NBER WORKING PAPER SERIES

AGGREGATE EMPLOYMENT DYNAMICS AND LUMPY ADJUSTMENT COSTS

Daniel S. Hamermesh

Working Paper No. 3229

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge, MA 02138
January 1990

This paper is part of NBER's research program in Labor Studies. Any opinions expressed are those of the author not those of the National Bureau of Economic Research.

NBER Working Paper #3229
January 1990

AGGREGATE EMPLOYMENT DYNAMICS AND LUMPY ADJUSTMENT COSTS

ABSTRACT

This study examines what one can infer from aggregate time-series of employment under the assumption that adjustment at the micro level is discrete because of lumpy adjustment costs. The research uses various sets of quarterly and monthly data for the United States and imposes assumptions about how sectoral dispersion in output shocks affects adjustment through aggregation. I find no consistent evidence of any effect of sectoral shocks on the path of aggregate employment.

I generate artificial aggregate time series from microeconomic processes in which firms adjust employment discretely. They produce the same inferences as the actual data. Standard methods of estimating equations describing the time path of aggregate employment yield inferences about differences in the size of adjustment costs that are incorrect and inconsistent with the true differences at the micro level. This simulation suggests that the large literature on employment dynamics based on industry or macro data cannot inform us about the size of adjustment costs, and that such data cannot yield useful information on variations in adjustment costs over time or among countries.

Daniel S. Hamermesh
Department of Economics
Michigan State University
East Lansing, MI 48823
(517)355-7349

1. Introduction

Walter Oi's Ph.D. dissertation (1961) and his nearly synonymous article (Oi, 1962) have had remarkably strong influences on subsequent research. To appreciate their impact consider evidence on the number of citations to them over the years. Though it does not provide a complete count of all references, a very extensive count is provided by the Social Science Citation Index. In Table 1 I present the chronology of citations to these two works. It is remarkable to note the growth from 1966 through 1980 in the number of references to the work on quasi-fixed labor, both absolutely and, especially important, relative to the total pages of citations to the entire corpus of social science research tabulated in the Index. As Quandt (1976) shows, the mean age of works cited in economics journals was only 9 years in 1970 (and the median was only 6 years). The work has clearly had staying power.

Only in the mid-1980s has Oi's work on labor demand become such a part of every economist's intellectual baggage that direct references to the work itself have diminished. The term "quasi-fixed factor," which

Table 1. Citations, 1966-1988*

Year Cited	Oi's Work: Quasi-Fixed Costs	Oi's Work: Other Research	Total Pages of Citations
1966-70	30	52	6548
1971-75	68	111	8779
1976-80	99	136	12293
1981-85	106	209	16045
1986-88	55	137	9947

*<u>Social Science Citation Index</u>, 1966 through 1988.

my detailed investigations suggest that Walter coined, and the hypothesis that employment adjusts slowly and with a speed that is inversely related to skill, have entered the central corpus of economic knowledge.

The work had vast influences on two quite diverse literatures in labor economics and the labor-economic aspects of macroeconomics. The first of these, the theory of implicit contracts, probably accounts for the upsurge of citations to the quasi-fixed factor papers in the 1976-80 period in Table 1. It is worth noting here that of the three papers that are generally credited with initiating the study of implicit contracts in macroeconomics (Azariadis, 1975; Baily, 1974; Gordon, 1974), the latter two both cite Oi's work as the empirical observation that rationalizes the inquiry.

The other area that has been heavily affected by the work on quasi-fixed factors is that of the dynamics of labor demand. The first estimates of lagged employment adjustment relied on Holt et al (1960) for the empirical underpinning of the dynamics. But Oi's work did include employment-output relations with geometric distributed lags rationalized by hiring and training costs; and much subsequent work explicitly justified the lagged relationships by pointing to the demonstration of the importance of these costs in the papers on quasi-fixed labor.

Subsequent empirical work, using geometric distributed lags, polynomial distributed lags, rational lag structures or vector autoregressions, implicitly assumed that the fixed costs of employment are quadratic in the change in the number of workers (or in person-hours) employed. There is nothing in the work on quasi-fixed labor to demonstrate that. Rather, Holt et al's approximation and analytical convenience established quadratic adjustment as the norm justifying linear empirical relationships.

In Hamermesh (1989b) I demonstrated that smooth adjustment does not describe the adjustment of employment to output shocks in individual plants as well as does discrete adjustment --- inertia and then a complete and instantaneous response. This suggests that lumpy fixed employment costs that firms face are more important than any increasing divisible fixed costs that confront them. Such lumpy costs include, for examples, the cost of disruption when any change is made in the staffing of a workplace, or that are incurred when any advertising must be done to fill a position. These are in contrast to such costs as possible disruptions that increase more than in proportion with the size of a change in staffing.

In this study I examine how the existence of these lumpy costs will be reflected in aggregated data. The approach assumes that information about sectoral shocks to output will be useful in aggregating to obtain representations about dynamic labor demand at the macro level. This leads to several new time-series representations of aggregate labor demand.

The purpose is not to conduct a "horse race" between models with quadratic adjustment and those with lumpy adjustment costs. That can only be done with micro data, as I already have done. Instead, it is to draw out the implications of lumpy costs for aggregate relationships and to see if they can explain some anomalies and add to our ability to track cyclical changes in labor productivity and the adjustment of employment and hours.

The results shed some new light on the debate over the role of sectoral shocks in aggregate employment (Lilien, 1982). More important, they carry a cautionary tale for the large group of researchers engaged in the study of the dynamics of aggregate factor demand and those interested in the effects of employment protection policies on the adjustment of employment. They demonstrate the impossibility of making structural inferences about the nature of adjustment costs from aggregated data. As such, just as Engle-Liu (1972) and Cristiano-Eichenbaum (1987) demonstrate the difficulties that temporal aggregation generates for macroeconomic inference, this work shows how spatial aggregation in the presence of nonlinearities can also wreak havoc with structural inferences.

1. Bang-Bang Employment Adjustment, Sectoral Shocks and Aggregation

In this Section I describe how a long-run profit-maximizing firm will adjust the employment of quasi-fixed labor if the source of the fixity is the presence of lumpy one-time costs, and I provide one approach to aggregating over the adjustment paths of firms. No attention has been paid to this issue in studies of aggregate labor productivity or employment adjustment; but Blinder (1981) and Blinder-Bar-Ilan (1987) considered it in the context of inventory adjustment and the path of purchases of consumer durables. Rather than actually aggregating microeconomic relationships, both studies instead simulated an economy with diverse firms and used the results to infer how an aggregate relationship might be changed. They did not use available data on the subaggregates to modify standard econometric specifications involving aggregate data. This study does that, thus providing the first effort to follow Nerlove's (1972) suggestion that:

> Aggregation is the key and much might be done with transactions-cost models if one were willing to make rather specific assumptions about the distributions of individual characteristics, so that micromodels could be made to yield results on aggregates.[1]

Consider a small profit-maximizing firm whose only costs of adjusting its input of labor services are the lumpy costs $k > 0$. I assume labor is homogeneous in this derivation, since that assumption is required to analyze the data used in this study. The adjustment cost function is then:

$$C(\dot{L}) = \begin{cases} k \text{ if } |\dot{L}| > 0 \\ 0 \text{ if } \dot{L} = 0 \end{cases} . \tag{1}$$

where the superior dot denotes the rate of change. Implicitly this cost structure is on net changes in employment, an approach taken in some but not all of the literature. The derivation would go through for gross changes in employment; but that model would be more complex and would not be so closely tied to the data on levels used in Section 3. Similarly, the assumption that fixed costs are equal for positive and negative changes in employment is arbitrary; but the basic result --- discrete adjustment --- is not affected by imposing this restriction. The theoretical discussion is in the context of dynamic adjustment by a firm that takes prices and wages as given.[2]

