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FIRM-LEVEL PRODUCTIVITY AND MANAGEMENT INFLUENCE: A COMPARISON OF U.S. AND JAPANESE AUTOMOBILE PRODUCERS*

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This study compares the productivity of six major US and Japanese motor vehicle manufacturers—General Motors, Ford, Chrysler, Toyota, Nissan and Mazda—from the early 1950's through 1987. Techniques of productivity measurement, conventionally applied at the level of industries or national economies, are adapted for the analysis of individual firms. Several potential determinants of growth in productivity are evaluated, including economies of scale, adoption of "just-in-time" manufacturing, and changes in top management.

The results show that productivity improvement by the six motor vehicle producers was attained primarily through more efficient utilization of labor; long-term growth in capital productivity was negligible for most firms. The three Japanese producers had achieved higher labor productivity than their US counterparts by the late 1970's. More recently, though, differences among firms within each country have become large relative to the gap between the US and Japan. Early productivity growth for Japanese producers was derived in part from the achievement of scale economies, but this source of improvement was largely exhausted by the mid-1960's. In both countries, significant shifts in the growth rate and level of firm productivity have followed changes in top management.
(PRODUCTIVITY, AUTOMOBILE INDUSTRY)

1. Introduction

International competition in manufacturing industries has been intensifying in recent decades, leading to shifts in global market shares and concerns about the continued "competitiveness" of US producers. Nowhere has this been more evident than in the automotive industry. Several studies performed in the early 1980's found that Japanese producers had attained substantial cost and productivity advantages over their US rivals. Since then, the fortunes of two US companies—Ford and Chrysler—have improved dramatically, while some Japanese producers such as Nissan have suffered serious setbacks. Japanese automakers have now set up manufacturing facilities in the US, and for firms such as Toyota and Honda, these facilities have proven to be far more efficient than typical US plants.

Exchange rate fluctuations and the vicissitudes of styling and marketing campaigns have clearly contributed to the changing fortunes of US and Japanese automakers. But to an important degree, relative productivity has been a determinant of competitive positions in the auto industry. In order to evaluate the competitive success and failure of firms in the auto industry—and many other industries as well—it is essential to understand the nature of interfirm differences in productivity.

While informal assessments of firm-level productivity are frequently made by industry analysts or reported in the trade press, there has been comparatively little academic research in this area. The basic concepts and tools of productivity measurement were developed by economists during the 1950's and 1960's (e.g., Solow 1957; Denison 1967; Griliches and Jorgenson 1967), and the economics literature now includes numerous comparative studies of productivity at the industry level. Such studies have assessed interindustry differences in productivity growth within a given country, as well as industry-

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level differences among countries.[1] However, only a handful of studies have attempted to compare productivity at the firm level.[2] The dearth of firm-level productivity research reflects economists' traditional emphasis on industry-level phenomena, reinforced by the ready availability of industry-level data collected by government statistical agencies.

In this paper we apply methods of productivity analysis at the level of individual manufacturing firms, and we use productivity as a metric for assessing firm performance. We focus on six major US and Japanese motor vehicle manufacturers—General Motors, Ford, Chrysler, Toyota, Nissan and Mazda—over a period from the early 1950's through 1987. Our analysis is based entirely on public data, primarily from company annual reports. We show that productivity analysis provides a useful method for assessing a firm's rate of improvement over time and its efficiency relative to competitors. The general framework is applicable beyond the specific context of the auto industry investigated here.

2. Prior Studies of US and Japanese Auto Industry Productivity

Numerous accounting and engineering-based productivity comparisons of US and Japanese automakers were performed in the early 1980's, triggered by the perceived decline of US producers (e.g., Harbour 1981; National Academy of Engineering 1982; Abernathy, Clark and Kantrow 1983; Flynn 1983). Such studies generally concluded that Japanese costs for small passenger cars were lower than US costs by a margin of roughly $2,000 per car. This differential was attributed partly to lower labor costs in Japan, and partly to superior productivity.

As part of a historical assessment of the rise of Toyota and Nissan, Cusumano (1985) made a detailed productivity comparison between these firms and US producers. Cusumano compared labor productivity (net value-added per employee) at Toyota, Nissan and Ford over the 1960–83 period. Labor productivity at Toyota was 83% of Ford's level in 1960, rising to about 200% of Ford by the early 1980's. Nissan's productivity was 53% of Ford's in 1960, rising to 134% by 1981 but subsequently falling. Cusumano found that US and Japanese automakers had comparable levels of capital stock per vehicle produced, which suggests that Japanese labor productivity growth was not the direct result of capital/labor substitution.

Other studies of the auto industry in the US and Japan have utilized econometric methods. Friedlaender, Winston and Wang (1983) used a quadratic cost function model to compare the Big Three US automakers over the 1955–79 period. On average across the three producers, they found constant returns to scale and a negligible rate of technical change. However, they identified firm-specific differences, with increasing returns to scale for General Motors and Chrysler (decreasing returns for Ford) and positive productivity growth for General Motors and Ford (negative productivity growth for Chrysler).

Aizcorbe, Winston and Friedlaender (1987) extended this econometric cost analysis to include eight major Japanese auto producers over the 1970–82 period. They found that the Japanese enjoyed a small car cost advantage of roughly $2,200 in the 1970's, declining to about $1,300 by the early 1980's. Controlling for differences in vertical integration, scale and product mix, they concluded that labor was 1.36 times more productive in Japan than in the United States in the early 1980's. On average, they found that automobile production was characterized by constant returns to scale in both countries. However, their methodology also yields the less plausible conclusion that productivity growth was negligible in both Japan (0.1% per year) and the US (0.5% per year).

[1] For assessments of industry-level productivity differences between the US and Japan, see Grossman and Sadler (1982) and Jorgenson, Kuroda and Nishimizu (1987).

[2] Note that even more disaggregated comparisons can be useful from a managerial standpoint; see Hayes and Clark (1985) for an innovative comparative analysis of productivity at the plant level.

Fuss and Waverman (1985) used an econometric cost function model to estimate total factor productivity growth for the Japanese, US and Canadian automotive sectors over the 1970–80 period. They found that the auto industry exhibited a small degree of economies of scale, with scale elasticities ranging from 1.04 in Canada to 1.09 in Japan. Their methodology identified positive productivity growth, with total factor productivity growing much faster in Japan (4.3% per year) than in Canada and the US (1.4% and 1.6% per year, respectively). In all three countries, about 20% of this growth was attributed to scale economies and 80% to technical change.

3. Productivity Measurement Methodology

3.1 *Labor, Capital, and Total Factor Productivity*

Productivity is a measure of the efficiency with which physical inputs are converted to physical outputs. Various productivity measures can be computed, depending on the treatment of inputs and outputs. *Single factor* productivity ratios give output per unit of input of a single type—labor, capital or materials. *Total factor* (or *multi-factor*) productivity ratios are computed by dividing output by a weighted sum of all input types.

In this study we measure output in terms of value-added, the difference between the firm's sales and its purchases of raw materials. Use of value-added allows us to ignore materials inputs in the productivity calculations.

All other inputs and outputs must be measured as real rather than nominal quantities. Accordingly, all reported values of output and capital input must be adjusted for inflation, and the capital stock must be depreciated in an economically-meaningful way. The price deflators and depreciation methodology used in this study are described in §4.

Labor productivity (output per unit of labor input) and capital productivity (output per unit of capital input) are only partial indexes and can thus give misleading indications of the average productivity level. For example, labor productivity can be augmented by simply raising the level of capital input—in other words, at the expense of capital productivity. Total factor productivity, which attempts to measure the change in output *net* of the changes in *all* inputs, is commonly regarded as a more appropriate measure of productivity. The following section describes the index number method for computing total factor productivity.

3.2. *Total Factor Productivity Methodology*

The traditional method for measuring total factor productivity (Solow 1957; Denison 1967; Griliches and Jorgenson 1967) takes it as a residual: the growth of real output net of the growth of factor inputs. In this formulation, the relationship at time t between output (or value-added), $Q(t)$, and the two inputs, capital, $K(t)$, and labor, $L(t)$, is expressed in terms of a production function:

$$Q(t) = A(t)F[K(t), L(t)], \tag{1}$$

where $A(t)$ is a time-varying efficiency parameter that allows for neutral shifts in the production function. Note that if the quantities of the inputs are held constant, the rate of change of output is precisely equal to the rate of change of $A(t)$. Thus, $A(t)$ may be identified as a measure of the *level* of total factor productivity.

