ON THE SOURCES AND SIZE OF EMPLOYMENT ADJUSTMENT COSTS

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ABSTRACT

Micro employment adjustment costs affect not only establishment-level dynamics but can also affect aggregate employment dynamics. The difficulties in directly observing and measuring these adjustment costs necessitate an indirect approach in order to learn more about the sources and size of these costs. This paper examines differences in employment adjustments by worker and establishment characteristics using micro-level data for approximately 11,000 U.S. manufacturing plants. Differences in the speed of adjustment within the organizing framework of the traditional partial adjustment model are used to identify the source and size of employment adjustment costs. The estimates are undertaken using three different techniques and under a variety of assumptions concerning market structure, worker heterogeneity, and degree of interrelation of inputs. The estimates show that employment adjustment speeds differ over worker and establishment characteristics in a manner that is consistent with the underlying adjustment cost stories. These differences suggest that systematic changes in the distribution of establishments over these characteristics can influence aggregate employment dynamics in response to a shock through compositional effects.

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1. Introduction

Microeconomic employment adjustment costs affect not only employment adjustments at the micro level but may also profoundly impact aggregate employment dynamics. At the beginning of their extensive review of the current state of research concerning factor demand adjustment costs, Hamermesh and Pfann (1996) note that two of the questions that need to be answered about adjustment costs concern the *source* and *size* of the adjustment costs facing an individual agent. Given that these costs are difficult to directly observe, this paper takes an indirect approach by comparing the relative speeds of adjustment from an extension of the traditional partial adjustment model over a variety of worker and establishment characteristics. Differences in employment adjustment speeds over these characteristics are used to help identify the *source* and *size* of employment adjustment costs.[1]

There are a variety of sources of net employment adjustment costs.[2] Explicit adjustment costs on the expansion side include the costs of contracted-out advertising, testing, processing, and training of new workers. On the employment contraction side, explicit adjustment costs mostly relate to legal requirements and regulations, including mandated unemployment benefits, severance payments, and compensation for breach of contract or failure to provide notice.[3] Other adjustment costs arise from

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[1] Their remaining questions about adjustment cost structure and aggregate implications, as well as these questions about source and size, are addressed in Foster (1999) using the state-dependent adjustment hazard model as a theoretical framework.

[2] As this paper focuses on adjustment costs in terms of the labor demand decision, changes in employment that reflect job matching or life cycle issues are not as relevant, and hence net employment changes are studied rather than gross employment changes.

[3] There are legal constraints to layoffs at both the federal and state levels. On the federal level, there is the Worker Adjustment and Retraining Notification Act of 1988. Some states also have laws concerning advance notification for layoffs and plant closings (see Abraham and Houseman (1992)). The experience rating system for unemployment benefits "provides a link between the average level of layoffs

restructuring the workforce (which include planning and organizational costs) or from changing the mix of inputs. If the other inputs have their own costs of adjustment, then these other input adjustment costs can impact employment adjustments. For employment increases that require expansions across other dimensions (such as expanding the physical plant), these adjustment costs can include the costs of obtaining access to financial capital. Finally, there are implicit employment adjustment costs which are costs internal to the production function representing the loss of productivity that ensues as work shifts from producing output to absorbing employment changes. These internal adjustment costs affect the employer's ability to alter production relationships. An example of internal adjustment costs is the loss of output from taking an existing production worker off the assembly-line to train a new production worker.

Since it has proven difficult to directly observe and measure employment adjustment costs,[4] this paper examines adjustment costs indirectly through the variations in employment adjustments by observable differences in worker and establishment characteristics. For example, if the primary source of adjustment costs is credit constraints, one would expect the size of the firm to matter a lot (since establishments that are part of a large firm may have greater access to credit) but worker type not to matter as much. On the other hand, if the explicit personnel types of costs are the primary source of adjustments costs, one would expect worker type to matter a lot. The establishment characteristics which are hypothesized to affect employment adjustment costs include average worker skill-level, technology, access to capital funds, institutional factors, and coverage by regulatory restrictions. To

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generated by the firm and its payments into a central fund for benefits.... (Nickell 1984, p.476)."

[4] See Oi (1962) and Nickell (1986) for further discussion.

analyze the influence of these effects employment adjustments are examined using establishment-level information on age, average plant and firm size, ownership type, industry classification, shutdown technology, location, input intensities, and workforce skill level. Worker characteristics are captured by distinguishing between the adjustment dynamics of blue collar and white collar workers.

The micro employment adjustments are examined within the partial adjustment model framework. Much of the existing empirical work in this area has used aggregated data (temporally, spatially, and/or over worker and establishment characteristics); more recent work uses micro data in recognition of the importance of using spatially disaggregated data.[5] This paper expands upon the literature by using micro level data and incorporating worker and establishment characteristics. Specifically, the paper uses annual establishment level data for approximately 11,000 U.S. manufacturing plants over 17 years. Estimations are done under a variety of assumptions concerning the heterogeneity of workers and establishments, market structure, and the interrelation of the employment inputs. The model is estimated using three different estimation techniques in an attempt to deal with the unobserved establishment heterogeneity and problems with traditional estimation techniques in this setting. In sum, this paper sheds light on the *source* and *size* of employment adjustment costs by examining differences in speeds of adjustment by worker and establishment characteristics using micro data.

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[5] Examples of estimates using data aggregated over these four dimensions include Epstein and Denny (1983) and Layard and Nickell (1986). Papers that use quarterly data include Sargent (1978), Meese (1980), and Nickell (1984). Papers that estimate speeds of adjustment by worker-types using quarterly data include Nadiri and Rosen (1973) and Palm and Pfann (1990). Many of these papers include inputs other than employment. As an example using micro data, Bresson, Kramarz, and Sevestre (1992a) use annual data for firms and estimate separate speeds of adjustment for production and nonproduction workers.

The paper is organized in the following manner. The partial adjustment model and its extensions are described in Section 2. The data and specification issues are outlined in Section 3. Section 4 presents the empirical results. Section 5 provides concluding remarks.

2. Partial Adjustment Model

The partial adjustment model derives its dynamic nature from the presence of input adjustment costs and hence provides a natural theoretical framework for some questions about adjustment costs. Although employment adjustment costs may have fixed and variable components, much of the dynamic labor demand literature makes the simplifying assumption that adjustment costs are quadratic. Under this assumption of quadratic adjustment costs, a model of dynamic labor demand can yield the familiar partial adjustment model's path of smooth adjustment from current employment (n_t) towards desired employment (n_t^*):

(1) $$n_t = \lambda n_{t-1} + (1-\lambda) n_t^*$$

Since the empirical analysis in this paper focuses on estimating λ, the stickiness of adjustment parameter, it is useful to describe the features of this model. The model presented in this paper is representative of the models in the partial adjustment literature, but is extended in three areas.[6] First, the model is modified to allow for both internal and external adjustment costs since worker and establishment characteristics may effect either of these costs. Second, since the empirical work will use

[6] For examples of this model see Sargent (1978), Hansen and Sargent (1980), Sargent (1987), Meese (1980), and Palm and Pfann (1990). These models vary in complexity due to differences in the number of inputs and degree of interrelation between inputs.

establishment level data, the model is modified to be consistent with plant-level decisions and heterogeneous establishments and workers. Finally, the model is estimated allowing for differences in adjustment speeds over establishment characteristics.

As a starting point, this paper relies on Sargent's (1978) concise model of dynamic labor demand with quadratic adjustment costs. This model makes the following assumptions: the production function is quadratic in employment (n), capital (k) is fixed over time, and there is a stochastic process affecting the productivity of employment (a_t). The costs faced by the producer include the costs of production (in this case wages (w)) and of adjustment. The adjustment costs in this model are by implication external adjustment costs.[7] Internal adjustment costs can be added to the Sargent-style model via a generalized production function in which an input can be used in one of two ways: producing output and changing the level of the input. In order to maintain the requirements of the underlying model, internal adjustment costs are additively separable from the level of the inputs.[8] Thus the internal adjustment costs are incorporated simply as a quadratic function in the production function. The generalized production function is:

(2) $$f(n_t,k) = (f_0 + a_{t+j})n_{t+j} - \frac{f_1}{2}n_{t+j}^2 - \frac{z}{2}(n_{t+j} - n_{t+j-1})^2$$

Where the parameters f_0, f_1, $z > 0$ and the last term in equation (2) represents internal adjustment costs.

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[7] To compare this to a model with internal adjustment costs only see Mortensen (1973) which compares the external adjustment cost model of Lucas (1967) to the internal adjustment cost model of Treadway (1971).

[8] Note that for the question at hand, internal and external adjustment costs do not need to be distinguishable empirically; the model includes both so that establishment characteristics, which may affect different types of adjustment costs differently, can be linked to the employment decision.

It is implicit that there are no labor supply constraints. The producer is assumed to take prices; the alternate assumption that producers are demand constrained is examined later in this section (the empirical analysis is done under both assumptions). Thus the producer chooses the path of employment so as to maximize the expected real present discounted value:

$$\textbf{(3)} \qquad E_t \sum_{j=0}^{\infty} \beta^j \left[(f_0 + a_{t+j} - w_{t+j}) n_{t+j} - \frac{z}{2}(n_{t+j} - n_{t+j-1})^2 - \frac{f_1}{2} n_{t+j}^2 - \frac{d}{2}(n_{t+j} - n_{t+j-1})^2 \right]$$

Where the parameter d >0 and the last term in equation (3) represents external adjustment costs. β is the discount rate. This maximization yields a series of Euler equations and a transversality condition. Solving these forward yields:

$$\textbf{(4)} \qquad n_{t+j+1} = \lambda_1 n_{t+j} + \frac{1}{f_1}(1-\lambda_1)(1-\beta\lambda_1) \sum_{i=0}^{\infty} (\beta\lambda_1)^i \, E_t \, (a_{t+j+i+1} + f_0 - w_{t+j+i+1})$$

λ_1 is the smaller of the roots ($0 < \lambda_1 < 1 < 1/\beta < \lambda_2$); it measures the smoothness of adjustment and is a function of the discount rate (β) and the ratio of the concavity of the production function (f_1) to the convexity of the external (d) and internal (z) adjustment cost functions. The more convex the adjustment cost functions (higher d or z), the slower and smoother the adjustment (higher λ_1) to the new desired level. Establishment characteristics that affect quadratic adjustment costs do so via their relationships with the parameters d and z. At the upper limit, the plant will not adjust employment at all (λ_1=1); at the lower limit, adjustment is instantaneous (λ_1=0).

In order to translate the forward solution into a decision rule, the expectations of the stream of current and future values for the forcing variables must be replaced by a formula (or variable) that is known by the agents at the time of the decision. If one assumes static expectations the resulting equation is the standard partial adjustment equation shown in equation (1). Much of the literature assumes rational expectations and an autoregressive process for the forcing variables. Assuming that these processes are first-order autoregressions (with parameters ρ_a and ρ_w), the decision rule is:

(5)
$$n_{t+j+1} = \lambda_1 n_{t+j} + \frac{1}{f_1}(1-\lambda_1)(1-\beta\lambda_1)\left[\frac{f_0}{1-\beta\lambda_1} + \frac{a_{t+j+1}}{1-\beta\lambda_1\rho_a} - \frac{w_{t+j+1}}{1-\beta\lambda_1\rho_w}\right]$$

In order to transform this decision rule into an estimation equation one must deal with the unobservable productivity shock (a). This paper follows Meese (1980) where the productivity shock is assumed to be white noise and hence is immediately subsumed into the error term.[9] Although many papers assume rational expectations this assumption is incorporated with varying degrees of formality. The most formal models incorporate cross-equation restrictions in order to identify deep structural parameters, while the less formal models eschew these cross-equation restrictions. In these less formal models, there is no attempt to solve for parameters of the objective function (f_1,d,z, β) , instead the parameter of the solution (λ) is estimated. In linking differences in estimates of λ to differences in adjustment costs, these papers make the implicit assumption that the concavity of the production function (f_1) and the discount factor (β) are not responsible for these differences. Under these assumptions, the decision rule in

[9] A drawback to this assumption is discussed in the multivariate model section. Sargent (1978) instead manipulates the decision rule by subtracting off ρ_a a_{t-1} and thus the productivity shock term is subsumed into the error term. This means, however, that the coefficient on the lagged dependent variable represents $\lambda+\rho_a$.

equation (5) is transformed into the following estimation equation of observable variables:[10]

(6)
$$n_t = \alpha_0 + \alpha_1 n_{t-1} + \alpha_2 w_t + \varepsilon_t$$

The coefficient on the lagged dependent variable (α_1) represents estimates of the smoothness of adjustment parameter (λ). The next section extends the model from this univariate case to the univariate, heterogenous case and then to several multivariate cases (which differ over degrees of input interrelation).

