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Productivity of Automobile Industries using the Malmquist Index: Evidence from the Last Economic Recession

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Abstract

In this paper, the financial information provided by *Fortune Magazine* is used to study the productivity changes in the global auto industry during 1991-1997, including automakers from the USA, Europe, Japan, and South Korean. The paper seeks to uncover global auto industry's productivity changes during the early 1990s economic recession. Data envelopment analysis (DEA) is used to identify the empirical performance frontier. A new DEA-based Malmquist productivity index is used to further analyze the two Malmquist components. The analysis not only reveals patterns of productivity change and presents a new interpretation along with the managerial implications of each Malmquist component, but also the analysis identifies the strategy shifts of individual companies based upon isoquant changes. The labor efficiency and overcapacity of the global auto industry is studied, and judgments can be made about whether such strategy shifts are favorable and promising.

Keywords: Data Envelopment Analysis (DEA), efficiency, Malmquist, productivity, auto industry.

JEL Classification code: C02

The automotive industry crisis during the period 2008 to 2010 was a part of a global financial downturn that affected U.S., European, and Asian automobile manufacturers. In particular, the U.S. auto industry is still on a slow road to recovery. The crisis raises questions about whether the U.S. auto industry will survive the recession and how the U.S., European, and Asian automobile manufacturers were performing during and after the economic recession of early 1990s.

"GM built 8.6 million cars and trucks in 1995. If they were lined up on the equator bumper to bumper, they would stretch all the way around the world, a lane of traffic 25,000 miles long" (Taylor III, 1996). This is a big achievement. However, its overall market share of 33.9% in 1995 still represents a steep decline from the 47.7% market share peak in 1978. Compared to the glory days of the 1950s and 1960s, GM has been spending much and making little; for example, return on assets, a measure of how efficiently a company uses its capital, skidded downward from 17% in 1965 to below zero, then nudging to 3.2% in 1995.

GM is not alone among American carmakers. After the worst decline in market share in the 1980s and huge profit losses at the beginning of the 1990s, American carmakers boosted their market share after a bottoming out in 1986 and registered record-high earnings between 1994 and 1996. Despite that recovery, the Big Three (GM, Ford, and Chrysler) are facing a challenge to break bottlenecks and squeeze out more production without investing in expensive facilities. Meanwhile, with the aggressive competition from Japanese and European carmakers, how to obtain productivity gain from the workforce is a tough challenge for the Big Three.

Excess capacity is another key issue of concern to carmakers. Overcapacity means not only high fixed costs but also the burden of heavy financial investment. According to AutoFacts Inc., worldwide auto sales were around 50 million vehicles a year, and plant overcapacity was 18 and 22 million vehicles for 1996 and 1998 respectively. North America alone has an excess capacity of about 3.4 million vehicles a year. If capacity were too far ahead of demand, factory closings, layoffs, business failures, and macroeconomic ramifications would be the result. William Pochiluk, the president of AutoFacts, claimed the key issue "is that overcapacity is a destabilizing influence. Good companies will be forced to do crazy things" (Simison, 1998).

According to a U.S. Federal Reserve Bulletin in January 1999, the rate of growth in industrial production is 8.9%, 0.6%, -1.4%, 12.8%, and -9.2% for the automobile industry from 1994 to 1998. The rate of growth in capacity is 5.5%, 8.4%, 3.9%, 3.2%, and 2.5% for the industry from 1994 to 1998. Destabilizing overcapacity and its influence are obvious in the auto industry and motivated this study on productivity change in the automobile industry.

In this paper, the financial information provided by *Fortune Magazine* is used to study productivity changes for the global auto industry, including automakers from the USA, Europe, Japan, and South Korean during the period 1991-1997. The information provided will enable examination of the performance of auto industries around the world after the economic recession in the world during the period 1990-1991.

Because multiple *Fortune Magazine* performance measures are used, the data envelopment analysis (DEA) based Malmquist productivity index will be used. The Malmquist index was first suggested by Malmquist (1953) as a quantity index for use in the analysis of consumption of inputs. Färe, Grosskopf, Lindgren, and Roos (1992) combined ideas on the measurement of efficiency from Farrell (1957) and the measurement of productivity from Caves, Christensen, and Diewert (1982) to construct a Malmquist productivity index directly from input and output data using DEA.

The DEA-based Malmquist productivity index has proven to be a good tool for measuring productivity change in organizations. For example, Färe, Grosskopf, Lindgren, and Roos (1994b) studied productivity developments in Swedish hospitals, and Löthgren and Tambour (1999) studied productivity change in the Swedish eye-care service provision. Grifell-Tatjé, and Lovell (1996) studied the effect of deregulation on Spanish saving banks, and Fulginiti and Perrin (1997) studied changes in agricultural productivity in 18 developing countries. Other examples include an empirical investigation of the catch-up hypothesis for a group of high and low-income countries (Taskin & Zaim, 1997), telecommunications productivity, technology catch up and innovation in 74 countries (Madden & Savage 1999), and total factor productivity (TFP) evolution in Organization for Economic Co-operation and Development (OECD) countries (Maudos, Pastor, & Serrano, 1999), among others.

The Malmquist productivity index is composed of two components measuring change in the technology frontier and technical efficiency. Chen and Ali (2004) examined the two components to reveal sources and patterns of productivity change obscured by the aggregated nature of the Malmquist index. The approach allows the identification of strategy shifts of individual DMUs in a particular period.

In this study, the Chen and Ali (2004) approach is applied to assess the productivity changes of the auto industry represented by 22 *Fortune* Global 500 automobile companies. In the study, the managerial implications of each component of the Malmquist productivity index will be revealed; The rest of the paper is organized as follows: In the following section, the Malmquist index and the development by Chen and Ali (2004) is introduced briefly. Thereafter, the data and results are presented and interpreted. The final section concludes the study.

Malmquist Productivity Index

Suppose n organizations (decision-making units or DMUs) exist. Each uses m inputs, x_i, (i =1, …., m) to produce s outputs y_r (r = 1, …, s). Suppose a production function in time period t as well as period $t+1$ is apparent. The Malmquist index calculation requires two single-period and two mixed-period measures. The two single-period measures can be obtained by using the CCR DEA model (Charnes Cooper, & Rhodes, 1978):

$$
\begin{aligned}
&D_o^t(x_o^t, y_o^t) = \text{Min } \theta \\
&\text{s.t.} \\
&\sum_{j=1}^{n} \ddot{e}_j x_{ij}^t \le \theta x_{io}^t,\ i = 1,2,...,m, \\
&\sum_{j=1}^{n} \lambda_j y_{rj}^t \ge y_{ro}^t,\ r = 1,2,...,s, \\
&\lambda_j \ge 0,\ j = 1,2,...,n.
\end{aligned}
\tag{1}
$$

where, x_{io}^t is the ith input and y_{ro}^t is the rth output for DMU_o in period t. Using $t+1$ instead of t for the above model, $D_o^{t+1}(x_o^{t+1}, y_o^{t+1})$ is obtained, the technical efficiency score for DMU_o in time period $t+1$.