Taking the logarithmic derivative of equation (1) gives

$$\frac{\dot{Q}}{Q} = \frac{\dot{A}}{A} + e_k\frac{\dot{K}}{K} + e_l\frac{\dot{L}}{L}, \tag{2}$$

where dots refer to time derivatives and e_k and e_l are the production elasticities with respect to capital and labor:

$$e_k = \frac{\partial Q}{\partial K}\frac{K}{Q}, \tag{3}$$

$$e_l = \frac{\partial Q}{\partial L}\frac{L}{Q}. \tag{4}$$

The rate of growth of total factor productivity growth can be computed as

$$\frac{\dot{A}}{A} = \frac{\dot{Q}}{Q} - e_k\frac{\dot{K}}{K} - e_l\frac{\dot{L}}{L}, \tag{5}$$

given data on the growth rates of output, capital and labor, and the production elasticities.

The growth rates of output and inputs are directly observable. The production elasticities are not, and must be estimated. Under the assumption of constant returns to scale, $e_k + e_l = 1$. (We shall maintain this assumption in this study.) If output and factor markets are competitive, so that capital and labor are paid their respective marginal products, then the production elasticities, e_k and e_l, are identical to the income (or equivalently, the value-added) shares of capital and labor, s_k and s_l. Data on labor's income share, s_l, are commonly available but data on capital's share are not. However, under the assumption of constant returns to scale, capital's income share can be estimated as the residual, $1 - s_l$.[3] Under these assumptions, the growth rate of total factor productivity can be computed as

$$\frac{\dot{A}}{A} = \frac{\dot{Q}}{Q} - (1 - s_l)\frac{\dot{K}}{K} - s_l\frac{\dot{L}}{L}, \tag{6}$$

Approximating the continuous growth rates on the right-hand side of equation (6) by annual differences in the natural logarithms of the variables gives

$$\dot{A}/A \cong [\ln Q_t - \ln Q_{t-1}] - (1 - \bar{s}_l)[\ln K_t - \ln K_{t-1}] - \bar{s}_l[\ln L_t - \ln L_{t-1}], \tag{7}$$

where $\bar{s}_l = \frac{1}{2}(s_{l,t} + s_{l,t-1})$. This representation of total factor productivity is often referred to as the "Törnqvist" index.

If the output market is *not* competitive (but the factor markets are, so that capital and labor are paid their marginal revenue products), then the production elasticities can no longer be identified with the income shares. Instead,

$$e_k(1 + 1/\eta) = s_k, \tag{8}$$

$$e_l(1 + 1/\eta) = s_l, \tag{9}$$

where η is the price elasticity of the market demand for output.[4] As η is in general a negative number, the income shares tend to underestimate the corresponding production elasticities.[5]

Under the assumption of constant returns to scale, $e_k + e_l = 1$. Hence

$$(1 + 1/\eta) = s_k + s_l, \tag{10}$$

which allows η to be estimated as

$$\eta = 1/(s_k + s_l - 1). \tag{11}$$

[3] Alternatively, if data on capital's income share are available, labor's income share can be estimated as a residual.

[4] In a competitive output market, the price elasticity equals minus infinity.

[5] In this case, the income shares of capital and labor will sum to less than unity.

More importantly, the production elasticities can be estimated as

$$e_k = s_k/(s_k + s_l) = w_k, \tag{12}$$

$$e_l = s_l/(s_k + s_l) = w_l, \tag{13}$$

where w_k and w_l are the cost shares of capital and labor, which by definition sum to unity. Under these assumptions, the growth rate of total factor productivity can be estimated as

$$\frac{\dot{A}}{A} = \frac{\dot{Q}}{Q} - (1 - w_l)\frac{\dot{K}}{K} - w_l\frac{\dot{L}}{L}, \tag{14}$$

or approximated with a Törnqvist index as in equation (7) above.

3.3. *Econometric Estimates of Total Factor Productivity*

In addition to the index number approach to total factor productivity measurement described above, the econometric approach is also used. The latter involves the statistical estimation of a specific representation of the production function in equation (1). Total factor productivity growth is indicated by the shift of the function $A(t)$ over time, which can be estimated. The econometric approach has the advantage that the production elasticities can be directly estimated without any assumptions on the behavior of the firm or the degree of competitiveness of the output and factor markets. In this paper we utilize a relatively simple but standard functional form, the Cobb-Douglas production function. This model allows us to test for shifts in the level and growth rate of productivity following changes in top management of the individual firms.

The basic form of a Cobb-Douglas production function with neutral technological change is

$$Q(t) = A(t)K(t)^{\alpha}L(t)^{\beta}, \tag{15}$$

where α and β are the production elasticities with respect to capital and labor respectively. Under the assumption of constant returns to scale, $\alpha + \beta = 1$, so the production function can be written in the form

$$Q(t) = A(t)K(t)^{1-\beta}L(t)^{\beta}. \tag{16}$$

If total factor productivity grows at a constant rate, $A(t)$ takes the exponential form, $A(t) = A_0e^{\gamma t}$, so that

$$Q(t) = A_0e^{\gamma t}K(t)^{1-\beta}L(t)^{\beta}, \tag{17}$$

where γ may be identified as the rate of growth of total factor productivity, and A_0 is a constant which can be interpreted as the level of total factor productivity at time zero.

Our estimation procedure utilizes time-series data for each firm. With a constant rate of productivity growth, the production function of firm i is given by

$$Q_{it} = A_{0i}e^{\gamma_i t}K_{it}^{(1-\beta_i)}L_{it}^{\beta_i}e^{\epsilon_{it}}, \tag{18}$$

where ϵ_{it} is a stochastic disturbance term satisfying the standard assumptions, including normality. If we allow for shifts in the production function following changes in top management, the production function becomes

$$Q_{it} = \prod_{j=1}^{J_i} A_{ij}(t)^{d_{ij}}K_{it}^{(1-\beta_i)}L_{it}^{\beta_i}e^{\epsilon_{it}}, \tag{19}$$

where $A_{ij}(t)$ is the level of total factor productivity of firm i during the jth management regime at time t, and d_{ij} is a dummy variable equal to one for the jth management regime, one-half for any transitional year, and zero otherwise; and J_i is the total number of management regimes for firm i during the sample period. It is further assumed that

$$A_{ij}(t) = A_{0ij}e^{\gamma_{ij}(t-t_{ij})}, \tag{20}$$

where t_{ij} is the year in which top executive j takes over the management of firm i, A_{0ij} can be interpreted as the *level* of productivity of firm i in the first year of office of the jth top executive, and γ_{ij} can be interpreted as the *growth rate* of productivity under the jth management regime. Substituting equation (20) into equation (19) and taking natural logarithms, we obtain

$$\ln Q_{it} = \sum_{j=1}^{J_i} d_j(\ln A_{0ij} + \gamma_{ij}(t - t_{ij})) + (1-\beta_i)\ln K_{it} + \beta_i \ln L_{it} + \epsilon_{it}. \tag{21}$$

Since we are interested in the *differences* in the level and rate parameters among the top executives of a given firm, we define the firm-specific average level and rate of growth of total factor productivity:

$$\ln A_{0i} \equiv \sum_{j=1}^{J_i} \ln A_{0ij}/J_i; \tag{22}$$

$$\gamma_i \equiv \sum_{j=1}^{J_i} \gamma_{ij}/J_i. \tag{23}$$

Substituting equations (22) and (23) into equation (21), we obtain

$$\ln Q_{it} = \ln A_{0i} + \sum_{j=1}^{J_i} d_{ij}(\ln A_{0ij} - \ln A_{0i}) + \gamma_i \sum_{j=1}^{J_i} d_{ij}(t - t_{ij})$$
$$+ \sum_{j=1}^{J_i} (\gamma_{ij} - \gamma_i) d_{ij}(t - t_{ij}) + (1-\beta_i)\ln K_{it} + \beta_i \ln L_{it} + \epsilon_{it} \tag{24}$$
$$= \ln A_{0i} + \sum_{j=1}^{J_i} d_{ij}(\ln A^*_{0ij}) + \gamma_i \sum_{j=1}^{J_i} d_{ij}(t - t_{ij})$$
$$+ \sum_{j=1}^{J_i} \gamma^*_{ij} d_{ij}(t - t_{ij}) + (1-\beta_i)\ln K_{it} + \beta_i \ln L_{it} + \epsilon_{it}, \tag{25}$$

where

$$\ln A^*_{0ij} \equiv \ln A_{0ij} - \ln A_{0i}, \tag{26}$$

and

$$\gamma^*_{ij} \equiv \gamma_{ij} - \gamma_i. \tag{27}$$

For each firm, the executive level and growth rate deviations sum to zero, i.e., $\sum_{j=1}^{J_i} \ln A^*_{0ij} = 0$, and $\sum_{j=1}^{J_i} \gamma^*_{ij} = 0$. We estimated equation (25) by ordinary least-squares, subject to the restrictions in equations (26) and (27) and after adding a dummy variable for the strike at Chrysler in 1954. The coefficient, $\ln A^*_{0ij}$ can be interpreted as the level of productivity of firm i during the first year of the jth management regime *relative* to the average level of productivity during the first year of all the management regimes considered for the firm. Similarly, γ^*_{ij} can be interpreted as the deviation in the growth rate of productivity under the jth management regime relative to the average rate of growth of all the management regimes considered.

