+ \right] \qquad \text{where } \psi^+ = \frac{1}{c^+} \tag{3}$$

For employment to expand, it must be true that the marginal profits generated by the expansion are positive. This requires q_t to satisfy:

$$q_t \geq \sqrt{2c^+ \cdot \left(\frac{a_0^+}{L_{t-1}} + a_1^+ \right)} + b^+ \tag{4}$$

Similarly contractions in employment obey:

$$\frac{\Delta L_t}{L_{t-1}} = \psi^- \left[q_t + b^- \right] \qquad \text{where } \psi^- = \frac{1}{c^-} \tag{3'}$$

Contractions occur when:

$$q_t \le -\sqrt{2c^- \cdot \left(\frac{a_0^-}{L_{t-1}} + a_1^- \right)} - b^- \tag{4'}$$

In all cases, the shadow value of employment, q_t, is:

$$q_t = E_t \sum_{j=0}^{\infty} \beta^j \left[F'(L_{t+\tau}) - w_{t+j} - \beta \cdot G_L(\Delta L_{t+j}, L_{t+j-1}) \right] \tag{5}$$

q_t represents therefore the present discounted value of the marginal product of capital, net of adjustment costs, minus the flow of wage costs associated to the marginal worker. In order to make the model estimable, we need to approximate the shadow value of a worker. We will assume that the latter is proportional to the sales to labor ratio. This could be justified if the production function is Cobb Douglas in labor and capital.[7] Moreover we assume that firms use simple AR(2) processes to forecast the sales to labor ratio and the wage rate. Finally, if we assume that the partial derivative of the cost function with respect to L_t, given net hiring, ΔL_t, denoted by G_L is dominated by the other two terms on the right hand side of (5), (i.e. that $(F'(.) - w) >> \beta \cdot G_L(.)$), we can write:

$$q_t = \gamma_0 + \gamma_1' Z_t - \varepsilon_t \tag{6}$$

where $Z_t = \left[(S/L)_{t-\tau}, (S/L)_{t-\tau-1}, w_{t-\tau}, w_{t-\tau-1} \right]$ and τ equals zero or one depending on whether contemporaneous information on the wage and sales to labor ratio is available or not.[8] Note we have added an error term ε_t to the definition of the shadow value of a worker to capture all those idiosyncratic factors at the firm level that are not observable by the econometrician. We will assume that ε_t (actually, ε_{it}) is normally independently distributed with mean zero and variance σ_{11}^2.

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[7] Imperfect competition can also be allowed for, provided the markup is constant.

8 In the current version of the paper we use $\tau = 0$ and $\tau = 1$. Thus, we assume that $Z_t = \left[(S/L)_t, (S/L)_{t-1}, w_t, w_{t-1} \right]$ or $Z_t = \left[(S/L)_{t-1}, (S/L)_{t-2}, w_{t-1}, w_{t-2} \right]$

One last simplification is useful in taking the model to the data when a_0 is non-zero, in order to keep the non-linearity of the problem manageable in estimation. We will take a first order linear expansion of the first term on the right hand side of (4) and (4') to rewrite the thresholds as[9]:

$$q_t \geq g_0^+ + g_1^+ \frac{1}{L_{t-1}} + \varepsilon_t \tag{4''}$$

$$q_t \leq -g_0^- - g_1^- \frac{1}{L_{t-1}} + \varepsilon_t \tag{4'''}$$

The log likelihood function for the problem summarized by (3), (3'), (4''), (4''') and (5) can be written as:

$$\begin{aligned} LogL = & \sum_{+} \log \frac{1}{\psi^+ \sigma_{11} \sqrt{2\Pi}} - \sum_{+} \frac{1}{2 \cdot (\psi^+)^2 \cdot \sigma_{11}^2} \left(\frac{\Delta L_{it}}{L_{it-1}} - h^+ - \psi^+ \gamma_1' Z_{it} \right)^2 \\ & + \sum_{-} \log \frac{1}{\psi^- \sigma_{11} \sqrt{2\Pi}} - \sum_{-} \frac{1}{2 \cdot (\psi^-)^2 \cdot \sigma_{11}^2} \left(\frac{\Delta L_{it}}{L_{it-1}} - h^- - \psi^- \gamma_1' Z_{it} \right)^2 \\ & + \sum_{0} \log \left\{ \Phi \left[(\gamma_1' Z_{it} + d_0^- + g_1^- \frac{1}{L_{it-1}}) \frac{1}{\sigma_{11}} \right] - \Phi \left[(\gamma_1' Z_{it} - d_0^+ - g_1^+ \frac{1}{L_{it-1}}) \frac{1}{\sigma_{11}} \right] \right\} \end{aligned} \tag{7}$$

where $h^+ = \psi^+[\gamma_0 - b^+]$, $h^- = \psi^-[\gamma_0 + b^-]$, $d_0^+ = (g_0^+ - \gamma_0)$, and $d_0^- = (g_0^- + \gamma_0)$, in addition to that $\sum_{+}, \sum_{-}, \sum_{0}$ denotes summation over the observations with respectively positive, negative or zero employment changes. This is a sort of two-sided generalized Tobit model. Note that the coefficients can be identified only up to the scale parameter σ_{11}. However we can identify the ratio of the quadratic adjustment costs parameters in the employment increase and decrease regimes. Moreover the components of fixed costs g_0^+ and g_0^- cannot be identified separately from the constant in the definition of q_t. However their sum can be