The first of the mixed-period measures, which is defined as $D_o^t(x_o^{t+1}, y_o^{t+1})$ for each DMU_o, $o \in \boldsymbol{Q} = \{1, 2\dots n\}$, is computed as the optimal value to the following linear programming problem:

$$
\begin{aligned}
&\text{Min } \theta \\
&\text{s.t.} \\
&\sum_{j=1}^{n} \lambda_j x_{ij}^t \le \theta\ x_{io}^{t+1},\ i = 1,2,...,m, \\
&\sum_{j=1}^{n} \lambda_j y_{rj}^t \ge y_{ro}^{t+1},\ r = 1,2,...,s, \\
&\lambda_j \ge 0,\ j = 1,2,...,n.
\end{aligned}
\tag{2}
$$

In a similar way, the other mixed-period measure, $D_o^{t+1}(x_o^t, y_o^t)$, can be obtained. Then the (input-oriented) Malmquist productivity index can be expressed as

$$
M_o = \left[\frac{D_o^t(x_o^{t+1}, y_o^{t+1})}{D_o^t(x_o^t, y_o^t)} \frac{D_o^{t+1}(x_o^{t+1}, y_o^{t+1})}{D_o^{t+1}(x_o^t, y_o^t)}\right]^{1/2} \tag{3}
$$

Färe, Grosskopf, Lindgren, and Roos (1992) suggested $M_o > 1$ indicates productivity gain; $M_o < 1$ indicates productivity loss; and $M_o = 1$ means no change in productivity from time t to $t+1$. Further, Färe, Grosskopf, Lindgren, and Roos (1992) decomposed their Malmquist productivity index into two components:

$$
\begin{aligned}
M_o &= \left[\frac{D_o^t(x_o^{t+1}, y_o^{t+1})}{D_o^t(x_o^t, y_o^t)} \frac{D_o^{t+1}(x_o^{t+1}, y_o^{t+1})}{D_o^{t+1}(x_o^t, y_o^t)}\right]^{1/2} \\
&= \frac{D_o^{t+1}(x_o^{t+1}, y_o^{t+1})}{D_o^t(x_o^t, y_o^t)} * \left[\frac{D_o^t(x_o^{t+1}, y_o^{t+1})}{D_o^{t+1}(x_o^{t+1}, y_o^{t+1})} \frac{D_o^t(x_o^t, y_o^t)}{D_o^{t+1}(x_o^t, y_o^t)}\right]^{1/2}
\end{aligned}
\tag{4}
$$

The first component, $TEC_o = \dfrac{D_o^{t+1}(x_o^{t+1}, y_o^{t+1})}{D_o^t(x_o^t, y_o^t)}$, measures the change in technical efficiency. The second component, $FS_o = \left[\dfrac{D_o^t(x_o^{t+1}, y_o^{t+1})}{D_o^{t+1}(x_o^{t+1}, y_o^{t+1})} \dfrac{D_o^t(x_o^t, y_o^t)}{D_o^{t+1}(x_o^t, y_o^t)}\right]^{1/2}$, measures the technology frontier shift between time period t and $t+1$.

Färe, Grosskopf, Lindgren, and Roos (1992) and Färe, Grosskopf, and Lovell, (1994a) pointed out that a value of $FS_o > 1$ indicates a positive shift or technical progress, a value of $FS_o < 1$ indicates a negative shift or technical regression, and value of $FS_o = 1$ indicates no shift in the technology frontier.

Chen and Ali (2004) studied $\frac{D_o^t(x_o^{t+1}, y_o^{t+1})}{D_o^{t+1}(x_o^{t+1}, y_o^{t+1})}$ and $\frac{D_o^t(x_o^t, y_o^t)}{D_o^{t+1}(x_o^t, y_o^t)}$ in FS_o and concluded the following:

(a) If $\frac{D_o^t(x_o^{t+1}, y_o^{t+1})}{D_o^{t+1}(x_o^{t+1}, y_o^{t+1})} > 1$ and $\frac{D_o^t(x_o^t, y_o^t)}{D_o^{t+1}(x_o^t, y_o^t)} > 1$, then the FS_o must be larger than 1, indicating that DMU_o is projected onto a facet that has a positive shift, and the technology of DMU_o progresses.

(b) If $\frac{D_o^t(x_o^{t+1}, y_o^{t+1})}{D_o^{t+1}(x_o^{t+1}, y_o^{t+1})} < 1$ and $\frac{D_o^t(x_o^t, y_o^t)}{D_o^{t+1}(x_o^t, y_o^t)} < 1$, then the FS_o must be less than one, indicating that DMU_o will be projected onto a facet that has a negative shift, and the technology of DMU_o declines.

(c) If $\frac{D_o^t(x_o^{t+1}, y_o^{t+1})}{D_o^{t+1}(x_o^{t+1}, y_o^{t+1})} > 1$ and $\frac{D_o^t(x_o^t, y_o^t)}{D_o^{t+1}(x_o^t, y_o^t)} < 1$, then FS_o could be larger or less than 1, then it is concluded the technology of DMU_o moves from a negative shift facet towards a positive shift facet. In addition, a change occurs in the tradeoff between the two inputs. Furthermore, $FS_o > 1$ indicates the change resulting from the positive shift facet is larger than is the negative shift facet, and on average, the technology of DMU_o progresses. $FS_o < 1$, indicates the change resulting from the positive shift facet is less than is the negative shift facet, and on average, the technology of DMU_o declines. $FS_o = 1$ indicates, on average, the technology of DMU_o remains the same.

(d) If $\frac{D_o^t(x_o^{t+1}, y_o^{t+1})}{D_o^{t+1}(x_o^{t+1}, y_o^{t+1})} < 1$ and $\frac{D_o^t(x_o^t, y_o^t)}{D_o^{t+1}(x_o^t, y_o^t)} > 1$, then FS_o could be larger or less than 1. It can be concluded the technology of DMU_o moves from a positive shift facet towards a negative shift facet. In addition, a shift occurs in the tradeoff between the two inputs. Similar to case (c), $FS_o > 1$ indicates, on average, the technology of DMU_o progresses. $FS_o < 1$, indicates, on average, the technology of DMU_o declines. $FS_o = 1$ indicates, on average, the technology of DMU_o remains the same.

For the last two cases (c) and (d), it can be said DMU_o changed its strategy because a change in the tradeoff between the two inputs occurred. From a productivity point of view, (c) is a more favorable situation for DMU_o than is (d). In this case, DMU represents the individual automaker.

Data and Results

In *Fortune Magazine*'s Global 500 companies, from 1991 to 1997, four American companies, eight Japanese companies, nine European companies, and one South Korean company represented the automobile industry. *Fortune Magazine* published a set of measures to characterize the performances of the companies. The measures were defined as follows:

- *Revenues:* Sales revenues in the annual income statement
- *Profits:* Net income before extraordinary items and discontinued operations in the annual incomes statement
- *Assets:* Total assets in the annual balance sheet, including total current assets and non-current assets
- *Equity:* Total equity in the annual balance sheet, which is equal to total assets minus total liabilities
- *Employees:* Number of employees, either a fiscal year-end or yearly average, as published by the corporation.

Although the currencies of the countries considered in this paper are different, such differences do not affect the DEA analysis. This is because revenue, profits, assets, and equity are measured in US$ by *Fortune Magazine*.

Based on the financial data of revenues, profits, assets, stockholders' equity, and number of employees, *Fortune Magazine* also ranked the top companies via six performance measures, namely, the biggest increases in revenues, highest profits, biggest increases in profits, highest returns on revenues, highest returns on assets, and largest number of employees. *Fortune Magazine*'s performance measures are traditional financial accounting measures popularly used in the business world.

Reported individual measures and simple ratios, such as return-on-assets and earnings-per-share, do not provide an assessment as comprehensive as possible when several measures are taken into account simultaneously, and sometimes, they may even give misleading signals for continuous improvement and innovation. Some managers and academic researchers have claimed, "The traditional financial performance measures worked well for the industrial era, but they are out of step with the skills and competencies [that companies] are trying to master today" (Kaplan & Norton, 1992).