Finally, we also estimated equation (25) subject to the additional restrictions that the β_i's are identical within each of the two countries and that the β_i's are identical across firms and countries.

4. Data Construction and Sources

Our data sample covers General Motors (1950–1987), Ford (1950–1987), Chrysler (1950–1987), Toyota (1961–1987), Nissan (1961–1987), and Mazda (1963–1987).[6] All company-specific data are from annual reports.[7] Price deflators and data on labor hours are from government sources.

4.1. *Output Measure*

The output measure used in the productivity calculations is the total value-added by the firm during its fiscal year in constant prices.[8] The average growth rate of real value-added varied greatly across producers, from a minimum of 4.0 percent per annum for Chrysler and General Motors to a maximum of 13.9 percent per annum for Toyota.

4.2. *Labor and Capital Input*

Labor input was taken as the total number of employees for the firm during the observation year, multiplied by a measure of average working hours in the auto industry. The working hours data are country- rather than firm-specific, which introduces some degree of error into the labor input measures.[9]

We constructed a real capital stock series for each firm using a perpetual inventory capital adjustment equation:

$$K_t = (1 - \delta)K_{t-1} + \text{deflated gross investment}, \qquad (28)$$

where gross investment is defined as the change in the firm's undepreciated capital stock since the preceding year,[10] and δ is the rate of economic depreciation, which we assumed to equal 10%.[11] The capital stock estimates are for the beginning of each fiscal year.[12]

[6] See Lieberman, Lau and Williams (1989) for additional detail on data sources and construction of the input and output measures.

[7] In addition to firms' domestic operations, the data include consolidated international subsidiaries, which are substantial for Ford and General Motors. The data on Japanese companies are available on the NEEDS financial data tape and in Daiwa's *Analysts' Guide*.

[8] This was computed from three annual data series: (1) total company sales, (2) the firm's value-added to sales ratio, and (3) the national price deflator for passenger cars. For the American companies we used the consumer price deflator for new passenger cars reported in the *U.S. Economic Report of the President*; for the Japanese companies we used the passenger car deflator from *Price Indexes Annual*.

[9] The Japanese figures are based on the total monthly hours worked in the transportation equipment industry, as reported in *Economic Statistics Annual*. American figures are for average weekly hours for production workers in the motor vehicle industry, as reported in the *Economic Report of the President* and the *Monthly Labor Review*.

[10] More specifically, gross investment equals the increase in gross property, plant and equipment, plus expenditures for special tooling. To deflate Japanese investment we used the gross domestic capital formation deflator from *Economic Statistics Annual*; to deflate American investment we used the implicit price deflator for total nonresidential gross private domestic investment from the *Economic Report of the President*.

[11] This 10% rate is consistent with a weighted average over asset categories of the economic depreciation rates reported by Hulten and Wykoff (1981).

[12] For the American firms, the initial capital stock, K_0, equals the deflated value of net property, plant and equipment in the initial year of the series (1939 for General Motors and Chrysler, and 1946 for Ford). We were unable to obtain capital stock data on the Japanese firms prior to 1961; moreover, the available data on net property, plant and equipment underestimate the true capital stock of the Japanese firms, given that accelerated depreciation was used. To find a reasonable capital stock estimate for 1961, we regressed each firm's gross investment in the 1960's on a time trend, extrapolating backward to obtain an investment series for prior years.

For the index number computations and Cobb-Douglas regressions, the firm's net capital stock, K_t, was multiplied by a capacity utilization rate. This rate equals the firm's total sales in the observation year, divided by a potential output level obtained by connecting successive peaks in annual sales.

4.3. *Factor Shares*

Data on the income and cost shares of labor and capital are required for the index number estimates of total-factor productivity growth. Labor's share of income was taken as total labor compensation divided by value-added; capital's share of income was computed as a residual. To calculate the cost shares, total cost was taken as the sum of labor compensation and an imputed rental cost of capital.[13]

For the US firms, labor's share of income has typically been about 60% to 70%, with higher values in years of low profitability. For Japanese firms, labor's share of income has historically been much lower, but rising over time. Labor's share of cost averaged 71% for the US firms and 58% for the Japanese firms over the sample period.

5. Productivity Analysis

5.1. *Labor Productivity Growth*

5.1.1. *Identity Relation for Decomposing Labor Productivity.* For purposes of analysis, it is instructive to decompose labor productivity, measured in terms of value-added per worker-hour, into the following identity:

$$\frac{\text{value-added}}{\text{worker-hour}} = \left(\frac{\text{vehicles}}{\text{worker}}\right) \times \left(\frac{\text{sales revenue}}{\text{vehicle}}\right) \times \left(\frac{\text{value-added}}{\text{sales revenue}}\right) \Big/ \left(\frac{\text{hours}}{\text{worker}}\right).$$

By definition, changes in labor productivity stem from changes in the four ratios on the right-hand side of this identity relation. For example, holding all but one of these ratios constant, a one percent increase in labor productivity could arise from either: (a) a one percent increase in raw vehicle output per worker, (b) a one percent increase in the average sales price per vehicle (measured in constant dollars), (c) a one percent increase in the firm's degree of vertical integration (value-added per dollar of sales),[14] or (d) a one percent decrease in average working hours per employee.

The first four panels in Table 1 report average annual percentage rates of change in these right-hand side ratios for each of the motor vehicle producers over the 1950–87 period. The fifth panel gives the resulting percentage growth rates of labor productivity. All ratios are measured over decade intervals except the last sequence which covers 1980–87 only. The ratios for Mazda during the 1970's have been split into two periods, 1970–75 and 1975–80, to take account of the fact that the firm was reorganized following virtual bankruptcy in 1975. Mazda's productivity growth increased dramatically after reorganization, as the firm began to adopt key features of the Toyota production system (Harvard Business School 1982; Pascale and Rholen 1983).

5.1.2. *Vehicles per Worker.* The first panel in Table 1 reports growth in total vehicle output per worker. This ratio is easily computed from the output and employment data published in company annual reports. The table shows that vehicles per worker remained essentially constant for US producers through the 1950's and 1960's, then increased at

[13] The imputed rental cost was assumed to be the rate of depreciation (10%) plus a real rate of return to capital of 4.6% in Japan and 11.2% in the United States as implied by the findings of Ando and Auerbach (1988).

[14] We use value-added/sales revenue as a measure of vertical integration. A better measure would be labor and capital cost as a fraction of total cost, where the latter includes the cost of materials.

TABLE 1

Labor Productivity Growth, 1950–87 (*Average Annual Percentage Rates of Change*)

	1950–60	1960–70	1970–80	1980–87
Vehicles/Worker				
GM	−0.3	−0.3	2.2	0.0
Ford	0.3	−0.5	−1.0	7.6
Chrysler	0.0	−0.5	2.2	4.7
Toyota	22.3	9.5	4.7	−1.1
Nissan	20.1	9.4	4.4	−1.3
Mazda	NA	3.0[a]	3.5/15.1[b]	3.4
Hours/Worker				
US	−0.2	−0.2	−0.1	0.9
Japan	NA	−0.9	−0.4	−0.3
Sales/Vehicle (average price)				
GM	1.5	2.3	3.2	3.7
Ford	0.1	3.2	4.9	1.7
Chrysler	2.0	0.9	4.5	3.1
Toyota	NA	−2.5	5.0	8.0
Nissan	NA	−0.5	4.8	4.3
Mazda	NA	2.1[a]	3.9/3.1[b]	2.0
Value-Added/Sales (vertical integration)				
GM	−0.4	−0.1	−1.8	0.8
Ford	0.8	−0.6	−1.7	1.6
Chrysler	0.4	−0.5	−3.8	4.8
Toyota	NA	0.0	−2.0	−1.7
Nissan	NA	−0.2	−1.2	−2.4
Mazda	NA	−0.3[a]	−10.1/−1.0[b]	−2.6
Value-Added/Worker-Hour (labor productivity)				
GM	0.9	2.1	3.7	3.6
Ford	1.4	2.3	2.4	10.0
Chrysler	2.5	0.1	3.0	11.7
Toyota	NA	7.8	8.1	5.6
Nissan	NA	9.6	8.4	0.9
Mazda	NA	5.7[a]	−.1/15.5[b]	3.2

[a] (1963–1970).
[b] (1970–1975)/(1975–1980).

a moderate rate for GM and Chrysler in the 1970's, and increased dramatically for Ford and Chrysler during the 1980's. The recent trend reflects increases in worker productivity as well as a general shift to smaller cars.

