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LABOR DEMAND AND THE SOURCE OF ADJUSTMENT COSTS

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ABSTRACT

Most models of dynamic labor demand are written in terms of costs of adjusting employment (net adjustment costs). A few are based on the costs of hiring and firing (gross adjustment costs). This study derives several models containing both types of adjustment costs. A dynamic-programming model with quadratic adjustment costs generates an estimate of the lower bound on the fraction of adjustment costs that are gross costs. A model with lumpy costs of adjustment also estimates the relative sizes of the two types of costs. The models are estimated over two sets of short monthly time series obtained from private sources, one from a medium-size hospital, the other describing three plants operated by a small manufacturing firm. The quadratic-cost model is also estimated using data describing small industries. The estimates demonstrate that the importance of the two types of costs differs across establishments, though gross adjustment costs appear relatively larger. The results provide evidence on issues of asymmetry in business cycles and the role of human capital in generating externalities in economic growth.

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I. Introduction

A huge literature has studied the dynamics of labor (employment and worker–hours) demand based on the costs of adjustment facing employers. The standard assumption underlying this research has been that these costs are convex, though recent investigations (Hamermesh, 1989; Pfann and Verspagen, 1989; Holtz–Eakin and Rosen, 1991) suggest that nonconvex costs provide a better description of the structure of adjustment costs. No standard assumption exists about the source of these costs. This study considers how alternative sources of adjustment costs affect employment dynamics and measures the relative importance of these alternatives.

Section II examines how this issue has been treated (more correctly, ignored) in the vast literature on dynamic factor demand and discusses its importance for several areas. In Section III I derive the firm's profit–maximizing employment path when it faces two distinct types of adjustment costs. Since it is not clear what the structure of these costs is, I present models based on convex and one type of nonconvex costs. Section IV describes the data sets, especially collected for use here, that are employed to examine these models. Section V uses these data to estimate forward–looking models generated by convex adjustment costs, while Section VI examines the models based on nonconvex costs. Section VII concludes.

II. History and Motivation

Adjustment costs can be classifed as gross or net, depending on their source. The former are incurred whenever a worker is laid off or hired. They reflect costs of hiring and training new workers or separating experienced ones, and can be viewed as linked to the identity of the individual filling a job. The latter arise along the path between levels of employment. They reflect costs generated by a movement between different long–run profit–maximizing levels of employment, and can be viewed as linked to changes in the number of jobs rather than their incumbents' identities.

Early discussions of adjustment costs did not distinguish between the sources. For example, Holt et al (1960, p. 52) note that, "The cost of laying off workers derives from terminal pay, reorganization, etc...," implicitly referring to both gross and net costs. Oi (1961, p. 539) observes that "fixed employment costs can be separated into two categories ... hiring and training costs," i.e., as gross costs.[1] Nadiri and Rosen (1969, p. 659) mention "search, hiring, training and layoff costs and associated morale problems among workers," which may mix gross and net costs. Despite the apparent recognition that the costs of adjusting employment are an amalgam of gross and net costs, empirical work in these and many other early studies was restricted to changes in the stock of employees (or worker–hours), i.e., to net changes in labor demand.

In subsequent research the firm's dynamic profit–maximizing path of employment has been derived using one or the other of these concepts of adjustment costs. Sargent's (1978) rational–expectations approach defined these costs in terms of changes in employment levels, i.e., based on net costs, as did the previous work that assumed static expectations, and as has most subsequent research. Nickell (1986) and a few others have modeled dynamics as based on costs of hiring and laying off — on gross costs, paying little attention to any of the internal costs of adjustment that a net change in employment might engender.[2] Within both traditions nearly all the econometric work that is linked to formal models has examined the path of employment or worker–hours, levels rather than flows of workers. Nowhere has there been an empirical examination of the source of these costs.

Gross and net costs are clearly distinct concepts, but if there are no voluntary separations from the firm they cannot be distinguished without detailed cost accounting. Each net change in employment results from an equal–sized flow of hires or layoffs. Voluntary separations do occur, though, and can constitute sizable fractions of the typical firm's workers each month.[3]

Their existence suggests that both sources of adjustment costs should be accounted for when we model dynamic labor demand; and empirical estimates tied to those formal models should generate estimates of the importance of the two types of cost.

Distinguishing between the two sources of adjustment costs is important for several reasons. In terms of labor–market policy, it would move us a step closer to being able to link policies that affect gross adjustment costs, e.g., restrictions on discharging workers, affirmative–action requirements, and others, to their impact on costs. It would thus provide an analytical basis for the evaluation of these policies.

On purely intellectual grounds it would demonstrate whether the focus on net changes in employment that pervades the empirical literature makes sense in terms of the nature of the underlying costs. That is, does slow adjustment of employment to shocks result because of disruptions in the workplace due to changes in staffing levels or because new workers must be processed? Answers to this question may underlie two unrelated major issues outside the area of labor economics, business–cycle asymmetry (see, e.g., Neftçi, 1984) and the possible externalities in economic growth arising from investment in human capital that resumed attracting substantial attention in the late 1980s (Romer, 1986).

III. Employment Adjustment with Gross and Net Costs

Throughout this Section I model labor as a one–dimensional stock of homogeneous workers denoted by L. Implicitly this means that hours of work cannot vary, so that we are deriving the firm's demand for employment. Obtaining the simultaneous demand for workers and hours with both sources of adjustment costs greatly increases the complexity of the problem. Finally, the firm never lays off workers; negative net changes in employment occur through attrition.[4] In Subsection A I treat adjustment costs as convex — — — I assume that both gross and net costs are variable and quadratic in the size of the change. In Subsection B I assume they are lumpy --- are independent of the size of the change in employment or hiring.

