ASSESSING THE RESOURCE BASE OF JAPANESE AND U.S. AUTO PRODUCERS

MARVIN B. LIEBERMAN
UCLA Anderson School of Management
110 Westwood Plaza
Los Angeles, CA 90095-1481

RAJEEV DHAWAN
Georgia State University

INTRODUCTION

In recent years strategic management scholars have expressed enormous interest in the resource-based view (RBV) of the firm. Despite its appeal as a conceptual framework, the RBV has often been criticized for lack of an empirical base. Few researchers have been able to develop measures of resources and capabilities, identify their importance in a specific industry context, and link firms' resource positions to dimensions of performance. In this paper we attempt such an investigation of Japanese and U.S. automobile companies from the 1960s through 1997. Our findings show long-lived differences in efficiency among the auto producers, which arguably are equivalent to sustained competitive advantage.

Our methodology draws upon work by Battese and Coelli (1995) on the estimation of stochastic frontier production function (SFPF) models, which provide a framework for identifying the sources of inter-firm differences in efficiency. We demonstrate the potential of SFPF models for adding empirical content to the RBV.

DRIVERS OF PRODUCTIVE EFFICIENCY IN THE AUTOMOTIVE INDUSTRY

Prior studies of the automotive industry offer guidance on the types of resources and capabilities likely to be important in that sector. In a widely cited book on the automotive industry, Womak, Jones and Roos (1990) suggest that best practice has shifted in recent decades from a paradigm of "mass production" to one of "lean production." Within these two broad categories, we collected public data on U.S. and Japanese auto companies and computed various measures relating to output and employment, capital investment, manufacturing and design capabilities, firm and plant scale, and vertical integration.

STOCHASTIC FRONTIER PRODUCTION FUNCTION MODEL

Whereas the RBV views the firm as a bundle of resources and capabilities, neoclassical economics regards the firm as a vessel in which labor, capital, (and other potential inputs) are combined to form productive outputs. This notion is captured by the concept of a "production function." Conceptually, the production function embodies the tradeoffs faced by an efficient firm that utilizes best practice methods for its industry. Most firms are not fully efficient, and thus they fall below the industry frontier. SFPF models identify the industry production frontier and the relative positions of firms, where "technical efficiency" (*TE*) corresponds to the firm's scaling factor relative to the frontier, in the range: $0 < TE \leq 1$.

The production frontier model has the general form,

$$Y_{it} = F(K_{it}, L_{it})\, TE(Z_{it}) \qquad (1)$$

Formatted: German (Germany)

where Y_{it} denotes the output of firm i in period t, and K_{it} and L_{it} are the firm's capital and labor inputs. Output is determined by the product of the industry production function $F(\bullet)$ and the firm's technical efficiency, $TE(\bullet)$, which is parameterized as a function of firm-specific factors, denoted by the vector, Z_{it} . Viewing capital and labor as the firm's basic resources, and Z_{it} as its vector of capabilities, the model formalizes some common notions of the RBV. For example, Amit and Shoemaker (1993: 35) state that resources are "stocks of available factors that are owned or controlled by the firm ... property, plant and equipment, human capital, etc. Capabilities, in contrast, refer to a firm's capacity to deploy resources ... they can abstractly be thought of 'intermediate goods' generated by the firm to provide enhanced productivity of its resources." Such conceptions of the RBV resemble the frontier production function model.

The stochastic frontier model can be written as:

$$\ln (Y/L)_{it} = \mu t + \theta \ln (K/L)_{it} + \gamma \ln (L)_{it} + V_{it} - U_{it} \quad (2)$$

where Y/L represents value added per employee, K/L is capital stock per employee, L is the number of employees, and V_{it} and U_{it} are the error terms of the SFPF model. The dependent variable in this transformed model is value added per employee, or labor productivity. We expect that productivity will rise with investment per worker (K/L), and possibly with the size of the firm (L). In addition, labor productivity will be influenced by other resources and capabilities of the firm, as represented by the factors in U_{it}.

We incorporate measures within the technical inefficiency component of the stochastic frontier as follows:

$$U_{it} = \delta_0 + \delta_1 \ln (W/S)_{it-1} + \delta_2 \ln (V/S)_{it-1,4} + \delta_3 (CD)_{it} + \delta_4 \ln (Q)_{it} + \delta_5 \ln (Q/N)_{it} + \delta_6 \ln (\Sigma Q)_{it} + W_{it} \quad (3)$$

where W/S_{it} is the WIP inventory to sales ratio (a proxy for manufacturing capabilities), $V/S_{it-1,4}$ is the four-year moving average of the value added to sales ratio (measuring the firm's degree of vertical integration), CD_{it} is a two-year moving average of the number of design citations awarded the firm by *Car and Driver* (a crude measure of design capabilities), Q_{it} is the total number of motor vehicles produced by the firm in its home market during year t, Q/N_{it} is the average vehicle output per assembly plant in year t, and ΣQ_{it} is the firm's historical cumulative domestic vehicle production through the start of year t. A positive value of the δ coefficient associated with any of these variables indicates that as the level of that variable goes up, the level of technical *inefficiency* also goes up and vice-versa.