Based upon the above measures, a labor efficiency index and a resource (capacity) utilization index are defined. The labor efficiency index uses an input-oriented CCR model with "employees" as the only input and "revenues," "assets," and "equity" as three outputs. The resource utilization index uses an input-oriented CCR model with "assets, "equity," and "employees" as the three inputs and "revenues" as the only output. Note the Malmquist approach used is based upon the CCR model, not the BCC model of Banker, Charnes, and Cooper (1984). This is because the BCC-based Malmquist model must be feasible for some units under evaluation. Please see Seiford and Zhu (1999) and Lee, Chu, and Zhu (2011).

In fact, corporations have recently been in flux and have sought to determine the effectiveness of the labor force. Downsizing, rightsizing, and production efficiency are based on the effective use of the labor force. The labor efficiency index is defined to determine a performance frontier (best practice) in terms of revenues, assets, and equity (output measures), and employees (input measure). The outputs are very important measures of financial performance and implicitly embody the activity of the labor force. The premise for this index is each employee contributes to the overall financial strength of a company.

The resource utilization index determines a performance frontier in terms of revenues (output measure) and assets, stockholders' equity, and employees (input measures). The index is based on the financial accounting measure *turnover*, which equals to revenues divided by assets. Turnover measures the rate at which a company's resources (assets) are turned into revenues. In the index used in this study, the concept of a company's resources is extended to a broader range, including equity and number of employees. The index also indicates whether a company generates healthy revenues with respect to these resources.

The Malmquist productivity index discussed in the previous section is used next to perform a study on measurement of productivity change in labor efficiency and resource (capacity) utilization in the automobile industry.

The results are presented first in Tables 1 to 10 as follows. Tables 1 and 2 report the technical efficiency change ratio (TEC_o) in terms of resource utilization and labor efficiency, respectively. Table 3 reports the frontier shift in terms of resource utilization. Table 4 reports the two ratios in FS_o in terms of the resource utilization. Table 5 reports the frontier shift in terms of labor efficiency. Table 6 reports the two ratios in FS_o in terms of labor efficiency. Table 7 represents the Malmquist productivity change in terms of resource utilization. Table 8 summarizes the ratio components for the Malmquist productivity change in terms of resource utilization. Table 9 represents the Malmquist productivity change in terms of the labor efficiency measure. Table 10 summarizes the ratio components for Malmquist productivity change in terms of the labor efficiency measure.

The performance of American auto companies during the period 1991-1997 is examined below. Because total motor vehicle sales reflect general economic conditions, and motor vehicle buying decisions are influenced heavily by changes in disposable personal income and consumer confidence levels, the national economic recession of 1991 had a strong impact on motor vehicle sales. The sharp sales decline in sales made numerous North American plants among the Big Three close temporarily for inventory correction, and car production was below planned levels in that year. Along with the recovery of the USA economy, sales of domestically produced cars in the USA, Canada, and Mexico rose 13%, to about 6.9 million in 1992.

The sales fluctuation had an impact on American auto companies' productivity change. From Table 3, in 1991-1992, the range of the Malmquist productivity improvement for the four American companies varies from

16.3% for TRW to 54.4% for GM in terms of resource utilization. During the same period, Table 9 indicates the range of the Malmquist productivity improvement for the four American companies varies from 4.5% for GM to 16.8% for TRW in terms of labor efficiency.

With respect to resource utilization, Table 8 indicates the productivity gains (M_o >1) for Ford and GM resulted from the technical efficiency progress (TEC_o >1) plus the technology movement from a negative shift facet (the second ratio in FS_o < 1) towards a positive shift facet (the first ratio in FS_o > 1). This indicates the strategy shift to dedicating most of their efforts and resources toward increasing production efficiency, improving quality, reducing costs, and shortening the time from concept to production paid off. The productivity gains for Chrysler and TRW resulted from the technical efficiency progress (TEC_o > 1 in Table 8) mixed with the technology regress (both ratios of FS_o < 1 in Table 8).

With respect to labor efficiency, Table 10 shows the Malmquist productivity changes for the Big Three resulted from the technology gain (both ratios of FS_o > 1 in Table 10) mixed with efficiency loss (TEC_o < 1 in Table 10). For TRW, the Malmquist productivity gain is from the efficiency progress (TEC_o > 1 in Table 10), mixed with technology regress (both ratios of FS_o < 1 in Table 10).

In 1992, Ford estimated and claimed the aggregate worldwide motor vehicle production capacity exceeded worldwide demand by approximately eight million units. It was mainly because of (a) Japanese automakers' recent capacity addition in North America, Asia, and the United Kingdom, and (b) the failure of GM to reduce its plant capacity to be in line with the market share losses during the 1980s.

The influence of this overcapacity trend in the resource utilization reports can be seen. Table 3 indicates (a) during 1991-1992, 19 of the 22 companies had negative technology frontier shift (FS_o < 1) and (b) during 1992 to 1993, 14 of 22 companies had negative technology frontier shifts. Overcapacity may be the main reason for the negative technology frontier shifts.

In 1993, U.S. automakers were in a better position to aggressively compete with foreign automakers in general and with Japanese automakers in particular because of (a) the strengthening of the U.S. economy; (b) rapid growth in the demand for light trucks (a market segment dominated by the Big Three); (c) a sharp rise in the value of the Japanese yen versus the U.S. dollar, which left Japanese automakers at a severe competitive disadvantage in terms of vehicle pricing; and (d) a significant improvement in the quality and styling of Big Three vehicles. Therefore, Chrysler, Ford, and GM have a Malmquist productivity gain 13.7%, 2.1%, and 12.6% for labor efficiency, and 7.1%, 11.1%, and 4.0% for resource utilization respectively during 1992 and 1993, as shown in Tables 7 and 9.

From 1993 to 1994, in terms of labor efficiency, Table 9 shows all four American companies have a Malmquist productivity gain, but only Chrysler is in the most desirable situation. The productivity gain of Chrysler is not only from the efficiency improvement (TEC_o > 1 in Table 10) but also from technology progress (both ratios in FS_o > 1 in Table 10). In terms of resource utilization, Table 7 shows only GM has a Malmquist productivity decline. Table 8 shows this loss was the result of an efficiency decline (TEC_o < 1). This may be due to two strikes by the United Auto Workers (UAW) union at the GM plants during the third quarter of 1994. The strikes forced GM to stop production at a number of assembly plants for several days.

Meanwhile, note that Chrysler's Malmquist productivity improves. The gain is the result of the positive value of the technology frontier shift; Table 8 shows (a) the technology of Chrysler moved from a positive shift facet to a negative shift facet, and (b) the technical efficiency of Chrysler even declined with respect to the regressed technology frontier facet. This is the most undesirable case because it indicates not only an unfavorable strategy shift, but also an efficiency decline with respect to the regressed technology frontier facet.

Despite the long-term worldwide capacity situation, in 1994, overcapacity in the North American market was beginning to decline. This is because of (a) the improving market demand in North America, (b) increased aggregate market share garnered by the Big Three, and (c) a steady increase in exports from North America to foreign markets. Note Table 3 shows 16 of the 22 companies during the 1993-1994 period, 21 of 22 during the 1994-1995 period, and 11 of 22 during the 1995-1996 period have positive technology frontier shifts in terms of resource utilization, which is strongly associated with the capacity utilization.

Although the problems caused by excess worldwide motor vehicle production capacity appeared to have abated in the 1994-1996 period, because the cyclical upturn in vehicle sales in the USA along with a market shift in the sales patterns in favor of light trucks permitted American automakers to earn strong profit in these years, Standard and Poor claimed in 1996 political shifts and socioeconomic change around the world would lead to a renewal of the problem. Table 3 shows that 21 of 22 companies have negative technology frontier shifts in terms of resource utilization, confirming Standard and Poor's statement.