A. A Forward–Looking Model with Quadratic Costs

In this model the firm's adjustment costs are:

$$(1) \qquad C_{t+i} = C_{\Delta L_{t+i}} + C_{H_{t+i}} = b_1[L_{t+i} - L_{t+i-1}]^2 + b_2 H_{t+i}^2,$$

where H_{t+i} denotes the number of hires during the time period t+i, i = 0, 1,..., and b_1 and b_2 are parameters describing adjustment costs. The first term in (1) reflects the costs of adjusting the level of employment (net costs), while the second measures the costs of hiring (gross costs). The stocks and flows that contribute to these costs are linked by the identity:

$$(2) \qquad H_t \equiv L_t - L_{t-1} + Q_t ,$$

where Q_t is the number of employees who quit between time t−1 and t. Following Sargent (1978) the firm maximizes the stream of expected future profits:

$$(3) \qquad \pi = E_t \sum_{i=0}^{\infty} R^i [(\bar{\alpha}_0 + \alpha_{0,t+i})L_{t+i} - .5\alpha_1 L_{t+i}^2 - w_{t+i}L_{t+i} - .5C_{t+i}] ,$$

where w is the wage rate, R < 1 is the discount factor, and the α are parameters of the production function, with $\alpha_{0,t+i}$ having a zero mean and positive variance. The novelty in this model is the inclusion of the two separate terms in adjustment costs in (1) with b_1, $b_2 > 0$.

The Euler equations describing the profit-maximizing path of L_t based on (3) are:

$$(4)\qquad RE_{t+i}L_{t+i+1} - [\frac{\alpha_1}{b_1+b_2}+R+1]L_{t+i} + L_{t+i-1} = [b_1+b_2]^{-1}[w_{t+i}-\alpha_0-\alpha_{0,t+i} -b_2(RE_{t+i}Q_{t+i+1}-Q_{t+i})] \ , \ i=0,1,....$$

Note that if $b_2 = 0$ or $Q_{t+i} = 0$, (4) reduces to the standard rational-expectations model of dynamic factor demand in the presence of quadratic net costs of adjustment. The solutions to (4) are:

$$(5)\quad L_t = \lambda L_{t-1} - \lambda[b_1+b_2]^{-1}\sum_{j=0}^{\infty}\delta^{-j}[w_{t+j}-\bar{\alpha}_0-\alpha_{0,t+j}-b_2(RQ_{t+j+1}-Q_{t+j})] \ ,$$

where $0 < \lambda < 1$ and $\delta > R^{-1}$ describe the factorization of the quadratic equation implicit in the terms in L in the Euler equations. Equation (5) contains the usual results on dynamic labor demand, with the level of employment depending negatively on the wage rate and positively on productivity shocks. Also, though, the final term in (5) implies that a higher constant rate of voluntary turnover reduces labor demand by an amount that increases with the convexity of C_H in (1), reflecting the user cost generated by quits.

Assume that the $\alpha_{0,t}$, w_t and Q_t are all described by first-order processes, with autocorrelation parameters ρ_α, ρ_w and ρ_Q. (The important operational assumption, that Q_t is AR(1), is explicitly tested in the empirical work.) Then the path of labor demand can be described by:

$$(5')\qquad L_t = \lambda L_{t-1} - \lambda[b_1+b_2]^{-1}[w_t(1-\frac{\rho_w}{\delta})^{-1}-\bar{\alpha}_0(1-\frac{1}{\delta})^{-1}-\alpha_{0,t}(1-\frac{\rho_\alpha}{\delta})^{-1} -b_2Q_t(R\rho_Q-1)(1-\frac{\rho_Q}{\delta})^{-1}] \ .$$

Equation (5') provides the basis for part of the estimation in Section V. The term in Q_t can be used to identify the relative importance of the two sources of adjustment costs, for it depends in part on the ratio of the b_i.

B. A Model with Lumpy Costs

One (of many) alternative approaches to the standard assumption of convex adjustment costs is to assume instead that they are lumpy. Let:

$$(6) \qquad C_t = \begin{cases} K_L, & \text{if } H_t \neq Q_t,\ H_t = 0\ ; \\ K_H, & \text{if } H_t = Q_t,\ H_t > 0\ ; \\ K_L + K_H, & \text{if } H_t \neq Q_t,\ H_t > 0\ , \end{cases}$$

where the K_i are parameters measuring the size of the lumpy costs associated with gross and net employment changes respectively. Assume that the firm forecasts demand conditions in period t, and let L^* be the level of employment that maximizes its expected profits in the absence of adjustment costs. Implicitly I am assuming employers have static expectations. This short-sightedness is clearly a step back from the forward-looking model of (3); but such models cannot be solved analytically under lumpy costs. The behavioral implications gained by allowing for the possible realism of nonconvex costs come at the cost of abandoning some of the realism about expectations.

Under this assumption, assuming too that $Q_t \neq 0$, and given its endowment of workers, L_{t-1}, only three possible choices could maximize the firm's profits: 1) Hire no one, and incur adjustment costs K_L because employment has changed (dropped); 2) Hire replacement workers, $H_t = Q_t$, and incur adjustment costs K_H; or 3) Hire sufficient workers to set $L_t = L^*$.

Letting π be the firm's profit function defined over employment, the conditions for making these choices are:

(7a) $$H_t = 0 ,$$

if $K_H + \pi(L^*) - \pi(L_{t-1}) > K_L + \pi(L^*) - \pi(L_{t-1} - Q_t)$,

and $$K_H + K_L > K_L + \pi(L^*) - \pi(L_{t-1} - Q_t) ;$$

(7b) $$H_t = Q_t ,$$

if $K_H + \pi(L^*) - \pi(L_{t-1}) < K_L + \pi(L^*) - \pi(L_{t-1} - Q_t)$,

and $$K_H + K_L > K_H + \pi(L^*) - \pi(L_{t-1}) ;$$

(7c) $$H_t = L^* - [L_{t-1} - Q_t] ,$$

if $$K_H + K_L < K_L + \pi(L^*) - \pi(L_{t-1} - Q_t) ;$$

and $$K_H + K_L < K_L + \pi(L^*) - \pi(L_{t-1}) .$$

Rearranging the three separate inequality conditions in (7a)–(7c) yields a set of constraints that defines the optimal choice for the firm for all combinations of values of L^*, L_{t-1} and Q_t. These conditions divide the (K_H, K_L) space into three regions, as shown in Figure 1. When K_L is very large (relative to the departure of L^* from L_{t-1}), the best choice is to set $H_t = Q_t$, unless K_H is so large that not even replacing quitters dominates doing some hiring. If K_H and K_L are small relative to the loss in profits when no hiring or only replacement hiring is done, the profit–maximizing choice is to set $L_t = L^*$. The sizes of the regions in Figure 1 depend on the slope of the profit function around L^*, with a greater slope increasing the firm's desire to set $L_t = L^*$ (enlarging the size of the rectangle along the axes). If we base