To simplify the analysis of the firm's optimal path, solve its problem by characterizing its discounted stream of profits as:

$$Z = \int_0^T [\pi(L_t) - k]e^{-rt}\, dt + \frac{\pi(L_T)\, e^{-rT}}{r} , \tag{2}$$

where $0 \le T \le \infty$ is the point when the firm stops adjusting labor demand in response to the shock that occurred at $t = 0$, the wage rate w is implicit in the function π that is for convenience defined only over the labor input L, and L_T is the value of L that is chosen at the endogenous time T. The firm wishes to maximize (2) subject to the initial condition $L(0) = L_0$ and under the arbitrary assumption that $L \ge L_0^*$ (i. e., w has decreased).[3]

In this simple case the typical variational problem disappears. The firm simply sets $T = 0$ and $L_T = L_0$ or $L_T = L^*$, its static profit-maximizing labor demand, depending on whether:

$$k \gtrless \frac{[\pi(L^*) - \pi(L_0)]}{r} .$$

With only lumpy adjustment costs it pays the firm to bear those costs immediately if the discounted stream of additional profits from moving to a new static optimum is large enough. If the gains are small relative to those costs, the firm remains at the previous static optimum, even though that is no longer the long-run profit-maximizing point.

In the presence of lumpy fixed costs the i'th firm's employment demand is thus described by:

$$L_{it} = L_{it-1}, \quad |y_{it}| \le K_i , \qquad (3a)$$

and

$$L_{it} = L^*_{it}, \quad |y_{it}| > K_i , \qquad (3b)$$

where K_i is a parameter that is an increasing function of the fixed adjustment costs facing the firm, and y_{it} is a shock that is correlated with the deviation of L_{it} from L_{it-1} and thus reflects the firm's static profit-maximizing incentives to change employment. Both y_i and K_i are measured in percentage terms, with K_i being the minimum size of the shock necessary to overcome the inertia produced by the lumpy fixed costs.

If some fraction γ_t of the subaggregates are not changing employment, because their $|y_{it}| \leq K_i$, employment demand at the aggregate level at time t will be:

$$L_t = [1-\gamma_t]L_t^* + \gamma_t L_{t-1} , \qquad (4)$$

a weighted average of (3a) and (3b) with weights γ_t and $1-\gamma_t$. Thus in the absence of any further information this derivation produces an aggregate relationship that is indistinguishable from the standard geometric distributed lag that results if micro units adjust smoothly. This shows the difficulty of using aggregate data to distinguish between underlying models of microeconomic adjustment, a problem to which I return in Section 4.

If (3a) and (3b) are correct, though, we can use them to add some information to (4) through the weighting parameter γ_t. Assume all units i are of equal size. Also assume that $K_i \equiv K$, so that there is some value common to all firms that determines the size of the shock sufficient to induce them to jump to the new employment equilibrium.[4] Finally, assume that the distribution of shocks to employment demand, y_{it}, is normal with mean $\bar{y}_t$ and variance $\sigma^2_{y_t}$. Assuming the number of units i is sufficiently large, the assumption of normality is not especially restrictive. Similar results to those derived here could be obtained, though with greater difficulty and less applicability to the data, with other symmetric distributions.

The fraction γ_t is equal to the area under the normal density of y_t between -K and K:

$$\gamma_t = \int_{-K_t}^{K_t} f(y_{it})\,dy_{it}$$

$$= \Phi\left(\frac{K - \bar{y}_t}{\sigma_{y_t}}\right) - \Phi\left(\frac{-K - \bar{y}_t}{\sigma_{y_t}}\right) . \qquad (5)$$

Substituting in (4):

$$L_t = [1 - \gamma_t(K, \bar{y}_t, \sigma_{y_t})]L_t^* + \gamma_t(K, \bar{y}_t, \sigma_{y_t})L_{t-1} . \qquad (6)$$

Like the standard equation (4), equation (6) has one adjustment parameter, in this case, K. Equation (6) is essentially a version of the geometric lag model, (4), in which the adjustment parameter varies in a restrictive way depending upon the time path of $\bar{y}_t$ and σ_{y_t}, the restrictions of the normal distribution and the freely-varying parameter K.

Under the assumption that adjustment costs are lumpy rather than divisible, our particular assumptions add no parameters to the standard model. They do, though, alter the interpretation of that model. In the standard model the parameter γ is interpreted as the percent of the gap between L_{t-1}^* and L_t^* that is not made up during the time interval t-1 and t. In this model γ is the fraction of micro units that do not adjust their employment during that interval.

The approach underlying equation (6) also brings information on the distribution of microeconomic shocks to bear on the path of aggregate employment adjustment. The mean and variance of the shocks to employment demand provide information about the time path of adjustment of aggregates. In particular, one can show that:

$$\frac{\partial \gamma_t}{\partial \sigma_{y_t}} < 0.$$ [5]

The estimating model described by (6) is based quite closely on the aggregation of a relationship describing behavior by micro units facing different shocks. The assumptions necessary for it to hold strictly are quite severe, particularly that the adjustment cost parameters, K_i, are equal across all industries. Consider instead two more loosely based ways of bringing information about sectoral shocks, the $\bar{y}_t$ and σ_{y_t}, to bear on the determination of aggregate labor demand. The first is simply to break Lilien's (1982) efforts to "explain" aggregate unemployment by macro phenomena and the dispersion of sectoral shocks into the components of labor supply and demand, the variation in which must underlie any reduced-form changes in unemployment. Accordingly, I estimate a version of the standard dynamic employment demand function that is augmented by the <u>ad hoc</u> addition of interactive and main-effect terms in σ_y:

$$L_t = \Sigma\Sigma a_{1ji} X_{j,t-i} + \Sigma a_{2i} \sigma_{y_{t-i}} + \Sigma\Sigma a_{3ji} [\sigma_y X_j]_{t-i} \ , \qquad (7)$$

where each X_j is a determinant of L^*, i refers to lag length, and the a_{kji} are parameters. This allows us to examine whether sectoral output shocks affect employment dynamics and/or equilibrium levels of employment demand. Moreover, it provides evidence that allows us to examine whether sectoral effects on unemployment (assuming they are real) stem from sectoral influences on labor demand.

The alternative approach is a compromise between the models (6) and (7). It combines the information in $\bar{y}_t$ and σ_{y_t} to form $\gamma_t(K, \bar{y}_t, \sigma_{y_t})$, but it allows for a more generally structured relationship between L and the determinants of L^*:

$$L_t = \Sigma\Sigma a'_{1ji} X_{j,t-i} + \Sigma a'_{2i} \gamma_{t-i} + \Sigma\Sigma a'_{3ji} [\gamma X_j]_{t-i} \ . \qquad (7')$$

Clearly, the estimate of K can no longer be interpreted as the size of the shock required to shift a plant to its new long-run optimizing employment level. Rather, this formulation of γ_t is a convenient way of combining all the information on sectoral shocks into one measure and of allowing for generalized interactions of that information with the variables X_j that determine L^*. This combination means that the estimates of the effects of σ_{y_t} are independent of changes in aggregate demand, for the respecification accounts for changes in $\bar{y}_t$.

Because aggregate employment-demand equations assume no timing effects, their divorce from the behavior of the underlying micro units means that they may fail to predict aggregate employment fluctuations that occur as behavior among micro units differs. Without providing any theory to account for this possibility, econometric studies of the determinants of aggregate employment (Fair, 1969; Gordon, 1979) have included timing effects to capture the observation that productivity grows unusually slowly as the economy nears a cyclical peak. Models (6), (7), and (7′) could provide a microeconomic foundation for these formulations of aggregate productivity equations and, more important, could describe the path of labor productivity better.