9 With the first order linear expansion approximations, we have; $\sqrt{2c^+ \cdot \left(\frac{a_0^+}{L_{t-1}} + a_1^+ \right)} + b^+ \cong g_0^+ + g_1^+ \frac{1}{L_{t-1}}$ and $\sqrt{2c^- \cdot \left(\frac{a_0^-}{L_{t-1}} + a_1^- \right)} + b^- \cong g_0^- + g_1^- \frac{1}{L_{t-1}}$.

identified, which allows us to identify the fixed component as well, if we assume that it is the same for employment increases and decreases.[10]

Parameters estimates can be obtained by maximizing the likelihood function in equation (7). Alternatively a Heckman type two step estimator can be used. First one estimates the ordered probit models to obtain the determinants of the shadow value of employment. The ordered probit model can be written:

$$
\begin{aligned}
LogL = & \sum_{+} \log \Phi\left[(\gamma_1' Z_{it} - d_0^{+} - g_1^{-} \frac{1}{L_{ti-1}}) \frac{1}{\sigma_{11}} \right] \\
& + \sum_{-} \log \left\{ 1 - \Phi\left[(\gamma_1' Z_{it} + d_0^{-} + g_1^{-} \frac{1}{L_{it-1}}) \frac{1}{\sigma_{11}} \right] \right\} \qquad (8) \\
& + \sum_{0} \log \left\{ \Phi\left[(\gamma_1' Z_{it} + d_0^{-} + g_1^{-} \frac{1}{L_{it-1}}) \frac{1}{\sigma_{11}} \right] - \Phi\left[(\gamma_1' Z_{it} - d_0^{+} - g_1^{+} \frac{1}{L_{it-1}}) \frac{1}{\sigma_{11}} \right] \right\}
\end{aligned}
$$

where $\Phi(.)$ denotes the standard normal cumulative distribution function. This allows us to recover estimates of the coefficients in (8) (relative to σ_{11}). These estimates can be used to construct a proxy for q_{it} and of the expected value of the error terms in the employment change equations, conditional on the probability of being in an employment increase or employment decrease regime. One can then estimate the following two equations:

$$
\frac{\Delta L_{it}}{L_{it-1}} = h^{+} + \psi^{+} \sigma_{11} \left(\frac{(\gamma_1' Z_{it})}{\sigma_{11}} + \lambda_{it}^{+} \right) + \eta_{it}^{+} \qquad (9)
$$

for employment increases and:

$$
\frac{\Delta L_{it}}{L_{it-1}} = h^{-} + \psi^{-} \sigma_{11} \left(\frac{(\gamma_1' Z_{it})}{\sigma_{11}} - \lambda_{it}^{-} \right) + \eta_{it}^{-} \qquad (9')
$$

[10] Note that in writing the likelihood, we are using the information on which regime the firm is in (positive employment changes, negative employment changes, no changes). The model estimated in Hamermesh (1989) is instead an unobservable regime model, basically because it is assumed that when firms want to keep employment constant, they succeed only on average (since there is a mean zero error term in the do nothing equation).

η_{it}^{+} and η_{it}^{-} denote zero means error terms, while λ_{it}^{+} and λ_{it}^{-} denote the appropriate inverse Mills ratios and are defined as:

$$\lambda_{it}^{+} = \frac{\phi\left[(\gamma_1' Z_{it} - d_0^{+} - g_1^{+}\frac{1}{L_{it-1}})\frac{1}{\sigma_{11}}\right]}{\Phi\left[(\gamma_1' Z_{it} - d_0^{+} - g_1^{+}\frac{1}{L_{it-1}})\frac{1}{\sigma_{11}}\right]} \tag{10}$$

$$\lambda_{it}^{-} = \frac{\phi\left[(\gamma_1' Z_{it} + d_0^{-} + g_1^{-}\frac{1}{L_{it-1}})\frac{1}{\sigma_{11}}\right]}{1-\Phi\left[(\gamma_1' Z_{it} + d_0^{-} + g_1^{-}\frac{1}{L_{it-1}})\frac{1}{\sigma_{11}}\right]} \tag{10'}$$