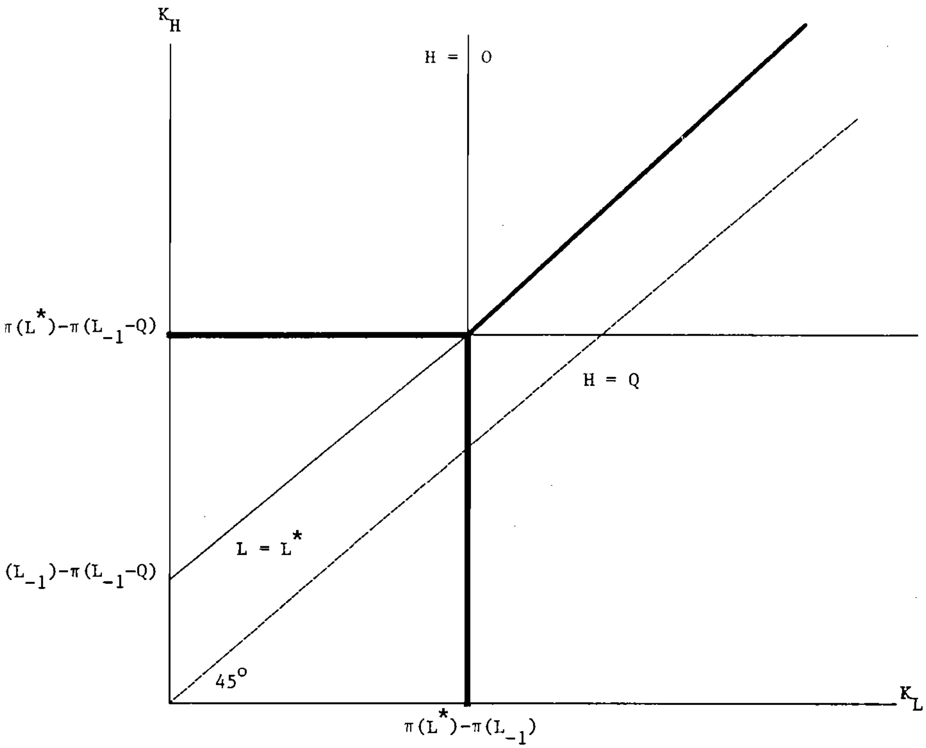


Figure 1. Lumpy Gross and Net Adjustment Costs and Hiring Decisions

empirical work on conditions (7), we can obtain direct estimates of the implied (lumpy) costs of hiring and of changing employment.

IV. Estimation Approach and Data

Consider how to estimate the models derived in Section III. In the model based on quadratic costs (5') relates the current period's employment to its lagged value, to the number of quits since the last observation on the process, and to a vector of forcing variables (wages and productivity shocks). The coefficient of interest, β_Q, measures the impact of additional quits on labor demand:

$$\text{(8)} \qquad \beta_Q = \lambda \frac{b_2}{b_1 + b_2}[R\rho_Q - 1][1 - \frac{\rho_Q}{\delta}]^{-1} .$$

In (8) λ is the autoregressive parameter describing L and can be easily inferred from (5'), while ρ_Q can be inferred from a first-order autoregression of Q. The solution (5) provides an inequality linking δ and R, so that (8) can be rearranged to yield:

$$\text{(8')} \qquad 1 \geq -\frac{\beta_Q}{\lambda[1 - R\rho_Q]} \geq \frac{b_2}{b_1 + b_2} \geq -\frac{\beta_Q}{\lambda} \geq 0 .$$

Using (8'), we can after some substitutions write the ratio of gross to total adjustment costs in (1) as:

$$(9) \qquad \frac{C_H}{C} > \frac{H^2}{-[\Delta L]^2[\frac{\lambda}{\beta_Q} + 1] + H^2}$$

The model thus does not allow us to infer the dollar amount of adjustment costs generated by a particular departure of L_t from L_{t-1}. It does, though, enable us to bracket the fraction of the total costs of adjustment, C, that stems from the costs of changing the identities of the employees as opposed to the costs of changing employment. In particular, the estimate of the right-hand side of (9) is based on the observed rates of hiring and net changes in employment, and on the estimates of the parameters β_Q and λ. It provides a lower bound on the fraction of the total cost of adjustment that is accounted for by gross costs. As such, we can infer the relative importance of the two types of adjustment cost.

The model with lumpy adjustment costs in (6) requires specifying the error terms. I follow my approach in Hamermesh (1989) and assume there are two sources of error. The first is a normally-distributed forecasting error ϵ stemming from:

$$(10) \qquad L_t^* = \gamma X_t + \epsilon_t ,$$

where γ is a vector of parameters linking the forcing variables X to the desired stock of employment. The second is a normally−distributed error μ stemming from errors in hiring to meet the target, L^*. Linearizing and rearranging (7) yields:

(7a') $\qquad H_t = 0 ,$

if $\qquad \epsilon_t \leq K_H + L_{t-1} - Q_t - \gamma X_t ,$

and $\qquad K_H - K_L \geq Q_t;$

(7b') $\qquad H_t = Q_t + \mu_t,$

if $\qquad \epsilon_t \leq K_L + L_{t-1} - \gamma X_t ;$

and $\qquad K_H - K_L < Q_t ;$

(7c') $\qquad H_t = \gamma X_t - [L_{t-1} - Q_t] + \mu_t + \epsilon_t ,$

if neither (7a') nor (7b') holds.

