*Asian Journal of Business and Management (ISSN: 2321 - 2802)*
*Volume 02 – Issue 03, June 2014*

# Performance of the Vietnamese Automobile Industry: A Measurement using DEA

Duc-Hiep Tran[1], Dang-Thanh Ngo[2]

[1] VNU University of Economics and Business
144 Xuan Thuy Road, Cau Giay District, Hanoi, Vietnam

[2] VNU University of Economics and Business
144 Xuan Thuy Road, Cau Giay District, Hanoi, Vietnam
*Email: ndthanhf {at} vnu.edu.vn*

**ABSTRACT -** ***In Vietnam, the automobile industry was seen as a very important sector of the economy. This paper studies the efficiency and productivity change of the Vietnamese automobile industry during the 2004-2007 periods, employing the Malmquist - Data Envelopment Analysis approach. For the best of our knowledge, this is the first study to do so.***

***Our findings showed that efficiency of the Vietnamese automobile firms were low, with the highest average score of 0.500 in 2007. Major issues concerning inefficiency in the industry related to a big waste in using capital resources and thus, the actual turnovers were far less than its capability. By utilizing their production capacity, automobile firms in Vietnam could increase their productivity; however, its speed was decreased. Since technology could affect capacity utilization, it could be better for Vietnam to focus on this issue with preference.***

**Keywords -** automobile industry, Vietnam, data envelopment analysis, performance

## 1 INTRODUCTION

The automobile industry is the "world's largest manufacturing activity" [1, p. 11]. The automobile industry, as a customer, motivates the development of iron–steel, petrochemical and tire industries. As a producer, it provides all types of motor vehicles for tourism, infrastructure maintenance, transportation, and agriculture. Therefore, any changes in the automobile industry will affect the entire economy [2].

Despite the important role of the automobile industry, studies on efficiency or performance of this sector are limited. In addition, since the development of this industry directly relates to the environment, most studies focus on the efficiency of the automobile sector in terms of fuel or energy consumption [3], CO2 emission [4; 5], or the supply chain management [6; 7].

Among the few studies that assess the efficiency (or competitiveness) of the automobile industry, Wad [8] revealed that the performance of this industry was affected by the foreign automobile suppliers, modularisation, and the domestic (automobile) policies and institutions. Barnes and Morris [9] concluded that in a developing country, in order to improve its efficiency and performance, the automobile industry needs to continuously upgrade its (labours') skills and technology. Ülengin *et al.* [2] summarised 15 indicators affecting the efficiency of this industry, of which technologies, scientists and engineers, and Research and Development (R&D) are important factors.

In Vietnam, the automobile industry was seen as a very important sector of the economy and thus, since 2004, the Government has announced an development project for the automobile industry in Vietnam toward 2010, vision to 2020 [10]. According to this project, this industry should be preferably developed as it could contribute to the industrialization and modernization of the country. With the incoming ASEAN Free Trade Agreement (AFTA) 2018, the Vietnam's Ministry of Industry and Trade (MOIT) is looking to make the automobile industry more competitive proposing that investment projects for this sector should be given preference. However, as the BMI pointed out in their reports [11], as well as observing the current situation of the Vietnamese automobile industry [12; 13], one could argue that the development of this industry was not successful and eventually could not be called an industry [14]. Therefore, a new project for the development of the automobile industry with the 2030 vision has been considered [14].

There are several studies on the Vietnamese automobile industry. The earliest one, to the best of our knowledge, was presented as an appendix of the Industrial Competitiveness Review of the Vietnam's Ministry of Planning and Investment [15]. This report explained the development of the automobile industry in Vietnam from 1951 to 1998 and concluded that the automobile assembly plants were operating far below their capacity. Therefore, in cooperation with the automakers, the Vietnamese government should invest in infrastructure and other programs that facilitate motorization; seek investments from foreign first-tier suppliers; and assist in the creation of the domestic second-tier supply-base [15]. Other studies appeared much later with the present of international institutions such as the Economist Intelligence Unit [16; 13], the PricewaterhouseCoopers [17], the Business Monitor International [11], etc. as well as domestic entities [18; 19]. Since 2007, the PricewaterhouseCoopers [17] had pointed out that the automobile will be a prospective industry, especially in medium-term, if several challenges regarding tax and regulatory policies, vehicle infrastructure investments, hi-tech industry promotions, and human resource developments could be addressed. A more recent report from the Business Monitor International [11], however, argued that the Vietnamese automobile industry was still in infancy with a small components sector. It led to a situation that carmakers are importing the complete knock-down kits (CKDs) from abroad to assemble and sell domestically [11] and thus, the industry has failed to reach its objective of selling cars at prices that suit Vietnamese consumers [13].