where $\phi(.)$ denotes the standard normal density function. Equations (9) and (9') can be estimated by OLS after replacing γ_1'/σ_{11}, λ_{it}^{+} and λ_{it}^{-} with the values constructed using the estimates obtained using the in the ordered probit model. Note again that on can only obtain estimates of $\psi^{-}\sigma_{11}$ and $\psi^{+}\sigma_{11}$, and not of ψ^{-} and ψ^{+}. Under the assumption that the variables in Z_{it} are uncorrelated with ε_{it}, the ordered probit yields consistent estimates of the coefficients and of their standard errors. OLS estimation of (9) and (9') yields consistent estimates of the parameters, but not of their standards errors, because of the well-known generated regressor problem. However, since there is only one generated regressor in each equation, the estimated value of $\left(\frac{(\gamma_1' Z_{it})}{\sigma_{11}} + \lambda_{it}^{+}\right)$ and $\left(\frac{(\gamma_1' Z_{it})}{\sigma_{11}} - \lambda_{it}^{-}\right)$ respectively, the *t*-statistics to test the hypothesis that its coefficient is zero is valid (see Pagan (1994)).[11]

A more general stochastic specification of the model would allow for an additional optimization error in the employment expansion equation, v_{it}^{+}, and in the employment contraction equation, v_{it}^{-}. The composite error term in such equations would then become $u_{1it} = v_{it}^{+} - \psi^{+}\varepsilon_{it}$, and $u_{1it} = v_{it}^{-} - \psi^{-}\varepsilon_{it}$. We will assume that $u_{1it}, u_{2it}, \varepsilon_{it}$ are jointly normally distributed with mean zero and covariance matrix Σ equal to:

[11] The values obtained in the two step estimator can be used as starting values in the Maximum Likelihood iterations. Note that one iteration of Newton-Raphson type of algorithm, yields an estimator that is asymptotically equivalent to the ML estimator.

$$\Sigma = \begin{bmatrix} \sigma_{11}^2 & \sigma_{12} & \sigma_{1\varepsilon} \\ \sigma_{21} & \sigma_{22}^2 & \sigma_{2\varepsilon} \\ \sigma_{\varepsilon 1} & \sigma_{\varepsilon 2} & 1 \end{bmatrix} \tag{11}$$

The likelihood function, using the information about sample separation, can be written as:

$$\begin{aligned} LogL = & \sum_{+} \log \frac{1}{\sigma_{11}\sqrt{2\Pi}} - \sum_{+} \frac{1}{2\cdot\sigma_{11}^2}\left(\frac{\Delta L_{it}}{L_{it-1}} - h^{+} - \psi^{+}\gamma_1' Z_{it}\right)^2 \\ & + \sum_{+} \log \Phi\left\{\left[\gamma_1' Z_{it} - d_0^{+} - g_1^{+}\frac{1}{L_{it-1}} - \frac{\rho_1}{\sigma_{11}}\left(\frac{\Delta L_{it}}{L_{it-1}} - h^{+} - \psi^{+}\gamma_1' Z_{it}\right)\right]\left[1-\rho_1^2\right]^{\frac{1}{2}}\right\} \\ & + \sum_{-} \log \frac{1}{\sigma_{22}\sqrt{2\Pi}} - \sum_{-} \frac{1}{2\cdot\sigma_{22}^2}\left(\frac{\Delta L_{it}}{L_{it-1}} - h^{-} - \psi^{-}\gamma_1' Z_{it}\right)^2 \\ & + \sum_{-} \log\left[1 - \Phi\left\{\left[\gamma_1' Z_{it} + d_0^{-} + g_1^{-}\frac{1}{L_{t-1}} - \frac{\rho_2}{\sigma_{22}}\left(\frac{\Delta L_{it}}{L_{it-1}} - h^{-} - \psi^{-}\gamma_1' Z_{it}\right)\right]\left[1-\rho_2^2\right]^{\frac{1}{2}}\right\}\right] \\ & + \sum_{0} \log\left\{\Phi(\gamma_1' Z_{it} + d_0^{-} + g_1^{-}\frac{1}{L_{it-1}}) - \Phi(\gamma_1' Z_{it} - d_0^{+} - g_1^{+}\frac{1}{L_{it-1}})\right\} \end{aligned} \tag{12}$$

where $\rho_1 = \frac{\sigma_{1\varepsilon}}{\sigma_{11}}$, and $\rho_2 = \frac{\sigma_{2\varepsilon}}{\sigma_{22}}$.

For this model as well one could easily write down the appropriate two step estimator.

5. Results

In this section we will report estimation result for the model summarized by (3), (3'), (4''), (4''') and (5), i.e. the model whose only stochastic element ε_{it} is the error term in the expression for the shadow value of labor q_{it}. We first present estimates based on Maximum Likelihood estimation of the Ordered Probit in (8) and OLS estimation of (9) and (9'). We then present the full Maximum Likelihood estimates of equation (7).