Toyota and Nissan show increases in vehicles per worker in excess of 20% per year during the 1950's, tapering off to zero by the 1980's. The extraordinary growth during the 1950's and early 1960's reflects post-war recovery and the attainment of basic economies of scale. Mazda, by contrast, shows fairly slow growth in vehicles per worker from the start of data in 1963 through 1975; but after the firm's reorganization in the mid-1970's, Mazda's output of vehicles per worker increased dramatically.

5.1.3. *Average Working Hours*. The second panel of Table 1 gives the change in hours per worker in the automotive industry in the US and Japan. (Company-level data on average working hours are not available.) The panel shows a gradual trend toward a shorter workweek in Japan. By comparison with the other ratios in Table 1, average working hours have been stable in both countries.

5.1.4. *Average Price per Vehicle*. The third panel in Table 1 describes the change in each firm's average sales revenue (deflated by the price index for passenger cars) per vehicle produced. Changes in average real price per vehicle reflect shifts in the firm's mix of vehicle size classes, as well as a general trend toward increased features. US producers generally show the most rapid price increases during the 1970's, which presumably reflects the adoption of pollution control equipment and other new features. Movement of Japanese producers from economy models to more upscale vehicles is reflected in the high average rates of real price increase in the late 1970's and early 1980's (particularly for Toyota).

5.1.5. *Vertical Integration*. The fourth panel in Table 1 gives rates of change in value-added per unit of sales, which corresponds roughly to the firm's degree of vertical integration. Japanese firms have historically been less integrated than their US counterparts. In 1985, for example, Toyota had a value-added to sales ratio of 19%, as compared with 45% for General Motors, the most integrated producer. The panel shows that there has been little change over time in the vertical integration of US producers, with the exception of a temporary drop for Chrysler when the firm restructured in the late 1970's. The three Japanese producers show a general tendency toward reduced integration (i.e., greater reliance on outside suppliers).

5.1.6. *Value-Added per Worker-Hour* (*Labor Productivity*). The bottom panel in Table 1 reports growth in labor productivity, measured as value-added per worker-hour. This productivity measure is the product of the four ratios discussed above.

The panel shows that all three US producers experienced more rapid growth in labor productivity during the 1970's than during the 1950's or 1960's. Moreover, for Ford and Chrysler, labor productivity grew much more rapidly during the 1980's than in previous decades. One interpretation of these findings is that pressure from Japanese competitors stimulated US automakers to boost productivity.

Among the Japanese producers, Toyota shows sustained labor productivity growth of roughly 5% to 8% per year. Nissan exhibited faster growth during the 1960's and 1970's but fell to near zero in the 1980's. Mazda also experienced sharp changes, particularly during the 1970's, when labor productivity declined in the first half of the decade, then increased by more than 15% per year. Prior to the 1980's, the labor productivity growth rates of all three Japanese producers exceeded those of the US firms.

5.2. *Capital Productivity Growth*

The top panel in Table 2 reports growth in capital productivity for the six auto producers. On average over the sample period, growth in capital productivity was negligible for all producers except Toyota. In other words, the amount of capital input per unit of value-added remained roughly constant. This contrasts with the appreciable growth observed for labor productivity.

5.3. *Total Factor Productivity Growth*

The bottom panel in Table 2 reports growth rates of total factor productivity, computed

TABLE 2
Capital and Total Factor Productivity Growth, 1950–87
(*Average Annual Percentage Rates of Change*)

	Value-Added/Capital Stock (capital productivity)			
	1950–60	1960–70	1970–80	1980–87
GM	−0.3	−1.3	2.4	−5.1
Ford	−6.2	1.9	1.9	1.2
Chrysler	−6.1	5.3	3.7	−3.7
Toyota	NA	2.6[a]	2.3	0.3
Nissan	NA	−3.0[a]	3.9	−1.4
Mazda	NA	−8.2[b]	5.3/15.5[c]	−5.7
	Labor's Share of Value-Added (%)			
	1950–60	1960–70	1970–80	1980–87
GM	56.3	58.1	70.1	73.8
Ford	54.2	63.6	72.2	72.2
Chrysler	67.2	68.8	88.5	73.8
Toyota	NA	26.6[a]	36.6	37.4
Nissan	NA	30.7[a]	47.2	58.7
Mazda	NA	39.1[b]	65.1/73.6[c]	59.7
	Total Factor Productivity			
	1950–60	1960–70	1970–80	1980–87
GM	0.5	0.3	3.3	1.9
Ford	−2.1	2.3	2.1	7.3
Chrysler	0.4	1.5	2.3	8.4
Toyota	NA	3.9[a]	4.3	2.4
Nissan	NA	0.3[a]	5.8	−0.3
Mazda	NA	−2.8[b]	2.0/15.6[c]	−0.4

[a] (1961–1970).
[b] (1963–1970).
[c] (1970–1975)/(1975–1980).

by the income shares method described in §3.2. (Total factor productivity growth is a weighted average of the growth rates of labor and capital productivity.) The estimates in Table 2 imply that Japanese producers had more rapid total factor productivity growth than US firms during the 1970's, but the reverse was true during the 1980's.

Table 3 gives a summary of the average annual growth rates of labor, capital and total factor productivity, measured over the entire period of sample coverage for each firm. Three estimates of total factor productivity growth are reported. These correspond, respectively, to the three alternative estimation methods described in §3: index numbers based on income shares, index numbers based on cost shares, and econometric estimation of a Cobb-Douglas production function.[15]

Over the sample period as a whole, Japanese producers experienced much more rapid growth in labor productivity than did their American counterparts. From the early 1960's to 1987, the average labor productivity growth of Japanese producers ranged from 5.7% per year at Mazda to 7.3% per year at Toyota. Labor productivity growth for US producers

[15] The Cobb-Douglas estimates in Table 3 are from regression 5.2a in Table 5, which assumes identical production elasticities for all firms within the same country.

TABLE 3
Average Annual Growth Rates of Labor, Capital and Total Factor Productivity

		Average Annual Growth Rate (%)				
				Estimates of Total Factor Productivity		
Company	Period	Labor Productivity	Capital Productivity	Income Shares	Cost Shares	Cobb-Douglas†
General Motors	1950–87	2.5	−0.7	1.5	1.5	2.0
Ford	1950–87	3.5	−0.4	2.0	2.4	2.1
Chrysler	1950–87	3.7	0.1	2.7	2.9	2.7
Toyota	1961–87	7.3	1.9	3.7	4.3	6.0
Nissan	1961–87	6.3	0.1	2.2	2.9	5.2
Mazda	1963–87	5.7	1.0	3.1	3.6	5.7

† Cobb-Douglas estimates from regression 5.2a.

over the 1950–87 period ranged from 2.5% per year at General Motors to 3.7% per year at Chrysler. Capital productivity growth was approximately zero for all producers except Toyota, whose capital productivity growth was positive but well below the growth rate of labor productivity. Thus, virtually all of the productivity improvement for both US and Japanese producers took the form of reductions in labor input per unit of output.

The last three columns of Table 3 give the estimates of the average annual growth rate of total factor productivity. All three methods indicate that General Motors had the lowest productivity growth rate of the six firms; Toyota had the highest growth rate. In addition, the rankings of the firms by the rate of productivity growth within each country are the same for all three methods. The average growth rate of total factor productivity for the three US firms ranges from 2.1% to 2.3% per year, depending on the method used. For the Japanese producers, the average annual rate of total factor productivity growth was 3.0% based on income shares, 3.6% based on cost shares, and 5.6% based on the Cobb-Douglas approach.

5.4. *Labor and Capital Productivity Levels*

Figures 1 and 2 provide a comparison of absolute levels of labor and capital productivity. Figure 1 plots labor productivity (value-added per worker-hour) in constant dollars for each of the six firms. A purchasing power parity rate of 260 yen per dollar in 1975 was used to convert the Japanese series to US dollars.[16] The figure reveals considerable interfirm and intertemporal variation in labor productivity levels. It appears that all three Japanese producers had achieved higher labor productivity than their US rivals by the late 1970s. During the 1980's, however, labor productivity differences among producers within each country began to exceed the average difference between countries. In particular, Ford, Chrysler and Toyota experienced dramatic labor productivity growth during the 1980's, while General Motors and Nissan did not.

Figure 2 plots capital productivity over time for each of the six producers. For the US firms, the vertical axis represents dollars of value-added per dollar of net capital stock. For the Japanese firms, the vertical axis gives yen of value-added per yen of net capital

[16] This is the purchasing power parity rate for small cars reported by Kravis, Heston and Summers (1982), p. 53. Adjustment for differential inflation of passenger car prices in the two countries yields a purchasing power parity rate of 155 yen per dollar in 1987, the final year of the sample. The actual exchange rate was 145 yen per dollar on average during 1987; a computation based on this rate would slightly augment the levels of Japanese labor productivity shown in Figure 1.