A. Multivariate Model

Adjustments can occur over a variety of margins. In the multivariate version of the partial adjustment model, the adjustment rate of one quasi-fixed input can depend on the difference between actual and desired of <u>all</u> quasi-fixed inputs. In order to make a tractable model, the first issue is choosing which inputs to include. Although other inputs are important, in keeping with much of the literature on employment adjustments, this paper focuses on the labor input. Adjustments in labor can occur over a variety of dimensions including effort, hours, and employment. Comparing adjustments of employment and hours over the business cycle, adjustments over hours are relatively smaller than adjustments over employment and occur prior to adjustments over employment.[11] Since this paper

[10] This specification is consistent with the more informal approach in which the agent minimizes two costs, the cost of adjusting employment and the cost of deviating from the desired employment level. A simple formulation of desired employment is optimal frictionless employment which is a function of the real wage and thus is consistent with the specification used in this paper.

[11] Rones (1981) notes that the tendency of firms to react to weak product demand by reducing hours before cutting employment "has been so cyclically consistent that average weekly hours of production

examines adjustment costs it makes sense to focus on the extensive margin where the labor adjustment costs are mostly likely concentrated. By doing so, the analysis may overstate the general labor adjustment costs that an establishment faces when it has been exposed to a shock.[12] A univariate model of total employment is acceptable when the inputs are subject to the same adjustment processes. In this case, the estimation equation is equation (6) above.

There is ample evidence in the literature, however, suggesting that the adjustment processes for production workers and nonproduction workers differ significantly. Nickell (1984) notes that it is particularly important to disaggregate labor into at least two different types when studying adjustment costs because of the enormous differences in adjustment costs between different worker types.[13] The univariate model with heterogenous worker types includes an additional lag on the lagged dependent variable and the forcing variables. The coefficient on the lagged dependent variable represents the sum of the adjustment parameters for the two types of workers which cannot be separately identified if there are any cross-adjustments.[14] In this case, the estimating equation is:

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workers in manufacturing is designated as one of the Nation's 12 major leading economic indicators ...(p.3)." He finds that the average gap between adjustments in hours and employment is about 5 months for production workers in durable manufacturing (1953-1980 sample). See also Abraham and Houseman (1992), Lilien and Hall (1986), and Bry (1959).

[12] Some authors, such as Palm and Pfann (1990), use manhours (hours times employment) and assume that there is no difference in adjustment costs over the two labor margins. Others, such as Bresson et al. (1992a), assume that there are no adjustment costs for hours so that firms always have the possibility of adjusting hours in such a way as to stay on their production frontier.

[13] In summarizing the few studies which measured explicit hiring and firing costs, Nickell (1986) concludes that "it seems reasonable to suppose that for white-collar workers, hiring or firing costs are between two weeks' and two months' pay, and for blue-collar workers they are between two days' and two weeks' pay (p. 518)."

[14] See Nickell (1984, 1986) and Bresson et al. (1992a).

(7)

$$n_t = \alpha_0 + \alpha_1 n_{t-1} + \alpha_2 n_{t-2} + \alpha_3 w_t + \alpha_4 w_{t-1} + \epsilon_t$$

$$\textit{Where} \quad \alpha_1 = \lambda_{nn} + \lambda_{pp} \quad \alpha_2 = \lambda_{nn}\lambda_{pp} - \lambda_{np}\lambda_{pn}$$

Where the subscripts on the adjustment parameters refer to the worker-types (p for production workers, n for nonproduction workers).

Given the availability of employment data for both worker types, a more appropriate model is a multivariate model with nonproduction and production employment as inputs. The next issue is deciding the degree of interrelation between the inputs. The choice inputs could be modeled such that the marginal cost of adjusting an input is affected by the rate of adjustments in other inputs, although many models instead assume that the adjustment costs for inputs are additively separable. The model in Sargent (1978) is multivariate, but the interrelation is minimal as the two choice variables are straight-time and overtime employment. The two choice variables are additively separable in the production function and in the adjustment costs, so that any interrelation in the demand equations comes from the fact that both inputs are affected by the same wages. In the case of no interrelation the estimating equation for worker-type j is therefore:

(8)

$$n_{jt} = \alpha_{j0} + \alpha_{j1} n_{jt-1} + \alpha_{j2} w_{jt} + \epsilon_{jt}$$

For the case where the two inputs are production and nonproduction workers a more relevant model is Meese's (1980) version of the Sargent model. Meese assumes a quadratic production function and a quadratic adjustment cost function each with interaction terms between the two inputs (capital and labor). Under Meese’s assumptions about expectations (white noise for the productivity shocks and autoregressive univariates for the input prices), the demand equations for the two inputs feature interrelation through both the cross-input prices (the two wages) and cross-inputs.[15] However, Palm and Pfann (1990) claim that the Meese model would not in fact have demand equations that are interrelated through the choice variables. Palm and Pfann show that the interrelation would be confined to the shared forcing variables because Meese has a quadratic objective function and his stochastic process for labor productivity is assumed to be white noise.[16] That is, the estimating equation for worker-type j would include the wages for both worker types j and i and thus would be:

$$n_{jt} = \alpha_{j0} + \alpha_{j1} n_{jt-1} + \alpha_{j2} w_{jt} + \alpha_{j3} w_{it} + \epsilon_{jt} \quad \textbf{(9)}$$

In the empirical section of the paper, the homogeneous (equation 6) and heterogeneous models are estimated. For the heterogeneous model the univariate (equation 7), no interrelation multivariate (equation 8), and semi-interrelation multivariate (equation 9) models are estimated. The estimations by establishment characteristic use the semi-interrelation model.

B. Establishment Characteristics

This section describes the connection between establishment characteristics and employment

[15] Note that there is no formal interrelation through the productivity shocks as they are both subsumed into the equation errors.

[16] In order to have full interrelation where cross-employment terms appear as well as the cross-wage terms, the stochastic processes for the labor productivity terms cannot be white noise and they must be bivariate. As noted in the section on expectations, this means that the resulting decision rule must be manipulated so that the productivity shock variable can be subsumed into the error term. In this case, the coefficient on the lagged dependent variable represents $\lambda+\rho_{j a}$. The cross-equation restrictions are used to identify these effects.

adjustment costs. Establishment characteristics can affect both the size and the structure of employment adjustment costs and hence can affect 8 and thereby all of the slope coefficients in the estimating model. The following establishment characteristics are considered here: general worker skill-level, plant technology, access to capital funds, and institutional and regulatory constraints. The production-nonproduction employment mix at the establishment can affect the employment adjustments costs since the worker-types are subject to different adjustment costs. As noted above, studies that have attempted to measure the explicit adjustment costs have found that they differ over production and nonproduction workers. In his pioneering paper, Oi (1962) found that nonproduction workers in manufacturing industries tend to be more specific to the firm than production workers; and since they have greater firm-specific human capital, nonproduction worker are less likely to be used to make employment adjustments.[17] Nonproduction worker adjustments may also be more costly than production worker adjustments because they are more likely to entail capital adjustments as well. Griliches (1969) and Bergstrom and Panas (1992) find evidence that skilled employment is more complementary with capital than is unskilled employment. This suggests that a shock that leads to an adjustment of skilled employment is likely to be associated with an adjustment of capital which imposes its own adjustment costs. Thus both the internal and external costs of adjustment for these two worker types are presumably different since the literature suggests that adjusting skilled workers is both more disruptive and features greater hiring, training, and firing costs than adjusting less-skilled workers.

Technological factors that constrain the plant manager may make it costly to adjust employment

[17] Similarly, Abraham and Houseman (1989) note that "For technological reasons, production workers are likely to be a more variable input in the production process than nonproduction workers (p.513)."

and/or affect the relative costs of adjusting over employment versus over other margins. Capital-intense establishments are likely to face high adjustment costs, as these employment adjustments have a greater chance of involving an adjustment in the capital stock which itself faces high adjustment costs. Also, due to human capital's complementarity with physical capital, one would expect establishments with greater capital intensity to employ a more skilled workforce. Although adjusting energy may be relatively costless, the energy intensity of an establishment may reveal information about its technology. Since energy intensive establishments tend to be also capital intensive, one might expect energy intensive establishments to have higher adjustment costs.

The use of shift work can affect the ease with which a plant manager can adjust an establishment's employment to accommodate a large shock. Adjustment costs associated with planning and restructuring may be smaller for establishments that employ shifts.[18] Shift-work tends to be more associated with occupations found in the production worker group than the nonproduction worker group and to be more associated with industries that are capital-intensive.[19] Of course, the presence of shifts does not necessarily mean that it is feasible to adjust over shifts; as noted below many establishments that have shifts are also continuous operators which makes adjustment over shifts infeasible.

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[18] Mayhsar and Solon (1993) find that "[w]hen full-time employment declines during a recession, about one-half of the decline for manufacturing production workers and one-third of the economy-wide decline occur on late shifts (p.227)."

[19] King and Williams (1985) note that the prevalence of a late-shift varies greatly among manufacturing industries, "ranging from less than 5 percent of the production workforce in such labor intensive industries as apparel ... to approximately one-half in more capital intensive industries such as cotton and manmade textiles..(p. 26)." Mellor (1986) finds that shift-work in manufacturing is most prevalent in primary metals, automobiles, paper products, chemicals, and rubber and plastics.

Continuous processing establishments have large start-up and shut-down costs that make adjustments over employment relatively more expensive than for assembly-type producers who have small start-up and shut-down costs. Mattey and Strongin (1994) find that:

> "...plants do differ quite a bit in how they accomplish output adjustments, depending largely on the shutdown costs aspect of technology; other things equal, assembly-type operations primarily vary the work period of the plant, whereas continuous processing plants adjust instantaneous flow rates of production.... To expand capacity, assemblers can lengthen the work period by adding shifts, which requires an employment increase; continuous processors generally need to relax physical capital constraints to expand capacity output (p.2)."

Plants in the paper, chemicals, petroleum, and primary metals industries tend to be continuous processors. Plants in the machinery and transportation industries tend to be assembly-type producers. One would expect that large employment adjustments are most easily accomplished in establishments that have shifts and are also assembly-type producers. In this manner, operating type and shift use would be expected to affect the ability to minimize disruptions due to adjustments and hence affect internal adjustment costs.

An establishment's access to capital funds (internal or external) can greatly affect its costs and ability to adjust. Whether or not the establishment is part of a large multi-plant firm can affect its access to capital funds. Plants that are part of a large multi-plant firm may have greater access to internal funds and have certain types of financial credit available that are unavailable to small firm plants. In addition, interest rates paid have been shown to be strongly inversely related to the size of the borrower.[20] Thus, these costs of upsizing may be greater for single-unit, smaller establishments.

Institutional constraints to adjusting employment include union agreements and laws that constrain layoffs. The unionization of an establishment may increase its costs of adjusting (internal and external) or make adjustments over some margins impossible. Hamermesh (1992a) notes that it "is likely ... that by increasing formalization in the workplace [unions] increase the fixed component [of adjustment costs] (p.736)." Finally, some costs of downwards employment adjustments may reflect the legal climate for layoffs. As noted earlier, there are legal constraints to layoffs on both the federal and state levels. In addition, the experience rating system of unemployment benefits, which differs by states, can produce costs of adjustments for those establishments that are below the threshold level. While direct measures of these institutional constraints are not readily available, variation by industry, region, and size of plant or firm are ways that these constraints may play a role in this analysis.

A plant's size has been linked to many of the characteristics that might be expected to affect the nature of its adjustment costs, including technology, general worker skill-levels, firm size, and the presence of institutional and regulatory constraints. Brown, Hamilton, and Medoff (1990) note that large firms (500 employees or more) tend to operate large establishments (100 employees or more). They find that these large firms are more likely to hire more educated, more experienced, older workers than small firms. One possible reason for this that they cite is that large firms may tend to be more capital intensive. In addition, they note that large firms pay more for labor inputs (even taking into

[20] See Brown, Hamilton, and Medoff (1990), and Davis, Haltiwanger, and Schuh (1996).

account the difference in workers), but that they pay lower prices for intermediate inputs and, as noted above, lower rates of interest for borrowed funds. Another reason size might matter is that many labor regulations exclude smaller firms and large firms are more likely to be unionized than small firms. In addition, size may be related to flexibility. Kandel and Pearson (1995) describe the employment decision as involving two types of workers, permanent and temporary. They show that in theory larger establishments will tend to hire more permanent workers *ceteris paribus*. Hence, increased establishment size may be associated with less flexibility and thus slower adjustment.