RESULTS

The first three parameters in Table 1 relate to the production frontier. The frontier is specified as a function of capital and labor inputs and is assumed to be shifting at a constant rate. The time trend, μ, implies that the frontier level of efficiency increased at an average rate of about 2.5% per year. The capital elasticity coefficient, θ, identifies a statistically and quantitatively significant association between greater capital investment and higher labor productivity. The returns to scale parameter, γ, suggests significant increasing returns to scale in the production function.

Table 1 about here.

The coefficients in the inefficiency model are of prime interest in our study. The WIP/sales coefficient, δ_1, is positive in all regressions and generally highly significant, suggesting that higher levels of WIP were associated with lower levels of efficiency, as expected. Thus, the results point to the importance of lean manufacturing skills on the factory floor.

Another strong result relates to plant scale. The coefficient for average output per assembly plant, δ_5, is negative and highly significant, implying that efficiency was higher for firms that produced more vehicles per plant. This finding may denote the joint influence of scale economies and manufacturing capabilities associated with mixed-model assembly. Firms with such capabilities are able to operate with lower levels of WIP inventory, which may account for the reduced coefficient for WIP/sales when volume per plant is included.

Our measures relating to supplier integration and product design give weak or insignificant results. Regressions 4, 5 and 7 show that the value added/sales measure of backward integration into parts production becomes significant when included with volume per plant. The positive sign of δ_2 implies that more integration into parts production was associated with greater inefficiency. The measure of design quality collected from *Car and Driver* is statistically insignificant in regressions 6 and 7 and carries the wrong sign. Thus, there is no evidence that firms with more design awards had higher levels of efficiency.

To summarize the main findings in Table 1, our estimates of the production function show that greater capital investment was associated with higher labor productivity, as expected. Moderate economies of scale are observed at the firm level. The best practice frontier gradually shifted outward, presumably as the result of technical progress not captured by factors in our model. Furthermore, estimates of the inefficiency model show the presence of scale economies at the plant level, and a connection between WIP inventory and efficiency. Less conclusive evidence suggests that firms with more vertical integration were less efficient. We find no indication of a general "learning curve" at the firm level, and no connection between firm efficiency and our *Car and Driver* measure of design quality.

EXPLAINING DIFFERENCES IN PERFORMANCE AMONG FIRMS

Technical efficiency is a summary measure of firms' performance. Figure 1 shows the estimated technical efficiency of the automotive producers in each year, based on regression 5. The top margin of the graph corresponds to the industry's efficiency frontier, which was increasing at a rate of about 2.8% per year, according to the value of μ in regression 5. The *TE* estimates in Figure 1 suggest that Toyota has operated close to the frontier since the late 1970s, whereas General Motors (GM) has been falling away from the frontier. Other firms typically lie in between.

Figure 1 about here.

One can apply the estimates from Table 1 to draw comparisons among firms. One challenge is to account for the substantial differences in performance that have existed between Toyota and GM. On average, GM's output (value added) per worker was only 62% of Toyota's. GM had more than 13 times as many employees as Toyota, but with only 79% as much investment per worker. GM's assembly plants had about one-fourth the average volume of Toyota's. Within its plants, GM held about ten times more WIP inventory, as a fraction of sales. GM also maintained substantially more backward integration into parts production: internal operations represented 46% of final sales revenue for GM, as compared with 18% for Toyota.

Taking the logarithm of these ratios and multiplying by the applicable regression coefficients, it is possible to make an estimate of the contribution of each factor in explaining the overall differential in output per worker. The labor productivity differential between GM and Toyota equals -0.48 in log terms. Based on the coefficients from regression 1 of Table 1, this differential can be attributed about equally to Toyota's superior positions relating to WIP inventory (2.35 x –0.1229 = -0.29) and output per plant (-1.27 x 0.1840 = -0.23), with an additional small effect due to Toyota's higher investment (-0.24 x 0.3655 = -0.09). Our estimates suggest that these disadvantages were partly offset by GM's greater economies of scale at the firm level (2.62 x 0.0897 = 0.24). Thus, the four factors in combination may account for about three-fourths (=0.37/0.48) of the labor productivity differential between GM and Toyota.