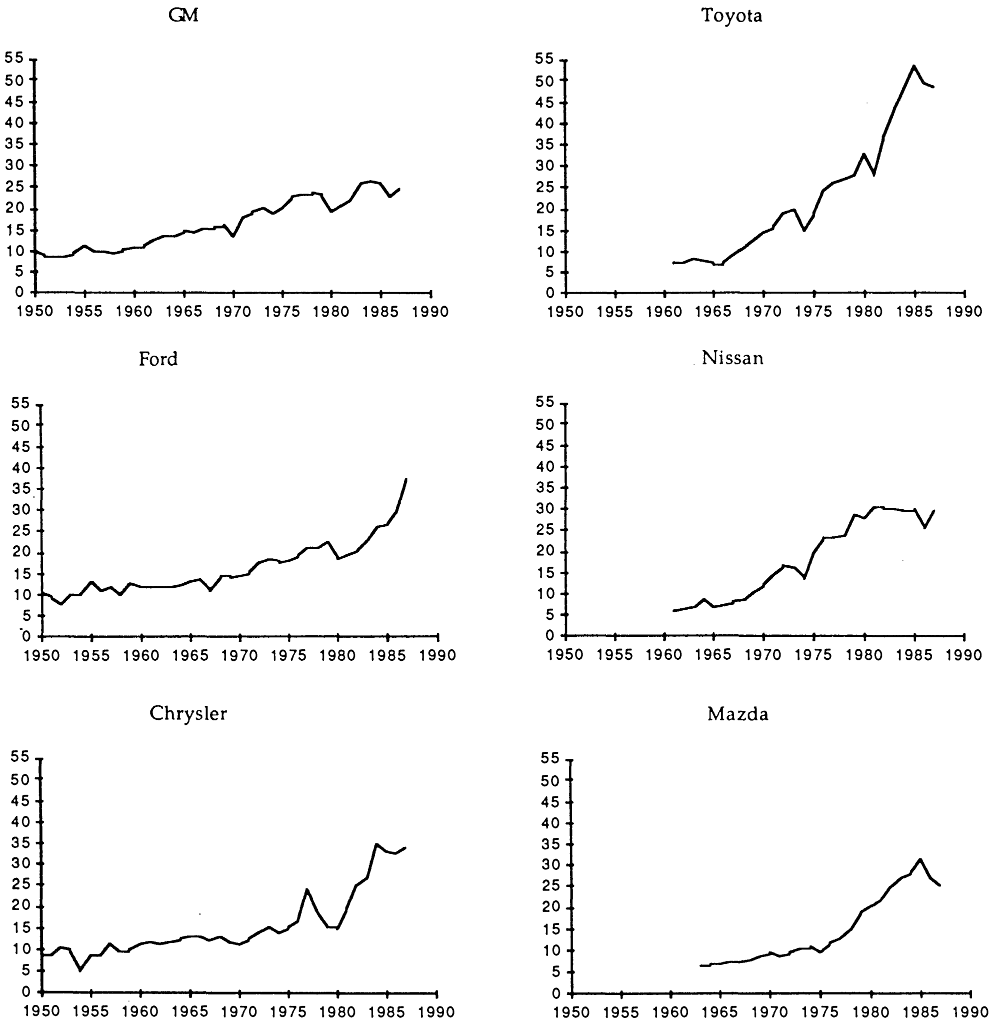

FIGURE 1. Value-Added per Worker-Hour (in 1985 Dollars).

stock. The two scales are equivalent if the price of output relative to the price of capital input was the same in both countries.[17]

Figure 2 shows that value-added per unit of capital stock averaged about 0.8 for US producers, compared with about 0.5 for the Japanese. Short-term fluctuations are apparent for all producers,[18] as well as an absence of any appreciable long-term trend. The latter is consistent with the negligible growth rates for capital productivity shown in Tables 2 and 3. The lower value-added per unit capital stock for Japanese producers may reflect a lower level of capital productivity or a higher relative price of capital goods in Japan.

In general, the observations in this section imply that long-term productivity improvement in the automotive industry involved gradual reductions in the required amount of

[17] Historically, capital goods have been somewhat more expensive in Japan; for example, the OECD (1987) reports a 1985 pruchasing power parity exchange rate of 187 yen per dollar for personal transport equipment, compared with 275 yen per dollar for gross fixed capital formation and 246 yen per dollar for machinery and equipment. Adjustment for this price differential would raise the values plotted for Japanese firms by 30% to 50%.

[18] In Figure 2 the capital stock estimates have not been adjusted for capacity utilization.

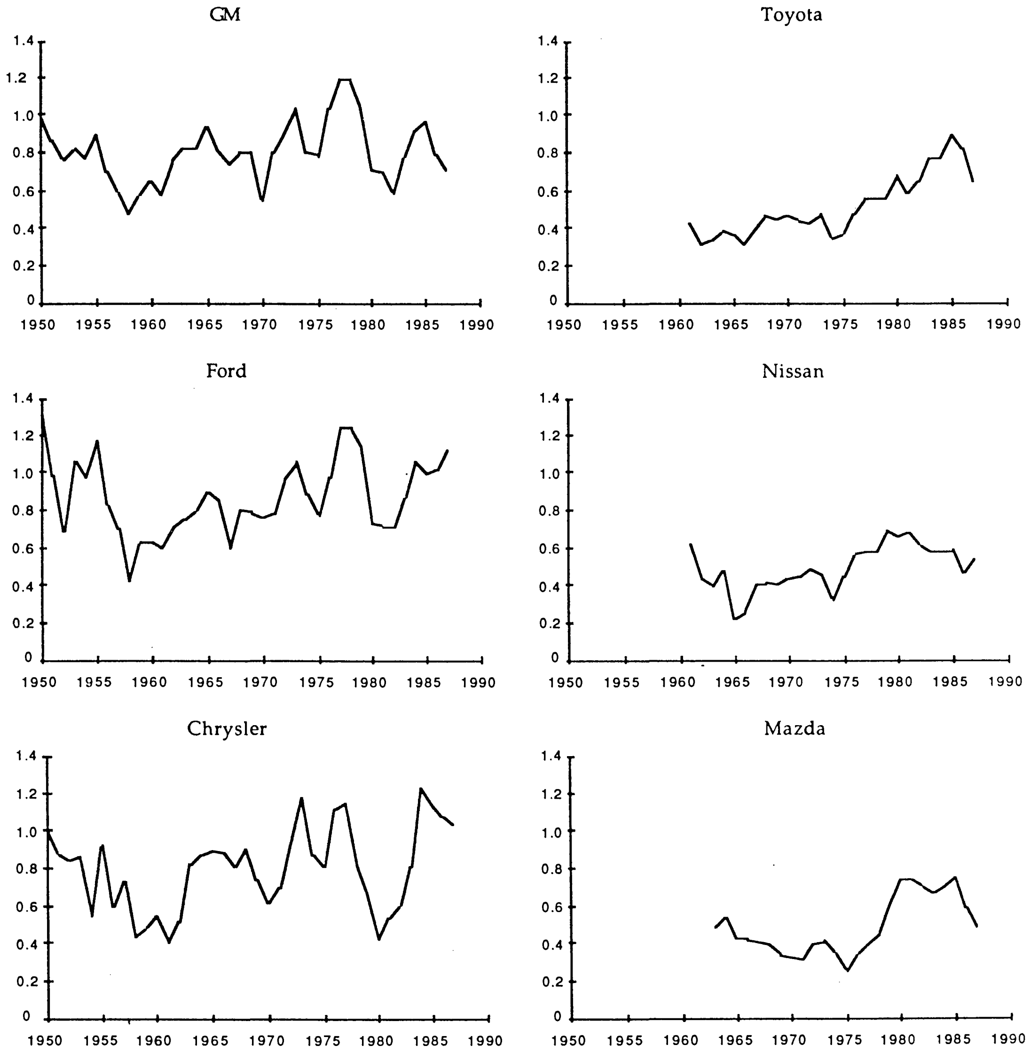

FIGURE 2. Value-Added per Unit of Capital Stock.*

* For U.S. firms, the vertical scale gives dollars of value-added per dollar of net capital stock both in 1985 prices in each year. For Japanese firms the vertical scale gives yen of value-added per yen of capital stock, again, both in 1985 prices. The two scales are equivalent if the price of motor vehicles (value-added) relative to plant and equipment (capital stock) was the same in both countries.

labor input, with capital input held roughly constant. This process appears to have proceeded more rapidly in Japan than in the United States. The next section assesses some explanations of the observed differences in productivity growth.