We have estimated various versions of the model with different specifications of the fixed components of adjustment costs, and based on different assumptions about the information set used by firms in forecasting the present value of returns to one additional worker. The results obtained when contemporaneous and once lagged sales and wages are used to construct q_t are reported in Table 3. Initially we have assumed that the purely fixed components a_0^+ and a_0^- equal zero, so that the probability of increasing, decreasing or keeping employment the same does not depend upon plant size, measured by past employment ($g_1^+ = g_1^- = 0$). Results are reported in the first column. Note that a ~ above a parameter denotes the ratio between the original parameter and σ_{11} (for instance, $\tilde{a}_0^+ = a_0^+ / \sigma_{11}$, etc.). Moreover, $\delta^+ = \psi^+ \sigma_{11}$ and $\delta^- = \psi^- \sigma_{11}$.

In the second column we allow a_0^+ and a_0^-, and hence a_0^+ and a_0^-, to differ from zero. Since size does not enter in the equation for net employment changes, but it enters the thresholds, we have now a useful exclusion restriction that can help us identifying the employment changes equations when we estimate them using a Heckman type of procedure.[12] In column three again we set $\tilde{g}_1^+$ and $\tilde{g}_1^-$ to zero, but we assume that the fixed components of adjustment costs that are proportional to size (a_1^+ and a_1^-) or the linear component in the change in employment (b^+ and b^-) differ between small and large plants. Small (large) plants are defined as those with less than (more than) 50 employees. In this model, therefore, the thresholds vary discretely with size, contrary to the model in the second column where size affects the thresholds continuously.[13] Size dummies are also included in the employment equations. Finally, in the last column we present the more general model with both a_0^+ and a_0^- different from zero <u>and</u> a_1^+ and a_1^- that differ between small and large plants.

The Ordered Probit results suggest that there are significant fixed components of adjustment costs or important linear components (in the change of employment). Their sum (i.e. $\tilde{a}_0^+ + \tilde{a}_0^-$, where $\tilde{a}_0^- = \left(g_0^- + \gamma_0\right)/\sigma_{11}$ and $\tilde{a}_0^+ = \left(g_0^+ - \gamma_0\right)/\sigma_{11}$) equals 0.554 (=-0.015+0.569) and it is significantly different from zero. If the fixed component was symmetric, its value would equal 0.277). The sign of the coefficients of the sales to labor ratio and of the wage rate are sensible. The coefficient of $\left(S/L\right)_{it}$ is positive significant and much larger (in absolute value) than the negative coefficient of $\left(S/L\right)_{it-1}$. The coefficient of the contemporaneous wage is negative and significant, while the lagged wage has a very small and insignificant

[12] See Lewbel (2001) for a semiparametric estimator of the second stage equation that relies on this exclusion restriction, with an application to investment.

[13] In future work we will also allow adjustment costs to differ between multi-plants and single plant firms.

coefficient. This means that, looking at the sum of the coefficients on the contemporaneous and lagged determinants of q_{it}, the sales to labor ratio has a positive effect and the wage a negative effect on the shadow value of labor q_{it}, as one would expect. As a result, a (permanently) higher sales to labor ratio is associated with an increase in the probability of observing an increase in employment, while a (permanently) higher wage is associated with a decrease in such probability. The opposite holds true for the probability of employment decreases. The average estimated probability of the employment expansion, employment contraction, and no change equal 0.384, 0.408 and 0.208 respectively. These figures make sense, given the descriptive statistics reported in Table 1.

The results in the first column also suggest that there are significant quadratic components of adjustment costs both in the case of employment expansion and employment contraction. The coefficient in the employment expansion equation is $\delta^+ = 0.193$ and the one in the employment contraction regime is $\delta^- = 0.404$, which would suggest that the coefficient of the quadratic component is approximately twice as large for employment expansions compared to employment contractions (expansions are more expensive at the margin). One can easily reject the hypothesis that the coefficient of the quadratic component is equal in the two regimes.

When we allow for the inverse of plant size to affect continuously the thresholds, the results suggest that $\tilde{g}_1^+$ and $\tilde{g}_1^-$ are significantly different from zero (see the second column of Table 3). This suggests that plant size matters in determining the threshold values of q_{it} beyond which the firm decides to increase or decrease employment. The range over which plants keep employment constant is wider for plants with smaller initial employment, because both the lower threshold decreases and the upper threshold increases. The effect of size is much larger on the lower threshold, which means that smaller plants face greater fixed adjustment costs particularly when they reduce employment. These overall econometric results seem to be very much consistent with the descriptive evidence discussed in Section 2, and in particular, with the larger frequency of zero employment changes episodes for smaller firms. Note that now the sum of the estimated values of $\tilde{d}_1^+$ and $\tilde{d}_1^-$ is much smaller than before (0.024 (=0.608-0.584) versus 0.554), indicating that the fixed component of cost proportional to size and the component linear in employment changes are not as important when we allow for a pure fixed component.