The age of the establishment can give information concerning the maximum vintage of the capital at the establishment, thus allowing for some comparison across establishments concerning technology. Berman, Bound, and Griliches (1994) found evidence of labor-saving technical change in the manufacturing sector over the latter part of the sample in this paper. During this period, nonproduction workers gained in relative importance at establishments. It may be that older establishments use older, more production-worker intensive technology. In addition, the age of the establishment gives an upper limit on the maximum tenure of its employees. Thus the relative age of an establishment can give information about the plant-specific human capital embodied at the establishment. In terms of adjustment costs for older establishments, higher costs are suggested by the presence of workers with greater tenure (and hence with greater plant-specific skills); on the other hand, lower costs are indicated by technology that is production-worker intensive.

C. Model When Using Micro Data

Three issues arise when using establishment-level data to estimate the partial adjustment model:

output price, market structure, and unobserved establishment heterogeneity.[21] Given that the maximization problem is specified in terms of the expected real present value, the forcing variables are measured in real terms (e.g., need to be real wages and real output).[22] The second issue is the assumption of price-taking behavior. Sims (1974) notes “some variables that might not be exogenous at the firm level may naturally be regarded so when measured as industry aggregates. This seems a particularly important point for output ... (p. 700)”. Similarly Nickell (1986) argues against assuming that output is exogenous at the firm level:

> “With regard to the firm’s environment, the big danger is to assume that the firm is demand constrained and that output is exogenous. This seems rather unlikely and it is almost inconceivable, for example, that a technology shock will not influence both employment and output simultaneously. Now it is, of course, perfectly legitimate to investigate employment conditional on output so long as it is remembered that output is not exogenous (p. 512).”

On the other hand, many empirical estimations of the partial adjustment model use output as a forcing variable often due to a lack of availability of other forcing variables. In justifying their ability to estimate

[21] In addition, some authors question the suitability of rational expectations in this setting. Nerlove and Balestra (1992) argue that assuming rational expectations is problematic when using panel data. They find that “rational expectations introduce a time-specific, individual non-specific, component in the error component formulation, as well as a fundamental failure of identifiability (p. 16).” This can only be avoided when the future values of the exogenous variables are in the information set when expectations are formed. Nevertheless, most models using panel data assume rational expectations.

[22] Sargent (1978) uses the CPI to create real wages, but as Nickell (1986) notes this is not the price that is relevant for firms.

the model with only output (and specifically without factor prices), these authors often cite Freeman (1977) who found that " the major factor determining changes in employment are shifts in demand, although shifts in supply and movements along demand schedules also contribute to observed changes (p.181)." Finally, Bresson et al. (1992a) note that it may be that some firms are output constrained and some are not. Given the lack of agreement on this matter, two versions of the model (price-taker and demand-constrained) are run in the empirical section of this paper. The estimation equations under the competing assumption of an output-constrained establishment include a real output term.

The last issue when using micro data concerns modeling unobserved exogenous heterogeneity. One finding that is common to empirical research using plant-level data is the tremendous heterogeneity of establishments (even within a given group such as four-digit industry). Unobserved heterogeneity can arise from a variety of factors including differences in managerial ability, institutional and technological factors, plant location, and so forth. There are arguments in favor of modeling this unobserved heterogeneity as a random effect (including that the observations are from a sample rather than a population), but since the effects are potentially correlated with the exogenous variables a fixed-effects framework must be used in empirical estimations.

3. Data and Specification Issues

A. Data

This section describes the data used in the empirical work in this paper and discusses its representativeness of the population as a whole. A data appendix provides further detail (Appendix A). The data are from the Longitudinal Research Database (LRD) which contains plant-level, U.S.

manufacturing data.[23] Plant startups and shutdowns are assumed to be fundamentally different events from other, less extreme adjustments and hence are not considered in this paper.[24] For this and practical reasons, the sample is limited to the establishments that can be linked over 1972-1991.[25] Thus most small establishments and any establishments that have started up or shutdown over the period are excluded from the sample. There are approximately 11,000 continuing plants with about 7 million full-time and part-time employees on average over the sample period. Figure 1 shows total employment for the aggregate of the continuer plants and two measures of total manufacturing employment. The upper panel shows total manufacturing employment from the Annual Survey of Manufacturers (ASM), the lower panel shows the Bureau of Labor Statistics' measure (using the 790 data). The sample total employment tracks the population total employment relatively well (the correlation between the ASM and the sample is .93).

To get a more complete picture of the relationship between the sample and the total population,

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[23] The LRD is composed of data from two sources, the Census of Manufacturers (CM) and the Annual Survey of Manufacturers (ASM). The CM is a census, conducted every five years, of all establishments whose primary activities occur within the manufacturing sector. There are approximately 350,000 plants in each census year. The ASM is a rotating sample of establishments from the CM. A new ASM sample is drawn one year after the CM takes place. The probability of selection for the ASM sample is related to the size of the establishment. Roughly speaking, establishments with 250 employees or more are selected with probability of 1. Smaller establishments are sampled with probabilities proportional to their size. The ASM contains roughly between 50,000 and 70,000 plants in a given year. See Davis, Haltiwanger, and Schuh (1996) for a description of the LRD.

[24] This is not to say that plant startups and shutdowns are unimportant. Davis, Haltiwanger, and Schuh (1996) found that plant births and deaths contribute significantly to annual changes in employment: shutdowns account for 23% of annual negative employment growth, startups for 16% of annual positive employment growth.

[25] The termination of the panel in 1991 reflects data availability for some of the measures used and the fact that the balanced panel has been cleaned and has desirable aggregate properties through 1991. The plants that appear in the sample are those that existed continuously from 1972 to 1993.

table 1 compares the sample in 1982 with the population of the 1982 Census over a variety of dimensions. Generally speaking, the sample performs reasonably well over these dimensions with the exceptions of the size variables. Unfortunately, it is not possible to compare the age distributions of the total and the sample as the age variable is not available for all establishments in 1982. However, since the sample is of continuers who are by definition aging over the sample, it is reasonable to suppose that the age distribution of the sample is unrepresentative of the total. Given the sampling algorithm and the use of continuer plants, it is not surprising that the sample distribution of plant size is very different from the total distribution. However, this is slightly mitigated if one looks at the distribution of size weighted by the number of employees (the figures in parentheses). That is the average plant is not as well represented as the experience of the average employee. Although the sample does not have many small plants, plant size is still a relevant characteristic in this sample as the existing literature has shown that there is substantial variation over medium size and large plants.[26] Similarly, small firms are under represented in the sample relative to the total but less so when one considers the distribution weighted by employment (the figures in parentheses). The sample is over representative of plants that are part of a multi-unit firm. Again, this over representation is not as bad when one looks at the employment weighted distribution. The sample matches total manufacturing reasonably well by two-digit industry. Industries that are not well represented are presumably either those with very large plants (and hence are over represented, like industry 26) or very small plants (and hence are under represented), or ones in which births and deaths are concentrated. One can see this in the distribution by shutdown

[26] See Davis, Haltiwanger, and Schuh (1996).

technology where continuous processors, which tend to be large plants, are over represented (again, not so badly when looking at the employment weighted distribution). The sample tracks the total relatively well for regions. Finally, the mean factor intensities and skill measures are relatively similar over the two groups of plants. In short, it is important to keep in mind that the sample over-represents large, older, multi-unit plants in capturing the experience of manufacturing plants, but that it is better at representing the experience of manufacturing employees.

Aggregation issues arise in terms of the unit of decision making, worker heterogeneity, and the frequency of observations. Assuming that the unit of decision making is the plant, this sample will avoid spatial aggregation issues. Avoiding spatial aggregation is important if there is a possibility that adjustment costs vary across producers and/or include a fixed component. Since data on production and nonproduction workers are available, this analysis can also avoid problems with aggregation over worker-types (broadly defined). Unfortunately, temporal aggregation issues are not as easily dismissed. Data on both nonproduction and production workers are available only annually as are the forcing variables. As Hamermesh and Pfann (1996) point out there is no consensus on the frequency of decision-making. If, as seems likely, the interval of decision making is more frequent, this analysis will suffer from a temporal aggregation bias. The temporal aggregation problem is slightly different in this case as the employment series are not averages over four quarters, but instead are employment in the pay period including the twelfth of March.

Turning to the forcing variables (real wages and real output), wages are measured using total manufacturing wages by worker-type from the Current Population Survey (CPS). [27] This assumes a market for workers that is national but confined to manufacturing. For output price it is assumed that the 4-digit industry adequately defines a product and thus the product price is measured by the 4-digit industry deflator. Output is measured as the total value of shipments deflated by the 4-digit industry-level shipments deflator. All of these forcing variables are year averages. Because employment is measured at the start of the year (March 12), to mitigate the timing differences, all forcing variables are lagged a year. In addition, many estimations include a trend term as a forcing variable partially in order to capture the effects of the omitted input capital.[28]

As noted earlier, establishment characteristics that can affect the adjustment costs of an establishment include technology, general worker skill level, ownership type, and location. The capital intensity of an establishment is measured as the ratio of its real capital stock (derived using the perpetual inventory method) to its total employment. Establishments are divided into five classes in each year depending on their position in the distribution of capital intensity (thus an establishment can change classes over time). The energy intensity of the establishment is measured as the ratio of energy costs to

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[27] In addition to plant-level employment by worker-type, the LRD also includes payments to these workers and some information on hours. Thus it is possible to create plant-level wage rates for production and nonproduction workers. However, the plant-level cross-sectional differences in wages are not indicative of the labor market conditions that an establishment faces, instead they measure differences in skill mix at the establishments. See Davis and Haltiwanger (1991) and Doms, Dunne, and Troske (1997) which find that between plant differences in wages largely reflect differences in the skill mix.

[28] Sargent (1978) provides the following justifications for detrending the data: "[T]he model ignores the effects of capital on employment, except to the extent that these can be captured by the productivity processes [a's]." "[And] the theory predicts that any deterministic components of the employment and real-wage processes will not be related by the same distributed lag models as are their indeterministic parts. Detrending prior to estimation is a device designed to isolate the indeterministic components (p.1027)."

total value of shipments, and like capital intensity, is divided into five classes. For establishment shutdown and startup costs, establishments are divided into three groups using the 4-digit industry classifications from Mattey and Strongin (1994). Unfortunately, there is no measure of shifts; instead this is proxied by measures of an establishment's two-digit industry classification (there are 20 industries at this level). The industry classification also picks up more general technology differences. There are two measures of general skill level at an establishment used in this analysis: the ratio of production worker employment to total employment and share of labor costs in total costs (both divided into five classes).[29] Greater production worker intensity and smaller labor cost shares are indicative of a lower general skill level. Plant size and firm size are measured as long-run average total employment. Plants are divided into three age groups (young, medium, and old) based on their age at the start of the sample. Since the sample is of continuously operating plants all of the plants are aging over the sample. Location is based on the Census Region. Finally, ownership measures whether a plant is part of a multi-unit firm or is a single plant firm.

B. Specification Issues

As noted above, theoretical considerations indicate using a fixed effects specification for estimating the model. Unfortunately, estimates for a dynamic model with a lagged dependent variable

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[29] See Dunne, Haltiwanger, and Troske (1997) for a discussion of other papers, such as Berman, Bound, and Griliches (1994), that have used nonproduction worker intensity as a measure of skill. Dunne, Haltiwanger, and Troske (1997) note that it is well established that nonproduction workers are generally more educated than production workers as a group. However, they warn that since the nonproduction worker category includes a disparate groups of workers (e.g., engineers and cafeteria workers) one should be cautious in interpreting this ratio as a measure of workforce skill.

are biased for small T and N64 when using the least squares dummy variable (LSDV) estimator. Nickell (1981) calculates the bias for the LSDV estimator and shows that it biases the estimates on the lagged dependent variable towards zero when the coefficient on the lagged dependent variable is positive. In his Monte Carlo simulations, Nerlove (1971) finds that the bias is downwards for LSDV but upwards for OLS estimates as does Kiviet (1995) in his Monte Carlo simulations. Furthermore, Nickell (1981) predicts, and Judson and Owen confirm in their Monte Carlo estimates, that the bias rises with the size of the true coefficient on the lagged dependent variable.[30] Since the bias goes to zero as T64, the first question is whether the bias is significant for T=17 (due to data availability, this analysis is for 1975-1991). Using Monte Carlo simulations, Judson and Owen (1996) conclude that "the bias of the LSDV estimator of [8] is not insignificant, even at T=20 (p.8)." The standard approach to this problem is to use first-differences and instrument the lagged dependent variable either with its twice-lagged level or change (Anderson and Hsiao (1982)). Other studies have found that, of these two, the twice-lagged level is a superior instrument.[31] For my sample this was also true; the estimates using the level as the instrument are slightly superior. In either case, these regressions perform very poorly even with additional instruments. As Judson and Owen (1996) find in estimating a savings equation "the [Anderson-Hsiao] method seems to apply a cure that is worse than the disease... (p.16)."

Kiviet (1995) describes two methods which allow one to avoid estimating in first-differences. Both of these methods estimate in levels but instrument the variables using either the variables' first-differences or their de-meaned counterparts (except for the lagged dependent variable which uses its

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[30] See also Beggs and Nerlove (1988).

