WORKER ATTITUDES AND THE COST OF PRODUCTION: HYPOTHESIS TESTS IN AN EQUILIBRIUM MODEL

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This paper extends the application of neoclassical production theory to include the effects of worker attitudes on productivity and cost of production, using data for the U.S. automobile industry. Behavioral indicators of worker attitudes are imbedded in a standard four-input translog cost function. The coefficients of the imbedded function are determined in estimation of the cost function simultaneously with its share equations. Hypotheses concerning the effects of worker attitudes on the cost function are tested, and the properties of the index of worker attitude that emerge from the estimation are examined.

I. INTRODUCTION

U.S. labor productivity growth, resulting in a tripling of real GNP from the end of World War II to 1973, began to slow down in the mid-1960s and continued to slow throughout the 1970s. By the decade of the 1980s, productivity growth as measured by the U.S. Department of Labor's Office of Productivity and Technology had fallen from the 3.5 percent annual levels of the previous two decades to less than 1 percent per year.

A number of authors have tried to link worker morale and attitudes to labor productivity. Katz, Kochan, and Gobielle [1984] seek to attribute declines in labor efficiency (as they measure it) and product quality to deterioration in labor morale as measured by the frequency of grievances, disciplinary actions, absenteeism, contract disputes, and by the general climate of worker-employer relations at the plant level. Weisskopf, Bowles, and Gordon [1984] attribute the slowdown to a decline in "effective" labor input per hour of purchased labor. They use a single equation macroeconomic model of aggregate production for the U.S.

This paper introduces an index of worker attitude constructed from various indicators, and estimates the effect of changes in this index on three measures of economic growth performance: labor productivity, multifactor productiv-

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Economic Inquiry
Vol. XXVIII, January 1990, 57-78

ity, and the costs of production. The study is based on the automobile industry in the United States. The model includes all purchased inputs, rather than the Katz, Kochan, and Gobielle [1984] and Weisskopf, Bowles, and Gordon [1984] approaches that studied labor productivity in isolation. Cost functions and input cost-share equations are estimated simultaneously. This procedure eliminates single-equation sensitivity to small changes in specification, and corrects for use of other inputs along with labor.

A major contribution of this paper is the simultaneous estimation of the index of worker attitude and its effects on production. The result is an index of worker attitude that is based on effective attitude measures as evidenced by slower productivity rather than a measure of worker attitudes taken from direct surveys of the workers. Such surveys may or may not measure an index of "effective" attitudes, because the attitudes measured may not lead to slower production.

Statistical results (see Norsworthy and Zabala [1985a; 1985b]) are very strong and consistent with the neoclassical theory of production, and the attitude indicators are similar to those discussed in Zabala [1983]. The fact that these models perform in a similar fashion at different levels of aggregation is persuasive evidence.

Major U.S. industries are performing better now than in recent times of economic recession, but many are operating at lower levels of production and with substantially smaller labor forces than in recent periods of prosperity. Competition from western Europe and Japan is extremely strong in both foreign and domestic markets. The results in this paper suggest strongly that U.S. industry could be made significantly more competitive by improved human resource management.

The following two hypotheses concerning attitudes on productivity and costs are tested: first, that worker attitudes have no effect on the cost of production; second, that the effects of worker attitude are factor neutral, having no effect on the relative efficiencies of capital, production-worker labor, nonproduction labor, and materials. Each of these hypotheses is tested in the context of two translog cost function models with alternate factor-share equations omitted.

Finally, the attitude indexes derived from the factor-neutral and factor-bias models are found to have similar properties and to be strongly correlated through time. There are also plausible correlations with labor productivity, total factor productivity, and the total unit cost of production. The success of the approach suggests a range of research opportunities based on behavioral data that are routinely collected in many producing establishments, particularly those that are unionized.

II. DATA AND MODEL SPECIFICATION

Output and cost data for the U.S. automotive industry[1] (taken from various surveys of the Bureau of Labor Statistics and the Bureau of the Census) are used to estimate the parameters of an index of worker attitude. Worker behavior data from proprietary sources include grievances, unresolved grievances, and unauthorized strikes. Industry-wide quit rates are developed from those published by the Bureau of Labor Statistics. (See appendix for data source discussions.)

The grievance data cover slightly more than half the labor force for the major U.S. automakers. Both open (unresolved) grievances and grievance rates per 100 employees are collected daily by plant personnel. These data are collected on a consistent basis and involve nearly identical grievance procedures and only minor variation in due process.

Unauthorized strike data are also from proprietary sources and represent nearly complete coverage of all companies. These data are collected regularly as well but are less reliable because of underreporting and classification errors. For example, a significant number of unauthorized strikes are reported as authorized strikes due to resolution of internal disputes between the locals and the United Auto Workers (UAW) prior to or shortly after a strike commences. These data are important, since they measure the breakdown of local collective bargaining and the intensity of shop-floor tensions. Behaviors measured by these data are likely to have a dampening effect on productivity and cost performance.

Quit data are collected annually in the Bureau of Labor Statistics *Employment and Earnings* survey; they provide complete and consistent industry coverage. Further discussion of attitude data can be found in Zabala [1983; 1986]. An equilibrium translog cost function is used, with constant returns to scale to describe the production process in the industry (see Binswanger [1974]), and with a homogeneous translog function to aggregate the indicators of worker attitude into a worker attitude index. Other functional forms might prove superior for application with plant-level data.