The three models essentially postulate variable lags in the adjustment of employment and hours to external shocks. There is nothing new about this: Tinsley (1971) was the first to explore empirically the possibility that adjustment costs vary and produce variable lags. Smyth (1984) and Burgess-Dolado (1989) are recent examples of that research. The novelty of this formulation is that it relates macroeconomic fluctuations in factor demand to shocks at the micro level. Since there is direct evidence from microeconomic data (Hamermesh, 1989a, 1989b) that standard specifications of aggregate employment adjustment do not describe behavior at the micro level, this approach may serve to link underlying behavior more closely to macroeconomic outcomes.

3. Estimates of Aggregate Labor Demand With Disaggregated Shocks

A. Estimating the Dispersion of Industry Shocks

Ideally the measure of σ_y should be taken across all decision-making units in the economy, an ideal that is patently unattainable. Failing that, I develop several series of measures using various disaggregations of industries. These are explicitly based on relative shocks to output rather than on the seemingly inappropriate disaggregated measures of changes in employment as in Lilien (1982). The first series is based on output by one-digit industry from the NIPA data. Like the others it is calculated as:

$$\sigma^2_{y_t} = \Sigma Y_{it}[y_{it} - \bar{y}_t]^2/Y_t, \qquad (8)$$

where Y_{it} is national income in the i'th sector, Y_t is the total of national income in the private sector, y_{it} is the logarithmic change in output, and all the series have been deflated by the implicit GNP deflator.[6] The 12 sectors are: Agriculture, forestry and fisheries; mining; construction; durable, and nondurable manufacturing; transportation; communications; utilities; wholesale, and retail trade; finance-insurance-real estate; and services. The series was calculated from 1953 through 1988:II on a quarterly basis.[7] Its mean and standard deviation, along with its range, are shown in the first column of Table 2. There is substantial intersectoral variation in quarterly output shocks, as shown

Table 2. Means of Sectoral Output Shocks, Standard Deviations and Ranges of Dispersion

Private Business, Quarterly 1954: III - 1988: II	Manufacturing, Monthly 1965.1-1988.6: Shipment/Inventory Data	Manufacturing, Monthly 1965.1-1988.6: Production Indices
.0226	.0394	.0261
(.0118)	(.0176)	(.0114)
(.0070, .0640)	(.0190, .1860)	(.0112, .1125)
Number of Industries		
12	31	42

by the mean of two percent for σ_{y_t}. The maximum is reached during the Steel Strike of 1959, and there are no inexplicable outliers in σ_{y_t}.

This measure is useful in equations describing employment adjustment for the entire private sector using quarterly data. The difficulties with it are that it is probably overaggregated both temporally and spatially. The temporal overaggregation is a problem given evidence (see the survey in Hamermesh, 1976) that lags in the adjustment of labor demand at the aggregate level are not very long and the more general evidence of studies beginning with Engle-Liu (1972). Spatial overaggregation is a problem, as we have gone from the ideal of information on output shocks at the plant level to data on output shocks for 12 large sectors! Two alternative sources permit the construction of series on σ_{y_t} based on disaggregated measures of output in manufacturing. The first is based on Federal Reserve Board indexes of industrial production for 42 industries. The calculation in (8) is used again, with the weights being the published shares in the aggregate manufacturing index for each industry in 1977. The second dispersion measure for manufacturing calculates output as the sum of shipments plus the change in inventories. Equation (8) is used here too, and each series is deflated by the producer price index.

Statistics describing the two monthly series on σ_{y_t} for manufacturing are shown in columns (2) and (3) of Table 2. Because one of the other series used in the analysis is only available beginning January 1964, all of the estimates using the data from manufacturing cover the time period 1965.1-1988.6. For the FRB data the mean and variance of the dispersion measure are somewhat surprisingly quite close to those for the quarterly data on the twelve sectors in private business.

Moreover, the outliers occur at about the same time as in the quarterly data. The shipments/inventories data yield far more drastic interindustry variations in the level of sectoral shocks; and the industry-level changes that generate many of the outliers are difficult to believe. This is consistent with the observation that these data have substantial measurement error. Accordingly, while all the work for manufacturing was done on both measures of σ_{y_t}, and while the results are qualitatively similar, only those using the FRB index are reported here.

B. Labor Demand in the Private Business Sector, 1954-1988

Tables 3 and 4 present estimates of various labor-demand equations based on quarterly data for the private business sector, 1954-1988. Table 3 is based on total employment and uses real compensation as the wage measure. Table 4 is based on total person-hours paid for in the private business sector. (Only the dependent variables differ between the two tables.) The contemporaneous real wage and output are used in the equations. Despite worries about possible simultaneity, some very clear evidence (Quandt-Rosen, 1989) shows this is not a problem. In all of the estimates an AR(1) error structure is specified and the autoregressive parameter ρ is estimated. All variables other than time are in logarithms.

Examination of the estimates in the first two columns shows how remarkably standard they are in this literature. The wage effects are fairly small, especially for the employment equation, but not unusually so among time-series estimates covering all workers (Hamermesh, 1986). The output elasticities are significantly below unity, but that too is quite standard in this literature. Finally, as is uniformly true in

Table 3. Alternative Estimates of Employment Equations, Private Business, 1954:III - 1988:II

	Basic	Geometric	(6)	Lags	(7)	(7')
$Employment_{-1}$		.511 (.036)	.006 (.003)			
Output	.523 (.041)	.439 (.025)	.533 (.040)	.890	.880	.930
Output Interactions					-.693	-.081
Real Wage	-.125 (.070)	-.090 (.044)	-.122 (.069)	-.207	-.250	-.263
Real Wage Interactions					3.073	.083
Time	.0020 (.0005)	-.0004 (.0003)	.0019 (.0004)	-.0003 (.0008)		-.0001 (.0007)
$\hat{K}$ or σ_y			.0025		-10.757	.030
$\hat{\gamma}$						.764
$\hat{\rho}$	.968	.962	.969	.984	.985	.979
$\hat{\sigma}_\epsilon$	.00524	.00331	.00510	.00361	.00364	.00352

Table 4. Alternative Estimates of Hours Equations, Private Business, 1954:III - 1988:II

	Basic	Geometric	(6)	Lags	(7)	(7')
$Hours_{-1}$		.382	.0041			
		(.038)	(.0022)			
Output	.714	.603	.722	1.014	1.004	1.062
	(.044)	(.034)	(.044)			
Output Interaction					(-.057)	-.090
Real Wage	-.299	-.273	-.298	-.341	-.377	-.386
	(.065)	(.036)	(.065)			
Real Wage Interactions					1.407	.092
Time	-.0002	-.0011	-.0002	-.0024	-.0023	-.0021
	(.0004)	(.0003)	(.0004)	(.0005)	(.0005)	(.0005)
$\hat{K}$, or σ_y			.0025		-6.037	.030
$\hat{\gamma}$						.764
$\hat{\rho}$	.931	.867	.933	.964	.965	.967
$\hat{\sigma}_\epsilon$	.00543	.00411	.00538	.00421	.00425	.00409

previous estimates (Hamermesh, 1976), the lag of employment behind output shocks is longer than that of person-hours behind output.

Column (3) in each table shows the results of attempts to estimate γ as a parameter of (6).[8] (The estimation was undertaken by searching over a grid of values of K, essentially a stepwise maximum likelihood approach.) The standard errors of estimate are uniformly much higher than in the equations containing the standard geometric lags. This approach really adds nothing even beyond the simplest static labor-demand equations shown in columns (1). Clearly, one cannot view standard equations describing lagged adjustment of labor demand as aggregates of lumpy adjustment with the aggregator implied by (6).