[31] See Judson and Owen (1996) for a discussion.

first-difference).[32] In his Monte Carlo exercises, Kiviet finds that the de-meaned version has "remarkable capabilities.... It is virtually unbiased, and its efficiency is favourable especially for the higher [λ] value (p.70)." The de-meaned version slightly dominates the differenced version when estimating the sample at hand, so that version is presented here. The IVAX estimation equation is:

$$\textbf{(10)}\qquad \begin{gathered} n_t = \beta_0 + \beta_1 n_{t-1} + \beta_2 w_t + \beta_3 t + \varepsilon_t \\ Instruments: \;\; 1,\; n_{t-1} - n_{t-2},\; w_t - \bar{w},\; t \end{gathered}$$

Where a bar denotes the mean of the variable. Nevertheless it is useful to keep in mind Kiviet's warning about estimation techniques:

> "As yet, no technique is available [for estimating dynamic panel data models] that has shown uniform superiority in finite samples over a wide range of relevant situations as far as the true parameter values and the further data generating mechanism, are concerned. Perhaps such a technique is just impossible (p. 72)."

The last important specification issue is deciding how to incorporate establishment characteristics into the estimations. Since the establishment characteristics influence the parameters d and z which in turn affect λ, they affect the slope parameters of all the forcing variables. Due to data constraints it is not possible to run a fully interacted model with all of the establishment characteristics as dummies. Instead, a regression is run for each establishment characteristic with dummies for the

[32] When applying this technique to the list of forcing variables under consideration, the constant and year terms serve as their own instruments.

different values interacted with each of the forcing variables. Although the preferred estimator is Kiviet's method, these regressions by plant-characteristic are run using both the least-squares dummy method (LSDV) and the Kiviet instrumental method (IVAX) as both methods incur some costs. The LSDV estimates are still subject to the same small sample bias problem, but the bias is such that comparisons of estimates for different values of a characteristic in a given regression are still meaningful. As noted above, the downward bias in the LSDV estimates is larger (in absolute value) for higher true values of the parameter. This suggests that, all other things equal, the differences in adjustment speed estimates will be compressed when using the LSDV estimator. For this LSDV method, the de-meaning process is such that the balanced nature of the panel is maintained. Thus the observable establishment characteristics enter through the slope coefficients and the unobservable establishment characteristics enter through the intercept term. The IVAX estimates are, as with any instrumental estimations, only as good as the instruments. For the IVAX method, the dummies for the establishment characteristic are interacted with all of the forcing variables and the instruments are the establishment characteristic dummies interacted with the demeaned (or differenced) variables. So for example, the estimation equation for the establishment characteristic ownership-type (which has two classes) is:

(11)
$$\begin{gathered} n_t = \alpha_0 + \alpha_1 n_{t-1} + \alpha_2 w_t + \alpha_3 t + \alpha_4 D_2 * n_{t-1} + \alpha_5 D_2 * w_t + \alpha_6 D_2 * t + \epsilon_t \\ \textit{Instruments}: \ 1,\ n_{t-1} - n_{t-2},\ w_t - \bar{w},\ t,\ \ D_2 * (n_{t-1} - n_{t-2}),\ D_2 * (w_t - \bar{w}),\ D_2 * t \end{gathered}$$

Where D_i denotes the establishment characteristic dummy for class i (i.e, in this case for single-unit firms as multi-unit firms are the omitted class).

Finally, although the model solves to an estimation equation in level terms, following standard practice, the estimations of the partial adjustment model are in logs.[33]

4. Results

This section presents the results of partial adjustment estimates for a variety of models starting with the simplest possible case (univariate, homogeneous workers, pooled) and working up to the more complex cases (multivariate, semi-interrelation, by establishment characteristic). As a check on the estimation technique, the first exercise compares the results for the simplest versions of the univariate and multivariate models using three estimation methodologies. Table 2 shows the results for ordinary least squares (OLS), standard fixed effects (LSDV), and Kiviet's instrumental variable (IVAX) estimations. Comparing regressions for OLS and LSDV estimates shows the expected relationship: the OLS estimates of the stickiness of adjustment parameter (8, the coefficient on lagged employment) exceed the LSDV estimates. On the other hand, the LSDV estimates of the stickiness of adjustment parameter are consistently higher than the estimates from the IVAX estimator. Given that Kiviet's Monte Carlo simulations show that IVAX estimator has a small negative bias and that the LSDV estimator has a larger negative bias this is a surprising result.[34] For both LSDV and IVAX estimates the wage and output coefficients have their expected signs. The OLS estimates, on the other hand, have positive own-wage coefficients. Finally, for all three estimation techniques, the demand-constrained versions give lower estimates of 8 relative to the price-taker versions.

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[33] See Nickell (1984), Abraham and Houseman (1992), and Bresson et al. (1992a).

[34] Kiviet (1995) runs Monte Carlo simulations on 14 different parameter combinations intended to capture different underlying aspects of the data. In the 6 combinations that are relevant for comparing IVAX and LSDV, the IVAX bias is (absolutely) smaller than that of LSDV.

Given that the estimates are based on annual data, one should be especially cautious about interpreting these in terms of the actual length of time that the adjustments take. That is, this paper focuses more on differences in the relative speeds of adjustment implied by differences in coefficients across worker and establishment characteristics than on absolute speeds of adjustment. Keeping this caveat in mind, it is nevertheless useful to have a sense of what the coefficients imply about the length of adjustment periods. Given that the adjustment process is asymptotic it makes sense to choose some measure of adjustment length that has a cutoff point. One such measure is the median lag length. The median length of the lag is "the time it takes for the system to move halfway to the eventual equilibria in response to a shock (Hamermesh (1993), p. 248)."[35] The following pairs of 8 and t* give a sense of the time periods implied by the estimations in this paper: (.25, 6 months), (.50, 1 year), (.62, 1 ½ years), (.71, 2 years), (.87, 5 years), and (.93, 10 years). Turning back to table 2, one sees that generalizing over the different specifications and assumptions, the OLS estimates imply a median lag length of over 10 years, the LSDV estimates imply median lag lengths of about 1 to 1 ½ years, and the IVAX estimates imply median lag lengths of about a year.

Starting with the univariate version of the partial adjustment model, the model is estimated under the two assumptions concerning worker-type adjustments (homogeneous vs. heterogeneous). The estimating equations are equations (6) and (7) and the results appear in table 3. All versions of the model have the expected signs on own wages and output. Again, the estimates of 8 for the price-taker version of the model are higher than for the demand-constrained version. Recall that the coefficient on

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[35] Hamermesh (1993) notes that this median lag length (t*) is obtained via $8^{t^*}=0.5$.

the lagged dependent variable for the univariate, heterogeneous model represents the sum of the adjustment coefficients for the two worker types. The implied adjustment parameters from this model are significantly lower than the estimates that are obtained in the multivariate, heterogeneous model.

Moving from the univariate version of the model to the multivariate version, the partial adjustment model is estimated under assumptions of varying degrees of interrelation. Recall that the estimating equations are equation (8) for no interrelation and equation (9) for semi-interrelation. The results are presented in table 4. The estimates of the stickiness of adjustment coefficient (8) are stable over the different degrees of interrelation. As before, the price-taker estimates are higher than those for the demand-constrained version. The adjustment speeds in these estimates are consistent with existing literature using annual data,[36] but as Hamermesh (1993) notes there are reasons to believe that the annual data overstates the slowness of adjustment. Confirming theoretical arguments concerning the relative size of adjustment costs for the two groups of workers, the adjustment parameter is higher for nonproduction workers (i.e., adjustments are slower) than it is for production workers for all specifications. These results are consistent with the existing empirical estimates of the partial adjustment model for these two groups.[37] Focusing on the price-taker specification, as noted above, the estimates of the adjustment coefficient are higher than are implied by the univariate, heterogeneous model. The wage (own and cross) and output series have their expected signs across all specifications.

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[36] See table 7.1 in Hamermesh (1993) for a summary of results from papers using annual data.

[37] See for example, Palm and Pfann (1990), Abraham and Houseman (1989), and Hamermesh (1993) who summarizes results from estimates on adjustment speed by skill of workers in table 7.7.

A. By Establishment Characteristics

The estimations by establishment characteristics were run for the univariate model (under homogeneous and heterogenous worker assumptions) and the interrelated multivariate model (under semi-interrelation). Establishment characteristics can affect employment adjustments either through the speed of adjustment or through the structure of the adjustment costs (i.e., some characteristics may be such that the fixed component of the adjustment costs dominates), but under the assumption of quadratic adjustment costs, only the former effect is captured. Therefore, these estimated coefficients may only reveal part of the effects of establishment characteristics. As described earlier, there are separate regressions for each establishment characteristic. Since the number of estimations is large, only the estimates on the coefficient of interest (8, the adjustment coefficient) are presented but the equations all have the same structure as those described above. In addition, because of the large number of model versions, only the semi-interrelated, price-taker case (estimation equation (9)) is presented. The results for the semi-interrelated, demand-constrained case are qualitatively very similar (but as usual, each 8 estimate is higher for the price-taker version). The results using LSDV appear in table 5 and those for IVAX in table 6. Although the model is estimated by worker-types, the establishment characteristic production-worker intensity is still relevant as it measures a slightly different effect (the overall skill-level at the establishment).

As discussed in Section 3, in principle the IVAX estimates are preferred but are subject to the limitations of the instruments.[38] Even though the LSDV results are subject to small sample biases on the

[38] The first-stage R^2 for the lagged dependent variable for the total sample for production workers is .02, for nonproduction workers it is .01. For the regressions by establishment characteristics there are 71 establishment characteristics classes considered here. The first-stage R^2 for the lagged dependent

time dimension, they are not dependent on the limitations of the instruments. Moreover, the LSDV results reported in Table 2 for total manufacturing are quite reasonable and similar to those generated by IVAX. Thus, the discussion of the results by establishment characteristics relies on both the IVAX and LSDV estimates. Fortunately, the results using the alternative estimations by establishment characteristics are qualitatively very similar over the estimation techniques. Over all the establishment characteristics, the IVAX estimations tend to be less significant than the LSDV estimations.[39] Before proceeding to the individual results, the F-tests indicate that the restricted model is rejected when estimating using LSDV or IVAX for each establishment characteristic.[40] Since the estimates differ significantly by establishment characteristics a change in the distribution of establishments across any one of these characteristics will have implications for the overall aggregate speed of adjustment.

The first panel in tables 5 and 6 shows the results for establishment age. For each panel, the first row reports the coefficient on the omitted characteristic and subsequent rows report the coefficients on the dummy class associated with that characteristic (i.e., they are relative to the first row in the panel). Starting with differences over age groups, recall that older establishments were likely to face higher adjustment costs associated with the greater maximum plant-specific tenure of their employees but

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variable for the omitted dummy class ranges from .02 for ownership for both worker types to .62 for nonproduction workers and .78 for production workers for plant size. Within this range, most of the R^2 for the lagged dependent variable for the omitted dummy class are less than .10.

[39] The exceptions are in the factor intensity and skill variables which show differences but not with a systematic pattern. In one case, the IVAX estimate appears to be inferior to the LSDV estimate; for the establishment characteristic production worker intensity, the nonproduction employment equation has coefficients on all of the variables (including the wage elasticities) that are unreasonable.

[40] There is one exception: the IVAX estimates of production workers by ownership type.

lower adjustment costs to the extent that the maximum vintage of the technology is older, more production-worker intensive. For both worker-types, the LSDV estimates indicate that older establishments are slower to adjust than younger establishments. This difference exists in spite of the fact that all of the establishments are aging over the sample. In order to get an idea about the importance of aging over the sample, the sample was divided into two equal time periods and the adjustment coefficients estimated. In splitting the time dimension in half, the problem of the bias on the estimator has increased. Keeping this caveat in mind, the adjustment coefficient implies faster speeds of adjustment in the earlier time period for both versions of the model. The IVAX estimates of the adjustment coefficient do not show the same clear pattern over the age characteristic.

The differences in the estimated adjustment coefficient for values of an establishment characteristic are most pronounced for the characteristics measuring size. The stickiness of adjustment generally rises as plant size increases for both worker types over both estimation techniques. However, the relationship is more pronounced and monotonic for the LSDV estimates. For the LSDV estimates, the adjustment coefficient for production workers rises from 0.46 for plants with less than 20 workers to 0.71 for plants with more than 5000 workers, for nonproduction workers it rises from 0.49 to 0.83. For IVAX estimates the adjustment coefficient for production workers rises from 0.41 for plants with less than 20 workers to 0.59 for plants with more than 5000 workers, for nonproduction workers it rises from 0.32 to 0.87. Taken at their face value, these estimates suggest enormously different adjustment speeds for the smallest plants and the largest plants.