The conditions (7a')−(7c') are defined by three inequalities. Let $\Delta = 1$ if the condition, $K_H - K_L \geq Q_t$, which is independent of the realizations of the disturbances, holds. The other two inequalities depend on the disturbances and require that this three−equation switching model be estimated in probabilistic terms. Thus following on and extending Goldfeld and Quandt (1976), let:

(11a) $\qquad D_1 = N([K_H + L_{t-1} - Q_t - \gamma X_t]/\sigma_\epsilon),$

where N is the cumulative unit normal distribution, and:

(11b) $$D_2 = N([K_L + L_{t-1} - \gamma X_t]/\sigma_\epsilon) .$$

Then the probability that (7a') holds is ΔD_1; the probability that (7b') occurs is $[1 - \Delta]D_2$; and the probability that the firm operates according to (7c') is $1 - \Delta D_1 - [1 - \Delta]D_2$. The likelihood function is maximized by finding values of the parameters γ, K_H, K_L, and the variances of μ_t and ϵ_t that generate the highest likelihood defined over the three (probabilistic) events (7a')–(7c').

Taking these models seriously imposes fairly stringent requirements on the underlying data. Because we know (Hamermesh, 1993, Chapter 7) that the lags in employment adjustment are fairly short and that annual data generate biased estimates of them, we must observe the process generating the path of employment at least quarterly. Second, since it is impossible to draw correct inferences about lag structures from aggregated data unless the quadratic model is correct, we need microeconomic data. The data set must contain not only the readily available series on employment and some forcing variable(s), such as labor costs, expected sales, etc., but must also provide information on flows of workers into or out of the firm. Finally, the theory is based on the choice about whether to replace quitters and excludes the more complex issue of laying off workers in whom the firm had previously invested and with whom some at least implicit contractual relationship may have existed. This means that the ideal data set should exclude employment situations where layoffs were occurring.

No publicly available data meet all these needs. The United States stopped collecting data on industrial turnover in 1981, and even before that the micro data are unavailable. There is one panel of quarterly data on manufacturing firms in the U.S., but it contains no information on gross flows. A number of panels of European establishments exist, and some include turnover information; but all are only annual and are thus ill–suited to drawing inferences about adjustment costs.

Given these difficulties it was necessary to obtain previously unassembled data. While the time series in each of the two data sets I collected are unfortunately quite short, these proprietary data did meet all the criteria for estimating the models of the previous section. The first is from a medium–size (250–bed) hospital for which employment, both a head–count and the number of full–time equivalent and on–call workers, and in– and out–patient revenues, were available from 1985:1 through 1990:1. Moreover, the number of workers who quit each month was available from 1987:12 through 1990:1. All the estimates presented in the next sections are based on the sample period 1988:1 through 1990:1. That this is a non–profit hospital does not present problems in applying the models of Section III so long as we can assume that the hospital minimizes (adjustment and other) costs.

The data on L and on real revenue (total revenue deflated by the CPI component for hospital costs) are graphed in Figure 2, while Figure 3 graphs the hire rate (hires as a percent of total employment), the quit rate and the

Figure 2. Employment and Revenue

Hospital

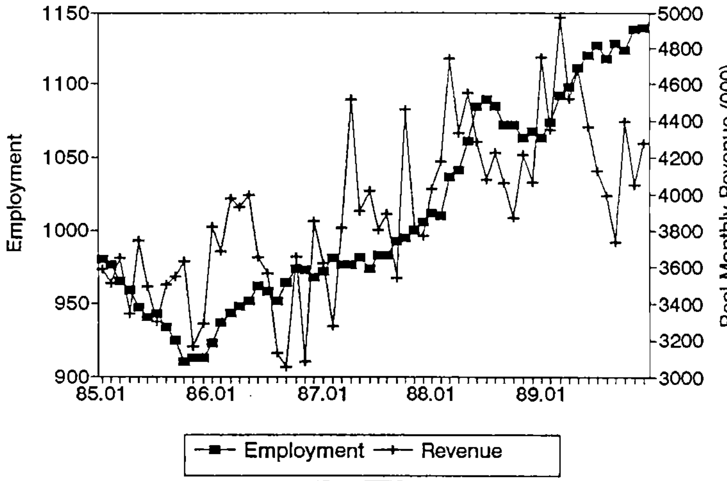
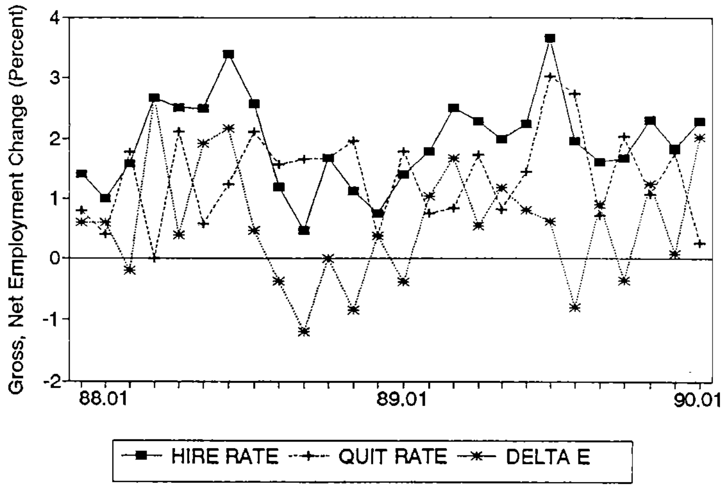


Figure 3. Turnover and Employment

Hospital



percent change in L. This is a fairly stable establishment: There are no sharp changes in employment. There is some apparent seasonal pattern in revenue and employment, which necessitates the inclusion of twelfth−order lags in revenue in the vector of forcing variables. Figure 3 shows that the firm is always hiring, suggesting that if the lumpy cost model applies we should find that the probability that the firm operates on (7a') is low. In many cases the firm is not replacing all the workers who quit. Finally, the data meet the conditions of the underlying model, as the hospital administrator claimed that no layoffs occurred during this period.