The next endeavor used the measure of the relative dispersion of output shocks, σ_{y_t}, directly in the labor-demand equations. Before presenting those results, though, a basis for comparison is necessary, namely the estimates of:

$$L_t = \Sigma\Sigma a_{iji} X_{j,t-i} \ .$$

The sums of the a_{ij} are presented in columns (4) of the table. They demonstrate the usual finding that the results of specifying geometric adjustment can be replicated by an equation specifying an unconstrained n-th order lagged adjustment in the independent variables. The sums of the parameter estimates for real wages and output differ little from the long-run elasticities implied by the estimates using the geometric model.

Columns (5) show estimates of (7), dynamic aggregate labor-demand equations modified to account for the dispersion of output shocks among sectors. The results are quite informative: For both employment and person-hours adding these extra main effects and interaction terms in σ_{y_t} raised the standard error of estimate.[9] Whatever it may do in describing fluctuations in unemployment, variation in the relative dispersion of output shocks does not add to the description of fluctuations in aggregate employment.

As in the estimates in columns (4), the γ_t estimated in (7') were generated by searching over a grid of values of K. The terms in γ add appreciably to the explanatory power of the equations; and for person-hours the standard error of estimate actually falls slightly below that of the geometric-adjustment model (whose parameter estimates are fraught with the recently forgotten difficulties of including lagged dependent variables). Apparently it is not just the dispersion of output shocks that determines the path of aggregate employment and person-hours. Rather, it is the size of that dispersion relative to the mean output shock that matters.

The sums of the interaction terms in the Tables are themselves of interest. First, the estimate of K, .03, is significantly different from zero: Relative dispersion matters in and of itself <u>and</u> compared to the difference between the mean shock and some fixed threshold. The effects of the dispersion of shocks are nearly identical in the two sets of estimates. In interpreting them one should remember that an increase in σ_{y_t} holding $\bar{y}_t$ constant reduces γ. This implies that greater dispersion of output shocks increases the absolute values of the responses of employment and person-hours to changes in output and real wages (since the sums of the interaction terms are opposite in sign from the sums of the main effects on output and real wages). This suggests that greater dispersion reduces rigidity in the adjustment of aggregate employment.

One impetus to this study was the anomalous set of findings on productivity near the ends of cyclical expansions. To examine whether accounting for intersectoral dispersion helps to explain these anomalies, I estimated the root mean-squared errors for the equations in columns (4) and (6) at cyclical peaks and troughs that occurred during the sample period, in each case for the quarter of the turning point and one quarter before. The averages are shown in the first part of Table 5 for the six cycles that occurred during the sample period. Except for person-hours at cyclical peaks, including the nonlinear transformation of σ_{y_t} and $\bar{y}_t$ in aggregate labor-demand equations improves the fit of those equations. The improvements are on the order of ten percent (of the residual errors around the turning points), suggesting that there is a fairly substantial gain in the ability to predict employment and hours fluctuations around cyclical turning points, and thus to predict fluctuations in labor productivity, from including measures of intersectoral dispersion.[10]

The magnitudes of the responses of employment and person-hours vary fairly sharply over the range of $\gamma_t(K, \bar{y}_t, \sigma_{y_t})$. The long-run impacts of an aggregate output shock of ten percent are shown in the bottom half of Table 5. Compared to the mean value of γ, or to the simulated impacts from the equations in columns (4), variations in γ_t over its entire range generate substantial variations in output elasticities. This underscores the conclusion that increased dispersion reduces employment rigidity and demonstrates that the reduction would not be tiny if dispersion were at its maximum within the sample period.

C. Labor Demand in Manufacturing, 1965-1988

In this part I present estimates of various versions of labor-demand equations for monthly data for manufacturing. The dependent variables are total employment, production-worker employment, and production-worker person-hours. A measure of average hourly earnings of

Table 5. Root Mean-Square Errors With and Without Sectoral Effects, and Impacts of Output Shocks, Employment and Person-Hours, Private Business, 1954:III - 1988:II

	Employment		Person-Hours	
	Sectoral Effects		Sectoral Effects	
RMSE	No	Yes	No	Yes
Average	.004830	.004336	.004708	.004361
Peaks	.003421	.002997	.003545	.003568
Troughs	.005913	.005350	.005635	.005031
	Long-Run Impact of a Ten-Percent Permanent Output Shock			
$\hat{\gamma}$				
Minimum		.0904		.1033
Mean	.0890	.0868	.1014	.0993
Maximum		.0849		.0972

production workers is used as the real wage measure for the latter two dependent variables, while real compensation in manufacturing is used in equations describing demand for all employees. Other than the differences the variables, and the use of monthly data, these estimates are produced in exactly the same way as those in the previous part.

Qualitatively the results are strikingly like those in Tables 3 and 4 for the private business sector. As with those estimates, employment-output elasticities are below one, person-hours-output elasticities are higher, but still less than one, and employment-wage elasticities are generally negative. The lags in employment adjustment exceed those in the adjustment of person-hours. While the implied average lags are shorter than those in the quarterly estimates of the previous part, this difference is the very common result of temporal disaggregation.

Estimates of (6) are not presented in the Tables. In all three cases $\hat{\sigma}_\varepsilon$ was far above its value even in the basic equation. As with the quarterly data for the private business sector, simply aggregating microeconomic bang-bang adjustment and using a measure of industrial dispersion of output shocks failed miserably in describing labor demand. Even using forty-two industries to estimate σ_{y_t}, we are still far from the appropriate aggregator of the underlying microeconomic adjustment. Nonetheless, it is still worth examining (7) and (7′) to see if, as in the aggregate quarterly data, accounting for interindustry dispersion improves the ability to predict employment around cyclical turning points, and if it helps to explain aggregate employment fluctuations.

Columns (3) of Tables 6-8 show the estimates of (7) without the terms in σ_{y_t}. In all three cases adding the lag terms improves the fit of the labor-demand equations. Moreover, the long-run labor demand-

Table 6. Alternative Estimates, Production-Worker Employment, Manufacturing, 1965.1 - 1988.6

	Basic	Geometric	Lags	(7)	(7')
Employment_{-1}		.317 (.042)			
Output	.535 (.029)	.424 (.031)	.827	.838	.772
Output Interactions				-.1903	.0636
Real Wage	-.045 (.054)	.0028 (.049)	-.016	-.0575	.0145
Real Wage Interactions				1.3690	-.0547
Time	-.0019 (.0002)	-.0014 (.0001)	-.0027 (.0003)	-.0027 (.0003)	-.0027 (.0003)
$\hat{K}$ or σ_y				-6.102	.045
$\hat{\gamma}$					.887
$\hat{\rho}$	.977	.966	.984	.985	.983
$\hat{\sigma}_\epsilon$	.00455	.00416	.00378	.00383	.00378

Table 7. Alternative Estimates, Production-Worker Person-Hours, Manufacturing, 1965.1 - 1988.6

	Basic	Geometric	Lags	(7)	(7')
$Hours_{-1}$		-.085 (.042)			
Output	.917 (.039)	.949 (.046)	1.012	1.030	.976
Output Interactions				-.0351	.1394
Real Wage	-.137 (.051)	-.145 (.059)	-.129	-.1238	-.0911
Real Wage Interactions				1.6722	-.0570
Time	-.0027 (.0001)	-.0028 (.0001)	-.0029 (.0001)	-.0030 (.0002)	-.0030 (.0002)
$\hat{K}$, or σ_y				2.095	.045
$\hat{\gamma}$					.887
$\hat{\rho}$	.881	.907	.873	.877	.881
$\hat{\sigma}_\epsilon$	.00714	.00711	.00678	.00685	.00682

NBER WORKING PAPER SERIES

AGGREGATE EMPLOYMENT DYNAMICS AND LUMPY ADJUSTMENT COSTS

Daniel S. Hamermesh

Working Paper No. 3229

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge, MA 02138
January 1990

This paper is part of NBER's research program in Labor Studies. Any opinions expressed are those of the author not those of the National Bureau of Economic Research.