6. Some Explanations for Differences in Productivity Growth

6.1. *Scale Economies*

One explanation for the faster average rates of productivity growth for Japanese firms is that they were gaining economies of scale as they approached the output level of US producers. All of our productivity estimates are based on the maintained hypothesis of constant returns to scale. As noted in §2, prior studies have found no evidence of substantial scale economies for US or Japanese producers, at least at the output levels observed in recent years.[19]

Most scale economies in the auto industry operate at the plant level. Engineering studies indicate that output of about 100,000 to 200,000 vehicles per year is required to attain most of the available scale economies for a vehicle assembly plant (e.g., Pratten 1971). In addition, there are important scale economies to be attained in the manufacture of engines and transmissions. These components require somewhat higher levels of annual output, as a single engine or transmission plant typically serves two or more final assembly plants.

Table 4 reveals that (with a few minor exceptions) US producers have historically operated at an efficient scale of output of roughly 100,000 to 200,000 annual vehicles per plant. The vehicle output of Japanese producers, by comparison, was minuscule during the 1950's. By the mid-1960's, however, their output had risen above the threshold where all major scale economies are attained.[20] Thus, the data in Table 4 suggest that

TABLE 4

Vehicle Output per Assembly Plant

Firm	Year	Total Domestic Motor Vehicle Production	Number of Domestic Assembly Plants	Average Vehicle Output Per Plant
GM	1950	3,653,358	21	173,969
	1960	3,687,696	22	167,623
	1970	3,591,906	23	156,170
	1980	4,653,286	24	193,887
Ford	1950	1,897,242	18	105,402
	1960	2,229,473	16	139,342
	1970	2,643,737	15	176,249
	1980	1,888,457	14	134,890
Chrysler	1950	1,313,239	8	164,155
	1960	1,089,600	6	181,600
	1970	1,452,043	7	207,435
	1980	758,206	9	84,245
Toyota	1950	11,706	1	11,706
	1960	149,694	2	74,847
	1970	1,592,888	4	398,222
	1980	3,254,942	5	650,988
Nissan	1950	12,458	2	6,229
	1960	129,893	2	64,947
	1970	1,421,142	5	284,228
	1980	2,648,674	6	441,446
Mazda	1960	43,142	1	43,142
	1970	429,847	2	214,924
	1980	1,121,016	2	560,508

Sources: Data for U.S. producers are from Wards Automotive Reports (except for 1950 production data which are from company annual reports). Data for Japanese producers are from company annual reports.

[19] Friedlaender, Winston and Wang (1983) found constant returns to scale on average for the major US auto producers since the 1950's; while Aizcorbe, Winston and Friedlaender (1987) obtained similar results for Japanese producers since 1970. Fuss and Waverman (1985) found slightly increasing returns to scale for US and Japanese automakers during the 1970's. Thus, there is little evidence from prior studies that Japanese or US productivity growth in the auto industry has been derived largely from economies of scale.

[20] Table 4 shows that the annual volume per assembly plant for Japanese producers did not level off after scale economies were achieved at roughly 200,000 annual vehicles per plant. Japanese producers have commonly expanded output by adding additional assembly lines to existing plants. Such behavior is induced by high land prices and the difficulty of procuring new factory space in Japan.

scale economies were an important factor contributing to the productivity growth of Japanese producers during the post-war economic recovery, but the role of scale economies was greatly diminished by the early 1960's, the start of coverage for most of the Japanese data used in this study.

6.2. *Just-in-Time Manufacturing Methods*

One frequently-cited reason for the rapid productivity growth of the Japanese auto producers is their development of "just-in-time" (JIT) manufacturing methods (Schoenberger 1982; Hall 1983; Shingo 1988). Pioneered by Toyota in the 1950's and perfected by the firm over the next two decades, the just-in-time system diffused to other Japanese producers during the 1970's, and to US producers during the 1980's.

One key feature of the just-in-time system is continual reduction in work-in-process inventory levels. Reduction of work-in-process inventories exposes defects in the manufacturing process and forces managers and workers to eliminate sources of production variability. Figure 3 plots the level of work-in-process plus raw materials inventory,[21] as a fraction of annual cost of goods sold, for US and Japanese automakers from the early 1960's through 1987.

Having developed the JIT system in the 1950's, Toyota appears in Figure 3 with consistently low inventory levels, which decline roughly 50% by the 1980's. Nissan begins with higher inventory levels and shows similar percentage reductions. Prior to 1975, Mazda had large and widely-fluctuating work-in-process levels; subsequent adoption of JIT methods led to dramatic inventory reductions.

Adoption of JIT manufacturing philosophies by the US firms starting in the mid-1970's yielded gradual but significant inventory reductions. By the mid-1980's, the raw materials and work-in-process inventory of US producers had fallen to less than half of their historical levels, although still well above those of the Japanese.

Several tests were performed to determine whether changes in work-in-process inventory levels were related to changes in productivity. Over the sample period as a whole, significant negative correlations were found between the inventory ratios in Figure 3 and labor productivity for each firm. In the Cobb-Douglas model, however, these effects became insignificant when simple time trends were included for each firm. Thus, we are

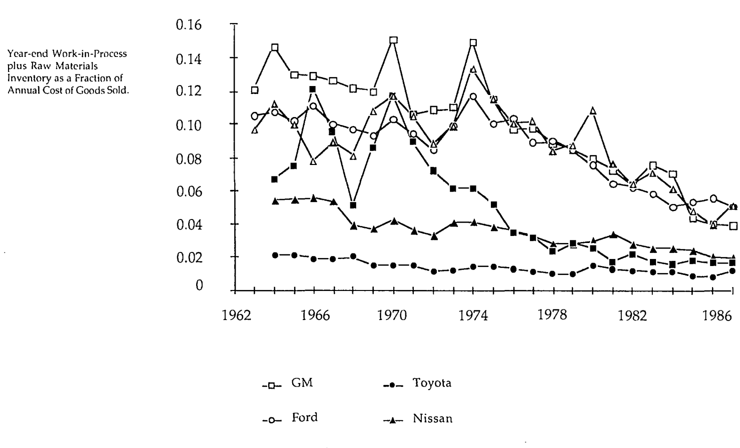

FIGURE 3. Work-in-Process Inventory Levels.

[21] In their 10-K reports, the US firms give combined figures for work-in-process and raw materials inventories; hence, raw materials inventories cannot be excluded from the data in Figure 3.

unable to conclude that the inventory ratios in Figure 3 have any causal link to productivity improvement by the six firms in the sample.

6.3. *Effect of Management Changes on Productivity Growth*

Tables 5a and 5b report the Cobb-Douglas production function estimates of total factor productivity growth. All regressions were estimated by ordinary least-squares, under the maintained hypothesis of constant returns to scale.[22]

Three pairs of regressions are shown in the table, where each pair corresponds to a different set of assumptions about β_i, the production elasticity of labor.[23] In regressions 5.1a and 5.1b, β_i is assumed to be distinct for each firm. In regressions 5.2a and 5.2b, β_i is assumed identical across firms within each country.[24] In regressions 5.3a and 5.3b, β_i is assumed identical across all six firms. Tests of these constraints support the hypothesis of identical production elasticities within each country (regressions 5.2a and 5.2b) but not across countries.[25]

Within each pair of regressions, the first equation assumes a constant rate of total factor productivity growth for each firm, while the second equation allows for productivity level and growth rate differences among management regimes of the firm.[26]

For each firm, we also tested the hypothesis of the absence of management effects, which is equivalent to

$$\ln A^*_{0,ij} = 0, \qquad j = 1, \ldots, J_i; \tag{29}$$

$$\gamma^*_{ij} = 0, \qquad j = 1, \ldots, J_i. \tag{30}$$

The test statistics are presented in Table 6. The hypothesis of no top management effects can be rejected at the 0.01 level for all of the firms except Toyota. Moreover, as Table 5a indicates, the Durbin-Watson statistics improve significantly with the inclusion of the top management effects.

A comparison of the estimated company growth rates (γ_i's) from regressions 5.2a and 5.2b indicates that they change drastically when top management effects are included. In particular, none of the US firms have a statistically significant average trend; much of each firm's long-term productivity growth is captured by jumps in the level of productivity between executive regimes.

The estimated management coefficients in Table 5b can be interpreted as follows, using Donald Petersen at Ford as an example. Petersen's [$\ln \hat{A}^*_{0ij}$] coefficient of 0.21 indicates that Ford's productivity level in the initial year of Petersen's regime was 21% above the average initial year productivity level of all Ford executives over the sample period. Petersen's γ^*_{ij} coefficient indicates that his annual rate of productivity growth was 3.1% above the average of all Ford executives; this deviation is statistically significant

[22] Tests of this maintained hypothesis showed that it could be accepted for all producers except Nissan.

[23] Under the assumption of constant returns to scale, the production elasticity of capital is $1 - \beta_i$.

[24] The production elasticity of labor for US firms estimated from regression 5.2b is 0.31, which is much lower than labor's observed shares of income and cost. (One possibility is that the labor market in the US is not perfectly competitive.) For Japanese firms the estimated production elasticity of labor is 0.58, which is about equal to the observed cost shares and slightly higher than the observed income shares.