This situation rises a question on how efficient the automobile industry in Vietnam is, regarding using both firms and government resources to provide components and end-user vehicles to the (domestic) market. Obviously, in this situation, we will not evaluate the efficiency of the Vietnamese automobile industry according to their supply chain management or energy/emission performance but the production aspect. Therefore, the X-efficiency or productive efficiency of the frontier analysis approach [20; 21] is suitable for this purpose.

This paper assesses the efficiency and productivity change in the Vietnamese automobile industry using Data Envelopment Analysis (DEA) approach and the productivity change was determined using the Malmquist Index approach. To the best of our knowledge, this is the first study to do so. The rest of the paper is constructed as follows. The next section describes the methodological issues of the research, the data on Vietnamese automobile industry, and the research models. Section 3 discusses the empirical results and section 4 concludes.

## 2 METHODOLOGY

### *2.1 X-efficiency of production: the DEA approach*

In frontier analysis, inefficiency is defined as the deviation from the efficient frontier, which is defined following the Pareto-efficient empirical production function where maximum observations of a production possibility set can form a production function [22]. Those deviations, usually is referred to as X-(in)efficiency, could be measured in two ways: the parametric and nonparametric approaches. The parametric approach has the advantage of hypothesis testing while the nonparametric one is more flexible with small sample sizes and multiple outputs[1]. Since the Vietnamese automobile industry is small, and due to data limitation, the Data Envelopment Analysis (DEA) of nonparametric approach is employed in this research.

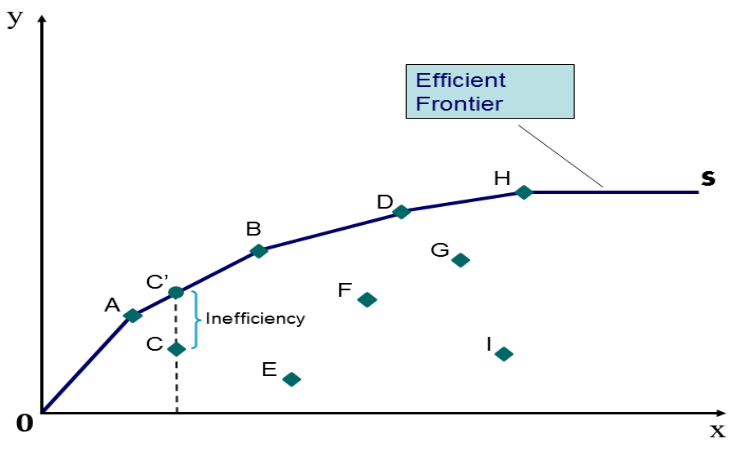


**Figure 1:** Nonparametric Efficient Frontier
*Source: Adapted from Seiford and Thrall [23]*

[1] The parametric approach is based on regression technique and thus, requires big sample. On the other hand, it can only relate multiple inputs (independent variables) to only one output (dependent variable), not to multiple outputs.

In DEA, the efficient frontier will be presented by an isoquant (0S, as in **Error! Reference source not found.**) which has (i) positive slope and (ii) there is no observed point lies above it[2]. Efficiencies of each firm will be calculated in comparison with this frontier, e.g. A is efficient and C is inefficient.