NBER Working Paper #3229
January 1990

AGGREGATE EMPLOYMENT DYNAMICS AND LUMPY ADJUSTMENT COSTS

ABSTRACT

This study examines what one can infer from aggregate time-series of employment under the assumption that adjustment at the micro level is discrete because of lumpy adjustment costs. The research uses various sets of quarterly and monthly data for the United States and imposes assumptions about how sectoral dispersion in output shocks affects adjustment through aggregation. I find no consistent evidence of any effect of sectoral shocks on the path of aggregate employment.

I generate artificial aggregate time series from microeconomic processes in which firms adjust employment discretely. They produce the same inferences as the actual data. Standard methods of estimating equations describing the time path of aggregate employment yield inferences about differences in the size of adjustment costs that are incorrect and inconsistent with the true differences at the micro level. This simulation suggests that the large literature on employment dynamics based on industry or macro data cannot inform us about the size of adjustment costs, and that such data cannot yield useful information on variations in adjustment costs over time or among countries.

Daniel S. Hamermesh
Department of Economics
Michigan State University
East Lansing, MI 48823
(517)355-7349

1. Introduction

Walter Oi's Ph.D. dissertation (1961) and his nearly synonymous article (Oi, 1962) have had remarkably strong influences on subsequent research. To appreciate their impact consider evidence on the number of citations to them over the years. Though it does not provide a complete count of all references, a very extensive count is provided by the Social Science Citation Index. In Table 1 I present the chronology of citations to these two works. It is remarkable to note the growth from 1966 through 1980 in the number of references to the work on quasi-fixed labor, both absolutely and, especially important, relative to the total pages of citations to the entire corpus of social science research tabulated in the Index. As Quandt (1976) shows, the mean age of works cited in economics journals was only 9 years in 1970 (and the median was only 6 years). The work has clearly had staying power.

Only in the mid-1980s has Oi's work on labor demand become such a part of every economist's intellectual baggage that direct references to the work itself have diminished. The term "quasi-fixed factor," which

Table 1. Citations, 1966-1988*

Year Cited	Oi's Work: Quasi-Fixed Costs	Oi's Work: Other Research	Total Pages of Citations
1966-70	30	52	6548
1971-75	68	111	8779
1976-80	99	136	12293
1981-85	106	209	16045
1986-88	55	137	9947

*Social Science Citation Index, 1966 through 1988.

my detailed investigations suggest that Walter coined, and the hypothesis that employment adjusts slowly and with a speed that is inversely related to skill, have entered the central corpus of economic knowledge.

The work had vast influences on two quite diverse literatures in labor economics and the labor-economic aspects of macroeconomics. The first of these, the theory of implicit contracts, probably accounts for the upsurge of citations to the quasi-fixed factor papers in the 1976-80 period in Table 1. It is worth noting here that of the three papers that are generally credited with initiating the study of implicit contracts in macroeconomics (Azariadis, 1975; Baily, 1974; Gordon, 1974), the latter two both cite Oi's work as the empirical observation that rationalizes the inquiry.

The other area that has been heavily affected by the work on quasi-fixed factors is that of the dynamics of labor demand. The first estimates of lagged employment adjustment relied on Holt et al (1960) for the empirical underpinning of the dynamics. But Oi's work did include employment-output relations with geometric distributed lags rationalized by hiring and training costs; and much subsequent work explicitly justified the lagged relationships by pointing to the demonstration of the importance of these costs in the papers on quasi-fixed labor.

Subsequent empirical work, using geometric distributed lags, polynomial distributed lags, rational lag structures or vector autoregressions, implicitly assumed that the fixed costs of employment are quadratic in the change in the number of workers (or in person-hours) employed. There is nothing in the work on quasi-fixed labor to demonstrate that. Rather, Holt et al's approximation and analytical convenience established quadratic adjustment as the norm justifying linear empirical relationships.

In Hamermesh (1989b) I demonstrated that smooth adjustment does not describe the adjustment of employment to output shocks in individual plants as well as does discrete adjustment --- inertia and then a complete and instantaneous response. This suggests that lumpy fixed employment costs that firms face are more important than any increasing divisible fixed costs that confront them. Such lumpy costs include, for examples, the cost of disruption when any change is made in the staffing of a workplace, or that are incurred when any advertising must be done to fill a position. These are in contrast to such costs as possible disruptions that increase more than in proportion with the size of a change in staffing.

In this study I examine how the existence of these lumpy costs will be reflected in aggregated data. The approach assumes that information about sectoral shocks to output will be useful in aggregating to obtain representations about dynamic labor demand at the macro level. This leads to several new time-series representations of aggregate labor demand.

The purpose is not to conduct a "horse race" between models with quadratic adjustment and those with lumpy adjustment costs. That can only be done with micro data, as I already have done. Instead, it is to draw out the implications of lumpy costs for aggregate relationships and to see if they can explain some anomalies and add to our ability to track cyclical changes in labor productivity and the adjustment of employment and hours.

The results shed some new light on the debate over the role of sectoral shocks in aggregate employment (Lilien, 1982). More important, they carry a cautionary tale for the large group of researchers engaged in the study of the dynamics of aggregate factor demand and those interested in the effects of employment protection policies on the adjustment of employment. They demonstrate the impossibility of making structural inferences about the nature of adjustment costs from aggregated data. As such, just as Engle-Liu (1972) and Cristiano-Eichenbaum (1987) demonstrate the difficulties that temporal aggregation generates for macroeconomic inference, this work shows how spatial aggregation in the presence of nonlinearities can also wreak havoc with structural inferences.

1. Bang-Bang Employment Adjustment, Sectoral Shocks and Aggregation

In this Section I describe how a long-run profit-maximizing firm will adjust the employment of quasi-fixed labor if the source of the fixity is the presence of lumpy one-time costs, and I provide one approach to aggregating over the adjustment paths of firms. No attention has been paid to this issue in studies of aggregate labor productivity or employment adjustment; but Blinder (1981) and Blinder-Bar-Ilan (1987) considered it in the context of inventory adjustment and the path of purchases of consumer durables. Rather than actually aggregating microeconomic relationships, both studies instead simulated an economy with diverse firms and used the results to infer how an aggregate relationship might be changed. They did not use available data on the subaggregates to modify standard econometric specifications involving aggregate data. This study does that, thus providing the first effort to follow Nerlove's (1972) suggestion that:

> Aggregation is the key and much might be done with transactions-cost models if one were willing to make rather specific assumptions about the distributions of individual characteristics, so that micromodels could be made to yield results on aggregates.[1]

Consider a small profit-maximizing firm whose only costs of adjusting its input of labor services are the lumpy costs $k > 0$. I assume labor is homogeneous in this derivation, since that assumption is required to analyze the data used in this study. The adjustment cost function is then:

$$C(\dot{L}) = \begin{cases} k \text{ if } |\dot{L}| > 0 \\ 0 \text{ if } \dot{L} = 0 \end{cases} . \qquad (1)$$

where the superior dot denotes the rate of change. Implicitly this cost structure is on net changes in employment, an approach taken in some but not all of the literature. The derivation would go through for gross changes in employment; but that model would be more complex and would not be so closely tied to the data on levels used in Section 3. Similarly, the assumption that fixed costs are equal for positive and negative changes in employment is arbitrary; but the basic result --- discrete adjustment --- is not affected by imposing this restriction. The theoretical discussion is in the context of dynamic adjustment by a firm that takes prices and wages as given.[2]