[25] Based on the regressions with top management effects, the hypothesis that the β_i's are identical within each country cannot be rejected given that the relevant F-statistic of 2.11 falls below the critical value of $2.43_{4,135}$ at the 0.05 level. The hypothesis that the β_i's are identical across countries, conditional on the first hypothesis, has an F-statistic of 6.54. This second hypothesis can be rejected at the .05 level (critical value $3.91_{1,135}$) but not at the 0.01 level (critical value $6.82_{1,135}$).

[26] The productivity growth rate parameter cannot be estimated for the most recent regime at Mazda, given that only one year of data is available.

TABLE 5a

Productivity Estimates Based on Cobb-Douglas Production Function Model†

	5.1a	5.1b	5.2a	5.2b	5.3a	5.3b
			$\ln A_{0i}$ (Company constant terms)			
General Motors	6.94**	10.8**	7.18**	10.4**	6.99**	8.21**
	(1.02)	(.60)	(.72)	(.85)	(.47)	(.56)
Ford	4.70**	7.71**	7.18**	10.4**	6.98**	8.25**
	(1.16)	(1.51)	(.73)	(.85)	(.47)	(.57)
Chrysler	8.79**	12.8**	7.18**	10.3**	6.99**	8.14**
	(1.08)	(1.07)	(.73)	(.87)	(.48)	(.58)
Toyota	7.09**	7.91**	6.76**	7.04**	6.96**	7.90**
	(.38)	(.60)	(.59)	(.68)	(.47)	(.56)
Nissan	9.19**	5.77**	6.60**	7.15**	6.80**	7.99**
	(1.65)	(1.57)	(.59)	(.68)	(.47)	(.56)
Mazda	2.36	5.73**	6.41**	7.32**	6.61**	8.17**
	(1.31)	(1.15)	(.60)	(.68)	(.48)	(.56)
strike dummy (Chrysler)	−0.17*	−0.03	−0.26**	−0.16**	−0.28**	−0.27**
	(.07)	(.06)	(.06)	(.05)	(.05)	(.03)
$\ln A^*_{0ij}$ (Management level effects)	—	(Table 5b)	—	(Table 5b)	—	(Table 5b)
			β_i (Labor elasticities)			
General Motors	0.63**	0.27**				
	(.09)	(.05)				
Ford	0.83**	0.55**	0.61**	0.31**		
	(.11)	(.13)	(.07)	(.08)		
Chrysler	0.46**	0.09				
	(.10)	(.09)			0.62**	0.50**
Toyota	0.61**	.50**			(.04)	(.05)
	(.03)	(.05)				
Nissan	0.41**	0.70**	0.64**	0.58**		
	(.15)	(.14)	(.05)	(.06)		
Mazda	1.00**	0.72**				
	(.12)	(.10)				
			γ_i (Company growth rates)			
General Motors	.020**	.003	.020**	.003	.020**	.001
	(.004)	(.006)	(.003)	(.006)	(.002)	(.007)
Ford	.027**	.028*	.021**	.008	.021**	.024**
	(.003)	(.013)	(.002)	(.008)	(.002)	(.007)
Chrysler	.025**	−.007	.027**	.004	.027**	.013
	(.003)	(.008)	(.002)	(.007)	(.002)	(.008)
Toyota	.058**	.056**	.060**	.059**	.059**	.056**
	(.003)	(.003)	(.004)	(.003)	(.004)	(.004)
Nissan	.038**	.051**	.052**	.047**	.051**	.045**
	(.010)	(.017)	(.006)	(.015)	(.005)	(.014)
Mazda	.071**	.021	.057**	.014	.057**	.009
	(.004)	(.017)	(.004)	(.015)	(.004)	(.014)
γ^*_{ij} (Management growth differences)	—	(Table 5b)	—	(Table 5b)	—	(Table 5b)
SSR	2.34	0.80	2.58	0.85	2.58	0.89
Log Likelihood	151.8	255.0	142.4	249.3	142.4	244.9
Durbin-Watson statistic	0.68	1.35	0.57	1.20	0.57	1.26
Number of observations	193	193	193	193	193	193

† See text for description of model. Numbers in parentheses are estimated standard errors.
* Significant at the 0.05 level.
** Significant at the 0.01 level.

TABLE 5b

Productivity Level and Growth Deviation from Company Averages Among Top Executives, Based on Cobb-Douglas Production Function Model†

CEO Name	5.1b		5.2b		5.3b	
	$\ln A^*_{0ij}$	γ^*_{ij}	$\ln A^*_{0ij}$	γ^*_{ij}	$\ln A^*_{0ij}$	γ^*_{ij}
GM:						
Sloan	−0.07	−.011	−0.09	−.009	−0.21**	.001
(1950–1956)	(.04)	(.006)	(.05)	(.007)	(.04)	(.009)
Bradley	−0.18**	−.014*	−0.19**	−.014*	−0.25**	−.013
(1956–1959)	(.02)	(.007)	(.02)	(.007)	(.02)	(.009)
Donner	−0.03	−.006	−0.04	−.003	−0.12**	.013
(1959–1968)	(.03)	(.007)	(.04)	(.008)	(.03)	(.008)
Roche	−0.13**	.013	−0.12**	.009	−0.06	−.010
(1968–1971)	(.03)	(.011)	(.03)	(.013)	(.03)	(.017)
Gerstenberg	0.07*	.023	0.09*	.018	0.17**	−.006
(1971–1974)	(.03)	(.017)	(.04)	(.019)	(.04)	(.023)
Murphy	0.21**	.010	0.22**	.011	0.26**	.013
(1974–1980)	(.03)	(.008)	(.03)	(.008)	(.03)	(.010)
Smith	0.14**	−.015	0.15**	−.012	0.21**	.002
(1980–)	(.03)	(.010)	(.04)	(.011)	(.04)	(.012)
Ford:						
Breech	−0.12	−.047**	0.05	−.054**	−0.09	−.049**
(1950–1960)	(.09)	(.009)	(.06)	(.008)	(.05)	(.009)
Henry Ford II	−0.33*	.005	−0.34**	.021**	−0.33**	.008
(1960–1979)	(.03)	(.012)	(.03)	(.007)	(.03)	(.007)
Caldwell	0.13**	−.000	0.07*	.003	0.12**	.000
(1979–1984)	(.04)	(.012)	(.03)	(.008)	(.04)	(.011)
Petersen	0.32**	.042**	0.21**	.031**	0.30**	0.40**
(1984–)	(.06)	(.016)	(.04)	(.010)	(.04)	(.014)
Chrysler:						
Keller	−0.07	−.010	−0.12**	−.018*	−0.16**	−.025**
(1950–1956)	(.03)	(.009)	(.03)	(.008)	(.03)	(.008)
Colbert	−0.21**	−.079**	−0.22**	−.062**	−0.23**	−.046**
(1956–1961)	(.02)	(.009)	(.03)	(.010)	(.04)	(.013)
Love	−0.07	.020	−0.07	.013	−.07	.007
(1961–1967)	(.06)	(.013)	(.05)	(.011)	(.04)	(.011)
Townsend	−0.15**	.047**	−0.13**	.034**	−0.11**	.022*
(1967–1975)	(.03)	(.009)	(.03)	(.009)	(.04)	(.010)
Riccardo	0.10*	.036**	0.17**	.024	0.23**	.013
(1975–1979)	(.04)	(.014)	(.04)	(.016)	(.06)	(.021)
Iacocca	0.40**	−.013	0.37**	.010	0.33**	.030*
(1979–)	(.06)	(.015)	(.06)	(.014)	(.06)	(.014)
Toyota:						
Ishida	−0.17**	−.007*	−0.21**	−.006*	−0.17**	−.007*
(1961–1971)	(.05)	(.003)	(.05)	(.003)	(.04)	(.003)
Toyoda	0.17**	.007*	0.21**	.006*	0.17**	.007*
(1971–)	(.05)	(.003)	(.05)	(.003)	(.04)	(.003)
Nissan:						
Kawamata	−0.58**	.014	−0.50**	.009	−0.45**	.007
(1961–1984)	(.10)	(.016)	(.06)	(.014)	(.05)	(.013)
Ishihara	0.58**	−.014	0.50**	−.009	0.45**	−.007
(1984–)	(.10)	(.016)	(.06)	(.014)	(.05)	(.013)
Mazda:						
T. Matsuda	−0.62**	−.005	−0.52**	−.015	−0.46**	−.019
(1963–1971)	(.07)	(.014)	(.06)	(.014)	(.05)	(0.14)

TABLE 5b (*cont'd*)

	5.1b		5.2b		5.3b	
CEO Name	$\ln A^*_{0ij}$	γ^*_{ij}	$\ln A^*_{0ij}$	γ^*_{ij}	$\ln A^*_{0ij}$	γ^*_{ij}
K. Matsuda	−0.45**	.017	−0.43**	.022	−0.42**	.024
(1971–1977)	(.04)	(.015)	(.03)	(.015)	(.03)	(.015)
Yamasaki	0.88	.058**	0.11*	.052**	0.13*	.049**
(1977–1984)	(.06)	(.015)	(.05)	(.014)	(.05)	(.014)
Watanabe	0.63**	−.069	0.56**	−.059	0.52**	−.054
(1984–1987)	(.08)	(.039)	(.07)	(.036)	(.06)	(.035)
Yamamoto	0.36**	—	0.28**	—	0.23**	—
(1987–)	(.08)		(.06)		(.05)	

† See text for description of model. Numbers in parentheses are estimated standard errors.
* Significant at the 0.05 level.
** Significant at the 0.01 level.

at the .01 level. The average annual rate of productivity growth for Petersen's regime from 1984 through 1987, $(\hat{\gamma}_i + \hat{\gamma}^*_{ij})$, was 3.9%.