In term of multiple inputs/outputs, the overall efficiency EF of using multiple inputs *x* to produce multiple outputs *y* is

$$EF = \frac{All\ Outputs}{All\ Inputs} = \frac{\sum y}{\sum x} \quad (1)$$

Since each input (output) has different role in the total inputs (outputs), they should be accompanied with weights. Since a fixed (and equal) weight scheme was proven to be incorrect [20], it is better to let the weights be assigned by the variables themselves. Charnes, Cooper and Rhodes (1978) proposed a mathematic programming to estimate these weights under the constant-returns-to-scale condition; while Banker, Charnes, and Cooper [24] modified the former model so it can deal with the variable-returns-to-scale. Nevertheless, these models independently focus on maximizing the weighted outputs while the inputs are constrained (output-oriented); or minimizing the weighted inputs while outputs are constrained (input-oriented). Considering the case of both maximize the outputs and minimize the inputs used at the same time, as well as to overcome the problem of units variant in a multi-dimensional context of DEA [25], Tone [26] proposed that a slack-based measure (SBM) of efficiency should be used.

Consider a set of *n* firms (or Decision Making Units - DMUs), with each DMU *j* (*j=1,…,n*) using *m* inputs $x_{ij}$ (*i=1,…,m*) to produce *k* outputs $y_{rj}$ (*r=1,…,k*). In this case, under the constant returns to scale assumption, a certain $j_0$-*th* DMU can maximize its SBM efficiency by solving the following mathematical problem:

$$EF_{j_0} = min_{\lambda,s^-,s^+} \quad \frac{1-\frac{1}{k}\sum_i^k s_i^-/x_{ij_0}}{1+\frac{1}{m}\sum_r^m s_r^+/y_{rj_0}} \quad (2)$$

*Subject to*

$$\sum_i^k \lambda_j x_{ij} + s_i^- = x_{ij_0},\ \forall j, i$$

$$\sum_r^m \lambda_j y_{rj} - s_r^+ = y_{rj_0},\ \forall j, r$$

$$\sum_j^n \lambda_j = 1,\ \forall j$$

$$\lambda_j, s_i^-, s_r^+ \geq 0,\ \forall j, i, r$$

Where input excesses is denoted by $s^-$, the output shortfalls is denoted by $s^+$, and λ is a dual variable of shadow price related to the constraint limiting the efficiency of each DMU to be less than one.

Since we also would like to analyze the efficiency or productivity change over time, we apply the (distance function) Malmquist Index approach [27; 28; 29] into the DEA studies as well. That approach is popularly applied in measuring changes through time of the Total Factor Productivity (TFP) as well as its components [30; 31; 32, ; among others]. Similar to Ngo and Nguyen [32], we measure the TFP changes (TFPCH) of the Vietnamese automobile industry through 2004-2008 as

$$m_0(x^{t+1}, y^{t+1}, x^t, y^t) = \left[\frac{d_c^t(x^{t+1}, y^{t+1})}{d_c^t(x^t, y^t)} \times \frac{d_c^{t+1}(x^{t+1}, y^{t+1})}{d_c^{t+1}(x^t, y^t)}\right]^{\frac{1}{2}}$$

$$= \frac{d_c^{t+1}(x^{t+1}, y^{t+1})}{d_c^t(x^t, y^t)} \times \left[\frac{d_c^t(x^{t+1}, y^{t+1})}{d_c^{t+1}(x^{t+1}, y^{t+1})} \times \frac{d_c^t(x^t, y^t)}{d_c^{t+1}(x^t, y^t)}\right]^{\frac{1}{2}} \quad (3)$$

TFPCH = EFCH × [TECHCH]

Where *($x^t$,$y^t$)* and *($x^{t+1}$,$y^{t+1}$)* are respectively the production points at time *t* and *t+1*; EFCH represents efficiency changes; and TECHCH represents technological changes. Data for our research is presented in the next section.

[2] Although Seiford and Thrall [23] originally described it as a piecewise linear surface which 'floats' on top of the observations.

### *2.2 Background on the Vietnamese automobile industry and data*

The first State-owned enterprise that manufactured cars and vehicles, mostly for the military, in Vietnam was Auto Hoa Binh Company. Since its establishment in 1951 to the beginning of 'Doi Moi", this company was the core of the Vietnamese automobile industry who mainly import fully assembled sedans from the Soviet-Union [15] or chassis from the German Democratic Republic to build buses of 46-50 seats [18] and sold to the domestic market. After the Vietnam Motor Corporation (VMC), a joint venture company of Auto Hoa Binh with Colombian Motors (Philippines) and Nichmen Corporation (Japan), was formed in 1991, the Vietnamese automobile industry began to change dramatically as many foreign automakers entered the market. To date, there are nearly 400 automobile firms [33] that produce around 94 thousand motor vehicles in Vietnam [34].