With respect to labor efficiency, Table 9 shows the productivity gain for the Big Three varies from 2.2% for Chrysler to 8.0% for Ford during the 1994-1995 period, from 4.7% for Chrysler to 12%% for GM during the 1995-1996 period, and from 7.7% for GM to 9.7% for Chrysler during the 1996-1997 period. Table 10 shows the gains resulting from a combined effect of efficiency improvement and technology decline. The only exception is GM during the 1996-1997 period. According to Standard and Poor's industry survey, during this particular period, GM's efforts to reduce the number of workers required to accomplish a given production level was facing increased resistance from the UAW. The continuous strike organized by UAW at various carefully selected plants forced GM to recognize continuing difficulties in achieving productivity gains from the UAW workforce. Thus, GM changed its labor efficiency strategy by reducing the number of workers required to accomplish a given production level and redesigned vehicles so that fewer parts and less time to manufacture were required. Tables 9 and 10 indicate this strategy shift. The analysis shows that GM's labor productivity gain resulted from the technical efficiency improvement mixed with the technology frontier shift, and the frontier moved from a negative shift facet to a positive shift facet. The analysis indicates this strategy shift is a desirable one.

With respect to resource utilization, a strategy shift can be identified for a particular company in a particular period; for example, Tables 3 and 4 show the 4.7% productivity gain for TRW during the 1996-1997 period is from technical efficiency improvement mixed with the movement of technology frontier, which shifted from a negative shift facet to a positive shift facet. This indicates the strategy shift is a desirable one. Furthermore, technical efficiency improved with respect to the positive shift frontier.

Finally, Table 8 shows that during the 1995-1996 period, the technology frontier of GM moved from a negative shift facet (the second ratio in $FS_o < 1$) to a positive shift facet (the first ratio in $FS_o > 1$) in terms of resource utilization. In fact, for the Big Three, the degree of reliance on independent parts suppliers varies greatly. GM purchases only 30% of its vehicle content from independent original equipment manufacturers (OEMs). By comparison, Ford outsources 50% of its vehicle content, and Chrysler more than 70%. Because its outsource level is much lower than that of its competitors, GM is seeking to reduce costs and improve efficiencies through a new resource utilization strategy called "common, common, common," that is, by using common global designs, platforms, parts, and processes. The assessment confirms this positive strategy shift.

Conclusions

Compared to Fortune 500 rankings and single ratio measures, more comprehensive information about the performance of an industry and company can be provided using resource utilization and labor efficiency measures. The Malmquist productivity indexes cannot only reveal productivity trends of industries and companies, but also identify the strategy shifts of companies over time and furthermore, provide information on whether shifts are beneficial.

Managerial information about strategy shifts obtained from the analysis of components of the Malmquist productivity indexes is important and valuable because managers desperately need to know whether particular strategies are working well. All strategies should be subject to future modification because external and internal factors are constantly changing.

The application in this paper uses *Fortune Magazine's* Global 500 data. Despite the limitations of the available data, the empirical study demonstrates the applicability of the new framework of productivity assessment developed in Chen and Ali (2004). In future research, the approach might be applied to service and manufacturing operations using more extensive data, such as a company's inventories, research and development investments, intangible assets, taxes payable, and operating expenses.

It should be acknowledged the automobile industry is currently undergoing a completely new phase due to current economic conditions throughout the world. Major car manufacturers worldwide have announced losses or declining profits. To obtain further information on the auto industry, the current analysis would need to be extended using data sets that are more recent.

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Appendix

Table 1
Resource Utilization Index for Auto Industry of Technical Efficiency Change

Company	92/91	93/92	94/93	95/94	96/95	97/96
Chrysler	1.4051	1.1684	0.9850	0.6835	1.2618	1.0545
Ford	1.2827	0.8761	0.9824	0.8649	0.9803	1.1039
GM	1.5177	1.5471	0.5424	0.8304	0.9997	1.2510
TRW	1.7849	1.0000	1.0000	1.0000	0.5925	1.0479
Fujiheavy	1.6606	0.9979	1.0443	1.0000	1.0000	1.0000
Honda	1.2666	1.0367	0.8721	0.8718	1.0377	1.1795
Isuzu	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Mazda	1.0000	1.0000	1.0000	0.7879	1.1298	1.0734
Mitsubishi	1.0773	0.9019	1.1088	1.0000	0.8006	1.2490
Nissan	1.1662	0.9281	0.9011	1.1393	1.0797	1.0178
Suzuki	1.2471	1.0000	1.0000	1.0000	1.0000	1.0000
Toyota	1.0000	0.6144	1.0565	0.9225	0.9939	0.9378
Peugeot	1.5730	1.0417	0.9306	0.7824	0.8754	1.1595
Renault	2.0495	0.6961	0.8391	0.8201	1.0430	1.1906
Bosch	1.7202	0.9718	0.8961	0.9239	0.7049	1.0511
Benz	1.5410	1.0277	0.8673	0.7578	0.8617	1.1523
BMW	1.8175	0.7273	0.4014	2.2487	0.9399	1.1412
Man	1.1040	1.2073	0.7897	1.1293	0.8518	1.0729
Volkswagen	1.6815	0.9060	0.7373	0.9408	1.0689	1.1534
Volvo	1.6910	1.0645	1.0912	0.7780	0.8967	1.2841
Fiat	1.7365	0.8831	0.9486	0.8238	0.9356	1.2320
Hyundai	1.3070	1.0326	1.1119	0.8064	0.9400	1.3788
Industry ave.	1.4377	0.9831	0.9139	0.9596	0.9543	1.1241

Note. * Industry average is the average of the sample.

Table 2
Labor Efficiency Index for Auto Industry of Technical Efficiency Change

Company	92/91	93/92	94/93	95/94	96/95	97/96
Chrysler	0.8433	0.8165	1.0343	1.1894	1.1248	1.1710
Ford	0.9570	0.8142	0.8934	1.2215	1.0706	1.1143
GM	0.9448	0.7497	0.9333	1.2101	1.1892	1.0835
TRW	1.2174	0.7734	0.9072	1.1401	1.1337	0.8485
Fujiheavy	1.6336	0.8782	0.8997	0.9407	0.8693	1.0627
Honda	1.0700	0.8626	0.9704	1.0578	1.1113	1.0711
Isuzu	1.1532	1.5038	0.8637	1.1578	1.0000	1.0000
Mazda	0.5955	1.2554	0.8257	0.8803	1.3409	0.8480
Mitsubishi	1.1829	0.7850	1.6455	1.0000	1.0000	1.0000
Nissan	1.1933	0.8856	0.9336	0.9641	0.9958	1.0126
Suzuki	1.1734	0.8831	1.7656	1.0710	1.0162	1.0262
Toyota	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000

Peugeot	1.1210	0.7718	1.0661	1.2337	1.0766	1.0179
Renault	0.7154	0.8766	0.9925	1.2465	0.9567	1.0003
Bosch	1.1816	0.7704	0.9369	1.2036	1.0229	1.0779
Benz	1.1145	0.7291	1.0188	1.2085	1.4281	1.1090
BMW	1.4455	0.5331	1.4352	0.6644	1.0952	1.0843
Man	1.1114	0.7614	0.8536	1.1441	1.1329	0.9594
Volkswagen	1.0371	0.6847	0.9844	1.2721	1.0222	0.9180
Volvo	0.8494	0.5958	1.3586	1.0327	1.2579	1.0381
Fiat	0.7587	0.7189	1.0426	1.3396	1.1769	1.0346
Hyundai	1.0007	0.8775	0.9373	1.1370	1.0657	0.9092
Industry ave.	1.0591	0.8421	1.0590	1.1052	1.0949	1.0176

Note. * Industry average is the average of the sample.