The other set of proprietary data is a panel of three manufacturing plants operated by a small, technologically advanced firm that produces extrusions for use in down−stream manufacturing processes. The data on employment and sales for these plants are available from 1985:1 through 1990:6, while data on hires are available only from 1988:01 through 1990:06. The estimates in Sections V and VI are thus based on this latter period and are presented for the plants separately and pooled.

Figures 4a through 4c present employment and revenue at each of the plants, while Figures 5a through 5c depict turnover and net employment changes. Because these plants employ many fewer people than does the hospital, there is much more variability in Figures 5 than in the hospital. It is worth noting too that at least in Plants 2 and 3 the firm was not hiring at

Figure 4a. Employment and Revenue
Manuf. Plant 1

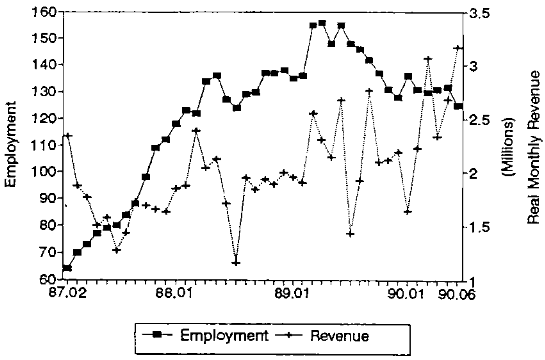


Figure 4b. Employment and Revenue
Manuf. Plant 2

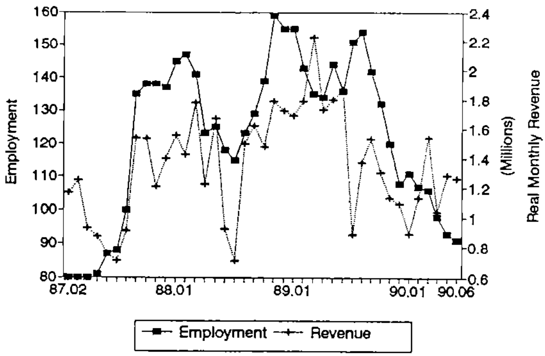


Figure 4c. Employment and Revenue
Manuf. Plant 3

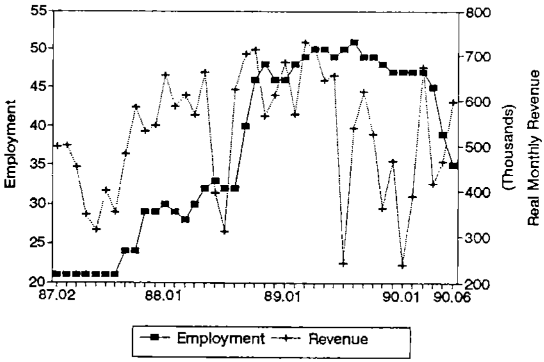


Figure 5a. Turnover and Employment
Manuf. Plant 1

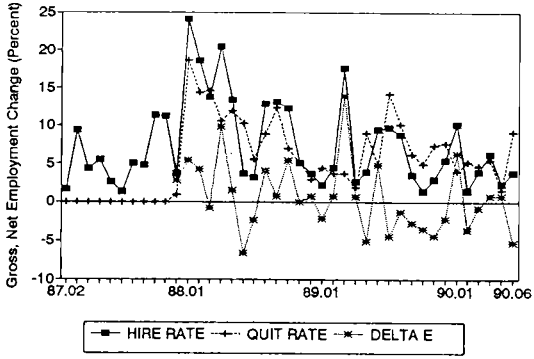


Figure 5b. Turnover and Employment
Manuf. Plant 2

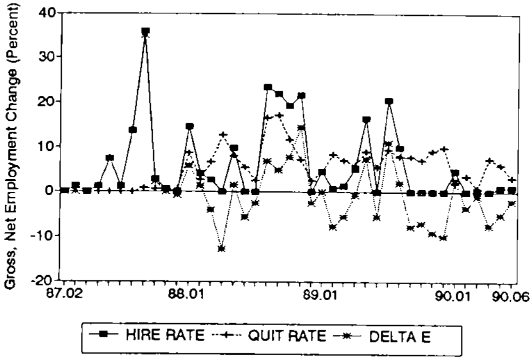
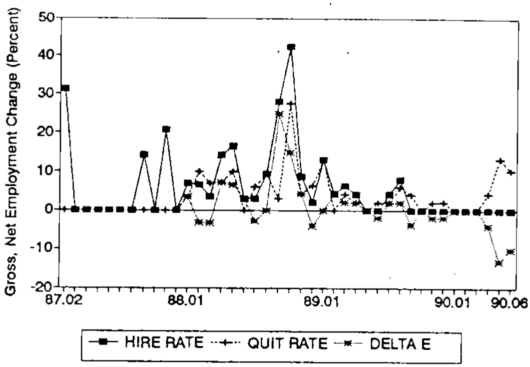


Figure 5c. Turnover and Employment
Manuf. Plant 3



all in some months, and in others hires and quits were approximately the same or even identical.

The paucity of information beyond that on employment and flows of workers severely limits our ability to represent the forcing variables in these new sets of data. I use the only information available --- on sales or revenue --- to represent expected output, Y_t^*, as an autoregressive process with lags of one, two, three and twelve months. Linear and quadratic time trends are also included in the vector of forcing variables in estimating both the quadratic-costs and lumpy-costs models.