**Table 1:** Automobile markets of some ASEAN countries, 2013 (*in number of vehicles*)

| Country | Productions | Sales |
|---|---|---|
| **Indonesia** | 1,208,211 | 1,229,901 |
| **Malaysia** | 601,407 | 655,793 |
| **Philippines** | 79,169 | 181,738 |
| **Thailand** | 2,457,057 | 1,330,672 |
| **Vietnam** | 93,630 | 98,649 |

*Source: AAF [35], OICA [34]*

**Table 2:** Production utilization of major automakers in Vietnam

| Firms | 1998 | | | 2006 | | |
|---|---|---|---|---|---|---|
| | *Productions* | *Capacity* | *% Utilization* | *Productions* | *Capacity* | *% Utilization* |
| **Daihatsu** | 2,000 | 556 | 27.80 | 1,800 | 483 | 26.83 |
| **Hino Motors** | 1,760 | 50 | 2.84 | 1,000 | 645 | 64.50 |
| **Isuzu** | 10,000 | 135 | 1.35 | 10,000 | 2,428 | 24.28 |
| **Mitsubishi** | 5,000 | 688 | 13.76 | 5,000 | 2,469 | 49.38 |
| **Toyota** | 5,000 | 1,400 | 28.00 | 20,000 | 13,976 | 69.88 |
| **Honda** | NA | NA | NA | 10,000 | 1,651 | 16.51 |
| **Suzuki** | NA | NA | NA | 10,000 | 1,296 | 12.96 |
| **Average** | 4,752 | 566 | 14.75 | 8,258 | 3,279 | 37.76 |

**Note:** Suzuki entered Vietnam in 1998, and Honda started producing cars in 2006 after ten years producing bikes only.

*Source: Sturgeon [15], PricewaterhouseCoopers [17]*

There are 12 joint venture automaker companies operating in Vietnam. Most of them were established during the 1995-1998 period, when the government allowed more automobile investments in Vietnam. These companies accounts for more than 90 percent of the Vietnamese automobile industry [18]; however, the productions were far lower than capacities even in those joint ventures. As described in Table 2, it is noticeable that from 1998 to 2006, the average production utilization of the Vietnamese automobile industry increased nearly three times; however, in comparison with its capacity, this proportion was still very small. In 2010, there were about 112,300 vehicles produced domestically while the capacity was 458,000 vehicles per year, resulting in a utilization ratio of 24.52 percent [33]. It is justify measuring the production efficiency of the industry using the frontier approach in order to evaluate how well it was in combining all inputs needed (such as labours and capital) to achieve the targeted outputs (such as productions and sales).

### *2.3 Data and variables*

Our data was extracted from the yearly general enterprises surveys (2005-2008) of the Vietnamese General Statistics Office (GSO). Since there are differences in the number and characteristics of enterprises surveyed in each year, we combined the four datasets using the matching method: we only keep enterprises working in the automobile industry (either producing/assembling autos or auto parts) that appeared throughout all surveys. Thus, we ended up with a panel data of eleven enterprises in four years, which made a total of 44 year-based observations. DEA will be employed to deal with that small sample issue.

It is obvious to apply the production approach[3] in selecting input and output variables of the DEA model. Here, inputs will include the number of labour (L) and total capital resources (K) needed for the production process. Note that the total capital resources include payments to labour (salaries and benefits), payments for tools and materials, and payments for the firm's construction. On the output side, value of productions (P) and turnovers (T) are considered. The statistical descriptive information of the data is presented in Table 3. Except for Labour where the unit is in person, the units for the other three variables are in million VND.