1. The cost of data are compiled in the appendix. Three of the worker attitude indicators—grievances, open grievances, and days lost due to unauthorized strikes—are proprietary and cannot be discussed. In an earlier paper that examined the structure of production in the U.S. automobile industry Norsworthy and Zabala [1982b] found the translog cost function to describe the production process reasonably well. Levy, Bowes, and Jondrow (1983) reach the same conclusion based on data developed independently, although a different approach to capital measurement is used, and energy input is separated from other purchased materials. While our earlier study recognized only three factors of production— capital, labor, and intermediate inputs (conventionally called materials)—in this study we disaggregate the labor input of production workers from that of nonproduction workers for the obvious reasons that the two types of labor would be expected to interact differently with worker attitudes, and the worker attitude indicator variables describe only the production-worker labor force. Further disaggregation to include energy as a separate input did not seem worthwhile because of energy's share in the total cost of production.

Other than work by Norsworthy and Zabala,[2] there are apparently no attempts to measure worker attitude as part of the cost of production, although Solow [1979] has suggested the introduction of attitude measures into production quite well. Further, because there is no consensus for measurement of capital in disequilibrium models, there are opportunities for "data mining" based on alternative measures of capital input. For these reasons, the equilibrium model—which, with all its limitations, is fully consistent with the neoclassical theory of production—is deemed appropriate for empirical analysis. In view of the unusual nature of the imbedded function of attitude indicators, methodological conservatism in other aspects of the study has been adopted throughout the estimation process.

The "seemingly unrelated" or Zellner [1962] estimation process is used in estimating coefficients. While this method is *asymptotically* equivalent to full information maximum likelihood estimation, its small-sample properties unfortunately implies that the estimation results are somewhat sensitive to the choice of the share equation that is dropped from the estimated model. Rather than simply argue that this effect is small, the model has been estimated twice with different share equations eliminated.

The popular translog cost function is used because it permits different elasticities of demand and substitution between pairs of inputs. In this respect, the translog is more general than the Cobb-Douglas and constant elasticity of substitution (CES) functional forms. In addition, estimating the cost function is superior to estimating the production function as a model of production because the implied assumptions about producer behavior are less restrictive than those implied by production function or profit function approach.

In using the cost function, it is assumed only that prices and output quantities are executed from the point of view of the decision maker who determines the quantities of each input factor to be used in production. Therefore, even in the case of the auto industry where wages are determined by industry-wide bargains, the plant-level decisions concerning the quantities of labor input are decentralized and based on wages that are not sensitive to hiring decisions at the given plant. By contrast, the production function model requires the added assumption that input *quantities* are exogenous as well. Otherwise the models must be estimated by some instrumental variables technique such as three stage least squares. The profit function model incorporates the profit maximization assumption in determination of input quantities and output and is generally applied where the demand for output is explicitly incorporated in the production model. This allows for divergence

2. Norsworthy and Zabala [1985b] discuss this approach in the context of industrial relations models that examine similar variables, but none of these parametrically determine the worker attitude measure in a cost function model of the production process.

between output price and marginal cost of production. Exogeneity of output (as assumed in the cost function model) is not particularly appealing as a description of input decisions in the U.S. automobile industry, but all production models incorporate some assumptions that depart from reality. Differences in cost, particularly in terms of labor and materials requirements, are substantial between large and small automobiles.

Norsworthy and Zabala [1982a] showed how a translog index of worker attitude indicator variables may be imbedded in a translog cost function. This results in an augmented cost function of the following form:

$$\ln C = a_0 + \Sigma_i a_i \ln P_i + 1/2 \Sigma_i \Sigma_j a_{ij} \ln P_i \ln P_j \qquad (1)$$

$$+ a_T T + 1/2 a_{TT} T^2 + \Sigma_i a_{iT} \ln P_i T$$

$$+ a_W W + 1/2 a_{WW} W^2 + \Sigma_i a_{iW} \ln P_i W + a_{TW} TW$$

$$\text{for } i,j = K,L,N,M$$

where K,L,N,M denote capital, production worker hours, nonproduction worker hours and all other purchased inputs ("materials"), respectively.

P_i denotes the price of input i in U.S. dollars.

T is a conventional index of technical change,

$T = 1, 2, \ldots$

C is the total unit cost of production in U.S. dollars.

W is a translog function of indicators of worker attitude described below.

Under conditions of cost minimization, the share equations for the cost model are given by

$$\partial \ln C / \partial \ln P_i = s_i = a_i + \Sigma_j a_{ij} \ln P_j + a_i T + a_{iW} W \qquad (2)$$

$$i, j = K,L,N,M$$

Symmetry and linear homogeneity in prices, technology and W are imposed by the parameter restrictions

$$a_{ij} = a_{ji} \qquad i,j = K,L,N,M \qquad \text{(symmetry)} \qquad (3)$$

$$\Sigma_i a_i = 1$$

$$\Sigma_i a_{ij} = 0 \qquad i,j = K,L,N,M \qquad Z = T,W \qquad \text{(homogeneity)}$$

$$\Sigma_i a_{iZ} = 0$$

The worker attitude index, I_w, is defined as follows:

$$\ln I_W = W = \Sigma_K b_k \ln R_k + 1/2\, \Sigma_k \Sigma_1 b_{k1} \ln R_k \ln R_1 \qquad (4)$$

$$k,1 = 1, \ldots, n$$

Thus W is simply a translog function of the worker attitude indicators R_k whose coefficients are to be determined in the estimation of the augmented cost function with its share equations. In this specification, the worker attitude indicators are weakly separable from the inputs. An estimate of $\ln I_W$ can be computed from equation (4), and subsequently I_W can be computed. W is linear homogeneous with the parameter restrictions

$$\Sigma_k b_k = 1 \qquad k = 1, \ldots, n \qquad (5)$$

$$\Sigma_k b_{k1} = 0 \qquad k,1 = 1, \ldots, n$$

If the worker attitude indicators R_k are acceptable, then an index of worker attitude in terms of its effects on the total unit cost of production has been created. In particular,

$$e_W = \partial \ln C / \partial \ln I_W = a_W + a_{WW} W + \Sigma_i a_{iW} \ln P_i W \qquad (6)$$

measures the elasticity of cost with respect to worker attitude; for consistently positive values of e_W, I_W will be an index of negative worker attitudes (positive effect on costs), and for consistently negative values of e_W, an index of positive worker attitudes.