For both worker types and estimation techniques the differences for firm size are more concentrated at the largest sizes (this is especially true for the IVAX estimates). The adjustment coefficient estimate from LSDV rises from 0.58 to 0.70 for the smallest firm size class to the largest for production workers and from 0.63 to 0.79 for nonproduction workers. Similarly, for the IVAX estimates the adjustment coefficient for production workers increases from 0.41 to 0.77 and for nonproduction workers from 0.54 to 0.81. Recall that plants associated with smaller firms (which tend to be smaller plants) were likely to face smaller adjustment costs associated with regulations or due to having a more flexible technology but greater adjustment costs associated with financing constraints. Due to a feature in the ASM sampling algorithm, small plants which are part of a large firm have a greater probability of being selected than small plants which are part of a small firm. This suggests that the small plants in this sample are less likely than other small plants to face constraints on their access to internal and external funds and thus most of the effects measured above might have less to do with financial constraints.

The ownership type of the establishment does not appear to significantly impact the stickiness of employment adjustment. For both the LSDV and IVAX estimates the adjustment coefficients is either not significantly different or has a small difference over establishments that are part of a single or multi-unit firm. In the actual population where single-unit firms include many more small plants than in this sample, there might be more variation in the estimates of the speed of adjustment for the ownership types.

Turning to the estimates by industry, the most striking finding is the large differences in the adjustment coefficient over industries and worker type. The LSDV adjustment coefficients range from 0.41 for production workers in petroleum to 0.75 for nonproduction workers in machinery and for IVAX from 0.16 for production workers in petroleum to 0.78 for nonproduction workers in tobacco.

The estimates by industries across the two estimation types are qualitatively similar, however, the IVAX results are less significant. The slow speeds of adjustment for the machinery industries (SIC35 and SIC36) for both types of workers and both estimation types are unexpected given that these are assembly-type establishments. It may be that the two-digit industry level is not suitable for addressing this question. The prevalence of shift-work in an industry does not seem to cause differences in the adjustment speeds at this level of industry aggregation as these industries do not have noticeably faster speeds of adjustment. Although there are a few industries in which the speed of adjustment is the same for the two worker-types there are very few industries in which the speed of adjustment is slower for production workers than it is for nonproduction workers (and if one concentrates on the more significant LSDV results, there are not any). While in many cases the relative speeds of adjustment are similar for the two workers, there are some industries in which these are very different. For example for the LSDV estimates (and less so for the IVAX results), the petroleum industry (SIC29) is one of the slowest to adjust for nonproduction workers, yet is one of the faster to adjust for production workers. This large difference is consistent with the high-capital intensity of these establishments which through a skill complementarity may make nonproduction employment adjustments relatively more expensive. Overall, the industry effects are relatively more important for production workers than nonproduction workers, especially for the LSDV estimations.

Using the establishments' four-digit classification to group them by their shutdown technologies yields an interesting difference between the two estimation techniques. Recall that one would expect the continuous operating establishments to have stickier adjustment than variable establishments. For the LSDV estimates, the continuous operating establishments are slightly (and not significantly) slower at adjusting than the variable operating establishments. However for the IVAX estimates, the continuously operating establishments have much faster speeds of adjustment than the variable operating establishments.

The location characteristic shows large differences in adjustment speeds across regions and across worker-types by regions. These differences partially reflect concentration of industries in the regions. The production worker adjustment speeds are much more variable over regions than are the nonproduction worker speeds. The estimation techniques yield very similar results for production workers, but the IVAX results are less significant than the LSDV results for nonproduction workers and show a different pattern of adjustment stickiness by region. The adjustment coefficient for LSDV estimation varies between 0.52 (East South Central) and 0.73 (New England) for production workers and between 0.65 (East South Central and West South Central) and 0.73 (Middle Atlantic and East North Central) for nonproduction workers.

The differences in adjustment speeds are not as stark over the other input intensities (capital and energy). For capital intensity and nonproduction workers, depending on the estimation technique there is either virtually no difference in adjustment speeds (LSDV) or the most capital-intense classes have the smallest adjustment coefficient (IVAX). This result is surprising given the fixity of capital and the capital-skill complementarity argument. Similarly for either estimation technique, for production workers, the establishments with the highest capital intensities are the fastest to adjust. Differences in energy intensity (weakly) affect the speed of adjustment for both worker types. Both worker types generally have faster speeds of adjustment for higher energy intensities over both estimation methods. The energy results, with the exception of the LSDV estimates for nonproduction workers, mimic the capital intensity results. This is not too surprising given that one would expect a high degree of correlation between energy and capital intensities.

In looking at the first of the two measures of skill, it is apparent that the IVAX estimation encounters some problems in regards to nonproduction workers. The wage elasticities (which are not shown) are greater than one and the omitted dummy class is negative for these workers. Hence the following discussion focuses on the LSDV results. The first result to note is that the relationship between skill and employment adjustments over the two worker-types differs over the two measures of skill. For nonproduction workers, as expected the establishments with the lowest concentration of production workers have the slowest adjustments (0.74 versus 0.68 for the most production-worker intense). However, the relationship is reversed for production workers (0.60 versus 0.67 for the most production-worker intense). Note that these simple comparisons mask the essentially flat relationship over most of the categories. The other skill measure is the share of labor costs. Since higher labor costs shares are a crude indicator of higher skill, one would expect higher labor costs classes to be associated with larger adjustment coefficients. The relationship between skill and stickiness of adjustment is essentially flat for nonproduction workers (LSDV) or rising (IVAX). For production workers, contrary to the production-worker intensities, the adjustment speeds are slower for the greater skill levels (LSDV and IVAX). The discrepancies in the results across the skill measures for a particular estimation technique (LSDV) may reflect differences in the measures' ability to capture relevant information about skill-heterogeneity within the worker-types.[41] From the pooled, multivariate

[41] The labor cost measure is for total labor costs, and it may be more relevant to look at relative labor costs by worker-type.

model estimates it is clear that the two types of workers face different adjustment processes. The establishment characteristics regressions using crude skill measures also weakly suggest that overall skill level is associated with different adjustment processes.

5. Conclusions

This paper has attempted to shed some light on the *source* and *size* of employment adjustments costs by estimating the stickiness of adjustment by establishment and worker characteristics using an extension of the traditional partial adjustment model as the organizing framework. In addition to micro implicatins, the results suggest that the micro employment adjustment costs have implications for understanding aggregate employment dynamics. The following conclusions emerge from the related empirical exercises in this paper.

1. At the micro level, employment adjustments are very different for nonproduction and production workers.

Employment adjustments differ substantially over the two types of employees: nonproduction workers have slower adjustments than production workers over estimation techniques and any assumptions about market-type and interrelation of inputs. In addition, production worker employment adjustment speeds appear to be more varied than nonproduction worker employment adjustment speeds for a variety of establishment characteristics. Moreover, the employment adjustments for these two workers are very different for some establishment characteristics. For example, for workers in the petroleum industry (SIC29), the adjustment speeds are among the fastest over any industry for production workers yet among the slowest over any industry for nonproduction workers. To summarize, at the micro level, there is clear evidence that worker characteristics related to skill matter in the speed of adjustment.

2. There are differences in adjustment speeds related to assumptions concerning market structure and worker heterogeneity, but not to the degree of interrelation among inputs.

The estimates of the partial adjustment model show that the competing assumptions about price-taking versus demand-constrained establishments influence the size of the adjustment parameter. The price-taker estimates are consistently higher (slower adjustment) than the demand-constrained estimates. The estimates of employment adjustments for total employment are higher for both price-taker and demand constrained models when assuming that the two underlying worker types are heterogeneous rather than homogeneous. In addition, the implied estimates of the adjustment coefficient are lower when using the univariate version of the heterogeneous worker model than when using the multivariate version of the heterogeneous worker model. For both worker types and market structures, the estimates of the speed of adjustment are the same whether one assume no interrelation of inputs or interrelation through the forcing variables.

3. Confirming Kiviet's warning, there is no clearly superior technique for estimating dynamic panel data models.

Due to the heterogeneity of the establishment -level data, a fixed effects estimation technique is required. Since the standard fixed effects technique (LSDV) has a small sample bias, other estimation techniques are considered. A traditional solution is to use first-differenced data and to instrument the lagged dependent variable (with either the twice lagged level or difference). However these run into problems with a high noise to signal ratio. Applying either of these techniques to my sample provided very poor results. A more recent solution is Kiviet's instrumental variable technique which estimates in levels and instruments using either difference or de-meaned data. Of these two techniques the de-meaned instrumental variable version (IVAX) outperformed the differenced version. Although the estimates from this technique are found to be virtually unbiased in Monte Carlo simulations, as with any instrumental variable estimation, they are only as good as the estimates. Since there is a trade-off for both the LSDV and IVAX estimations, many of the specifications were run using both techniques. Fortunately, they generally yielded qualitatively similar results.

4. At the micro level, there are significant differences in employment adjustments over a wide variety of establishment characteristics.

Employment adjustment speeds differ over a variety of establishment characteristics associated with differences in adjustment costs. In all cases considered, permitting the parameters of the model to vary by establishment characteristics dominates the restricted model that requires the parameters to be the same across the establishment characteristics in question. The characteristics that show the greatest differences in adjustment speeds are plant and firm size, industry, and region. The other characteristics, age, ownership, shutdown technology, input intensities, and general skill level of the establishment show less variation in adjustment speeds. The estimates are consistent with the notion that adjustment costs are in general higher for older establishments. The estimates show substantially faster speeds of adjustment for smaller plants and for plants that are part of smaller firms. The results on firms suggest that factors that contribute to lower adjustment costs at small firms (such as the looser regulatory environment or more flexible technology) dominate factors that contribute to higher adjustment costs at small firms (such as greater financial constraints). Perhaps due to the nature of the sample, comparisons across the simpler question of whether the plant is part of a multi-unit firm are not as relevant. Industry differences in adjustment speeds are also among the most striking. Like many of the characteristics, the differences in adjustment speed over industry and regions are most pronounced for production workers. The effects of the quasi-fixed nature of capital on employment adjustments is not captured by the estimates; the relationship between capital intensity and employment adjustment speed is either weak (for nonproduction workers) or perverse (for production workers). So too, the energy intensity results are inconsistent with an adjustment cost interpretation. Finally, there are mixed results concerning the relationship between overall skill level at the establishment and the speed of adjustment. These mixed results on the measures of overall skills at the establishment should not be confused with the pervasive result emphasized above that nonproduction workers exhibit slower speeds of adjustment than production workers. It may be that the overall level of skill measures at the establishment used are too crude and that distinguishing between worker types is a more successful way to capture relevant worker characteristics in this environment.

5. The heterogeneity at the micro level suggests that compositional issues may be important in examining aggregate employment dynamics.

One of the ways in which microeconomic adjustment costs affect macroeconomic employment dynamics is through compositional effects: if employment adjustment costs differ by worker and or establishment characteristics then changes in the mix of workers and or establishments over these characteristics will affect the aggregate employment dynamics.[42] Moreover as Nickell (1986) points out, aggregation over different worker types and establishment types will introduce additional lags on the dependent variable in the partial adjustment model and change the structure of the coefficients on its desired employment term. That is, heterogeneity at the plant-level means that the simple partial adjustment model is misspecified when applied to aggregate data. This results presented in this paper suggest that compositional issues are important in any attempt to understand aggregate employment dynamics.

Taken together, these estimates show variations in employment adjustment speeds across worker and establishment characteristics that are mostly consistent with hypothesized *sources* and *size* differences in adjustment costs.

[42] The other way is via the structure of adjustment costs. Caballero and Engel (1993) demonstrate that in theory the presence of nonconvexities in adjustment costs will introduce complex sectoral and aggregate employment dynamics. Using establishment-level data, Caballero, Engel, and Haltiwanger (1997) find that the micro nonlinearities have a substantial aggregate impact.

REFERENCES

Abraham, Katherine G. and Susan Houseman. 1992. Employment Security and Labor Adjustment: A Comparison of West Germany and the United States. Working paper, University of Maryland.

Abraham, Katherine G. and Susan Houseman. 1989. "Job Security and Work Force Adjustment: How Different are U.S. and Japanese Practices?" *Journal of the Japanese and International Economies* 3: 500-21.

Adams, James D. and Adam B. Jaffe. 1994. "The Span of the Effect of R&D in the Firm and Industry." *Center for Economic Studies Discussion Papers* 94-7.

Anderson, T.W., and Cheng Hsiao. 1982. "Formulation and Estimation of Dynamic Models Using Panel Data." *Journal of Econometrics* 18: 47-82.

Bartelsman, Eric J. and Wayne Gray. 1996. "The NBER Manufacturing Productivity Database." *NBER Technical Working Paper Series* 205.