**Table 3:** Variables of the study

| Year | Variable | Mean | Standard Deviation | Minimum | Maximum |
|---|---|---|---|---|---|
| **2004** | *L* | 464 | 437 | 20 | 1,497 |
| | *K* | 44,548 | 42,432 | 828 | 141,800 |
| | *P* | 23,799 | 30,836 | 1,073 | 88,089 |
| | *T* | 200,629 | 225,505 | 13,485 | 657,872 |
| **2005** | *L* | 393 | 365 | 5 | 1,205 |
| | *K* | 44,809 | 47,977 | 336 | 125,383 |
| | *P* | 99,915 | 128,050 | 815 | 467,456 |
| | *T* | 159,151 | 188,627 | 15,129 | 594,612 |
| **2006** | *L* | 473 | 464 | 15 | 1,569 |
| | *K* | 66,384 | 95,353 | 428 | 325,452 |
| | *P* | 92,690 | 112,113 | 1,178 | 411,740 |
| | *T* | 289,539 | 335,566 | 20,277 | 997,241 |
| **2007** | *L* | 428 | 459 | 23 | 1,623 |
| | *K* | 71,996 | 128,345 | 188 | 435,026 |
| | *P* | 103,902 | 123,214 | 3,342 | 449,426 |
| | *T* | 363,863 | 557,393 | 16,064 | 1,858,085 |

## 3 RESULTS AND DISCUSSIONS

We first report the efficiency (EF) of each automobile firm in each year of the 2004-2007 periods in Table 4. The (average) production efficiency of the industry increased during the examined period, however, the small figures shows that inefficient existed in the Vietnamese automobile industry. In 2007, the average score reached 0.500, suggesting that automobile firms in Vietnam were operating at about 50% of their production capacity, consistent with the above discussion (see Table 2).

**Table 4:** Efficiency scores of individual firm

| | DMU 1 | DMU 2 | DMU 3 | DMU 4 | DMU 5 | DMU 6 | DMU 7 | DMU 8 | DMU 9 | DMU 10 | DMU 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **2004** | 0.394 | 0.027 | 0.019 | 0.058 | 0.108 | 0.125 | 0.142 | 0.027 | 0.063 | 0.136 | 1.000 |
| **2005** | 0.118 | 0.564 | 0.012 | 0.068 | 0.393 | 0.050 | 1.000 | 0.047 | 1.000 | 1.000 | 1.000 |
| **2006** | 0.235 | 0.244 | 0.205 | 0.205 | 0.397 | 0.136 | 1.000 | 0.074 | 1.000 | 0.493 | 1.000 |
| **2007** | 1.000 | 0.145 | 0.100 | 0.283 | 0.321 | 0.079 | 1.000 | 0.098 | 0.475 | 1.000 | 1.000 |
| **Average** | 0.437 | 0.245 | 0.084 | 0.153 | 0.305 | 0.098 | 0.785 | 0.062 | 0.634 | 0.657 | 1.000 |

According to Table 4, DMU 11 is the best practice firm in the industry as it was on the production frontier for the whole time (EF=1.000). Meanwhile, DMU 3, 6, and 8 were the worst performers. We also can see a significant improvement of DMU 1, 3, and 10 in 2007. It was because these firms reduced their input resources and thus reduced wastes while still maintained an increase in outputs.

**Table 5:** Slacks in the Vietnamese automobile industry, 2004-2007

| DMU | Excess labour (L) | Excess capital (K) | Shortage production (P) | Shortage turnover (T) |
|---|---|---|---|---|
| **DMU 1** | 132 | 418,007 | 0 | 7,190,595 |

[3] Discussions on this approach, as well as other alternatives, could be found in Berger and Humphrey [36].

| | | | | |
|---|---|---|---|---|
| **DMU 2** | 98 | 22,844 | 40,442 | 967,934 |
| **DMU 3** | 0 | 100,014 | 84,552 | 4,508,183 |
| **DMU 4** | 0 | 194,683 | 97,736 | 5,230,679 |
| **DMU 5** | 1,237 | 340,330 | 0 | 4,741,692 |
| **DMU 6** | 132 | 862 | 30,122 | 1,566,862 |
| **DMU 7** | 0 | 70,468 | 32,269 | 876,741 |
| **DMU 8** | 617 | 54,629 | 331,056 | 11,034,555 |
| **DMU 9** | 0 | 17,826 | 109,101 | 1,490,632 |
| **DMU 10** | 22 | 2,048 | 41,920 | 799,172 |
| **Total slacks** | 2,236 | 1,221,712 | 767,199 | 38,407,044 |
| **Total original value** | 19,352 | 2,505,109 | 3,523,362 | 11,145,001 |
| **Total slacks (%)** | 11.56 | 48.77 | 21.77 | 344.61 |