Table 3

Resource Utilization Index for Auto Industry of Technology Frontier Change

Company	92/91	93/92	94/93	95/94	96/95	97/96
Chrysler	0.8787	0.9735	1.0372	1.3834	0.8923	0.9122
Ford	0.9753	1.1656	1.0793	1.1416	1.0136	0.8944
GM	1.0173	0.7284	1.3076	1.0843	1.0011	0.8400
TRW	0.6518	0.9674	1.0742	1.0798	1.7031	0.9989
Fujiheavy	0.8336	1.1414	1.1021	1.2054	0.9627	0.9005
Honda	0.7431	0.9672	1.0340	1.3515	0.9923	0.8193
Isuzu	1.0952	1.3406	0.9796	1.0535	1.0632	0.8742
Mazda	0.7794	0.9970	0.9813	1.3552	0.8988	0.8968
Mitsubishi	0.8821	1.0873	0.9177	1.1947	1.1958	0.8542
Nissan	0.8102	1.1000	1.0491	1.1677	0.9370	0.9076
Suzuki	0.7388	0.9748	0.9352	1.2069	0.9911	0.9322
Toyota	0.9292	1.5554	0.8899	1.2358	1.0266	0.9256
Peugeot	0.6689	0.9215	1.0532	1.2443	1.2391	0.8114
Renault	0.7806	0.9518	1.0791	1.2893	1.0152	0.8759
Bosch	0.6419	0.9455	1.0448	1.1362	1.4738	0.9561
Benz	0.7021	0.9478	1.1145	1.2542	1.0350	0.8136
BMW	0.7622	0.9561	1.0141	1.2766	1.1225	0.8653
Man	0.7559	0.9482	1.1030	1.2429	1.3829	0.9207
Volkswagen	0.7504	0.9536	1.2902	1.2037	0.9757	0.8681
Volvo	0.7807	0.9591	1.0472	1.3168	1.0913	0.8145
Fiat	0.7644	0.9520	1.0452	1.2595	1.0640	0.8589
Hyundai	0.7633	0.9497	1.0395	1.2182	1.0898	0.9057
Industry ave.	0.7972	1.0106	1.0512	1.2197	1.0840	0.8826

Note. * Industry average equals to geometrical mean of the sample.

Table 4

Resource Utilization Index for Auto Industry of Component Information on Technology Frontier Change

Time	92/91		93/92		94/93		95/94		96/95		97/96	
Company	$\frac{DB_o^t(x_o^{t+1},y_o^{t+1})}{DB_o^{t+1}(x_o^{t+1},y_o^{t+1})}$	$\frac{DB_o^t(x_o^t,y_o^t)}{DB_o^{t+1}(x_o^t,y_o^t)}$	$\frac{DB_o^t(x_o^{t+1},y_o^{t+1})}{DB_o^{t+1}(x_o^{t+1},y_o^{t+1})}$	$\frac{DB_o^t(x_o^t,y_o^t)}{DB_o^{t+1}(x_o^t,y_o^t)}$	$\frac{DB_o^t(x_o^{t+1},y_o^{t+1})}{DB_o^{t+1}(x_o^{t+1},y_o^{t+1})}$	$\frac{DB_o^t(x_o^t,y_o^t)}{DB_o^{t+1}(x_o^t,y_o^t)}$	$\frac{DB_o^t(x_o^{t+1},y_o^{t+1})}{DB_o^{t+1}(x_o^{t+1},y_o^{t+1})}$	$\frac{DB_o^t(x_o^t,y_o^t)}{DB_o^{t+1}(x_o^t,y_o^t)}$	$\frac{DB_o^t(x_o^{t+1},y_o^{t+1})}{DB_o^{t+1}(x_o^{t+1},y_o^{t+1})}$	$\frac{DB_o^t(x_o^t,y_o^t)}{DB_o^{t+1}(x_o^t,y_o^t)}$	$\frac{DB_o^t(x_o^{t+1},y_o^{t+1})}{DB_o^{t+1}(x_o^{t+1},y_o^{t+1})}$	$\frac{DB_o^t(x_o^t,y_o^t)}{DB_o^{t+1}(x_o^t,y_o^t)}$
Chrysler	0.8487	0.9098	0.9719	0.9752	0.9962	1.0798	1.3777	1.3890	0.8999	0.8847	0.9118	0.9126
Ford	1.0196	0.9330	1.2046	1.1278	1.0610	1.0980	1.1441	1.1392	1.0141	1.0131	0.9012	0.8876
GM	1.2339	0.8388	0.6971	0.7612	1.0935	1.5635	1.1302	1.0404	1.0025	0.9996	0.8479	0.8321
TRW	0.6518	0.6519	0.9469	0.9883	1.0434	1.1059	1.0279	1.1343	1.6960	1.7102	1.0334	0.9656
Fujiheavy	0.8817	0.7883	1.1638	1.1194	1.1047	1.0995	1.2688	1.1452	0.9878	0.9382	0.9065	0.8946
Honda	0.7353	0.7509	0.9732	0.9612	1.0175	1.0508	1.3463	1.3568	0.9976	0.9870	0.8182	0.8204
Isuzu	1.1773	1.0189	1.6507	1.0888	0.9837	0.9754	1.1420	0.9719	1.0640	1.0625	0.8766	0.8717
Mazda	0.7684	0.7905	1.0400	0.9557	0.9789	0.9837	1.3887	1.3226	0.8881	0.9095	0.8762	0.9179
Mitsubishi	0.8969	0.8675	1.1220	1.0536	0.7959	1.0582	1.1913	1.1980	1.1910	1.2007	0.8529	0.8555
Nissan	0.8601	0.7632	1.1641	1.0394	1.0581	1.0402	1.2456	1.0947	0.9226	0.9518	0.9060	0.9093
Suzuki	0.7330	0.7447	0.9633	0.9864	0.8245	1.0608	1.1419	1.2756	0.9571	1.0263	0.9259	0.9385
Toyota	0.9083	0.9506	1.5756	1.5355	0.8896	0.8902	1.2335	1.2381	1.0224	1.0308	0.9274	0.9239
Peugeot	0.6718	0.6660	0.9217	0.9213	1.0543	1.0521	1.2571	1.2316	1.2553	1.2230	0.8066	0.8163
Renault	0.7056	0.8635	0.9472	0.9565	1.0443	1.1151	1.3041	1.2746	1.0339	0.9968	0.8736	0.8782
Bosch	0.6376	0.6463	0.9436	0.9475	1.0433	1.0463	1.1361	1.1363	1.4535	1.4943	0.9577	0.9546
Benz	0.7130	0.6914	0.9463	0.9492	1.0558	1.1765	1.2776	1.2311	1.1275	0.9501	0.8056	0.8217
BMW	0.7684	0.7561	0.9565	0.9557	1.0148	1.0134	1.2310	1.3238	1.1174	1.1276	0.8668	0.8638
Man	0.7675	0.7445	0.9477	0.9486	1.0739	1.1328	1.2024	1.2849	1.4057	1.3605	0.9426	0.8994
Volkswagen	0.7559	0.7448	0.9608	0.9464	1.2973	1.2832	1.1697	1.2388	0.9786	0.9728	0.8774	0.8589
Volvo	0.8125	0.7502	0.9520	0.9664	1.0398	1.0546	1.2983	1.3357	1.0691	1.1139	0.8108	0.8181
Fiat	0.7684	0.7604	0.9528	0.9511	1.0412	1.0491	1.2818	1.2376	1.0447	1.0837	0.8614	0.8564
Hyundai	0.7580	0.7688	0.9536	0.9459	1.0369	1.0422	1.2368	1.1999	1.0432	1.1384	0.9443	0.8688