It is important to estimate the W function in a reasonably complex model of the production process. First, because annual data for the years 1959–76 are used, a model with several factors—and therefore several share equations to be estimated simultaneously with the cost function—is required to provide a reasonably large number of degrees of freedom. Second, insofar as the effects of capital, nonproduction worker labor, materials and other net trends (collectively described as "technology") are represented in the model, the effects of the worker attitude function may be said to be purged of, or adjusted for, the effects of these other determinants in the cost production. Of course, effects of those factors that are *not* described in a homogeneous second-order-approximation-in-logarithms may still contaminate the W function.

Inspection of equation (1) shows that the worker attitude function enters the cost function in precisely the same manner as T, the index of "technological progress." And in just the same way, factor-bias effects of W can be tested for—that is, for Hicks neutrality (zero relative factor bias) of W in the hypothesis that

$$a_{iW}=0, \qquad i=K,L,N,M.$$

In the more general case, where a_{iW} differs, worker attitude may change the *relative* intensity of input factor use. The *absolute* factor-using or factor-saving bias of worker attitude is of course given by $a_W + a_{iW}$.

The worker attitude indicators that enter the worker attitude function are grievances, G; unresolved (open) grievances at year end, O; unauthorized strikes, Z; and voluntary separations (quits), Q. The first three variables are expressed in annual rates per worker. The variable Q is published for motor vehicles and parts, industry 371 in the Standard Industrial Classification (SIC). These variables are discussed in the labor relations literature, and may reasonably be defended as strongly related to worker attitude, although not all scholars would agree about their relative merits.[3] These are hard data that are routinely collected in unionized enterprises, and thus offer a firm empirical basis for modeling. It cannot be argued, however, that the proprietary data (variables G, O and Z) are representative of the industry in the sense of a random sample; nor do they all have the same coverage. However, the coverage is substantial (for Z it is virtually complete); and while the results may be biased by systematic nonrepresentation in these data, the exercise of estimating and interpreting W is nonetheless an interesting one (from equations (4), (5) and (6)). Several commentators have suggested that absenteeism would be a better—and presumably more revealing—indicator of an important dimension of worker attitude than the quit rate, Q. This is quite true, but a measure of absenteeism was unavailable from the companies or from federal statistics.

This cost function model with the imbedded worker attitude function embodies the assumption that the worker attitude indicators are determined by forces that are exogenous to cost determination. In the broadest sense, worker attitudes are seen to be influenced in part by endogenous processes (the technology of production, labor compensation) and in part by exogenous processes (the composition of the labor force in demographic and ethnographic terms, alternative job opportunities); see Norsworthy and Zabala [1985a]. There are several possible approaches to dealing with this simultaneity issue. One is to use iterative three-stage least squares estimation, using estimates of the worker attitude indicators based on instrumental variables exogenous to the model. While this could be done in principle, it seemed unreasonable to include among the instruments even a few variables that

3. These ideas are discussed in detail by Zabala [1983].

could realistically be described as influencing worker attitudes.[4] Another approach would be to gather data for an explicit model of attitude formation based on various labor policies, labor force composition, and so forth, as discussed in Norsworthy and Zabala [1985]. Indeed, while this has been and remains a long-term goal, the data are simply not available without an extensive and expensive data collection effort that is not feasible. The third alternative was finally adopted. A strong case is made in Zabala [1983] that grievances, G, and (particularly) open grievances, O, are leading indicators of overtly expressed worker dissatisfaction. Thus logged values of these variables were used in the estimation process, eliminating the bias for those variables. For unauthorized strikes, Z, and quits, Q, which are surely indicative of contemporary attitudes, the contemporary variables were used. In consequence, while there undoubtedly remains some simultaneity bias in the model estimation, it is far less serious than it might be.[5]

Prices and cost shares for output and the factors of production in the U.S. auto industry are presented and described in the appendix.

III. THE ESTIMATION RESULTS: WORKER ATTITUDE-AUGMENTED COST FUNCTIONS

The translog cost function is estimated in three forms: a standard (unaugmented) model, an augmented model permitting factor bias, and an augmented model restricting the effects of W to factor neutrality. The cost function and three share equations were estimated simultaneously using Zellner's [1962] "seemingly unrelated" technique as embodied in the Time Series Processor (TSP) version 3.5 (see Halland Hall [1980]). Two variants were estimated: the first eliminated the equation for the "materials" (M) share; the second eliminated the nonproduction worker share in total unit cost of production, because (as noted above) the small-sample properties of the estimator make the results sensitive to the choice of the input share equation to be dropped. The results show that the hypotheses tested are not sensitive to the equation that is eliminated. Restriction of the second-order parameter a_{WW} to zero proved necessary to obtain convergence. Thus, a total of twenty-nine

4. To use slavishly a standard set of exogenous variables appropriate (or at least customarily used) for a macroeconomic model seems to conform to the letter of the "how-to-deal-with-endogeneity" law and completely avoid its spirit. In particular, we know that production decisions about the technology of production such as supervisory ratios, assembly line layout, degree of automation, etc. strongly influence the worker's environment and attitude toward his job. Similarly, the general state of labor-management relations in the country at large (as, say, during the recent period of concession bargaining) may also affect worker attitudes. However, the proper way to deal with these phenomena is in our view to model them explicitly, rather than to incorporate numerical coincidence between broad macroeconomic variables and the worker attitude indicators in a particular industry. In other work, we have formulated an explicit model of attitude formation and hope to implement it. The efforts required to collect relevant data will be formidable.