To simplify the analysis of the firm's optimal path, solve its problem by characterizing its discounted stream of profits as:

$$Z = \int_0^T [\pi(L_t) - k]e^{-rt}\, dt + \frac{\pi(L_T)\, e^{-rT}}{r} , \qquad (2)$$

where $0 \leq T \leq \infty$ is the point when the firm stops adjusting labor demand in response to the shock that occurred at t = 0, the wage rate w is implicit in the function π that is for convenience defined only over the labor input L, and L_T is the value of L that is chosen at the endogenous time T. The firm wishes to maximize (2) subject to the initial condition $L(0) = L_0$ and under the arbitrary assumption that $L \geq L_0^*$ (i. e., w has decreased).[3]

In this simple case the typical variational problem disappears. The firm simply sets T = 0 and $L_T = L_0$ or $L_T = L^*$, its static profit-maximizing labor demand, depending on whether:

$$k \gtrless \frac{[\pi(L^*) - \pi(L_0)]}{r} .$$

With only lumpy adjustment costs it pays the firm to bear those costs immediately if the discounted stream of additional profits from moving to a new static optimum is large enough. If the gains are small relative to those costs, the firm remains at the previous static optimum, even though that is no longer the long-run profit-maximizing point.

In the presence of lumpy fixed costs the i'th firm's employment demand is thus described by:

$$L_{it} = L_{it-1}, \quad |y_{it}| \leq K_i , \qquad (3a)$$

and

$$L_{it} = L_{it}^*, \quad |y_{it}| > K_i , \qquad (3b)$$

where K_i is a parameter that is an increasing function of the fixed adjustment costs facing the firm, and y_{it} is a shock that is correlated with the deviation of L_{it} from L_{it-1} and thus reflects the firm's static profit-maximizing incentives to change employment. Both y_i and K_i are measured in percentage terms, with K_i being the minimum size of the shock necessary to overcome the inertia produced by the lumpy fixed costs.

If some fraction γ_t of the subaggregates are not changing employment, because their $|y_{it}| \le K_i$, employment demand at the aggregate level at time t will be:

$$L_t = [1-\gamma_t]L_t^* + \gamma_t L_{t-1} , \quad (4)$$

a weighted average of (3a) and (3b) with weights γ_t and $1-\gamma_t$. Thus in the absence of any further information this derivation produces an aggregate relationship that is indistinguishable from the standard geometric distributed lag that results if micro units adjust smoothly. This shows the difficulty of using aggregate data to distinguish between underlying models of microeconomic adjustment, a problem to which I return in Section 4.

If (3a) and (3b) are correct, though, we can use them to add some information to (4) through the weighting parameter γ_t. Assume all units i are of equal size. Also assume that $K_i \equiv K$, so that there is some value common to all firms that determines the size of the shock sufficient to induce them to jump to the new employment equilibrium.[4] Finally, assume that the distribution of shocks to employment demand, y_{it}, is normal with mean $\bar{y}_t$ and variance $\sigma^2_{y_t}$. Assuming the number of units i is sufficiently large, the assumption of normality is not especially restrictive. Similar results to those derived here could be obtained, though with greater difficulty and less applicability to the data, with other symmetric distributions.

The fraction γ_t is equal to the area under the normal density of y_t between -K and K:

$$\gamma_t = \int_{-K_t}^{K_t} f(y_{it})\,dy_{it}$$

$$= \Phi\left(\frac{K - \bar{y}_t}{\sigma_{y_t}}\right) - \Phi\left(\frac{-K - \bar{y}_t}{\sigma_{y_t}}\right) . \qquad (5)$$

Substituting in (4):

$$L_t = [1 - \gamma_t(K, \bar{y}_t, \sigma_{y_t})]L_t^* + \gamma_t(K, \bar{y}_t, \sigma_{y_t})L_{t-1} . \qquad (6)$$

Like the standard equation (4), equation (6) has one adjustment parameter, in this case, K. Equation (6) is essentially a version of the geometric lag model, (4), in which the adjustment parameter varies in a restrictive way depending upon the time path of $\bar{y}_t$ and σ_{y_t}, the restrictions of the normal distribution and the freely-varying parameter K.

Under the assumption that adjustment costs are lumpy rather than divisible, our particular assumptions add no parameters to the standard model. They do, though, alter the interpretation of that model. In the standard model the parameter γ is interpreted as the percent of the gap between L_{t-1}^* and L_t^* that is not made up during the time interval t-1 and t. In this model γ is the fraction of micro units that do not adjust their employment during that interval.

The approach underlying equation (6) also brings information on the distribution of microeconomic shocks to bear on the path of aggregate employment adjustment. The mean and variance of the shocks to employment demand provide information about the time path of adjustment of aggregates. In particular, one can show that:

$$\frac{\partial \gamma_t}{\partial \sigma_{y_t}} < 0.$$ [5]

The estimating model described by (6) is based quite closely on the aggregation of a relationship describing behavior by micro units facing different shocks. The assumptions necessary for it to hold strictly are quite severe, particularly that the adjustment cost parameters, K_i, are equal across all industries. Consider instead two more loosely based ways of bringing information about sectoral shocks, the $\bar{y}_t$ and σ_{y_t}, to bear on the determination of aggregate labor demand. The first is simply to break Lilien's (1982) efforts to "explain" aggregate unemployment by macro phenomena and the dispersion of sectoral shocks into the components of labor supply and demand, the variation in which must underlie any reduced-form changes in unemployment. Accordingly, I estimate a version of the standard dynamic employment demand function that is augmented by the <u>ad hoc</u> addition of interactive and main-effect terms in σ_y:

$$L_t = \Sigma\Sigma a_{1ji} X_{j,t-i} + \Sigma a_{2i} \sigma_{y_{t-i}} + \Sigma\Sigma a_{3ji} [\sigma_y X_j]_{t-i} \ , \qquad (7)$$

where each X_j is a determinant of L^*, i refers to lag length, and the a_{kji} are parameters. This allows us to examine whether sectoral output shocks affect employment dynamics and/or equilibrium levels of employment demand. Moreover, it provides evidence that allows us to examine whether sectoral effects on unemployment (assuming they are real) stem from sectoral influences on labor demand.

The alternative approach is a compromise between the models (6) and (7). It combines the information in $\bar{y}_t$ and σ_{y_t} to form $\gamma_t(K, \bar{y}_t, \sigma_{y_t})$, but it allows for a more generally structured relationship between L and the determinants of L^*:

$$L_t = \Sigma\Sigma a'_{1ji} X_{j,t-i} + \Sigma a'_{2i} \gamma_{t-i} + \Sigma\Sigma a'_{3ji} [\gamma X_j]_{t-i} \ . \qquad (7')$$

Clearly, the estimate of K can no longer be interpreted as the size of the shock required to shift a plant to its new long-run optimizing employment level. Rather, this formulation of γ_t is a convenient way of combining all the information on sectoral shocks into one measure and of allowing for generalized interactions of that information with the variables X_j that determine L^*. This combination means that the estimates of the effects of σ_{y_t} are independent of changes in aggregate demand, for the respecification accounts for changes in $\bar{y}_t$.

Because aggregate employment-demand equations assume no timing effects, their divorce from the behavior of the underlying micro units means that they may fail to predict aggregate employment fluctuations that occur as behavior among micro units differs. Without providing any theory to account for this possibility, econometric studies of the determinants of aggregate employment (Fair, 1969; Gordon, 1979) have included timing effects to capture the observation that productivity grows unusually slowly as the economy nears a cyclical peak. Models (6), (7), and (7′) could provide a microeconomic foundation for these formulations of aggregate productivity equations and, more important, could describe the path of labor productivity better.