Because most aggregated data include units that are laying off workers, they are not perfectly suited for estimating the models developed in Section III. Because of the nonlinearity in $\min\{C_H/C\}$ the degree of aggregation renders them unsuited to estimating this ratio. Because the lumpy-costs model cannot be aggregated usefully, they are completely unsuited to estimating it. Ignoring the first two problems, I also present estimates of the quadratic model using monthly time series from 1960:1 through 1978:12 describing production-worker employment in three small manufacturing industries in the United States: SIC 3221, glass containers; SIC 3632, household refrigerators and freezers; and SIC 3633, household laundry equipment. The forcing variables used in estimating (5') with this set of data are a time trend and a vector of lags in output (in this case, in the Federal Reserve Board Index of Industrial Production corresponding to the particular industry), essentially the same as are used for the hospital and manufacturing plants.[5]

V. Estimates of the Quadratic-Costs Model

A. Microeconomic Data

Estimates of (5') based on the microeconomic time series (the manufacturing plants and the hospital) are shown in Table 1. The equations are estimated in the logarithms of employment and output and using the quit rate.[6] The standard errors of the estimates of $\min\{C_H/C\}$ are computed from the variance–covariance matrix by assuming a Taylor–series expansion around the ratio λ/β_Q. The estimates for the individual manufacturing plants are generated by an iterative seemingly unrelated method to account for the possibility that the error terms are correlated in these establishments that are subject to at least some central control.[7]

In no case is the first–order autoregressive parameter in the quit rate, ρ_Q, significantly negative, and except in Plant 3 and for the employee count in the hospital it is significantly positive. Moreover, tests of higher–order autoregressive terms suggest they are not statistically important.[8] The results on ρ_Q suggest we are justified in using the estimate λ/β_Q to compute the lower bound to the ratio C_H/C.

While the estimates of (5'), which are autoregressions in L, fit the data fairly well, some problems are worth noting. Durbin's h–statistic fails to reject the hypothesis of no serial correlation for Plant 3 in the

Table 1. Estimates of (5′) Using Microeconomic Time Series[a]

ρ_Q	λ	β_Q	$\min(C_H/C)$	ΣY	$\bar{R}^2$	h
MANUFACTURING PLANTS						
Pooled						
.243	.844	-.091	.257	-.026	.991	2.18
(.10)	(.05)	(.14)	(.32)			
Plant 1						
.492	.505	-.353	.910	.148	.633	----
(.14)	(.19)	(.23)	(.20)			
Plant 2						
.314	.735	-.228	.499	-.048	.827	1.56
(.18)	(.12)	(.29)	(.44)			
Plant 3						
.073	.544	-.088	.357	-.050	.948	2.29
(.19)	(.13)	(.12)	(.39)			

Residual correlations:

$\rho_{12} = .200$
$\rho_{13} = .331$
$\rho_{23} = .380$

ρ_Q	λ	β_Q	$\min(C_H/C)$	ΣY	$\bar{R}^2$	h
HOSPITAL						
Employee Count						
-.186	.927	-.734	.929	.104	.974	-.14
(.21)	(.12)	(.19)	(.09)			
FTE Count						
.467	.898	-.602	.871	.067	.862	-.99
(.19)	(.14)	(.18)	(.12)			

[a]Standard errors are in parentheses below the parameter estimates, here and in Table 2. All equations in both tables contain the additional forcing variables time and time squared. The pooled equations includes a constant and separate dummy variables for each plant. The other equations include constant terms. The separate equations for the manufacturing plants are estimated using an iterative seemingly unrelated estimator.

manufacturing firm; but the hypothesis is rejected for Plant 3 and the pooled data, and cannot be calculated for Plant 1. For both employment measures at the hospital the hypothesis cannot be rejected. These problems suggest that, while the firm may respond to shocks according to the model derived in Section III, any shocks that generate the adjustment must be ones that are not well captured by the quadratic in time and expected real revenue.

The main focus of this section is on the estimates of $\min\{C_H/C\}$, the lower bound on the fraction of quadratic adjustment costs arising from hiring as opposed to changing the level of employment. These are calculated using the estimates of β_Q and λ and the averages of H^2 and $[\Delta L]^2$ in each unit. In Plant 1 nearly all of the adjustment costs are due to the costs of hiring, and the estimate is sufficiently precise that we can be quite sure that gross adjustment costs are very important. In the other two plants, while the point estimates imply that gross adjustment costs constitute over one–third of the total, the estimate of $\min\{C_H/C\}$ is so imprecise that we really cannot say much about this fraction. It may be that the entire cost of adjustment stems from changing employment levels, or gross costs may account for most of the total. At the hospital the estimates of $\min\{C_H/C\}$ are essentially the same for the count of employees and full–time employment, especially when we note that $\rho_Q < 0$ in the count of employees. We can be quite sure that gross costs are important, and it may be that there are no net costs of adjustment.

The results suggest strongly that gross costs (of hiring) are important; and it may be that net costs are truly unimportant in this sample of small manufacturing plants and a hospital. One could speculate about why the point estimates are nearly one for Plant 1 and the hospital, but below one half for Plants 2 and 3. In all four units H^2 averages from two to four times $[\Delta L]^2$, so the estimates of $\min\{C_H/C\}$ do not differ because costs at Plants 2 and 3 are dominated by relatively large movements in employment levels. Rather, to the extent that the imprecise estimates for these two plants allow any conclusion, it must be that something inherent in their adjustment–cost technology is generating differences between them and the other units. Clearly, though, with only four possibly independent units (the three manufacturing plants and the hospital) we cannot satisfactorily determine those cases where one type of costs or the other will be relatively more important.

B. Small Industries

The data on small industries are incapable of distinguishing among these possibilities, because they cannot provide evidence of differences in the structure of adjustment costs (for example, the presence of nonconvex costs), because layoffs are occurring in some plants in these industries at all times, and because they are aggregations of plants growing at different rates. Nonetheless, they might provide some additional evidence on the basic model in (5'), so that I present estimates for these industries in Table 2. The

Table 2. Estimates of (5′), Small Industries, 1960-78

ρ_Q	λ	β_Q	$\min(C_s/C)$	ΣY	$\bar{R}^2$	h
			SIC 3221			
.533	.796	-1.224	-.377	-.623	.475	----
(.06)	(.12)	(.67)	(.05)			
			SIC 3632			
.467	.779	-.974	1.119	.023	.831	-2.69
(.06)	(.04)	(.17)	(.19)			
			SIC 3633			
.336	.785	-.274	.187	.094	.798	1.41
(.06)	(.05)	(.22)	(.08)			

estimates of ρ_Q are significantly positive and, as in Table 1, higher-order terms are not jointly significant.