5. Prices and cost shares for output and the factors of production in the U.S. auto industry are presented and described in the appendix.

TABLE I
Hypothesis Tests Cost Function, K, L, N Share Equations Estimated

	Test Statistic	Degrees of Freedom	Critical Chi-Square[a] Value ($\alpha = .01$)
Factor Bias Model versus Standard Model	383.90	14	29.1
Factor-Bias Model versus Factor-Neutral Model	287.18	3	11.3
Factor-Neutral Model versus Standard Model	90.72	11	24.7
Cost Function, K, L, M Shares Equations Estimated			
Factor Bias Model versus Standard Model	383.90	14	29.1
Factor-Bias Model versus Factor-Neutral Model	140.68	3	11.3
Factor-Neutral Model versus Standard Model	250.82	11	24.7

[a]Snedecor and Cochran [1967, 550].

parameters were estimated in the augmented model and fifteen in the unaugmented model, with forty-seven and sixty-one degrees of freedom, respectively. Results are shown in Table I.

The hypothesis tests are based on likelihood ratio tests. Results are presented in Table II. The test statistic is computed as

$$2\ (LLF_U - LLF_R)$$

where LLF_U and LLF_R are the logs of the likelihood functions for the unrestricted and restricted estimates respectively. These functions are chi-square distributed with degrees of freedom equal to the number of parameters eliminated in moving from the unrestricted to the restricted model.[6]

The worker attitude augmented model with factor bias (or all-factor augmentation) outperforms the restricted factor-neutral model and the standard cost function models by wide margins, judged by the hypothesis tests. And the factor-neutral augmented model also outperforms the standard model. There is very strong evidence, therefore, that the inclusion of worker attitude

6. Likelihood ratio tests are used, even though F-ratio or Wald tests are more finely discriminating, as Berndt and Savin [1977] argue. The results of the (simpler) likelihood ratio tests are so strong as to render fine discrimination pedantic.

TABLE II
Worker Attitude Index, 1959–76

a. Values of I_W, 1959–76

Year	Factor Bias (FBM)	Factor Neutral (FNM)	Factor Bias (FBN)	Factor Neutral (FNN)
1959	62.0	61.5	60.6	61.8
1960	58.0	57.7	56.2	58.1
1961	52.8	53.4	51.4	53.3
1962	59.1	59.7	58.7	59.4
1963	57.5	58.9	57.9	58.3
1964	79.7	80.2	77.8	80.2
1965	90.4	93.4	93.9	92.1
1966	101.9	102.9	104.7	103.9
1967	100.0	100.0	100.0	100.0
1968	116.2	116.2	114.2	117.3
1969	105.4	104.8	106.0	105.2
1970	106.0	107.4	104.3	107.2
1971	93.6	95.7	94.6	94.9
1972	101.2	104.0	104.7	103.2
1973	111.7	110.9	11.0	112.1
1974	94.5	96.3	97.0	96.0
1975	76.3	81.0	80.90	79.8
1976	90.7	94.3	94.3	93.0

b. Correlation Matrix for Levels of I_W, 1959–76

Model

	(FBM)	(FNM)	(FBN)	(FNN)
FBM	1.0000	.9972	.9946	.9989
FNM	.9972	1.0000	.9983	.9993
FBN	.9946	.9983	1.0000	.9973
FNN	.9989	.9993	.9973	1.0000

B. Correlation Matrix for Changes in I_W, 1960–76

	(FBM)	(FNM)	(FBN)	(FNN)
FBM	1.0000	.9915	.9784	.9957
FNM	.9915	1.0000	.9854	.9972
FBN	.9785	.9854	1.0000	.9820
FNN	.9957	.9972	.9820	1.0000

indicator variables substantially improves the explanatory power of the model.

An alternative formulation mentioned in Norsworthy and Zabala [1982a] restricting the effects of the worker attitude function entirely to changing the effective price of production-worker input was attempted, but convergence could not be obtained, even with simpler expressions for the worker attitude aggregator function. While such an outcome cannot be interpreted as rejection of the hypothesis that the effects of worker attitudes are limited to production-worker labor, it certainly strengthens the case for the factor-bias model.

For all estimated models, the own price elasticities of demand are strongly negative, except in the 1974–75 period where the demand for capital is perverse. This locally perverse result has been observed in a variety of industries for that time period.[7]

The parameters associated with the worker attitude indicator variables in the factor-bias model with the materials (*M*) equation eliminated appear to be strongest, judged by the size of their t-statistics. Therefore discussion is focused on that model in developing the properties of the worker attitude function and its role in cost determination. However, it is worth first noting several results in Table I.

The augmented factor bias models in this table, when compared to the standard models, show generally stronger second-order parameters, and weaker first-order parameters. The parameters measuring the bias in technical change—the a_{iT}'s—become larger in both models except for *AKT*. This is probably due to sorting out the attitude-related factor bias effects picked up in the a_{iW} parameters. The first-order parameters in the worker attitude function—the b_k's—are similar in all models, and so generally are the second-order parameters in that function. The factor-bias parameters for the worker attitude function—the a_{iW}'s—are quite similar in the two factor-bias models, although the a_{TW} parameter varies considerably. The capital-using bias associated with worker attitudes is particularly strong and is offset by materials-saving and production worker-saving biases.