The three models essentially postulate variable lags in the adjustment of employment and hours to external shocks. There is nothing new about this: Tinsley (1971) was the first to explore empirically the possibility that adjustment costs vary and produce variable lags. Smyth (1984) and Burgess-Dolado (1989) are recent examples of that research. The novelty of this formulation is that it relates macroeconomic fluctuations in factor demand to shocks at the micro level. Since there is direct evidence from microeconomic data (Hamermesh, 1989a, 1989b) that standard specifications of aggregate employment adjustment do not describe behavior at the micro level, this approach may serve to link underlying behavior more closely to macroeconomic outcomes.

3. Estimates of Aggregate Labor Demand With Disaggregated Shocks

A. Estimating the Dispersion of Industry Shocks

Ideally the measure of σ_y should be taken across all decision-making units in the economy, an ideal that is patently unattainable. Failing that, I develop several series of measures using various disaggregations of industries. These are explicitly based on relative shocks to output rather than on the seemingly inappropriate disaggregated measures of changes in employment as in Lilien (1982). The first series is based on output by one-digit industry from the NIPA data. Like the others it is calculated as:

$$\sigma^2_{y_t} = \Sigma Y_{it}[y_{it} - \bar{y}_t]^2/Y_t, \qquad (8)$$

where Y_{it} is national income in the i'th sector, Y_t is the total of national income in the private sector, y_{it} is the logarithmic change in output, and all the series have been deflated by the implicit GNP deflator.[6] The 12 sectors are: Agriculture, forestry and fisheries; mining; construction; durable, and nondurable manufacturing; transportation; communications; utilities; wholesale, and retail trade; finance-insurance-real estate; and services. The series was calculated from 1953 through 1988:II on a quarterly basis.[7] Its mean and standard deviation, along with its range, are shown in the first column of Table 2. There is substantial intersectoral variation in quarterly output shocks, as shown

Table 2. Means of Sectoral Output Shocks, Standard Deviations and Ranges of Dispersion

Private Business, Quarterly 1954: III - 1988: II	Manufacturing, Monthly Shipment/Inventory Data 1965.1-1988.6	Manufacturing, Monthly Production Indices 1965.1-1988.6
.0226	.0394	.0261
(.0118)	(.0176)	(.0114)
(.0070, .0640)	(.0190, .1860)	(.0112, .1125)
Number of Industries		
12	31	42

by the mean of two percent for σ_{y_t}. The maximum is reached during the Steel Strike of 1959, and there are no inexplicable outliers in σ_{y_t}.

This measure is useful in equations describing employment adjustment for the entire private sector using quarterly data. The difficulties with it are that it is probably overaggregated both temporally and spatially. The temporal overaggregation is a problem given evidence (see the survey in Hamermesh, 1976) that lags in the adjustment of labor demand at the aggregate level are not very long and the more general evidence of studies beginning with Engle-Liu (1972). Spatial overaggregation is a problem, as we have gone from the ideal of information on output shocks at the plant level to data on output shocks for 12 large sectors! Two alternative sources permit the construction of series on σ_{y_t} based on disaggregated measures of output in manufacturing. The first is based on Federal Reserve Board indexes of industrial production for 42 industries. The calculation in (8) is used again, with the weights being the published shares in the aggregate manufacturing index for each industry in 1977. The second dispersion measure for manufacturing calculates output as the sum of shipments plus the change in inventories. Equation (8) is used here too, and each series is deflated by the producer price index.

Statistics describing the two monthly series on σ_{y_t} for manufacturing are shown in columns (2) and (3) of Table 2. Because one of the other series used in the analysis is only available beginning January 1964, all of the estimates using the data from manufacturing cover the time period 1965.1-1988.6. For the FRB data the mean and variance of the dispersion measure are somewhat surprisingly quite close to those for the quarterly data on the twelve sectors in private business.

Moreover, the outliers occur at about the same time as in the quarterly data. The shipments/inventories data yield far more drastic interindustry variations in the level of sectoral shocks; and the industry-level changes that generate many of the outliers are difficult to believe. This is consistent with the observation that these data have substantial measurement error. Accordingly, while all the work for manufacturing was done on both measures of σ_{y_t}, and while the results are qualitatively similar, only those using the FRB index are reported here.

B. Labor Demand in the Private Business Sector, 1954-1988

Tables 3 and 4 present estimates of various labor-demand equations based on quarterly data for the private business sector, 1954-1988. Table 3 is based on total employment and uses real compensation as the wage measure. Table 4 is based on total person-hours paid for in the private business sector. (Only the dependent variables differ between the two tables.) The contemporaneous real wage and output are used in the equations. Despite worries about possible simultaneity, some very clear evidence (Quandt-Rosen, 1989) shows this is not a problem. In all of the estimates an AR(1) error structure is specified and the autoregressive parameter ρ is estimated. All variables other than time are in logarithms.

Examination of the estimates in the first two columns shows how remarkably standard they are in this literature. The wage effects are fairly small, especially for the employment equation, but not unusually so among time-series estimates covering all workers (Hamermesh, 1986). The output elasticities are significantly below unity, but that too is quite standard in this literature. Finally, as is uniformly true in

Table 3. Alternative Estimates of Employment Equations, Private Business, 1954:III - 1988:II

	Basic	Geometric	(6)	Lags	(7)	(7')
$Employment_{-1}$		.511 (.036)	.006 (.003)			
Output	.523 (.041)	.439 (.025)	.533 (.040)	.890	.880	.930
Output Interactions					-.693	-.081
Real Wage	-.125 (.070)	-.090 (.044)	-.122 (.069)	-.207	-.250	-.263
Real Wage Interactions					3.073	.083
Time	.0020 (.0005)	-.0004 (.0003)	.0019 (.0004)	-.0003 (.0008)		-.0001 (.0007)
$\hat{K}$ or σ_y			.0025		-10.757	.030
$\hat{\gamma}$						.764
$\hat{\rho}$	.968	.962	.969	.984	.985	.979
$\hat{\sigma}_\epsilon$	.00524	.00331	.00510	.00361	.00364	.00352

Table 4. Alternative Estimates of Hours Equations, Private Business, 1954:III - 1988:II

	Basic	Geometric	(6)	Lags	(7)	(7')
$Hours_{-1}$		.382 (.038)	.0041 (.0022)			
Output	.714 (.044)	.603 (.034)	.722 (.044)	1.014	1.004	1.062
Output Interaction					(-.057)	-.090
Real Wage	-.299 (.065)	-.273 (.036)	-.298 (.065)	-.341	-.377	-.386
Real Wage Interactions					1.407	.092
Time	-.0002 (.0004)	-.0011 (.0003)	-.0002 (.0004)	-.0024 (.0005)	-.0023 (.0005)	-.0021 (.0005)
$\hat{K}$, or σ_y			.0025		-6.037	.030
$\hat{\gamma}$						.764
$\hat{\rho}$	.931	.867	.933	.964	.965	.967
$\hat{\sigma}_\epsilon$	.00543	.00411	.00538	.00421	.00425	.00409

previous estimates (Hamermesh, 1976), the lag of employment behind output shocks is longer than that of person-hours behind output.

Column (3) in each table shows the results of attempts to estimate γ as a parameter of (6).[8] (The estimation was undertaken by searching over a grid of values of K, essentially a stepwise maximum likelihood approach.) The standard errors of estimate are uniformly much higher than in the equations containing the standard geometric lags. This approach really adds nothing even beyond the simplest static labor-demand equations shown in columns (1). Clearly, one cannot view standard equations describing lagged adjustment of labor demand as aggregates of lumpy adjustment with the aggregator implied by (6).