Figure 4 plots the levels of total-factor productivity for each of the management regimes, based on the estimates in regressions 5.1b, 5.2b, and 5.3b. (Our preferred specification is regression 5.2b, but the reader may choose otherwise.) For firm i and management regime j, what is plotted is the estimated total factor productivity, given by

$$\ln \hat{A}_{ij}(t) = [\ln \hat{A}_{0i} - \ln \hat{A}^*_{0ij} + (\hat{\gamma}_i + \hat{\gamma}^*_{ij})(t - t_{ij})]d_{ij}, \tag{31}$$

with the 1970 level of productivity normalized to equal 100. The figure illustrates the shifts in productivity level and growth rate associated with specific regimes. It is clear that significant differences in firm performance (as measured by productivity) existed under top management regimes at all of the firms except perhaps Toyota.

7. Conclusions

Our results show that productivity improvement in the auto industry has been attained primarily through more efficient utilization of labor; long-term growth in capital productivity was close to zero for most firms. All three Japanese producers in our sample had attained significant labor productivity advantages over their US rivals by the late 1970's. More recently, though, considerable divergence has occurred among firms within each country, with large productivity gains for Ford and Chrysler in the US and a slowing of productivity of growth for Nissan in Japan.

Our results provide insight into some of the factors that have influenced productivity growth. The early post-war growth of Japanese producers was derived in part from attainment of scale economies, but this source of improvement was largely exhausted by the mid-1960's. In more recent years, adoption of just-in-time manufacturing systems

TABLE 6
Significance Tests of Top Management Effects

	GM	Ford	Chrysler	Toyota	Nissan	Mazda
F-Ratio	3.77	6.44	6.93	3.79	15.35	9.57
Degrees of Freedom	12,135	6,135	10,135	2,135	2,135	7,135
Critical Value at:						
1 percent	2.31	2.93	2.45	4.76	4.76	2.77
5 percent	1.82	2.16	1.89	3.06	3.06	2.07

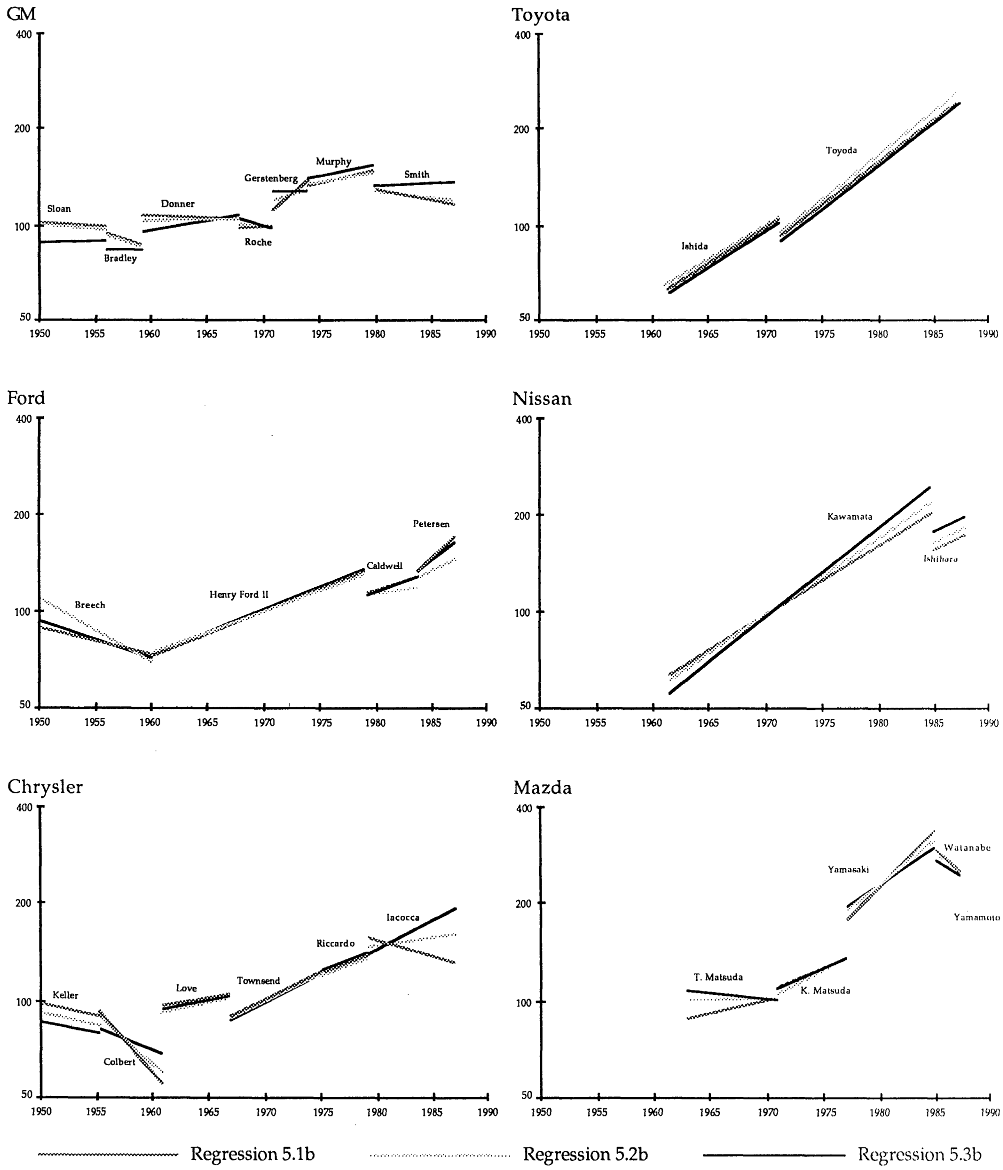

FIGURE 4. Total Factor Productivity Estimates for Chief Executive Regimes.†

† Vertical scale gives estimated total factor productivity relative to the firm's level in 1970 (=100).

appears to have contributed to productivity gains in both Japan and the US (although the evidence on this point remains circumstantial). The strongest statistical findings relate to the effects of managerial succession: for all companies except Toyota, changes in top management were followed by significant shifts in the level and growth rate of total factor productivity.

Prior studies have reached varying conclusions regarding the impact of management turnover on firm performance (e.g., Hambrick and Finkelstein 1987; Friedman and Singh 1989). Our findings support the view that top management often exerts a strong influence.[27] More generally, our results suggest that management effects, rather than

[27] Our tests do not, however, rule out the possibility that management turnover and productivity change were stimulated by common, external factors.

country-specific factors, are now the major source of productivity differences among American and Japanese manufacturing companies, at least in the automotive industry. For some firms (such as Toyota) superior performance has been sustained for decades, while for others (such as Mazda and Ford) there have been large shifts in productivity associated with changes in managerial regime. While our findings imply the existence of top management effects, additional research is needed to identify the exact nature of managerial influence and the conditions under which its impact is greatest.

The measurement techniques employed in this study offer potential for future application in strategy research. We have shown that firm-level productivity analysis provides a feasible and informative method of performance evaluation.[28] It enables quantitative assessment of an organization's improvement over time, as well as comparison with competitors. Moreover, we have demonstrated a method for testing the impact of management changes on productivity. The productivity measurement methodology appears to provide reasonably accurate performance assessments, in that the specific findings of this study are generally consistent with less formal evaluations in the business press.[29]

[28] An advantage of the methodology is that it can be implemented with publicly-available data. One limitation is that productivity comparisons can be difficult when producers are undiversified. For the six firms in our sample, nonautomotive operations have historically accounted for less than ten percent of company sales.

[29] We are grateful for comments by Jeffrey Pfeffer, an anonymous referee, and seminar participants at Chicago, UBC, UCLA, USC and the Wharton Conference on Strategy Research.

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