There are two interesting aspects to the factor-using and factor-saving biases of the effects of worker attitudes. First, even if the negative effects

7. The failure to obtain convergence for this model specification was not particularly surprising. Restricting the effects of worker attitudes to operate through a single variable—the price of labor—creates asymmetry in the model which simply makes it harder to estimate, and much more dependent on starting values for parameters that are reasonably close to the solution values. Estimation algorithms for nonlinear simultaneous equations models (ours is nonlinear in the parameters *and* the variables) are quite sensitive to starting values; this property extends to all econometric estimation packages we have used. Further, we expected to find that the effects of worker attitudes affected other inputs beyond labor, based on our earlier work, and on Lichtenberg's finding that workers' experience on the job strongly influences total factor productivity rather than just labor productivity. However, it would have been preferable to test (and presumably reject) the hypothesis directly.

of worker attitudes operate through the production-worker labor input, it does not follow that other factors would necessarily be substitutable for the production labor input; it could be the case that *more* rather than less production labor would be required if the inputs could not be substituted. And note that the production labor-saving bias, a_{LW}, is smaller than the capital-using bias, a_{KW}. Capital is substituted both for production-worker labor and for *materials* inputs. Materials are primarily purchased from industry suppliers with similar labor components.[8]

The elasticity of production cost with respect to (negative) worker attitudes, measured by the a_W parameter, is considerably larger in the factor-bias models (about .25) than in the factor-neutral models (where it is .11). This means that a 1 percent increase in the negative attitude index results in a .25 percent increase in the total cost of production and a corresponding decrease in total factor productivity. The similar sizes of the parameter across the factor-bias models suggest that the results reflect real phenomena. Further evidence of the regularity of the estimate across model variants is displayed in Table II, which shows the worker attitude index as derived from the estimates of the four models. The estimate based on the factor-biased case with the materials equation eliminated (FBN) shows the standard errors of the parameter estimates in the W function, as movements in all variants of the index are highly correlated. This is confirmed in the correlation matrices for the levels and changes in the index, providing strong evidence of the stability of I_W.

The derivatives of I_W with respect to the various indicators of worker attitude for the preferred (FBM) model are shown in Table III.[9] As the parameters of the attitude function indicate, grievances generally have the greatest impact, with a rising trend from about .4 in the early years to .9 and .8 in 1975 and 1976, respectively. In general, the grievance rate is likely to be positively associated with negative attitude. This expectation is borne out by the empirical evidence. The volatility of the derivative of I_W with respect to grievance, G, is rather high, reflecting the influence of the second-order terms in the attitude function. The large second-order terms mean that the

8. The period covered is too early to reveal the effects of recent "out-sourcing" by U.S. auto manufacturers, the importation of a rising fraction of components and subassemblies to take advantage of lower production costs abroad. For example, Norsworthy and Malmquist [1983] find this result in equilibrium translog models for Japanese and U.S. manufacturing. An apparently closely related problem was encountered by Jorgenson and Fraumeni [1981] with respect to convexity in the sectoral demand for capital.

9. The derivatives are computed, e.g.,

$$\partial \ln I_W / \partial \ln G = b_G + b_{GG} \ln G + b_{GO} \ln O + b_{GQ} \ln Q + b_{GZ} \ln Z$$

Attempts to model worker attitude with a log-linear (Cobb-Douglas) form for the worker attitude function were unsuccessful. The change to a homogeneous second-order function led to immediate and substantial improvement. While we did not formally test the hypothesis that the second-order parameters are all zero, it would certainly be rejected.

TABLE III
Derivatives of Worker Attitude Index, I_W with Respect to Indicators of Worker Attitude (FBM Model)

Year	Grievances (*G*)	Open Grievances (*O*)	Unauthorized Strikes (*Z*)	Voluntary Separations (*Q*)
1959	.465	.019	.348	.152
1960	.424	.030	.343	.158
1961	.558	–.043	.323	.141
1962	.642	–.051	.322	.126
1963	.709	–.017	.278	.097
1964	.543	–.031	.331	.089
1965	.777	–.067	.330	.089
1966	.623	.074	.384	.110
1967	.589	–.015	.346	.079
1968	.445	–.016	.374	.079
1969	.539	.044	.355	.090
1970	.549	–.087	.363	.069
1971	.724	–.090	.319	.051
1972	.779	–.174	.356	.062
1973	.482	.008	.368	.085
1974	.715	–.118	.360	.088
1975	.915	–.176	.301	.065
1976	.821	–.117	.318	.063

interactions among the attitude indicators are large; in behavioral terms the attitudes that are revealed by, say, grievance writing and quits are strongly substitutable, since the interaction term between the two is negative. Thus the influences that would lead a worker to quit when other jobs are plentiful could lead to formal grievances when alternative jobs are scarce.

More revealing exploration of these phenomena can be undertaken based upon plant level data for attitude indicators, inputs, outputs and costs at that level, where the behavioral regularities could be greater. Most important, however, is that attitude formation can be more meaningfully modeled at the plant level where, for example, the introduction of new technology can be dated and identified in the investment stream, where differences in labor policies and supervisory practices can be measured, where trends in the composition of the labor force can be traced, and where variations in output can be accounted for.

In general, the effect of open grievances, O, is negative and fairly small in magnitude in most years, but again quite volatile. There is no behavioral reason to expect a negative association between unresolved grievances and negative worker attitudes; this result may well be a statistical artifact. Most of the influence of O is exerted through its second-order terms.

Voluntary separations, Q, have a larger impact on worker attitudes that is relatively stable, around .34, and the direction of the impact is as expected—negative worker attitude is (positively) associated with quits.

Unauthorized strikes, Z, have the least volatile influence on the attitude function and a rather small impact that declines from the earliest years and then settles into the .06-.08 neighborhood in the most recent ten years. The impact on costs is positive, as expected.