Finally, also in this specification the quadratic components of costs remain important, and different in expansions and contraction. However, the nature of the asymmetry is completely different. The estimated value of $\delta^{+} = \psi^{+}\sigma_{11}$ and of $\delta^{-} = \psi^{-}\sigma_{11}$ equal 0.224 and 0.154 respectively. Now the quadratic components of cost suggest that reductions in the labor force are more expensive at the margin then increases in the labor force, which is exactly the opposite of the results obtained with the more restrictive model presented in column 1. Both quadratic coefficients are significantly different from zero and from each other.

In the third column of Table 3 we set $\tilde{g}_1^{+}$ and $\tilde{g}_1^{-}$ equal to zero again, but allow size to affect d_0^{+} and d_0^{-} discretely. Again we obtain that it is less costly to adjust for large plants, so that the probability of observing zero employment changes episodes is smaller for them. The quadratic coefficients again suggest that downward adjustments in employment are less costly at the margin than employment expansions. However, when we allow both for size dummies and for non zero $\tilde{g}_1^{+}$ and $\tilde{g}_1^{-}$ (results reported in column 4), we conclude that employment expansions are less expensive than contractions at the margin. Given the presence of a useful exclusion restriction when size is allowed to affect the thresholds, and given the significance of $\tilde{g}_1^{-}$ in all specifications and the near significance of $\tilde{g}_1^{+}$, the models allowing for a purely fixed component of adjustment costs represent a more satisfactory specification, leading one to have more faith in the conclusion that the marginal adjustment costs of employment decreases exceed those associated with employment increases.

In the lower half of Table 3 we report the Maximum Likelihood estimates of the various versions of the model. The estimation results are in part disappointing: while some of the parameters are well determined some are not. In particular, the threshold parameters $\tilde{d}_0^{+}$, $\tilde{d}_0^{-}$, $\tilde{g}_1^{+}$ and $\tilde{g}_1^{-}$ result difficult to estimate precisely. Moreover, the point estimates imply unreasonable values of the estimated probabilities of each regime. For instance, the estimated probability of the inaction regime is very close to one, while the ones for the employment expansion and contraction regimes are very close to zero. One conjecture is that in the full likelihood model, the thresholds parameters are basically pinned down only by the zero observations (see equation (8)), while in the Ordered Probit Model the positive and negative employment changes observations contribute to their determination. This makes it possible in our sample to estimate those parameters more precisely using the Ordered Probit model. Note however, that all the other parameters, such as those entering in the equation for the shadow value of employment and those determining the quadratic components of adjustment cost, are well determined. As before, contemporaneous sales enter with a positive coefficient, while lagged sales with a much smaller negative coefficient. The coefficient of contemporaneous wages is negative, while the one for lagged wages is positive, but much smaller. All of them are significantly different from zero. Finally, now in all specifications we obtain the result that, at the margin, it is more expensive to contract employment than to expand it.

Table 4 mirrors Table 3 and contains the results obtained when only lagged information is used in forming a proxy for the shadow value of employment. This reduces the potential endogeneity problems due to the correlation between contemporaneous sales and possibly wages and the error term. Most of the previous conclusions still hold. One exception is that the coefficient of wages lagged once is now negative and significant, while the one for wages lagged twice is positive and significant. The value of the latter exceeds the absolute value of the former, which is less than satisfactory, since it implies a positive steady state effect of wages on the shadow value of employment. Sales continue to play the role implied by the results of Table 3. The purely fixed components of adjustment costs appear again to be important, so that the area of inaction is greater for smaller plants. The ambiguities concerning the asymmetries in the quadratic components of adjustment costs reappear here, but, as before, the cost of reduction in employment is greater in the more general models, containing also a purely fixed component of adjustment costs. The problem of estimating the threshold parameters with Maximum Likelihood is confirmed.

6. Conclusions

It would be premature, a this stage, to reach definitive conclusions. However, the initial results we have presented suggest that the framework proposed in this paper is potentially a fruitful one. In particular, the q model of employment with a general specification of adjustment costs, seems to be a useful way to organize the analysis of employment changes at the firm level. The initial results imply that it is important to depart from the standard specification of convex and symmetric adjustment costs. Fixed (or linear) costs are important factors that the firm must consider when changing its employment levels. The evidence suggests that the fixed components are relatively larger for smaller plants (with size measured by past employment). This is partly because fixed costs contain a component that are unrelated to size, in addition to a components proportional to size. As a result, the area of inaction is greater for smaller plants.

Quadratic components of costs are also important, and although some ambiguities exist on the nature of the asymmetries, the evidence from the more general models suggests that those costs are higher during employment contractions compared to expansions.