Table 5
Labor Efficiency Index for Auto Industry of Technology Frontier Change

Company	92/91	93/92	94/93	95/94	96/95	97/96
Chrysler	1.1060	1.3120	1.2116	0.8597	0.9315	0.9365
Ford	1.1060	1.3655	1.1827	0.8840	0.9423	0.9788
GM	1.1060	1.3867	1.1650	0.8855	0.9424	0.9936
TRW	0.9597	1.3047	1.2102	0.9665	0.9099	0.9103
Fujiheavy	1.0811	1.3438	1.1938	1.0797	0.9212	0.8988
Honda	0.9597	1.2350	1.1597	0.9309	0.9119	0.9111
Isuzu	0.9768	1.4331	1.1452	0.9549	0.9483	0.9580
Mazda	0.9597	1.3116	1.2286	1.0054	0.9053	0.9050
Mitsubishi	0.9597	1.3393	1.2299	0.9666	0.9227	0.9357
Nissan	1.1060	1.2805	1.2075	0.8578	0.9323	0.9346
Suzuki	0.9597	1.2687	1.1734	0.9484	0.9096	0.9200
Toyota	1.0302	1.1358	1.0740	0.8106	0.9101	0.9210
Peugeot	0.9597	1.1896	1.1310	0.9000	0.9181	0.9230
Renault	1.0302	1.3117	1.2181	0.8584	0.9325	0.9352
Bosch	0.9597	1.2635	1.1795	0.9461	0.9107	0.9085
Benz	0.9820	1.3098	1.2173	0.9046	0.9369	0.9400
BMW	1.0120	1.2960	1.1508	0.8504	0.9318	0.9114
Man	1.0318	1.3110	1.2230	0.9107	0.9081	0.9078
Volkswagen	1.0302	1.3315	1.2093	0.8793	0.9431	0.9539
Volvo	1.1060	1.2912	1.1818	0.8936	0.9178	0.8999
Fiat	1.1060	1.2906	1.2051	0.8539	0.9311	0.9377
Hyundai	1.0164	1.3133	1.2235	1.0109	0.9032	0.9049
Industry ave.	1.0231	1.2997	1.1867	0.9142	0.9236	0.9281

Note. * Industry average equals to geometrical mean of the sample.

Table 6
Labor Efficiency Index for Auto Industry of Component Information on Technology Frontier

Time	92/91		93/92		94/93		95/94		96/95		97/96	
Company	$\frac{DB_o^t(x_o^{t+1},y_o^{t+1})}{DB_o^{t+1}(x_o^{t+1},y_o^{t+1})}$	$\frac{DB_o^t(x_o^t,y_o^t)}{DB_o^{t+1}(x_o^t,y_o^t)}$	$\frac{DB_o^t(x_o^{t+1},y_o^{t+1})}{DB_o^{t+1}(x_o^{t+1},y_o^{t+1})}$	$\frac{DB_o^t(x_o^t,y_o^t)}{DB_o^{t+1}(x_o^t,y_o^t)}$	$\frac{DB_o^t(x_o^{t+1},y_o^{t+1})}{DB_o^{t+1}(x_o^{t+1},y_o^{t+1})}$	$\frac{DB_o^t(x_o^t,y_o^t)}{DB_o^{t+1}(x_o^t,y_o^t)}$	$\frac{DB_o^t(x_o^{t+1},y_o^{t+1})}{DB_o^{t+1}(x_o^{t+1},y_o^{t+1})}$	$\frac{DB_o^t(x_o^t,y_o^t)}{DB_o^{t+1}(x_o^t,y_o^t)}$	$\frac{DB_o^t(x_o^{t+1},y_o^{t+1})}{DB_o^{t+1}(x_o^{t+1},y_o^{t+1})}$	$\frac{DB_o^t(x_o^t,y_o^t)}{DB_o^{t+1}(x_o^t,y_o^t)}$	$\frac{DB_o^t(x_o^{t+1},y_o^{t+1})}{DB_o^{t+1}(x_o^{t+1},y_o^{t+1})}$	$\frac{DB_o^t(x_o^t,y_o^t)}{DB_o^{t+1}(x_o^t,y_o^t)}$
Chrysler	1.1060	1.1060	1.3204	1.3037	1.2048	1.2184	0.8552	0.8642	0.9314	0.9315	0.9359	0.9372
Ford	1.1060	1.1060	1.3665	1.3644	1.1881	1.1772	0.8839	0.8842	0.9423	0.9422	0.9744	0.9832
GM	1.1060	1.1060	1.3867	1.3867	1.1700	1.1601	0.8828	0.8881	0.9424	0.9425	1.0079	0.9795
TRW	0.9597	0.9597	1.2951	1.3143	1.2076	1.2127	0.9624	0.9706	0.9098	0.9099	0.9027	0.9181
Fujiheavy	1.0568	1.1060	1.3529	1.3347	1.1792	1.2085	1.0797	1.0797	0.9135	0.9290	0.8951	0.9025
Honda	0.9597	0.9597	1.2382	1.2318	1.1514	1.1680	0.9453	0.9168	0.9117	0.9120	0.9101	0.9122
Isuzu	0.9836	0.9701	1.4348	1.4314	1.1510	1.1395	1.0178	0.8959	0.9554	0.9412	1.0140	0.9051
Mazda	0.9597	0.9597	1.3113	1.3120	1.2311	1.2261	1.0172	0.9937	0.9059	0.9047	0.9034	0.9067
Mitsubishi	0.9597	0.9597	1.3357	1.3429	1.2359	1.2240	1.0797	0.8654	0.9441	0.9019	0.9813	0.8921
Nissan	1.1060	1.1060	1.2870	1.2741	1.2115	1.2036	0.8588	0.8567	0.9326	0.9321	0.9339	0.9354
Suzuki	0.9597	0.9597	1.2564	1.2811	1.1649	1.1820	0.9659	0.9312	0.9097	0.9095	0.9223	0.9177
Toyota	1.1060	0.9597	1.1774	1.0957	1.0971	1.0514	0.8614	0.7629	0.9231	0.8972	0.9506	0.8923
Peugeot	0.9597	0.9597	1.1877	1.1915	1.1310	1.1310	0.8978	0.9021	0.9163	0.9200	0.9422	0.9041
Renault	0.9597	1.1060	1.3184	1.3049	1.2161	1.2202	0.8574	0.8595	0.9331	0.9319	0.9359	0.9345
Bosch	0.9597	0.9597	1.2544	1.2727	1.1786	1.1804	0.9487	0.9434	0.9099	0.9116	0.9115	0.9054
Benz	0.9655	0.9988	1.3138	1.3059	1.2065	1.2282	0.9409	0.8697	0.9302	0.9437	0.9407	0.9393
BMW	0.9597	1.0671	1.2802	1.3120	1.1056	1.1978	0.9126	0.7924	0.9318	0.9318	0.9168	0.9060
Man	1.1060	0.9626	1.3192	1.3029	1.2133	1.2328	0.9669	0.8578	0.9069	0.9094	0.9063	0.9094
Volkswagen	0.9597	1.1060	1.3284	1.3346	1.2075	1.2110	0.8801	0.8785	0.9430	0.9431	0.9454	0.9625
Volvo	1.1060	1.1060	1.2948	1.2876	1.1540	1.2102	0.9068	0.8805	0.9188	0.9168	0.9000	0.8997
Fiat	1.1060	1.1060	1.2857	1.2955	1.2077	1.2025	0.8533	0.8544	0.9310	0.9312	0.9375	0.9380
Hyundai	1.0046	1.0283	1.2982	1.3285	1.2318	1.2153	1.0276	0.9944	0.9023	0.9042	0.9150	0.8950