In sum, the derivatives of the worker attitude function with respect to its constituent worker attitude indicators have the expected impacts, except for the open grievances variable, O. The derivatives display considerable diversity in their movements through time, as the second-order approximation permits.

Table IV shows the worker attitude index, I_W, the elasticity of the total unit cost of production with respect to worker attitude, and an estimate of the cost savings that would be associated with a 10 percent improvement in worker attitude—a 10 percent decline in I_W. Table IV shows the measured elasticity of cost with respect to the worker attitude index, I_W, as estimated in the preferred model. The elasticity rises monotonically throughout the period studied, to .5 in 1976, the final year of the study. The third column shows the simulated reduction in cost that would be associated with a 10 percent improvement (decline) in the worker attitude index. In the final years of the study, such an improvement is estimated to be worth three to five billion dollars.[10]

There is a strong procyclical movement in I_W, providing support for the speculations by Mitchell [1913] and Kendrick [1977] that worker attitudes—in this case the manifestation of those attitudes in the cost of production—are more favorable to production under the pressure of contracting job opportunities. The fact that the seniority system differentially protects the jobs of more experienced workers may also contribute to the cyclical pattern.

In the overall elasticity of the cost of production with respect to time, represented in the a_{TW} term, is also important, but its role is secondary to

10. Full information maximum likelihood estimates gave very similar results for estimated parameters, the worker attitude index I_W, the derivatives of I_W, the estimated cost elasticities, and the simulated cost reduction brought about by a 10 percent change in I_W. However, some features of the FIML routine were not working properly, so that the estimation results are not reportable.

TABLE IV
Effect on Total Unit Cost of Worker Attitude (FBM Model)

Year	Worker Attitude Index I_W	Cost Elasticity with Respect to I_W	Estimated Cost Reduction of 10% Improvement in I_W (Millions of current dollars)
1959	62.0	.008	24.7
1960	58.0	.045	150.3
1961	52.8	.071	195.8
1962	59.1	.119	436.5
1963	57.5	.149	558.1
1964	79.7	.181	790.4
1965	90.4	.210	1154.4
1966	101.9	.231	1260.2
1967	100.0	.247	1101.1
1968	116.2	.289	1736.7
1969	105.4	.317	1895.9
1970	106.0	.325	1486.7
1971	93.6	.375	2391.6
1972	101.2	.393	2722.3
1973	111.7	.425	3707.3
1974	94.5	.425	3041.3
1975	76.3	.448	2931.3
1976	90.7	.501	5066.1

that of grievances. While the model does not explain the relationship between time, T, and the worker attitude index, W, it *does* assert that there is a strong one. This relationship, moreover, is unlikely to be spurious for two reasons. First, the coefficient a_{TW} has a relatively small standard error (large t-statistic). Second, T and W occur separately in the model as well as in conjunction with each other and with the price variables, so that the resulting coefficient is to be interpreted as representing a strong interaction between W and (aspects of) omitted variables that are strongly associated with time. (In a model of this type, the coefficients associated with T should not be interpreted as representing "real" technical change, but only as directing the search for

TABLE V
Correlation Matrix for Year-to-Year Changes in Variables, 1960–1976

	I_W	*TFP*	*LPR*	*TUC*
I_W	1.00	–.30	–.62	.24
TFP	–.30	1.00	.61	–.52
LPR	–.62	.61	1.00	–.73
TUC	.24	–.52	–.73	1.00

I_W – Index of Effects of Worker Attitude, FBM Model

TFP – Total Factor Productivity

LPR – Labor Productivity

TUC – Total Unit Cost of Production

deeper explanation.) However, because the model includes input prices in a generalized second-order function, one would *not* expect to find further important first- or second-order effects associated with the inputs.

Table V shows the correlation relationships between the changes in worker attitude index, I_W, and changes in the total unit cost of production (*TUC*), labor productivity (*LPR*), and total factor productivity (*TFP*). It should be understood that these variables could be strongly related in a complex model like the one estimated here without having effects easily discernible in simple correlation. In this case, however, the changes in the productivity and cost variables (more revealing than the levels of those variables) have the expected relationship with changes in the worker attitude index, I_W. This is a cost-weighted attitude index negatively associated with production worker labor productivity (*LPR*), a less strong but still negative association with total factor productivity (*TFP*), and positive association with the total unit cost of production (*TUC*). These are exactly the results expected from an index of worker attitude on these variables.

These results from industry data may misstate the effect of negative worker attitude on costs in the auto industry; recall that the worker attitude indicators—except for quits, *Q*—cannot be described as representative of the industry. But the small standard errors of the estimated parameters and of the implied worker attitude index, I_W, strongly indicate that quantitatively important and systematic forces associated with them are at work in the industry. While evidence from plant level data would be more compelling regarding the shape of the worker attitude function (as well as the cost function), the plausible and stable nature of the overall results is persuasive. The evidence validates this approach to measure the effects of worker attitudes on productivity and costs directly in the cost function model.

IV. CONCLUSIONS

There is evidence of a strong relationship between behavioral indicators of worker attitudes and productivity and costs in the U.S. automobile industry. To explore this relationship, two hypotheses concerning the relationship between worker attitudes and the cost of production have been tested and rejected by wide margins. These tests indicate that worker attitudes as revealed by worker attitude indicators (grievances, unresolved grievances, unauthorized strikes, and quits) have substantial effects on the cost of production and corresponding (dual) effects on total factor productivity. Furthermore worker attitudes are input-factor-specific in their effects. In particular, their effects lead to larger capital input and smaller production-worker labor input than would otherwise be used in production.