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Table 1. Net Employment Changes, $\frac{\Delta L_t}{L_{t-1}}$

$\frac{\Delta L_t}{L_{t-1}}$	# obs.	Freq. (overall)	Freq. (<0,>0)	Share; ΔL/sum(ΔL)	Percent, by plant size 4-25	26-50	51-100	101-
< -0.5	51	0.006	0.014	0.048	0.46	0.64	1.14	0.40
-0.5, -0.4	89	0.010	0.024	0.099	0.83	1.13	1.14	1.47
-0.4, -0.3	211	0.023	0.058	0.104	2.67	1.35	1.55	1.74
-0.3, -0.2	563	0.061	0.154	0.232	6.56	4.96	5.57	4.81
-0.2, -0.1	1332	0.144	0.364	0.314	14.95	13.76	11.76	14.15
-0.1, 0.0	1413	0.152	0.386	0.204	8.39	24.26	31.68	33.24
= 0	1886	0.204	-	-	27.45	9.72	4.54	2.67
0.0, 0.1	1192	0.129	0.320	0.214	7.09	22.41	24.87	26.70
0.1, 0.2	1222	0.132	0.328	0.283	14.06	12.84	10.42	10.28
0.2, 0.3	601	0.065	0.161	0.158	7.97	3.90	3.92	2.54
0.3, 0.4	251	0.027	0.067	0.099	3.16	2.34	1.65	1.07
0.4, 0.5	220	0.024	0.059	0.074	3.21	0.99	0.62	0.40
0.5, 1.0	210	0.023	0.056	0.132	2.92	1.49	0.62	0.53
>1.0	26	0.003	0.007	0.041	0.29	0.21	0.52	0.00
Total	9267	1.000	3.000	3.000	#obs = 6139	#obs = 1410	#obs = 969	#obs = 749

Table 2. Hirings $\frac{H_t}{L_{t-1}}$

$\frac{H_t}{L_{t-1}}$	# obs.	Freq.	Share H/sum(H)	Percent 4-25	by plant 26-50	size 51-100	101-
= 0	2047	0.221	0.000	30.18	10.21	4.13	1.34
0.0, 0.1	1955	0.211	0.163	10.96	31.77	45.10	53.00
0.1, 0.2	2410	0.260	0.288	24.30	30.00	28.38	29.37
0.2, 0.3	1328	0.143	0.229	15.10	14.04	12.38	11.08
0.3, 0.4	593	0.064	0.113	6.65	8.16	4.95	2.94
0.4, 0.5	458	0.049	0.068	6.39	2.41	2.58	0.93
0.5, 0.6	117	0.013	0.037	1.47	0.92	0.93	0.67
0.6, 0.7	135	0.015	0.026	1.92	0.71	0.41	0.40
0.7, 0.8	56	0.006	0.012	0.80	0.43	0.00	0.13
0.8, 0.9	64	0.007	0.018	0.94	0.28	0.10	0.13
0.9, 1.0	44	0.005	0.015	0.57	0.50	0.21	0.00
>1.0	60	0.006	0.032	0.72	0.57	0.83	0.00
Total	9267	1.000	1.000	#obs = 6139	#obs = 1410	#obs = 969	#obs = 749