Similar calculations show that Toyota enjoyed substantial advantages in labor productivity relative to most producers. These advantages were based on many factors considered in this study: capital investment, firm and plant scale, and WIP.

CONCLUSIONS

The contributions of our study are methodological and substantive. By combining the perspective of the resource-based view with the methods of production economics, we have outlined an approach for making the RBV operational. Applying the SFPF model of Battese and Coelli (1995) to public data on eleven automotive companies, we have identified firms' positions relative to the industry best practice frontier. Furthermore, we have shown how the parameter estimates of the model shed light on potential determinants of firm performance in the auto industry. Our estimates suggest that productivity differentials among automakers have been mostly the result of differences in organization and scale.

Our findings point to the importance of operational effectiveness as a source of competitive advantage in the automotive industry. Toyota has long been the industry's most efficient producer and has increased its lead over time. Porter (1996) argues that operational effectiveness alone is not sufficient for a firm to achieve sustainable competitive advantage; the firm must also have a market position that insulates it from competitors. While this is true in industries where operational improvements can be easily imitated, the differentials we have identified in the automotive industry have been sustained for long periods. Many years or decades have been required for the imitation of superior scale and organizational skills. Consequently, lagging firms have converged only slowly to industry best practice (if at all), while stronger firms such as Toyota that define the frontier have made continual advances, thereby maintaining or expanding their lead. Such findings raise questions about the relative importance of operational effectiveness versus market position as sources of competitive advantage.

REFERENCES

Amit, R. & Schoemaker, P. 1993. Strategic Assets and Organizational Rent. **Strategic Management Journal,** 14: 33-46.

Battese, G.E. & Coelli, T. J. 1995. A Model of Technical Inefficiency Effects in Stochastic Frontier Production Functions for Panel Data. **Empirical Economics,** 20: 325-332.

Porter, M. E. 1996. What is Strategy? **Harvard Business Review** (Nov.-Dec.).

Womack, J. P., Jones, D. T. & Roos, D. 1990. **The Machine that Changed the World: The Story of Lean Production**. Rawson Associates.

Table 1. Parameter Estimates of the Stochastic Frontier Model*

		1	2	3	4	5	6	7
Stochastic Frontier								
Time	μ	**0.024** (0.003)	**0.027** (0.003)	**0.023** (0.003)	**0.025** (0.003)	**0.028** (0.003)	**0.025** (0.003)	**0.029** (0.003)
Capital/Labor Ratio	θ	**0.364** (0.051)	**0.321** (0.060)	**0.388** (0.062)	**0.317** (0.064)	**0.265** (0.061)	**0.347** (0.055)	**0.260** (0.061)
Employees	γ	**0.090** (0.011)	**0.105** (0.013)	**0.089** (0.014)	**0.108** (0.014)	**0.114** (0.014)	**0.098** (0.011)	**0.113** (0.014)
Inefficiency Model								
Constant	δ_0	**3.029** (0.462)	**0.747** (0.214)	**1.216** (0.268)	**1.182** (0.129)	**3.316** (0.442)	**1.117** (0.109)	**3.366** (0.449)
WIP/Sales Ratio (lagged)	δ_1	**0.123** (0.030)	**0.186** (0.024)	**0.192** (0.028)	**0.166** (0.030)	0.062 (0.034)	**0.201** (0.027)	**0.078** (0.036)
Value-Added/Sales Ratio (lagged)	δ_2				0.105 (0.072)	**0.196** (0.071)		**0.161** (0.076)
Design Quality	δ_3						0.035 (0.022)	0.035 (0.023)
Number of Vehicles Produced	δ_4			-0.011 (0.021)				
Volume per Plant	δ_5	**-0.184** (0.040)				**-0.197** (0.039)		**-0.202** (0.039)
Cumulative Production	δ_6		0.022 (0.012)					
Variance Parameters								
	σ^2_S	0.052 (0.006)	0.054 (0.006)	0.055 (0.007)	0.054 (0.006)	0.050 (0.005)	0.055 (0.006)	0.050 (0.006)
	γ	0.563 (0.169)	0.700 (0.149)	0.599 (0.204)	0.633 (0.184)	0.577 (0.162)	0.649 (0.164)	0.589 (0.154)
Loglikelihood Function		45.03	33.28	31.95	32.78	48.62	32.00	49.75
# Observations		336	336	336	336	336	336	336

* Standard errors in parentheses. Coefficients in bold are significant at the .05 level.

Figure 1. Technical Efficiency by Firm and Year