Examination of the resulting indices of the effects of worker attitudes on the cost of production show that (a) the intertemporal patterns of the indices are quite similar for variations in the estimation method for both factor-neutral and factor-biased specifications of the index, although the factor-biased specification shows larger effects; (b) the negative effects of worker attitudes on production costs rise substantially through the period studied; and (c) the relationship between the negative attitude index and the total unit cost of production, labor productivity, and total factor productivity are quite large and in the expected directions: costs rise substantially, and total factor productivity falls, with rising negative attitudes.

The results of this study suggest an agenda for further investigations of the role of worker attitude in the production process. It appears that industrial sociology can suggest hypotheses that are quite useful in the empirical study of production and that the neoclassical theory of production can be extended to accommodate and examine hypotheses from industrial sociology. One such hypothesis—that worker attitudes as revealed in commonly measured variables describing worker behavior have no important effect on the cost of production—is resoundingly rejected.

The large capital-using bias in the effects of worker attitudes is both plausible and intriguing. While there is some simultaneity bias in the parameter estimates, the chief results obtained here would most likely survive in a more complete model that explicitly includes the determination of the worker attitude indicators in the model of the production process. The ideal situation for application of this approach to understanding worker attitudes and productivity is the individual plant where local collective bargaining, work rules, technology, and grievance presentation and resolution data can be brought into a model of attitude formation to be estimated jointly with the cost function. Higher-frequency data—monthly or quarterly—would also permit examination of the intertemporal structure of attitude formation.

Finally, a (methodologically) positive approach such as this one is helpful in moving past the usually hostile rhetoric surrounding the discussion of worker attitudes toward an approach that focuses only on those aspects of worker attitudes that can be based on objective measurement, and only insofar as they lead to behaviors that affect productivity and the cost of production.

APPENDIX

Data for the U.S. Auto Industry

The U.S. automobile industry is defined as comprising SIC 3711 and SIC 3714. *Output* data are derived as follows: The value of shipments from the Annual Survey of Manufactures (ASM) and Census of Manufactures (CM) is adjusted for inventory and deflated by the price index for autos and auto parts from the Consumer Price Index.

Labor input data are based on production workers' employment, wages, and hours taken from the Annual Survey of Manufacturers. Employment and salaries of nonproduction workers are also from that same source. The quality of data describing average weekly or annual hours for nonproduction workers was judged to be not sufficiently reliable. For that reason, the input quantity measure is simply employment. The corresponding price is obtained by dividing the nonproduction worker payroll by employment.

Materials, costs in current dollars are likewise from the ASM and CM. The materials deflator is from the real product division of the Bureau of Economic Analysis, and is based on the patterns of intermediate inputs in successive input-output studies from 1958 to 1972.

Capital stock of equipment and structures in constant dollars is taken from the Bureau of Labor Statistics (BLS) [1979] capital stock study updated by BLS through 1976. The CM, and subsequently the ASM, redefined capital in the auto industry to include special tools, which had been treated as intermediate goods in earlier CMs and ASMs. Duke and Finger (1981) of BLS made estimates back to 1958, based on expenditures of the auto industry of machine tools for input-output years. For the three components of the capital stock—structures, equipment and special tools—service prices for the U.S. manufacturing aggregate from Norsworthy and Malmquist [1983] were used as a basis. For structures and equipment (except special tools) the manufacturing service prices were used directly. For special tools, the service price was taken as 30 percent higher than that for equipment, to reflect more rapid depreciation of that form of capital. These service prices were used to aggregate the three components of the capital stock by the Divisia method. The resulting Divisia quantity index was then used with the total return to capital in the auto industry to obtain a price index for the total input of capital services. Omitting inventories from the stock of capital was deemed more appropriate than their inclusion because in a cyclical industry such as automobile manufacturing, there is a strong countercyclical involuntary investment in inventories that would perversely bias the substitution parameters in the models to be estimated.

Table A-1 shows statistics for the worker attitude indicator variables.

TABLE A-1
Worker Attitude Indicator Variables Based on Indexes, 1967 = 1.00

	Grievances *G*	Open Grievances *O*	Quit Rate *Q*	Unauthorized Strikes *E*
Mean	.929	1.124	.761	1.050
Standard Deviation	.209	.491	.333	.494