	NJCR < 0	NJCR == 0	NJCR > 0
HR==0	1214	833	0
HR > 0	2445	1053	3722

Figure 1. Distribution of Net Employment Changes, $\frac{\Delta L_t}{L_{t-1}}$

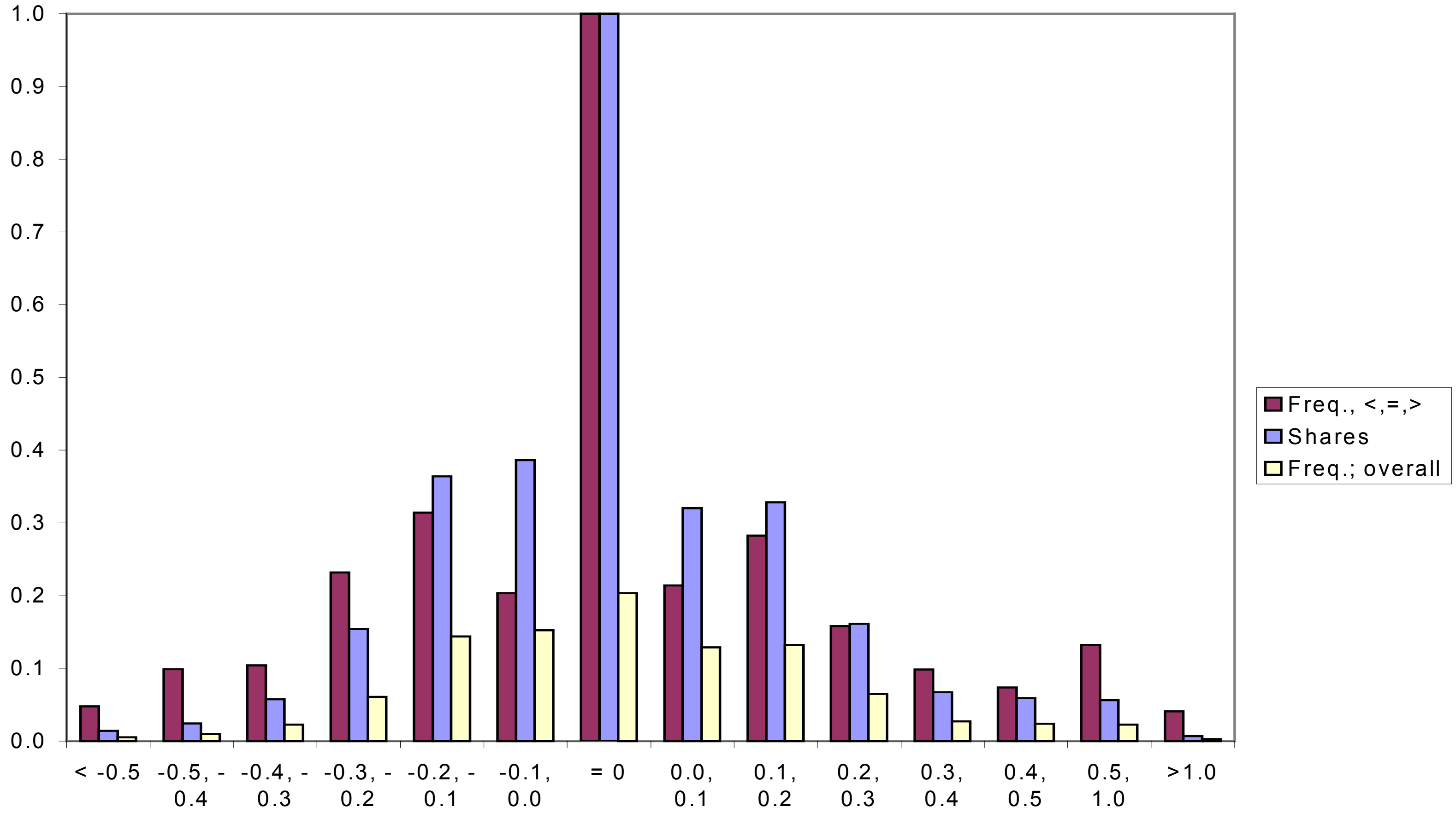

Table 3: Estimation Results for the Net Job Change Model

	Coeff.	z-value	Coeff.	z-value	Coeff.	z-value	Coeff.	z-value
Ordered probit results								
$(S/K)_{it}$	0.192	20.99	0.193	20.78	0.195	21.17	0.193	20.78
$(S/K)_{it-1}$	-0.084	-9.47	-0.079	-8.78	-0.082	-9.22	-0.079	-8.78
w_{it}	-0.189	-2.98	-0.146	-2.29	-0.181	-2.87	-0.147	-2.31
w_{it-1}	0.047	0.75	0.053	0.84	0.049	0.78	0.053	0.84
d tilde -	-0.015	-0.28	-0.584	-9.70	0.058	1.08	-0.554	-8.57
d tilde +	0.569	10.59	0.608	10.10	0.605	11.17	0.605	9.41
g tilde -			6.698	24.07			6.423	18.79
g tilde +			0.604	2.32			0.608	1.93
probit *big* -					-0.539	-14.30	-0.050	-1.10
probit *big* +					-0.032	-0.84	0.017	0.38
Log L	-8005.2		-7453.0		-7763.1		-7451.8	
Estimated probabilities								
Contraction	0.408		0.408		0.408		0.408	
Zero changes	0.208		0.209		0.208		0.210	
Expansion	0.384		0.383		0.384		0.383	
OLS w/ inverse Mills ratios								
Contraction								
delta -	0.404	18.13	0.154	19.43	0.358	17.09	0.168	16.69
empl. *big* -					-0.089	-10.06	-0.012	-2.17
h tilde -	0.150	9.08	-0.054	-10.52	0.122	7.37	-0.043	-5.89
Expansion								
delta +	0.193	9.65	0.224	11.82	0.198	10.46	0.221	11.97
empl. *big* +					-0.102	-11.83	-0.102	-11.96
h tilde +	-0.060	-2.25	-0.120	-4.45	-0.052	-2.03	-0.096	-3.65
Maximum likelihood								
$(S/K)_{it}$	0.122	15.14	0.122	15.19	0.123	15.29	0.123	15.28
$(S/K)_{it-1}$	-0.050	-6.26	-0.050	-6.29	-0.048	-6.00	-0.048	-6.00
w_{it}	-0.301	-5.08	-0.300	-5.07	-0.301	-5.07	-0.302	-5.09
w_{it-1}	0.134	2.24	0.135	2.25	0.124	2.07	0.123	2.05
d tilde -	4.339	1.95	3.677	1.13	4.413	1.68	4.043	0.66
d tilde -	4.734	2.10	4.257	1.38	4.509	2.97	4.840	0.93
h tilde -	-0.151	-26.55	-0.151	-26.59	-0.160	-28.32	-0.160	-28.29
h tilde +	0.163	15.55	0.162	15.47	0.185	17.85	0.186	17.91
g tilde -			6.764	0.14			4.530	0.06
g tilde +			4.197	0.10			0.981	0.02
probit *big* -					1.612	0.01	0.351	0.02
probit *big* +					0.579	0.02	-0.014	0.00
empl. *big* -					0.039	8.95	0.039	8.95
empl. *big* +					-0.109	-12.73	-0.109	-12.73
delta -	0.107	80.29	0.107	80.47	0.106	80.48	0.106	80.43
delta +	0.192	78.26	0.192	78.35	0.187	78.34	0.187	78.30
Log L	3307.6		3307.6		3426.8		3426.8	
Number of obs	7853		7853		7853		7853	