While the estimates of λ seem reasonable, though perhaps a bit low (cf. Hamermesh, 1993, Chapter 7), the employment-expected output elasticities are again nearly zero or, as in SIC 3221, surprisingly negative. As with the micro data most of whatever shocks are causing the slow adjustment are not captured by these forcing variables. Finally, while Durbin's h-statistic does not reject the serial independence of the disturbances in SIC 3633, it does for SIC 3632, and for SIC 3221 it cannot be computed.

The results on C_H/C for these small aggregates present real difficulties. Though the estimates are all significantly different from zero, for SIC 3221 the estimate is negative, and for SIC 3632 it exceeds one (which, since the estimate should represent the lower bound of a positive fraction, violates the model). There are two reasons to discount the results: 1) Equation (1), on which the estimates are based, is highly nonlinear. The underlying data, though, are linear aggregates of individual plants' behavior. We are thus trying to infer from these aggregates behavior that can be inferred only from plant-level data (unless we know the distribution of shocks across plants at each point in time). 2) In each month of the nineteen years at least some layoffs occurred in each industry. Since the underlying model assumed no layoffs, it is again unsurprising that its restrictions are violated by the estimates.

In sum, these results illustrate the oft–made point that we cannot infer nonlinear relationships from linear aggregates. Indeed, here the underlying model assumes the quadratic costs that generate linear decision rules; but because we wish to infer a nonlinear combination of parameters and costs, aggregated data present problems.

VI. Estimates of the Fixed-Cost Model using Microeconomic Time Series

Attempts to estimate the three–regime switching model (7a')–(7c') with the stochastic conditions (11a) and (11b) and freely–varying K_H, K_L and σ_ϵ using standard numerical methods of maximum–likelihood were unsuccessful.[9] As a first step to overcome the problems of maximizing this function the parameters were restricted by letting $K_H = \sigma_\epsilon$. Even with this constraint the standard maximization algorithms failed to converge. As a second step, the likelihood function was concentrated on the parameters K_H, K_L and σ_ϵ, and the maxima of the partial likelihood functions for each pair of a grid of values of K_H $(=\sigma_\epsilon)$ and $K_H/[K_L+K_H]$ was found. The global likelihood function is maximized by the pair (K_H, $K_H/[K_L+K_H]$) for which the <u>maximum maximorum</u> of these partial likelihoods is obtained.

This procedure was applied to all the microeconomic time series used in Section V.[10] An examination of the partial likelihood functions shows that for all three plants in the manufacturing company, and for both the employee count and the count of full–time equivalents at the hospital, the global likelihoods have numerous local maxima. The failure to maximize these functions directly is thus hardly surprising. The global likelihood functions are also quite flat along values of the vector K_H ($=\sigma_\epsilon$). However, they vary much more along the vector $K_H/[K_L+K_H]$ so that, as in Section V, we can reasonably interpret the findings here as showing the <u>relative</u> importance of net and gross (lumpy) costs of adjustment.

Table 3 presents estimates based on this search method. For the maximizing values of $K_H/[K_L+K_H]$ and K_H ($=\sigma_\epsilon$) I list the mean probabilities Δ, D_1 and D_2 describing the switching conditions and their standard deviations in the particular samples. Also shown are the mean probabilities that employment in each sample behaves according to each of (7a')–(7c').

The maximizing value of $K_H/[K_L+K_H]$ shows the relative importance of the two types of lumpy adjustment costs. It is analogous to the estimate of $\min\{C_H/C\}$ in the quadratic–costs model in Section V. The difference is that there we were able to estimate the deterministic split between the two types of costs. It makes no sense to combine the ratio $K_H/[K_L+K_H]$ with indicator variables on whether the firm hires or changes employment, since those decisions in this model are explicitly probabilistic.

For the employee count in the hospital the likelihood function is maximized where gross (lumpy) costs are about the same as the net (lumpy) adjustment costs. In the other four sets of estimates we find that gross fixed adjustment costs are relatively more important than net costs. The results in Plants 2 and 3 show the interaction of gross costs with the shocks to labor

Table 3. Maximizing Values of the Fixed-Cost Parameters and Their Implications[a]

Unit ($K_H/[K_L+K_H]$, $K_H=\sigma_\epsilon$)	Δ	D_1	D_2	Pr(L=L_{-1}-Q)	Pr(L=L_{-1})	Pr(L=L*)
Manufacturing:						
Plant 1						
(.67, .03)	0	.491	.731	0	.731	.269
	(0)	(.41)	(.35)			
Plant 2						
(.67, .27)	.931	.788	.726	.733	.050	.217
	(.25)	(.17)	(.19)			
Plant 3						
(1, .27)	.966	.834	.712	.805	.025	.170
	(.19)	(.23)	(.33)			
Hospital:						
Employee Count						
(.50, .003)	0	.420	.597	0	.597	.403
	(0)	(.48)	(.48)			
FTE Count						
(1, .001)	.20	.513	.690	.103	.552	.346
	(.41)	(.50)	(.46)			

[a]Standard deviations in parentheses.

demand. In those plants the probability that no hiring is done is quite high. When hiring does occur, it is sufficient to keep employment at the long-run profit-maximizing level L^*, i.e., $Pr\{L_t=L_{t-1}\}$ is very small in these two plants.