Table 7
Resource Utilization Index for Auto Industry of Malmquist Productivity Change

Company	92/91	93/92	94/93	95/94	96/95	97/96
Chrysler	1.2347	1.1374	1.0216	0.9455	1.1259	0.9619
Ford	1.2510	1.0211	1.0603	0.9874	0.9937	0.9873
GM	1.5440	1.1270	0.7092	0.9004	1.0008	1.0508
TRW	1.1635	0.9674	1.0742	1.0798	1.0091	1.0468
Fujiheavy	1.3843	1.1390	1.1509	1.2054	0.9627	0.9005
Honda	0.9412	1.0027	0.9018	1.1782	1.0296	0.9664
Isuzu	1.0952	1.3406	0.9796	1.0535	1.0632	0.8742
Mazda	0.7794	0.9970	0.9813	1.0678	1.0154	0.9626
Mitsubishi	0.9503	0.9806	1.0175	1.1947	0.9574	1.0669
Nissan	0.9449	1.0209	0.9454	1.3303	1.0117	0.9238
Suzuki	0.9214	0.9748	0.9352	1.2069	0.9911	0.9322
Toyota	0.9292	0.9557	0.9401	1.1401	1.0203	0.8680
Peugeot	1.0521	0.9599	0.9801	0.9735	1.0846	0.9409
Renault	1.5998	0.6626	0.9055	1.0573	1.0589	1.0429
Bosch	1.1043	0.9189	0.9363	1.0497	1.0389	1.0050
Benz	1.0819	0.9740	0.9666	0.9504	0.8918	0.9375
BMW	1.3853	0.6954	0.4070	2.8707	1.0551	0.9875
Man	0.8345	1.1447	0.8710	1.4036	1.1779	0.9878
Volkswagen	1.2617	0.8640	0.9513	1.1324	1.0429	1.0012
Volvo	1.3201	1.0210	1.1428	1.0245	0.9786	1.0458
Fiat	1.3274	0.8407	0.9915	1.0376	0.9954	1.0582
Hyundai	0.9977	0.9807	1.1558	0.9823	1.0244	1.2488
Industry ave.	1.1203	0.9766	0.9384	1.1327	1.0225	0.9877

Note. * Industry average equals to geometrical mean of the sample.

Table 8
Resource Utilization Index for Auto Industry of Component Information on Malmquist Productivity Change

Time	92/91				93/92				94/93				95/94				96/95				97/96			
Ratios	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Chrysler	<1	<1	>1	>1	<1	<1	>1	>1	<1	>1	<1	>1	>1	>1	<1	<1	<1	<1	>1	>1	<1	<1	>1	<1
Ford	>1	<1	>1	>1	>1	>1	<1	>1	>1	>1	<1	>1	>1	>1	<1	<1	>1	>1	<1	<1	<1	<1	>1	<1
GM	>1	<1	>1	>1	<1	<1	>1	>1	>1	>1	<1	<1	>1	>1	<1	<1	>1	<1	<1	>1	<1	<1	>1	>1
TRW	<1	<1	>1	>1	<1	<1	=1	<1	>1	>1	=1	>1	>1	>1	=1	>1	>1	>1	<1	>1	>1	<1	>1	>1
Fujiheavy	<1	<1	>1	>1	>1	>1	<1	>1	>1	>1	>1	>1	>1	>1	=1	>1	<1	<1	=1	<1	<1	<1	=1	<1
Honda	<1	<1	>1	<1	<1	<1	>1	>1	>1	>1	<1	<1	>1	>1	<1	>1	<1	<1	>1	>1	<1	<1	>1	<1
Isuzu	>1	>1	=1	>1	>1	>1	=1	>1	<1	<1	=1	<1	>1	<1	=1	>1	>1	>1	=1	>1	<1	<1	=1	<1
Mazda	<1	<1	=1	<1	>1	<1	=1	<1	<1	<1	=1	<1	>1	>1	<1	>1	<1	<1	>1	>1	<1	<1	>1	<1
Mitsubishi	<1	<1	>1	<1	>1	>1	<1	<1	<1	>1	>1	>1	>1	>1	=1	>1	>1	>1	<1	<1	<1	<1	>1	>1
Nissan	<1	<1	>1	<1	>1	>1	<1	>1	>1	>1	<1	<1	>1	>1	>1	>1	<1	<1	>1	>1	<1	<1	>1	<1
Suzuki	<1	<1	>1	<1	<1	<1	=1	<1	<1	>1	=1	<1	>1	>1	=1	>1	<1	<1	=1	<1	<1	<1	=1	<1
Toyota	<1	<1	=1	<1	>1	>1	<1	<1	<1	<1	>1	<1	>1	>1	<1	>1	>1	>1	<1	>1	<1	<1	<1	<1
Peugeot	<1	<1	>1	>1	<1	<1	>1	<1	>1	>1	<1	<1	>1	>1	<1	<1	>1	>1	<1	>1	<1	<1	>1	<1
Renault	<1	<1	>1	>1	<1	<1	<1	<1	>1	>1	<1	<1	>1	>1	<1	>1	>1	<1	>1	>1	<1	<1	>1	>1
Bosch	<1	<1	>1	>1	<1	<1	<1	<1	>1	>1	<1	<1	>1	>1	<1	>1	>1	>1	<1	>1	<1	<1	>1	>1
Benz	<1	<1	>1	>1	<1	<1	>1	<1	>1	>1	<1	<1	>1	>1	<1	<1	>1	<1	<1	<1	<1	<1	>1	<1
BMW	<1	<1	>1	>1	<1	<1	<1	<1	>1	>1	<1	<1	>1	>1	>1	>1	<1	<1	<1	>1	<1	<1	>1	<1
Man	<1	<1	>1	<1	<1	<1	>1	>1	>1	>1	<1	<1	>1	>1	>1	>1	>1	<1	<1	>1	<1	<1	>1	<1
Volkswagen	<1	<1	>1	>1	<1	<1	<1	<1	>1	>1	<1	<1	>1	>1	<1	>1	>1	>1	>1	>1	<1	<1	>1	>1
Volvo	<1	<1	>1	>1	<1	<1	>1	>1	>1	>1	>1	>1	>1	>1	<1	>1	>1	>1	<1	<1	<1	<1	>1	>1
Fiat	<1	<1	>1	>1	<1	<1	<1	<1	>1	>1	<1	<1	>1	>1	<1	>1	>1	>1	<1	<1	<1	<1	>1	>1
Hyundai	<1	<1	>1	<1	<1	>1	>1	<1	>1	>1	>1	>1	>1	>1	<1	<1	>1	>1	<1	>1	<1	<1	>1	>1

Note. Ratio 1 (first component of FS_o^B) = $\dfrac{DB_o^t(x_o^{t+1}, y_o^{t+1})}{DB_o^{t+1}(x_o^{t+1}, y_o^{t+1})}$,

Ratio *1* (second component of FS_o^B) = $\dfrac{DB_o^t(x_o^t, y_o^t)}{DB_o^{t+1}(x_o^t, y_o^t)}$,

Ratio 3 (TEC_o^B) = $\dfrac{DB_o^{t+1}(x_o^{t+1}, y_o^{t+1})}{DB_o^t(x_o^t, y_o^t)}$,

Ratio 4 (M_o^B) = $[\dfrac{DB_o^t(x_o^{t+1}, y_o^{t+1})}{DB_o^t(x_o^t, y_o^t)} \dfrac{DB_o^{t+1}(x_o^{t+1}, y_o^{t+1})}{DB_o^{t+1}(x_o^t, y_o^t)}]^{1/2}$.