The next endeavor used the measure of the relative dispersion of output shocks, σ_{y_t}, directly in the labor-demand equations. Before presenting those results, though, a basis for comparison is necessary, namely the estimates of:

$$L_t = \Sigma\Sigma a_{iji} X_{j,t-i} .$$

The sums of the a_{ij} are presented in columns (4) of the table. They demonstrate the usual finding that the results of specifying geometric adjustment can be replicated by an equation specifying an unconstrained n-th order lagged adjustment in the independent variables. The sums of the parameter estimates for real wages and output differ little from the long-run elasticities implied by the estimates using the geometric model.

Columns (5) show estimates of (7), dynamic aggregate labor-demand equations modified to account for the dispersion of output shocks among sectors. The results are quite informative: For both employment and person-hours adding these extra main effects and interaction terms in σ_{y_t} raised the standard error of estimate.[9] Whatever it may do in describing fluctuations in unemployment, variation in the relative dispersion of output shocks does not add to the description of fluctuations in aggregate employment.

As in the estimates in columns (4), the γ_t estimated in (7′) were generated by searching over a grid of values of K. The terms in γ add appreciably to the explanatory power of the equations; and for person-hours the standard error of estimate actually falls slightly below that of the geometric-adjustment model (whose parameter estimates are fraught with the recently forgotten difficulties of including lagged dependent variables). Apparently it is not just the dispersion of output shocks that determines the path of aggregate employment and person-hours. Rather, it is the size of that dispersion relative to the mean output shock that matters.

The sums of the interaction terms in the Tables are themselves of interest. First, the estimate of K, .03, is significantly different from zero: Relative dispersion matters in and of itself <u>and</u> compared to the difference between the mean shock and some fixed threshold. The effects of the dispersion of shocks are nearly identical in the two sets of estimates. In interpreting them one should remember that an increase in σ_{y_t} holding $\bar{y}_t$ constant reduces γ. This implies that greater dispersion of output shocks increases the absolute values of the responses of employment and person-hours to changes in output and real wages (since the sums of the interaction terms are opposite in sign from the sums of the main effects on output and real wages). This suggests that greater dispersion reduces rigidity in the adjustment of aggregate employment.

One impetus to this study was the anomalous set of findings on productivity near the ends of cyclical expansions. To examine whether accounting for intersectoral dispersion helps to explain these anomalies, I estimated the root mean-squared errors for the equations in columns (4) and (6) at cyclical peaks and troughs that occurred during the sample period, in each case for the quarter of the turning point and one quarter before. The averages are shown in the first part of Table 5 for the six cycles that occurred during the sample period. Except for person-hours at cyclical peaks, including the nonlinear transformation of σ_{y_t} and $\bar{y}_t$ in aggregate labor-demand equations improves the fit of those equations. The improvements are on the order of ten percent (of the residual errors around the turning points), suggesting that there is a fairly substantial gain in the ability to predict employment and hours fluctuations around cyclical turning points, and thus to predict fluctuations in labor productivity, from including measures of intersectoral dispersion.[10]

The magnitudes of the responses of employment and person-hours vary fairly sharply over the range of $\gamma_t(K, \bar{y}_t, \sigma_{y_t})$. The long-run impacts of an aggregate output shock of ten percent are shown in the bottom half of Table 5. Compared to the mean value of γ, or to the simulated impacts from the equations in columns (4), variations in γ_t over its entire range generate substantial variations in output elasticities. This underscores the conclusion that increased dispersion reduces employment rigidity and demonstrates that the reduction would not be tiny if dispersion were at its maximum within the sample period.

C. Labor Demand in Manufacturing, 1965-1988

In this part I present estimates of various versions of labor-demand equations for monthly data for manufacturing. The dependent variables are total employment, production-worker employment, and production-worker person-hours. A measure of average hourly earnings of

Table 5. Root Mean-Square Errors With and Without Sectoral Effects, and Impacts of Output Shocks, Employment and Person-Hours, Private Business, 1954:III - 1988:II

	Employment		Person-Hours	
	Sectoral Effects		Sectoral Effects	
RMSE	No	Yes	No	Yes
Average	.004830	.004336	.004708	.004361
Peaks	.003421	.002997	.003545	.003568
Troughs	.005913	.005350	.005635	.005031
Long-Run Impact of a Ten-Percent Permanent Output Shock				
$\hat{\gamma}$				
Minimum		.0904		.1033
Mean	.0890	.0868	.1014	.0993
Maximum		.0849		.0972

production workers is used as the real wage measure for the latter two dependent variables, while real compensation in manufacturing is used in equations describing demand for all employees. Other than the differences the variables, and the use of monthly data, these estimates are produced in exactly the same way as those in the previous part.

Qualitatively the results are strikingly like those in Tables 3 and 4 for the private business sector. As with those estimates, employment-output elasticities are below one, person-hours-output elasticities are higher, but still less than one, and employment-wage elasticities are generally negative. The lags in employment adjustment exceed those in the adjustment of person-hours. While the implied average lags are shorter than those in the quarterly estimates of the previous part, this difference is the very common result of temporal disaggregation.

Estimates of (6) are not presented in the Tables. In all three cases $\hat{\sigma}_\epsilon$ was far above its value even in the basic equation. As with the quarterly data for the private business sector, simply aggregating microeconomic bang-bang adjustment and using a measure of industrial dispersion of output shocks failed miserably in describing labor demand. Even using forty-two industries to estimate σ_{y_t}, we are still far from the appropriate aggregator of the underlying microeconomic adjustment. Nonetheless, it is still worth examining (7) and (7′) to see if, as in the aggregate quarterly data, accounting for interindustry dispersion improves the ability to predict employment around cyclical turning points, and if it helps to explain aggregate employment fluctuations.

Columns (3) of Tables 6-8 show the estimates of (7) without the terms in σ_{y_t}. In all three cases adding the lag terms improves the fit of the labor-demand equations. Moreover, the long-run labor demand-

Table 6. Alternative Estimates, Production-Worker Employment, Manufacturing, 1965.1 - 1988.6

	Basic	Geometric	Lags	(7)	(7')
$Employment_{-1}$		.317 (.042)			
Output	.535 (.029)	.424 (.031)	.827	.838	.772
Output Interactions				-.1903	.0636
Real Wage	-.045 (.054)	.0028 (.049)	-.016	-.0575	.0145
Real Wage Interactions				1.3690	-.0547
Time	-.0019 (.0002)	-.0014 (.0001)	-.0027 (.0003)	-.0027 (.0003)	-.0027 (.0003)
$\hat{K}$ or σ_y				-6.102	.045
$\hat{\gamma}$					.887
$\hat{\rho}$	.977	.966	.984	.985	.983
$\hat{\sigma}_\epsilon$	.00455	.00416	.00378	.00383	.00378

Table 7. Alternative Estimates, Production-Worker Person-Hours, Manufacturing, 1965.1 - 1988.6

	Basic	Geometric	Lags	(7)	(7')
$Hours_{-1}$		-.085 (.042)			
Output	.917 (.039)	.949 (.046)	1.012	1.030	.976
Output Interactions				-.0351	.1394
Real Wage	-.137 (.051)	-.145 (.059)	-.129	-.1238	-.0911
Real Wage Interactions				1.6722	-.0570
Time	-.0027 (.0001)	-.0028 (.0001)	-.0029 (.0001)	-.0030 (.0002)	-.0030 (.0002)
$\hat{K}$, or σ_y				2.095	.045
$\hat{\gamma}$					.887
$\hat{\rho}$	.881	.907	.873	.877	.881
$\hat{\sigma}_\epsilon$	.00714	.00711	.00678	.00685	.00682