Comparing these results with those in Section V, the estimates here suggest the same conclusion for manufacturing Plant 1 and the two sets of employment data on the hospital: Gross adjustment costs are at least as important as net costs. For Plants 2 and 3 the two sets of estimates suggest opposite conclusions, with gross convex costs being relatively unimportant, while gross lumpy costs seem large. Despite this apparent anomaly the two sets of results on these two plants are not necessarily inconsistent. We must remember that the estimates for them in Table 1 were very imprecise and were in any case lower bounds. Also, in a complete model that allowed for gross and net fixed and variable adjustment costs this apparent contradiction could arise.[11] Taken together they do, though, suggest the complexity of the problems of handling adjustment costs once we recognize that distinctions arise from both their structure and their sources.

VII. Conclusions and Implications

This research has not demonstrated definitively that all the costs of adjusting labor demand arise from gross changes (hiring and training independent of changes in employment) or from net changes (enlarging the work force). Our time series are regrettably quite short, though we do replicate the results on three manufacturing plants and for the hospital. Within these microeconomic units, though, the preponderance of evidence suggests that gross costs constitute the greater share of total adjustment costs. The specific results suggest that recent research deriving models of employment demand based on gross adjustment costs represents a more profitable route than that based solely on net adjustment costs. The broader conclusion from the derivations and estimates, though, is that both types of adjustment costs are important. This implies that, just as one should not expect the structure of adjustment costs to be all quadratic and variable, all fixed, or any other particular structure (Hamermesh, 1992), one must allow for both sources of adjustment costs that can affect the path of labor demand.

Coupled with the size and sharp cyclicality of quits, the presence of both types of adjustment costs in labor demand provides a basis for asymmetric business cycles. We know (cf. Hamermesh and Pfann, 1992) that voluntary turnover is strongly procyclical, much more so than employment. During booms quits rise rapidly, so that any expansion in employment generates net costs and substantial gross (replacement) costs. In a recession quits are very few, and the response to the drop in product demand represents nearly entirely the costs of changing employment levels. Even if net costs are symmetric, the procyclicality of quits, and the gross costs whose importance I have demonstrated here guarantee that we will observe asymmetry in the path of aggregate employment in response to output shocks.

That some of the costs of adjusting employment are gross suggests that even in a dynamic equilibrium there may be a spillover into other firms that adopt a new technology. By undertaking training, including imparting the skill of dealing with the task of adapting to the environment of work, firms obviously create an externality. The results imply that turnover itself provides the means for creating additional external benefits, to the extent that the training is firm–general. This is a long–run dynamic externality, not just the well–known static role of turnover in providing the flows that lead markets to equilibrium more rapidly.

The dual nature of the costs of adjusting employment suggests that great care is in order in linking international or intertemporal differences in employment lags to imposed changes in the costs of hiring or firing.[12] Ignoring all the potential econometric problems and the possibility that varying supply constraints may affect observed lags in adjustment, differences in the lengths of lags by themselves tell us nothing about the effects of policies that alter hiring or firing costs. This is true even if all adjustment costs are convex. Lags in adjustment may lengthen, not because hiring/firing costs have increased, but because net costs of adjustment have risen, for example, due to a rise in the cost of changing the scale of operations to accommodate a new technology.

The discussion has been based on adjustment costs in labor demand. Yet exactly the same distinction applies in the analysis of the demand for investment (and for the services of capital). Here too, some of the early theoretical literature was based on net costs (e.g., Lucas, 1967), while other studies assumed that adjustment costs arise from the cost of altering gross investment flows (e.g., Gould, 1968). Empirical research has not distinguished between these two types of costs --- has not examined whether adjustment costs for replacing depreciated capital differ from those that are generated by changes in the amount of capital in place. Examining the gross/net distinction in the market for capital goods should yield substantial advances.

Spoilage and scale changes both generate adjustment costs. Their simultaneous existence needs to be recognized in dynamic factor-demand models, and their relative importance in various markets needs to be examined empirically. Such analyses will generate insights into factor-market and macroeconomic dynamics that cannot be obtained by imposing the assumption that adjustment costs have only one source.

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FOOTNOTES

1. Oi is one of the very few actually to attempt to measure adjustment costs directly (see also Barron et al, 1985). Such direct measurement essentially dictates concentrating on accounting for gross costs.

2. This tradition is mostly restricted to Europe (see also Bentolila and Bertola, 1990), while modeling adjustment based on net costs is more prevalent in North America. One possible reason for this difference may be the greater concern in Europe with trying to account for the more prevalent policies that impose firing costs on the employer.

3. Even in the depressed U.S. economy of 1981, the last year for which data were collected, the average quit rate in manufacturing was 1.3 percent per month. (Employment and Earnings, February 1982.)

4. This assumption is clearly incorrect. Yet it is a reasonable characterization of the micro data used in the subsequent empirical work; and it greatly simplifies the derivation.

5. These are three of the four small industries whose definition remained intact during this period and for which the FRB Index was based exclusively on physical measures of output. (Much of the FRB Index imputes output based on employment, rendering it obviously inappropriate for purposes of analyzing labor demand.)

6. Estimating the equation in levels generates very small changes in the parameters and has no qualitative effect on the results.

7. Equations that included first-order lags of revenue in Plants j and k in the equation for Plant i were also estimated. The pairs of terms in $Y_{j,t-1}$ and $Y_{k,t-1}$ were not jointly significant in any of the three equations, and their inclusion had very minor effects on the estimates of λ and β_Q.

8. These are autoregressions of deviations from the series means.

9. A variety of initial values and all the algorithms in the MAXLIK procedure in GAUSS were used. In every case the likelihood function failed to converge.

10. While it could just as easily be applied to the more aggregated data, those smooth over the effects of lumpy costs and make it difficult to draw inferences about their structure (e.g., Hamermesh, 1989).

11. Not surprisingly, deriving any implications about adjustment paths in such a model is extremely difficult. Moreover, given the problems in estimating even the lumpy–costs model with the particular, very short microeconomic time series used here, attempting to estimate a more general model would be a fruitless exercise.

12. These are discussed in Hamermesh (1993, Chapter 8). Nickell (1979), Abraham and Houseman (1989), and Bentolila and Bertola (1990) are just a few who link these policies to differences in adjustment speeds.