Table 4: Estimation Results for the Net Job Change Model (lagged infomation)

	Coeff.	z-value	Coeff.	z-value	Coeff.	z-value	Coeff.	z-value
Ordered probit results								
$(S/K)_{it-1}$	0.120	12.35	0.124	12.60	0.122	12.53	0.124	12.59
$(S/K)_{it-2}$	-0.076	-7.98	-0.074	-7.65	-0.075	-7.78	-0.074	-7.65
w_{it-1}	-0.121	-1.76	-0.082	-1.18	-0.117	-1.70	-0.082	-1.18
w_{it-2}	0.199	2.83	0.205	2.90	0.199	2.84	0.205	2.90
d tilde -	-0.023	-0.40	-0.579	-8.72	0.050	0.84	-0.576	-8.08
d tilde +	0.557	9.42	0.598	9.02	0.590	9.90	0.605	8.55
g tilde -			6.559	21.49			6.519	17.25
g tilde +			0.573	2.00			0.512	1.47
probit *big* -					-0.494	-12.08	-0.001	-0.03
probit *big* +					-0.054	-1.31	-0.011	-0.21
Log L	-6722.4		-6270.9		-6530.5		-6270.8	
Estimated probabilities								
Contraction	0.407		0.408		0.407		0.408	
Zero changes	0.207		0.207		0.206		0.207	
Expansion	0.386		0.385		0.386		0.385	
OLS w/ inverse Mills ratios								
Contraction								
delta -	0.329	8.44	0.133	13.81	0.291	7.89	0.128	10.66
empl. *big* -					-0.056	-4.17	0.005	0.77
h tilde -	0.084	3.05	-0.071	-12.01	0.061	2.17	-0.075	-9.18
Expansion								
delta +	0.203	4.33	0.346	8.26	0.230	5.19	0.316	7.65
empl. *big* +					-0.090	-9.50	-0.090	-9.54
h tilde +	-0.068	-1.13	-0.279	-4.89	-0.089	-1.53	-0.221	-3.90
Maximum likelihood								
$(S/K)_{it-1}$	0.056	6.30	0.056	6.28	0.058	6.53	0.058	6.50
$(S/K)_{it-2}$	-0.025	-2.86	-0.025	-2.84	-0.025	-2.76	-0.025	-2.75
w_{it-1}	-0.249	-3.82	-0.251	-3.85	-0.254	-3.89	-0.254	-3.89
w_{it-2}	0.274	4.05	0.273	4.03	0.270	3.99	0.270	4.00
d tilde -	4.181	1.93	3.972	0.61	4.112	2.16	3.577	1.08
d tilde +	4.557	1.82	4.355	0.68	4.420	2.30	4.005	1.28
h tilde -	-0.162	-25.35	-0.162	-25.28	-0.172	-26.88	-0.172	-26.93
h tilde +	0.158	13.56	0.159	13.63	0.179	15.50	0.179	15.52
g tilde -			5.296	0.06			4.421	0.12
g tilde +			4.200	0.05			2.903	0.09
probit *big* -					0.192	0.01	0.347	0.04
probit *big* +					0.252	0.01	0.342	0.03
empl. *big* -					0.039	8.95	0.039	8.10
empl. *big* +					-0.101	-10.62	-0.101	-10.65
delta -	0.109	72.53	0.109	72.46	0.108	72.45	0.108	72.52
delta +	0.193	70.60	0.193	70.61	0.189	70.59	0.189	70.65
Log L	2643.1		2643.1		2731.3		2731.2	
Number of obs	6439		6439		6439		6439	