Beggs, John J. and Marc Nerlove. 1988. "Biases in Dynamic Models with Fixed Effects." *Economics Letters* 26: 29-31.

Bergstrom, Villy and Epaminodas Panas. 1992. "How Robust is the Capital-Skill Complementarity Hypothesis?" *Review of Economics and Statistics* 74: 540-6.

Berman, Eli, John Bound, and Zvi Griliches. 1994. "Changes in the Demand for Skilled Labor Within U.S. Manufacturing: Evidence from the Annual Survey of Manufacturers." *Quarterly Journal of Economics* 109: 367-97.

Bresson, G., F. Kramarz, and P. Sevestre. 1992a. "Heterogeneous Labor and the Dynamics of Aggregate Labor Demand: Some Estimations Using Panel Data." *Empirical Economics* 17: 153-168.

Bresson, G., F. Kramarz, and P. Sevestre. 1992b. "Dynamic Labour Demand Models," in *The Econometrics of Panel Data*, ed. Laszlo Matyas and Patrick Sevestre. Netherlands: Kluwer Academic Publishers.

Brown, Charles, James Hamilton, and James Medoff. 1990. *Employers Large and Small*. Cambridge MA: Harvard University Press.

Bry, Gerhard. 1959. "The Average Workweek as an Economic Indicator." *NBER Occasional Paper* 69.

Caballero, Ricardo J. and Eduardo M. R. A. Engel. 1993. "Microeconomic Adjustment Hazards and Aggregate Dynamics." *Quarterly Journal of Economics* 108: 313-58.

Caballero, Ricardo J., Eduardo M. R. A. Engel, and John Haltiwanger. 1997. "Aggregate Employment Dynamics: Building from Microeconomic Evidence." *American Economic Review* 87: 115-37.

Davis, Steven and John Haltiwanger. 1991. "Wage Dispersion Between and Within U.S. Manufacturing Plants, 1963-1986." *Brookings Papers on Economic Activity: Microeconomics*: 115-200.

Davis, Steven, John Haltiwanger, and Scott Schuh. 1996. *Job Creation and Destruction*. Cambridge: MIT Press.

Doms, Mark and Timothy Dunne. 1994. "Capital Adjustment Patterns in Manufacturing Plants." *Center for Economic Studies Discussion Papers* 94-11.

Doms, Mark, Timothy Dunne, and Kenneth Troske. 1997. "Workers, Wages, and Technology." *Quarterly Journal of Economics* 112: 253-290.

Dunne, Timothy, John Haltiwanger, and Kenneth Troske. 1997. Wage and Productivity Dispersion in U.S. Manufacturing: The Role of Computer Investment. Typescript, December.

Dunne, Timothy, Mark Roberts, and Larry Samuelson. 1989. "Plant Turnover and Gross Employment Flows in the U.S. Manufacturing Sector." *Journal of Labor Economics* 7: 48-71.

Epstein, Larry and Michael Denny. 1983. "The Multivariate Flexible Accelerator Model: Its Empirical Restrictions and an Application to U.S. Manufacturing." *Econometrica* 51: 647-73.

Foster, Lucia. 1999. "Employment Adjustment Costs and Establishment Characteristics." Typescript, April.

Freeman, Richard. 1977. "Manpower Requirements and Substitution Analysis of Labor Skills: A Synthesis." *Research in Labor Economics* 1: 151-83.

Griliches, Zvi. 1969. "Capital-Skill Complementarity." *Review of Economics and Statistics* 51: 465-8.

Hamermesh, Daniel S. 1993. *Labor Demand*. Princeton, N.J.: Princeton University Press.

_________ 1992a. "A General Model of Dynamic Labor Demand." *Review of Economics and Statistics* 74: 733-7.

_________ 1992b. "Spatial and Temporal Aggregation in the Dynamics of Labor Demand." *NBER Working Paper* 4055.

_________ 1990. "Aggregate Employment Dynamics and Lumpy Adjustment Costs." *Carnegie Rochester Conference Series on Public Policy* 33: 93-130.

_________ 1989. "Labor Demand and the Structure of Adjustment Costs." *American Economic Review* 79: 674-89.

Hamermesh, Daniel S. and Gerard A. Pfann. 1996. "Adjustment Costs in Factor Demand." *Journal of Economic Literature* 34: 1264-92 .

Hansen, Lars Peter and Thomas J. Sargent. 1980. "Formulating and Estimating Dynamic Linear Rational Expectations Models." *Journal of Economic Dynamics and Control* 2: 7-46.

Judson, Ruth A. and Ann L. Owen. 1996. "Estimating Dynamic Panel Data Models: A Practical

Guide for Macroeconomists." *Federal Reserve Board Finance and Economics Discussion Series*, January.

Kandel, Eugen and Neil D. Pearson. 1995. The Value of Labor Force Flexibility. Typescript, University of Rochester, June 27.

King, Sandra L. and Harry B. Williams. 1985. "Shift Work Pay Differentials and Practices in Manufacturing." *Monthly Labor Review* 108: 26-33.

Kiviet, Jan F. 1995. "On Bias, Inconsistency, and Efficiency of Various Estimators in Dynamic Panel Data Models." *Journal of Econometrics* 68: 53-78.

Layard, Richard and Stephen Nickell. 1986. "Unemployment in Britain." *Economica* 53: 121-69.

Lichtenberg , Frank R. 1988 "Estimation of the Internal Adjustment Costs Model Using Longitudinal Establishment Data." *Review of Economics and Statistics* 70: 421-30.

Lilien, David and Robert Hall. 1986. "Cyclical Fluctuations in the Labor Market" in *Handbook of Labor Economics*, ed. Orley Ashenfelter and Richard Layard. Amsterdam: North-Holland Press.

Lucas, Robert E. Jr. 1967. "Optimal Investment Policy and the Flexible Accelerator." *International Economic Review* 8: 78-85.

Mattey, Joe and Steve Strongin. 1994. Factor Utilization and Margins for Adjusting Output: Evidence from Manufacturing Plants. Typescript, November.

Mayshar, Joram and Gary Solon. 1993. "Shift Work and the Business Cycle." *American Economic Review* 83: 224-8.

Meese, Richard. 1980. "Dynamic Factor Demand Schedules for Labor and Capital under Rational Expectations." *Journal of Econometrics* 14: 141-58.

Mellor, Earl F. 1986. "Shift Work and Flexitime: How Prevalent are They?" *Monthly Labor Review* 109: 14-21.

Mortensen, Dale T. 1973. "Generalized Costs of Adjustment and Dynamic Factor Demand Theory." *Econometrica* 41: 657-65.

Nadiri, M. I. and Sherwin Rosen. 1973. *A Disequilibrium Model of Production*. New York: National Bureau of Economic Research.

Nerlove, Marc. 1971. "Further Evidence on the Estimation of Dynamic Economic Relations from a Time Series of Cross Sections." *Econometrica* 39: 359-82.

Nerlove, Marc and Pietro Balestra. 1992. "Formulation and Estimation of Econometric Models for Panel Data," in *The Econometrics of Panel Data*, ed. Laszlo Matyas and Patrick Sevestre. Netherlands: Kluwer Academic Publishers.

Nickell, S.J. 1986. "Dynamic Models of Labour Demand," in *Handbook of Labor Economics,* ed. Orley Ashenfelter and Richard Layard. Amsterdam: North-Holland Press.

Nickell, Stephen. 1984. "An Investigation of the Determinants of Manufacturing Employment in the United Kingdom." *Review of Economic Studies* 51: 529-57.

Nickell, Stephen. 1981. "Biases in Dynamic Models with Fixed Effects." *Econometrica* 49: 1417-26.

Oi, Walter Y. 1962. "Labor as a Quasi-Fixed Factor." *Journal of Political Economy* 70: 538-55.

Palm, Franz C. and Gerard A. Pfann. 1990. "Interrelated Demand Rational Expectations Models for Two Types of Labour." *Oxford Bulletin of Economics and Statistics* 52: 45-67.

Palm, Franz C. and Gerard A. Pfann. 1993. "Asymmetric Adjustment Costs in Non-linear Labour Demand Models for the Netherlands and U.K. Manufacturing Sectors." *Review of Economic Studies* 60: 397-412.

Pfann, Gerard and Bart Verspagen. 1989. "The Structure of Adjustment Costs for Labour in the Dutch Manufacturing Sector." *Economic Letters* 29: 365-71.

Rones, Philip R. 1981. "Response to Recession: Reduce Hours or Jobs?" *Monthly Labor Review* 104: 3-11.

Sargent, Thomas J. 1987. *Macroeconomic Theory* (2nd edition). London: Academic Press.

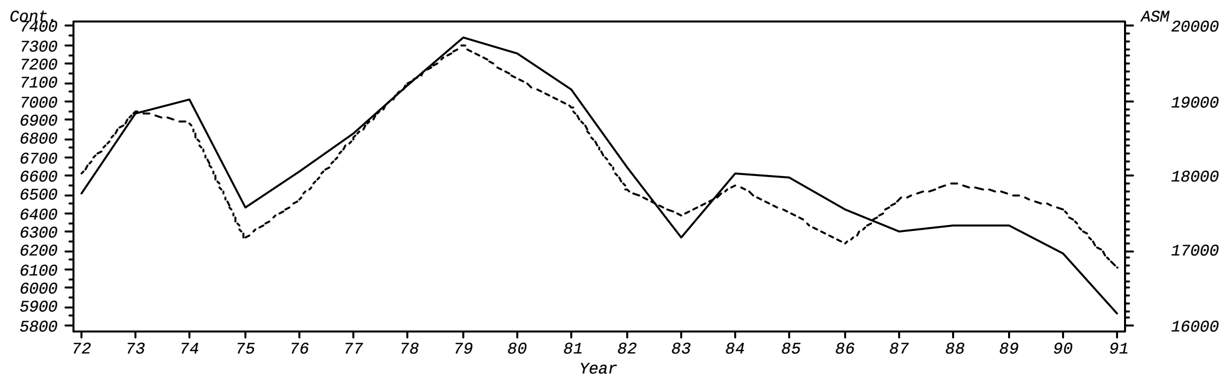
Sargent, Thomas J. 1978. "Estimation of Dynamic Labor Demand Schedules under Rational Expectations." *Journal of Political Economy* 86: 1009-43.

Sims, Christopher. 1974. "Output and Labor Input in Manufacturing." *Brookings Papers on Economic Activity* 3: 695-735.

Treadway, Arthur B. 1971. "The Rational Multivariate Flexible Accelerator." *Econometrica* 39: 845-55.

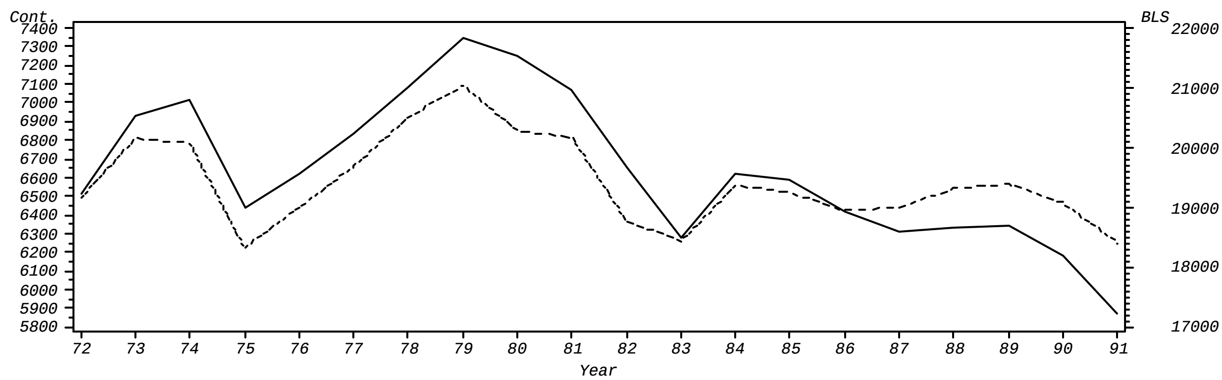
Figure 1: Sample vs. Total Manufacturing Employment

Total Manufacturing ASM Definition



SOLID line: sample continuers, DOTTED line: ASM.

Total Manufacturing BLS Definition



SOLID line: sample continuers, DOTTED line: BLS.