Table 9
Labor Efficiency Index for Auto Industry for the Malmquist Productivity Change

Company	92/91	93/92	94/93	95/94	96/95	97/96
Chrysler	0.9327	1.0713	1.2531	1.0225	1.0477	1.0967
Ford	1.0585	1.1117	1.0566	1.0798	1.0088	1.0906
GM	1.0450	1.0396	1.0873	1.0715	1.1208	1.0766
TRW	1.1683	1.0091	1.0979	1.1019	1.0315	0.7724
Fujiheavy	1.7662	1.1802	1.0740	1.0157	0.8008	0.9552
Honda	1.0268	1.0653	1.1254	0.9847	1.0133	0.9760
Isuzu	1.1265	2.1551	0.9892	1.1056	0.9483	0.9580
Mazda	0.5715	1.6466	1.0144	0.8850	1.2140	0.7675
Mitsubishi	1.1352	1.0513	2.0238	0.9666	0.9227	0.9357
Nissan	1.3198	1.1341	1.1274	0.8270	0.9284	0.9463
Suzuki	1.1260	1.1204	2.0718	1.0157	0.9243	0.9441
Toyota	1.0302	1.1358	1.0740	0.8106	0.9101	0.9210
Peugeot	1.0758	0.9181	1.2058	1.1103	0.9884	0.9395
Renault	0.7371	1.1498	1.2090	1.0700	0.8921	0.9355
Bosch	1.1339	0.9735	1.1051	1.1387	0.9316	0.9792
Benz	1.0945	0.9550	1.2402	1.0932	1.3381	1.0424
BMW	1.4628	0.6909	1.6515	0.5650	1.0206	0.9882
Man	1.1468	0.9982	1.0440	1.0420	1.0288	0.8710
Volkswagen	1.0685	0.9116	1.1904	1.1185	0.9640	0.8757
Volvo	0.9394	0.7692	1.6056	0.9228	1.1545	0.9342
Fiat	0.8391	0.9278	1.2564	1.1439	1.0958	0.9702
Hyundai	1.0171	1.1524	1.1469	1.1494	0.9626	0.8228
Industry ave.	1.0580	1.0685	1.2284	0.9996	1.0049	0.9414

Note. * Industry average equals to geometrical mean of the sample.

Table 10
Labor Efficiency Index for Auto Industry of Component Information on the Malmquist Productivity Change

Time	92/91				93/92				94/93				95/94				96/95				97/96			
Ratios	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Chrysler	>1	>1	<1	<1	>1	>1	<1	>1	>1	>1	>1	>1	<1	<1	>1	>1	<1	<1	>1	>1	<1	<1	>1	>1
Ford	>1	>1	<1	>1	>1	>1	<1	>1	>1	>1	<1	>1	<1	<1	>1	>1	<1	<1	>1	>1	<1	<1	>1	>1
Gm	>1	>1	<1	>1	>1	>1	<1	>1	>1	>1	<1	>1	<1	<1	>1	>1	<1	<1	>1	>1	>1	<1	>1	>1
Trw	<1	<1	>1	>1	>1	>1	<1	>1	>1	>1	<1	>1	<1	<1	>1	>1	<1	<1	>1	>1	<1	<1	<1	<1
Fujiheavy	>1	>1	>1	>1	>1	>1	<1	>1	>1	>1	<1	>1	>1	>1	>1	>1	<1	<1	<1	<1	<1	<1	>1	<1
Honda	<1	<1	>1	>1	>1	>1	<1	>1	>1	>1	<1	>1	<1	<1	>1	<1	<1	<1	>1	>1	<1	<1	>1	<1
Isuzu	<1	<1	>1	>1	>1	>1	>1	>1	>1	>1	<1	<1	>1	<1	>1	>1	<1	<1	=1	<1	>1	<1	=1	<1
Mazda	<1	<1	<1	<1	>1	>1	>1	>1	>1	>1	<1	>1	>1	<1	>1	<1	<1	<1	>1	>1	<1	<1	<1	<1
Mitsubishi	<1	<1	>1	>1	>1	>1	<1	>1	>1	>1	>1	>1	>1	<1	=1	<1	<1	<1	=1	<1	<1	<1	=1	<1
Nissan	>1	>1	>1	>1	>1	>1	<1	>1	>1	>1	<1	>1	<1	<1	>1	<1	<1	<1	<1	<1	<1	<1	>1	<1
Suzuki	<1	<1	>1	>1	>1	>1	<1	>1	>1	>1	>1	>1	<1	<1	>1	>1	<1	<1	>1	<1	<1	<1	>1	<1
Toyota	>1	<1	=1	>1	>1	>1	=1	>1	>1	>1	=1	>1	<1	<1	=1	<1	<1	<1	=1	<1	<1	<1	=1	<1
Peugeot	<1	<1	>1	>1	>1	>1	<1	<1	>1	>1	>1	>1	<1	<1	>1	>1	<1	<1	>1	<1	<1	<1	>1	<1
Renault	<1	>1	<1	<1	>1	>1	<1	>1	>1	>1	<1	>1	<1	<1	>1	>1	<1	<1	<1	<1	<1	<1	>1	<1
Bosch	<1	<1	>1	>1	>1	>1	<1	<1	>1	>1	<1	>1	<1	<1	>1	>1	<1	<1	>1	>1	<1	<1	>1	<1
Benz	<1	<1	>1	>1	>1	>1	<1	<1	>1	>1	>1	>1	<1	<1	>1	>1	<1	<1	>1	>1	<1	<1	>1	<1
Bmw	<1	>1	>1	>1	>1	>1	<1	<1	>1	>1	>1	>1	<1	<1	>1	<1	<1	<1	>1	>1	<1	<1	>1	>1
Man	>1	<1	>1	>1	>1	>1	<1	<1	>1	>1	<1	>1	<1	<1	>1	>1	<1	<1	>1	<1	<1	<1	<1	<1
Volkswagen	<1	>1	>1	>1	>1	>1	<1	<1	>1	>1	<1	>1	<1	<1	>1	>1	<1	<1	>1	>1	<1	<1	<1	<1
Volvo	>1	>1	<1	<1	>1	>1	<1	<1	>1	>1	>1	>1	<1	<1	>1	<1	<1	<1	>1	>1	<1	<1	>1	<1
Fiat	>1	>1	<1	<1	>1	>1	<1	>1	>1	>1	>1	>1	<1	<1	>1	>1	<1	<1	>1	<1	<1	<1	>1	<1
Hyundai	>1	>1	>1	>1	>1	>1	<1	>1	>1	>1	<1	>1	<1	<1	>1	>1	<1	<1	>1	>1	<1	<1	<1	<1

Note. Ratio 1 (first component of FS_o) = $\dfrac{DB_o^t(x_o^{t+1}, y_o^{t+1})}{DB_o^{t+1}(x_o^{t+1}, y_o^{t+1})}$,

Ratio 2 (second component of FS_o) = $\dfrac{DB_o^t(x_o^t, y_o^t)}{DB_o^{t+1}(x_o^t, y_o^t)}$,

Ratio 3 (TEC_o) = $\dfrac{DB_o^{t+1}(x_o^{t+1}, y_o^{t+1})}{DB_o^t(x_o^t, y_o^t)}$,

Ratio 4 (M_o) = $\left[\dfrac{DB_o^t(x_o^{t+1}, y_o^{t+1})}{DB_o^t(x_o^t, y_o^t)} \dfrac{DB_o^{t+1}(x_o^{t+1}, y_o^{t+1})}{DB_o^{t+1}(x_o^t, y_o^t)}\right]^{1/2}$.