Correlation Matrix

	G	*O*	*Q*	*Z*
G	1.000			
O	.882	1.000		
Q	.480	.301	1.000	
Z	.013	–.016	.127	1.000

TABLE A-2
Translog Cost Function: K, L, N Shares and Cost Function Estimated

Standard Model (SM)			Augmented Model with Biased Worker Attitude Effects (FBM)					Augmented Model with Hicks-Neutral Worker Attitude Effects (FNN)					
Parameter	Coefficient	T-Statistic	Coefficient	T-Statistic	Parameter	Coefficient	T-Statistic	Parameter	Coefficient	T-Statistic	Parameter	Coefficient	T-Statistic
AO	10.6225	1534.91	10.6539	735.27	AW	.2467	6.85	AO	10.6374	1078.46	AW	.1072	5.46
AK	.1651	121.03	.1720	55.75	AKW	.0458	8.17	AK	.1611	47.35	AKW	—	—
AN	.0442	71.74	.0475	59.81	ALW	.0036	1.32	AN	.0447	48.84	AUW	—	—
AL	.1538	138.79	.1559	157.08	ANW	.0117	4.50	AL	.1539	174.27	ANW	—	—
AT	-.0120	-10.17	-.0105	-3.57	ATW	.0291	15.96	AT	-.0051	-2.00	ATW	.0433	3.39
ATT	-.0002	-0.80	-.0011	-12.85				ATT	-.0024	-2.62			
AKN	-.0081	-6.72	-.0139	-8.63	BG	.5895	10.23	AKN	-.0036	-2.24	BG	.6084	4.72
ALN	.0227	3.73	.0344	8.83	BO	-.0148	-0.58	ALN	.0411	6.70	BO	.0068	0.07
ANM	-.0099	-1.74	-.0187	-2.64	BZ	.0790	15.95	ANM	-.0373	4.60	BZ	.0554	1.56
AKL	-.0204	-6.41	-.0318	-18.13	BGO	.0795	36.17	AKL	-.0209	-14.64	BGO	.0385	0.84
AKM	-.0427	-8.31	-.0384	-6.61	BGQ	-.1452	-23.22	AKM	-.0950	-39.37	BGQ	-.1928	-1.97
ALM	-.0542	-3.92	-.0581	-7.75	BGZ	-.2155	-14.57	ALM	-.0688	-5.96	BGZ	-.2869	2.42
AKT	-.0032	-8.58	-.0032	-4.43	BOQ	.0654	31.45	AKT	-.0012	-2.89	BOQ	.0767	5.44
ALT	-.0007	-1.05	-.0019	-5.28	BOZ	.0423	7.55	ALT	-.0012	-2.49	BOZ	.0677	1.83
ANT	-.0003	-1.03	-.0014	-4.26	BQZ	.0209	6.73	ANT	-.0009	-2.35	BQZ	.0264	1.12
AM	.6370	339.51	.6247	187.62	AMW	-.0611	-6.99	AM	.6403	143.29	AMW	—	—
AKK	.0713	15.18	.8400	19.39	BQ	.3463	12.60	AKK	.1195	92.81	BQ	.3293	4.74
ALL	.0519	4.22	.0555	13.39	BGG	.2812	13.42	ALL	.0487	8.57	BGG	.4413	1.68
ANN	.0048	-0.86	-.0018	-0.47	BOO	-.1872	-42.68	ANN	-.0012	-0.04	BOO	-.1829	-35.79
AMM	.1069	5.90	.1152	7.47	BQQ	.0589	11.88	AMM	.2011	10.87	BQQ	.0898	1.50
AMT	.0042	5.01	.0065	7.07	BZZ	.1522	24.67	AMT	.0033	3.06	BZZ	.1928	3.32
Log of Likelihood Function:		296.49			488.44					421.08			

TABLE A-2 (continued)

Translog Cost Function: K, L, N Shares and Cost Function Estimated

Standard Model (SM)			Augmented Model with Biased Worker Attitude Effects (FBM)					Augmented Model with Hicks-Neutral Worker Attitude Effects (FNN)					
Parameter	Coefficient	T-Statistic	Coefficient	T-Statistic	Parameter	Coefficient	T-Statistic	Parameter	Coefficient	T-Statistic	Parameter	Coefficient	T-Statistic
AO	10.6282	1553.97	10.6652	603.42	AW	.2804	4.54	AO	10.6419	773.90	AW	.1085	3.21
AK	.1650	120.24	.1727	44.32	AKW	.0538	6.64	AK	.1614	50.89	AKW	—	—
AN	.0506	83.45	.0536	61.88	ALW	.0009	0.28	AN	.0513	69.52	AUW	—	—
AL	.1538	138.90	.1555	134.11	ANW	.0104	3.80	AL	.1538	163.40	ANW	—	—
AT	-.0119	-10.03	-.0077	-4.27	ATW	.0437	3.01	AT	.0022	0.67	ATW	.0519	2.52
ATT	-.0006	-2.72	-.0021	-2.29				ATT	-.0032	-2.26			
AKN	-.0090	-8.68	-.0149	-10.08	BG	.5871	6.93	AKN	-.0094	-6.06	BG	.5599	4.40
ALN	.0190	3.20	.0297	7.05	BO	.0100	0.14	ALN	.0345	5.28	BO	.0190	0.17
ANM	-.0069	-1.46	-.0154	-2.28	BZ	.0422	1.22	ANM	-.0217	-3.25	BZ	.0715	1.32
AKL	-.0198	-6.17	-.0321	-15.83	BGO	.0408	0.87	AKL	-.0244	-14.27	BGO	.0624	0.92
AKM	-.0434	-8.63	-.0412	-6.79	BGQ	-.2282	-2.23	AKM	-.0739	-11.87	BGQ	-.2437	-1.72
ALM	-.0556	-3.99	-.0556	-6.16	BGZ	-.2483	-2.33	ALM	-.0502	-3.96	BGZ	-.2635	1.73
AKT	-.0031	-8.50	-.0027	-11.11	BOQ	.0870	4.92	AKT	-.0001	-0.32	BOQ	.0938	3.64
ALT	-.0007	-1.07	-.0019	-4.66	BOZ	.0338	1.04	ALT	-.0009	-1.76	BOZ	.0472	1.00
ANT	-.0001	-0.36	-.0011	-3.50	BQZ	.0407	2.01	ANT	-.0005	-1.44	BQZ	.0310	1.04
AM	.6306	334.17	.6182	148.76	AMW	-.0651	-6.08	AM	.6335	168.67	AMW	—	—
AKK	.0723	15.43	.0882	19.75	BQ	.3606	7.36	AKK	.1077	27.01	BQ	.3497	4.84
ALL	.0564	4.22	.0580	10.67	BGG	.4357	1.70	ALL	.0400	5.83	BGG	.4449	1.23
ANN	-.0031	-0.53	-.0005	-0.12	BOO	-.1616	-46.79	ANN	-.0033	-0.57	BOO	-.2033	-35.15
AMM	.1059	6.23	.1122	7.18	BQQ	.1005	1.56	AMM	.1458	8.71	BQQ	.1189	1.38
AMT	.0039	4.96	.0058	7.98	BZZ	.1738	3.24	AMT	.0015	1.51	BZZ	.1854	2.48
Log of Likelihood Function:		295.67			491.42					344.85			

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