Table 1: Comparing the Sample to Total Manufacturing (1982)				
Characteristic	Total Manufacturing		Sample	
Summary Statistics				
Number of plants	348,385		10,916	
Total Employment	17,818		6,515	
Production Workers	12,401		4,356	
Total Value of Shipments	1,960,206		939,562	
Age Distribution (%)				
Youngest	NA		2.0	
Medium	NA		31.9	
Oldest	NA		66.1	
Plant Size Distribution (%)				
0-19	66.2	(7.7)	1.0	(0.0)
20-49	16.0	(9.6)	3.0	(0.2)
50-99	7.8	(10.5)	7.8	(1.0)
100-249	6.1	(18.2)	24.9	(7.0)
250-499	2.3	(15.1)	31.3	(18.2)
500-999	1.0	(13.0)	19.5	(21.8)
1000-2499	0.4	(11.8)	9.1	(22.2)
2500-4999	0.1	(6.5)	2.3	(13.0)
5000 or more	0.0	(7.8)	1.1	(16.6)
Firm Size Distribution (%)				
0-249	86.9	(30.7)	6.4	(1.6)
250-499	2.3	(6.5)	10.5	(5.5)
500-999	1.8	(6.0)	9.7	(7.2)
1000-2499	2.1	(8.1)	13.7	(11.5)
2500-4999	1.5	(6.5)	14.0	(11.4)
5000-9999	1.8	(8.2)	14.2	(12.6)
10000-24999	2.0	(13.3)	23.3	(24.3)
25000-49999	1.3	(10.1)	4.1	(9.7)
50000 or more	0.4	(10.5)	4.0	(16.3)
Ownership Distribution (%)				
Single unit	79.3	(26.5)	4.3	(2.4)
Multi-unit	20.7	(73.5)	95.7	(97.6)

Characteristic	Total Manufacturing		Sample	
Industry Distribution (%)				
Food (20)	6.4	(8.0)	14.1	(8.1)
Tobacco (21)	0.0	(0.3)	0.2	(0.4)
Textile Mill (22)	1.9	(4.0)	5.4	(5.0)
Apparel (23)	7.0	(6.6)	4.1	(2.9)
Lumber (24)	9.5	(3.1)	3.3	(1.1)
Furniture (25)	2.9	(2.4)	2.3	(1.9)
Paper (26)	1.8	(3.4)	7.7	(4.5)
Printing (27)	15.3	(7.1)	4.8	(5.3)
Chemicals (28)	3.4	(4.9)	8.8	(7.3)
Petroleum (29)	0.7	(0.8)	1.9	(1.3)
Rubber & Plastics (30)	3.9	(3.8)	4.3	(2.8)
Leather (31)	0.8	(1.1)	0.9	(0.7)
Stone, Clay, Glass (32)	4.7	(2.9)	3.6	(2.4)
Primary Metals (33)	2.0	(5.1)	5.9	(7.7)
Fabricated Metals (34)	10.2	(8.3)	8.0	(6.0)
Machinery ex. Elect (35)	15.2	(12.7)	8.5	(11.1)
Electrical Machinery (36)	4.7	(10.7)	8.0	(12.9)
Transportation (37)	2.7	(9.1)	4.4	(13.9)
Instruments (38)	2.3	(3.5)	2.5	(3.8)
Miscellaneous (39)	4.6	(2.1)	1.2	(1.0)
Shutdown Technology Distribution (%)				
Variable processors (1)	42.3	(47.3)	39.7	(47.3)
Continuous processors (2)	2.7	(8.7)	15.0	(15.5)
Other (3)	39.1	(35.8)	40.0	(33.3)
Not classified (4)	15.9	(8.1)	5.3	(3.9)
Region Distribution (%)				
New England (10)	7.5		6.0	
Middle Atlantic (20)	18.2		14.1	
East North Central (30)	18.7		24.5	
West North Central (40)	6.7		7.6	
South Atlantic (50)	13.6		17.9	
East South Central (60)	5.2		9.0	
West South Central (70)	8.9		8.5	
Mountain (80)	4.2		2.1	
Pacific (90)	17.0		10.3	

Characteristic	Total Manufacturing	Sample
Mean Factor Intensities		
Production worker	0.75	0.72
Production worker wages	0.70	0.65
Capital	NA	NA
Energy	0.02	0.04

1) Summary statistics are in thousands of units.
2) Distributions show the percent of plants within a category, and, in parentheses, the percent of total employment within a category.
3) Definitions vary slightly from those used elsewhere as only 1982 data are used in this table.

Table 2a: Different Estimation Procedures (Univariate, Homogeneous Case)

Version	n_{it}	n_{it-1}	w_{it}	q_t	t	R^2
A. OLS						
Price-Taker	total	.97 (.001)	.02 (.004)		-.39 (.012)	.95
Demand-Constrained	total	.95 (.001)	.03 (.004)	.02 (.001)	-.44 (.012)	.95
B. LSDV						
Price-Taker	total	.69 (.002)	-.01 (.005)		-.49 (.013)	.96
Demand-Constrained	total	.57 (.002)	-.13 (.005)	.17 (.002)	-.59 (.013)	.96
C. IVAX						
Price-Taker	total	.55 (.011)	-.02** (.012)		-.55 (.030)	.77
Demand-Constrained	total	.37 (.017)	-.22 (.015)	.28 (.010)	-.71 (.032)	.75

OLS and IVAX estimations include a constant.

All individual coefficient estimates are significant at the 1% level, <u>except</u> where * denotes significance at the 5% level and ** denotes insignificance at 5% level.

Table 2b: Different Estimation Procedures, Continued (Multivariate, No Interrelation Case)

Version	n_{it}	n_{it-1}	w_{it}	q_t	t	R^2
A. OLS						
Price-Taker	non-production	.97 (.001)	.03 (.005)		-.35 (.016)	.94
	production	.96 (.001)	.01* (.005)		-.40 (.014)	.93
Demand-Constrained	non-production	.95 (.001)	.04 (.005)	.04 (.001)	-.42 (.016)	.94
	production	.94 (.001)	.02 (.005)	.03 (.001)	-.46 (.014)	.93
B. LSDV						
Price-Taker	non-production	.69 (.002)	-.03 (.007)		-.30 (.017)	.95
	production	.62 (.002)	-.02 (.006)		-.61 (.014)	.94
Demand-Constrained	non-production	.63 (.002)	-.13 (.007)	.14 (.002)	-.34 (.017)	.95
	production	.51 (.002)	-.16 (.006)	.20 (.002)	-.82 (.014)	.95
C. IVAX						
Price-Taker	non-production	.60 (.009)	- .04 (.013)		-.30 (.033)	.80
	production	.47 (.010)	-.02** (.014)		-.72 (.032)	.68
Demand-Constrained	non-production	.56 (.009)	-.15 (.013)	.18 (.006)	-.34 (.030)	.84
	production	.33 (.013)	-.23 (.015)	.30 (.009)	-1.00 (.034)	.70

OLS and IVAX estimations include a constant.

All individual coefficient estimates are significant at the 1% level, <u>except</u> where * denotes significance at the 5% level and ** denotes insignificance at 5% level.

Table 3: Univariate Model with Different Assumptions about Worker-Types

Version	n_{t-1}	n_{t-2}	w_t	w_{t-1}	q_t	q_{t-1}	t	R^2
A: Homogeneous Workers								
Price-Taker	.57 (.011)		-.03* (.013)				-.60 (.033)	.79
Demand-Constrained	.43 (.016)		-.19 (.014)		.24 (.010)		-.70 (.033)	.79
B: Heterogeneous Workers								
Price-Taker	.68 (.006)	.10 (.005)	-.14 (.016)	.14 (.015)			-.51 (.021)	.91
Demand-Constrained	.59 (.010)	.13 (.008)	-.19 (.016)	.15 (.016)	.15 (.005)	-.09 (.007)	-.52 (.023)	.91

Estimated using IVAX method, all estimations include a constant. Standard errors in parentheses.

All individual coefficients are significant at the 1% level unless noted by * for significant at the 5% level.

Table 4: Multivariate Model under Different Degrees of Interrelation

Version	n_{it}	n_{it-1}	n_{jt-1}	w_{it}	w_{jt}	q_t	t	R^2
A: No Interrelation								
Price-Taker	non-production	.60 (.009)		-.04 (.013)			-.30 (.033)	.80
	production	.47 (.010)		-.02** (.014)			-.72 (.032)	.68
Demand-Constrained	non-production	.56 (.009)		-.15 (.013)		.18 (.006)	-.34 (.030)	.84
	production	.33 (.013)		-.23 (.015)		.30 (.009)	-1.00 (.034)	.70
B: Semi-Interrelation								
Price-Taker	non-production	.60 (.009)		-.17 (.061)	.14* (.062)		-.23 (.044)	.80
	production	.47 (.010)		-.43 (.066)	.41 (.065)		-.95 (.048)	.68
Demand-Constrained	non-production	.56 (.009)		-.17 (.055)	.02* (.055)	.18 (.006)	-.34 (.040)	.84
	production	.33 (.013)		-.56 (.064)	.33 (.064)	.30 (.009)	-1.19 (.047)	.70

Estimated using IVAX method, all estimations include a constant. Standard errors in parentheses.

All individual coefficients are significant at the 1% level unless noted by * for significant at the 5% level or ** for not significant at the 5% level.

Table 5: Estimates of 8 by Plant Characteristics, LSDV Estimation.
Price-taker, semi-interrelation.

Estimates of 8 are from coefficient on lagged employment. Standard errors in parentheses. For each panel, the first row reports the coefficient on the omitted characteristic. Subsequent rows report the coefficients on the dummy variable associated with that characteristic.

Plant Characteristic	Production Worker	Nonproduction Worker
Age		
Youngest (0-2)	.59 (.010) *	.63 (.009) *
Medium (3-14)	.02 (.010) *	.03 (.010) *
Oldest (15+)	.03 (.010) *	.07 (.010) *
Plant Size		
[0, 20)	.46 (.029) *	.49 (.028) *
[20, 50)	.14 (.032) *	.12 (.030) *
[50, 100)	.18 (.030) *	.12 (.029) *
[100, 250)	.11 (.029) *	.18 (.028) *
[250, 500)	.14 (.029) *	.18 (.028) *
[500, 1000)	.22 (.029) *	.23 (.028) *
[1000, 2500)	.23 (.029) *	.26 (.028) *
[2500, 5000)	.26 (.031) *	.30 (.030) *
[5000+)	.25 (.031) *	.34 (.031) *
Firm Size		
[0, 250)	.58 (.011) *	.63 (.011) *
[250, 500)	.05 (.013) *	.00 (.012)
[500, 1000)	.03 (.013) *	.01 (.012)
[1000, 2500)	.03 (.012) *	.04 (.012) *
[2500, 5000)	.03 (.012) *	.07 (.012) *
[5000, 10000)	.04 (.012) *	.03 (.012) *
[10000, 25000)	.03 (.011) *	.06 (.011) *
[25000, 50000)	.10 (.013) *	.11 (.013) *
[50000+)	.12 (.014) *	.16 (.014) *
Ownership		
Multi-Unit	.63 (.002) *	.69 (.002) *
Single Unit	.00 (.007)	-.02 (.006) *

Plant Characteristic	Production Worker	Nonproduction Worker
Industry		
Food (20)	.60 (.005) *	.67 (.004) *
Tobacco (21)	-.18 (.025) *	.07 (.036) *
Textile Mill (22)	-.02 (.010) *	-.02 (.009)
Apparel (23)	-.05 (.011) *	-.06 (.007) *
Lumber (24)	-.14 (.010) *	.01 (.011)
Furniture (25)	-.02 (.013)	-.00 (.012)
Paper (26)	-.08 (.011) *	.01 (.010)
Printing (27)	.11 (.013) *	.04 (.010) *
Chemicals (28)	.09 (.008) *	.02 (.008) *
Petroleum (29)	-.19 (.013) *	.05 (.012) *
Rubber & Plastics (30)	.06 (.010) *	-.01 (.009)
Leather (31)	-.07 (.019) *	-.07 (.019) *
Stone, Clay, Glass (32)	.07 (.012) *	.02 (.012)
Primary Metals (33)	.07 (.009) *	.07 (.009) *
Fabricated Metals (34)	.01 (.008)	-.00 (.008)
Machinery ex. Elect. (35)	.09 (.007) *	.08 (.007) *
Electrical Machinery (36)	.10 (.008) *	.06 (.007) *
Transportation (37)	.00 (.008)	.03 (.009) *
Instruments (38)	.07 (.011) *	.04 (.011) *
Miscellaneous (39)	.07 (.017) *	.02 (.016)
Shutdown Technology		
Variable	.62 (.003) *	.69 (.003) *
Continuous	.01 (.005)	.01 (.005)
Other	.01 (.004) *	-.02 (.003) *
Not Classified	.04 (.008) *	-.02 (.007) *
Region		
New England (1)	.73 (.008) *	.70 (.007) *
Middle Atlantic (2)	-.06 (.010) *	.03 (.009) *
East North Central (3)	-.10 (.009) *	.03 (.008) *
West North Central (4)	-.08 (.011) *	-.02 (.010) *
South Atlantic (5)	-.14 (.010) *	-.04 (.009) *
East South Central (6)	-.21 (.011) *	-.05 (.010) *
West South Central (7)	-.11 (.011) *	-.05 (.010) *
Mountain (8)	-.17 (.015) *	.01 (.015)
Pacific (9)	-.14 (.010) *	-.03 (.009) *

Plant Characteristic	Production Worker	Nonproduction Worker
Other Input Intensities:		
Capital Intensity		
Class 1 (lowest)	.67 (.003) *	.67 (.003) *
Class 2	-.00 (.003)	.02 (.003) *
Class 3	-.02 (.004) *	.01 (.003) *
Class 4	-.06 (.004) *	.01 (.003) *
Class 5 (highest)	-.10 (.004) *	.00 (.003)
Energy Intensity		
Class 1 (lowest)	.64 (.003) *	.69 (.003) *
Class 2	-.01 (.002) *	-.00 (.002)
Class 3	-.02 (.003) *	-.01 (.003) *
Class 4	-.03 (.003) *	-.02 (.003) *
Class 5 (highest)	-.04 (.004) *	-.02 (.003) *
General Skill Level:		
Prod. Worker Intensity		
Class 1 (lowest)	.59 (.002) *	.74 (.003) *
Class 2	.06 (.003) *	.00 (.003)
Class 3	.08 (.003) *	.01 (.003)
Class 4	.09 (.003) *	-.00 (.004)
Class 5 (highest)	.08 (.004) *	-.06 (.004) *
Labor Cost Share		
Class 1 (lowest)	.60 (.003) *	.68 (.003) *
Class 2	.01 (.003) *	.01 (.003) *
Class 3	.04 (.003) *	.01 (.003) *
Class 4	.04 (.004) *	.01 (.004)
Class 5 (highest)	.05 (.004) *	.02 (.004) *

* Individual coefficient estimate significant at the 5% level.
All regressions reject the restricted version of the model at the 1% level.

Table 6: Estimates of 8 by Plant Characteristics, IVAX Estimation.
Price-taker, semi-interrelation.

Estimates of 8 are from coefficient on lagged employment. Standard errors in parentheses. For each panel, the first row reports the coefficient on the omitted characteristic. Subsequent rows report the coefficients on the dummy variable associated with that characteristic.

Plant Characteristic	Production Worker	Nonproduction Worker
Age		
Youngest (0-2)	.49 (.051) *	.66 (.043) *
Medium (3-14)	.03 (.053)	-.07 (.045)
Oldest (15+)	-.04 (.052)	-.03 (.044)
Plant Size		
[0, 20)	.41 (.071) *	.32 (.074) *
[20, 50)	.15 (.080)	.19 (.083) *
[50, 100)	.14 (.074)	.22 (.078) *
[100, 250)	.04 (.072)	.27 (.076) *
[250, 500)	.07 (.071)	.28 (.075) *
[500, 1000)	.15 (.072) *	.37 (.076) *
[1000, 2500)	.13 (.073) *	.44 (.077) *
[2500, 5000)	.32 (.077) *	.50 (.081) *
[5000+)	.18 (.081) *	.56 (.081) *
Firm Size		
[0, 250)	.41 (.050) *	.54 (.044) *
[250, 500)	.08 (.062)	.05 (.051)
[500, 1000)	.07 (.060)	.01 (.051)
[1000, 2500)	.06 (.056)	.03 (.048)
[2500, 5000)	.05 (.056)	.09 (.050)
[5000, 10000)	.01 (.057)	.03 (.049)
[10000, 25000)	.00 (.054)	.11 (.047) *
[25000, 50000)	.14 (.066) *	.17 (.055) *
[50000+)	.36 (.065) *	.27 (.054) *
Ownership		
Multi-Unit	.46 (.011) *	.60 (.009) *
Single Unit	.03 (.048)	-.06 (.045)

Plant Characteristic	Production Worker		Nonproduction Worker	
Industry				
Food (20)	.46	(.023) *	.58	(.019) *
Tobacco (21)	.10	(.108)	.20	(.407)
Textile Mill (22)	-.03	(.049)	-.01	(.043)
Apparel (23)	-.11	(.048) *	.00	(.031)
Lumber (24)	-.17	(.041) *	.04	(.049)
Furniture (25)	-.02	(.062)	.09	(.056)
Paper (26)	-.11	(.049) *	.13	(.044) *
Printing (27)	.32	(.062) *	.02	(.057)
Chemicals (28)	.04	(.047)	-.13	(.039) *
Petroleum (29)	-.30	(.054) *	-.07	(.062)
Rubber & Plastics (30)	.23	(.058) *	-.01	(.052)
Leather (31)	-.10	(.074)	-.02	(.078)
Stone, Clay, Glass (32)	.12	(.064)	-.02	(.057)
Primary Metals (33)	-.07	(.055)	-.03	(.056)
Fabricated Metals (34)	.03	(.038)	-.07	(.041)
Machinery ex. Elect. (35)	.06	(.039)	.14	(.044) *
Electrical Machinery (36)	.27	(.041) *	.14	(.035) *
Transportation (37)	.08	(.040)	.06	(.046)
Instruments (38)	.13	(.069)	-.13	(.067)
Miscellaneous (39)	-.01	(.092)	-.08	(.102)
Shutdown Technology				
Variable	.49	(.015) *	.62	(.015)*
Continuous	-.21	(.035) *	-.14	(.037) *
Other	.01	(.023)	.00	(.020)
Not Classified	.08	(.047)	-.08	(.045)
Region				
New England (1)	.66	(.047) *	.59	(.034) *
Middle Atlantic (2)	-.17	(.056) *	.09	(.044)
East North Central (3)	-.18	(.052) *	.02	(.041)
West North Central (4)	-.14	(.061) *	.03	(.046)
South Atlantic (5)	-.19	(.053) *	-.00	(.039)
East South Central (6)	-.31	(.056) *	-.03	(.045)
West South Central (7)	-.20	(.058) *	-.02	(.043)
Mountain (8)	-.26	(.079) *	.17	(.062) *
Pacific (9)	-.22	(.053) *	.03	(.040)

Plant Characteristic	Production Worker		Nonproduction Worker	
Other Input Intensities:				
Capital Intensity				
Class 1 (lowest)	.52	(.041) *	.64	(.016) *
Class 2	.19	(.059) *	.00	(.029)
Class 3	-.09	(.069)	-.04	(.031)
Class 4	-.22	(.057) *	-.11	(.033) *
Class 5 (highest)	-.23	(.044) *	-.12	(.026) *
Energy Intensity				
Class 1 (lowest)	.52	(.020) *	.59	(.017) *
Class 2	.05	(.031)	.00	(.028)
Class 3	-.05	(.032)	-.04	(.029)
Class 4	-.11	(.030) *	.02	(.028)
Class 5 (highest)	-.11	(.031) *	-.01	(.030)
General Skill Level:				
Prod. Worker Intensity				
Class 1 (lowest)	.28	(.014) *	-.03	(.072)
Class 2	.30	(.044) *	.34	(.109) *
Class 3	.24	(.063) *	.31	(.125) *
Class 4	.12	(.092)	.30	(.136) *
Class 5 (highest)	-.12	(.084)	.48	(.078) *
Labor Cost Share				
Class 1 (lowest)	.44	(.018) *	.48	(.019) *
Class 2	.02	(.028)	.13	(.029) *
Class 3	.03	(.027)	.13	(.028) *
Class 4	.07	(.029) *	.11	(.030) *
Class 5 (highest)	.14	(.028) *	.19	(.026) *

* Individual coefficient estimate significant at the 5% level.
All regressions reject the restricted version of the model at the 1% level except production workers for ownership.

APPENDIX A: Data

Series Used in Basic Regressions

Employment

The total and production worker employment series in the LRD are manipulated to provide annual employment series based on observations of the pay period including March 12 for total, production, and nonproduction employment. A few plants which had zero employment for one of the two worker types were deleted from the regression analysis.

The employment series cover employees at the establishment who either worked or received pay for any part of the specified pay period (and thus includes workers on paid holiday, vacation, or sick leave). Production workers are employees up through the working foreman level who do the following types of tasks: processing, fabricating, assembling, inspecting, receiving, packing, maintenance, repair, watchman, and janitorial. Nonproduction workers include employees who do the following types of tasks: factory supervision above the working foreman level, sales, sales delivery, clerical, executive, financing, advertising, legal, and personnel (including cafeteria workers).

Output

Nominal output is measured as the total value of shipments. To get real output this series is deflated by the 4-digit industry-level shipments deflator from the NBER Productivity Database (see Bartelsman and Gray (1996) for a description).

Wages

Nominal wages are measured using total manufacturing CPS wages by worker-type. To get real wages, these are deflated by the 4-digit shipments price deflator from the NBER Productivity Database.

Plant Characteristics

Age

The age classes for the plants are youngest, medium, and oldest. Since the plants in the samples are continuously operating plants, the plants are assigned to these categories based on their age in 1972. Youngest plants are plants that are 0-2 years old, medium are plants that are 3-15 years old, and oldest plants are plants that are 16 years or older. The age is determined by using the birth year of the plant. This birth year is measured as the minimum of: a) the year in which the plant first appears in the LRD, b) the year that the plant gave as its birth year in the 1975 ASM special question, and c) the year that the plant gave as its birth year in the 1981 ASM special question.

Capital Intensity

The capital-labor ratio is the ratio of real equipment and structures capital stocks to total long-run average employment. Real capital stocks are generated by the perpetual inventory method using a measure of real investments. See Adams and Jaffe (1994) for a description of the data used in the perpetual inventory method. For the analyses capital intensity is divided into 5 classes based on the distribution of plants in these classes in each year. When capital intensity was zero), the intensity variable was set to missing. Plants can migrate across classes over time.

Energy Intensity

Energy intensity is the ratio of the cost of fuels and electricity to total value of shipments of the plant. For the analyses energy intensity is divided into 5 classes based on the distribution of plants in these classes in each year. When energy intensity fell outside the natural bounds of (0,1), the intensity variable was set to missing. Plants can migrate across classes over time.

General Skill Level

There are two measures of general skill used in the paper: production-worker intensity and labor cost share. The production-worker intensity is the share of production worker employment in total employment at the plant. Labor cost share is measured as the ratio of labor costs to total costs. Labor costs are measured as total wages and salaries, supplemental labor costs, and costs of contract work. Supplemental labor costs include legally required supplemental costs (costs for programs required by state and federal programs such as unemployment compensation) and voluntary supplemental labor costs (costs for programs either initiated by the employer or through collective bargaining). Total costs include labor, materials, and energy costs (but not capital costs). For the analyses both of these general skill variables are divided into 5 classes based on the distribution of plants in these classes in each year. When a skill variable fell outside the natural bounds of (0,1), the skill variable was set to missing. Plants can migrate across classes over time.

Industry

The plant's industry is the two-digit standard industrial classification (1972 SIC definition) in each year. That is, plants can change industry affiliation over time. The sample period covers the 1987 SIC redefinition. As a fix for this redefinition, plants are kept at their 1987 SIC72 classification for the remaining years. At the two-digit level, this assumption is not too severe; for my sample, 395 plants switched their two-digit industry classification over the period 1988-1991.

Ownership

Ownership is determined using the establishment identification number. There are two-types of ownership considered in this paper: establishments that are single-unit firms (the firm conducts business at only one plant site) and establishments that are part of a multi-unit firm (the firm conducts business at many sites). Note that plants are that are part of a multi-unit firm may produce different products (as opposed to the Census definition of a company).

Region

Regions are the Census classification of regions. The regions and their states are:

1) New England	CT, ME, MA, NH, RI, VT
2) Middle Atlantic	NJ, NY, PA

3) East North Central IL, IN, MI, OH, WI
4) West North Central IA, KS, MN, MO, NE ,ND, SD
5) South Atlantic DC, DE, FL, GA, MD, NC, SC, VA, WV
6) East South Central AL, KY, MS, TN
7) West South Central AR, LA ,OK, TX
8) Mountain AZ, CO, ID, MT, NM, UT, WY
9) Pacific AK, CA, HI, NV, OR, WA

Shutdown Technology

Plants are divided into three groups (continuous processing, assembly-type, and other) using Mattey and Strongin's (1994) classification of four-digit industries (1972 SIC definition). Because there are some plants that are in industries that are not classified by Mattey and Strongin, there is a fourth category called not classified. As with the two-digit classifications, plants are kept at their 1987 SIC72 classification for 1988-1991. See their appendix for the exact breakdown of industries.

Size

Plant size is the geometric average of the number of total employees over the period 1963-1993. Firm size is the geometric average of the number of total employees in Census years over the period 1963-1992. By definition these size measures fix a plant in one class over the entire period. For the analyses plant and firm sizes are divided into 9 classes. Because most of the plants in the sample are part of multi-unit firms, firm sizes are expected to be significantly greater than plant sizes. The size classes chosen for plants and firms reflect this difference (firm size classes show more detail for large classes, less detail for small classes).