Since DMU 11 was on the frontier, it had no slack on input or output, i.e. no excess inputs or shortage outputs. For the others, the slacks are different for each firm but in overall, they account for at least 11% of the original value. In particular, automobile firms in Vietnam were using about 11% more labour and 49% more capital than needed to achieve 22% less production and 345% less turnover than they could (see Table 5).

When examining the productivity change over time, we observed that DMU 9, 2, 7, and 10 were ones with high improvement in term of total factor productivity. In overall, the TFP of the Vietnamese automobile industry improved nearly 3.5 times during the 2004-2007 periods. These improvements were resulted from the increasing of pure technical efficiency catch-up (EFCH) rather than from increasing in technological efficiency frontier-shift (TECHCH). It suggests that, while the technology did not change much during the examined period (average value of TECHCH is 1.337), automobile firms in Vietnam were step by step utilized their production capacity. The estimated (average) speed of capacity utilization, however, was decreased from around 561% in 2004/2005 to 289% and 128% in 2005/2006 and 2006/2007, respectively.

**Table 6:** TFP changes of automobile firms in Vietnam, 2004-2007

| DMU # | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **EFCH** | 2.205 | 7.214 | 6.133 | 1.851 | 1.816 | 1.233 | 3.154 | 1.538 | 6.125 | 3.726 | 0.881 | 3.262 |
| **TECHCH** | 1.020 | 1.654 | 1.282 | 0.989 | 1.363 | 1.488 | 1.558 | 1.028 | 1.552 | 1.641 | 1.130 | 1.337 |
| **TFPCH** | 1.457 | 6.504 | 2.591 | 1.452 | 3.373 | 1.392 | 5.457 | 1.604 | 8.436 | 4.887 | 0.972 | 3.466 |

## 4 CONCLUSIONS

We studied the efficiency and productivity change of the Vietnamese automobile industry during the 2004-2007 periods. Data for our empirical study was extracted from the yearly national enterprises surveys. The production X-efficiency was analysed using Data Envelopment Analysis approach and the productivity change was determined using the Malmquist Index approach. For the best of our knowledge, this is the first study to do so.

Our findings showed that efficiency of the Vietnamese automobile firms were low, with the highest average score of 0.500 in 2007, consistent with previous studies [15; 17]. Major issues concerning inefficiency in the industry related to a big waste in using capital resources (nearly 50% of total capital) and thus, the actual turnovers were about 350% less than its capability. By utilizing their production capacity, automobile firms in Vietnam could increase their productivity; however, its speed was decreased. Although technology is important [9; 2], it did not contribute much to the TFP growth of the Vietnamese automobile firms. Since technology could affect capacity utilization, it could be better for Vietnam to focus on this issue with preference.

## 5 REFERENCES

Womack, J. P., Jones, D. T., & Ross, D., The Machine that Changed the World, Rawson Associates, New York, NY, 1990.

Ülengin, F., Önsel, Ş., Aktas, E., Kabak, Ö., & Özaydın, Ö., "A decision support methodology to enhance the competitiveness of the Turkish automotive industry", European Journal of Operational Research, vol. 234, no. 3, 789-801, 2014.

McKenna, R., Reith, S., Cail, S., Kessler, A., & Fichtner, W., "Energy savings through direct secondary reuse: an exemplary analysis of the German automotive sector", Journal of Cleaner Production, vol. 52, 103-112, 2013.

Berggren, C., & Magnusson, T., "Reducing automotive emissions—The potentials of combustion engine technologies and the power of policy", Energy Policy, vol. 41, no. 0, 636-643, 2012.

Nieuwenhuis, P., Beresford, A., & Choi, A. K.-Y., "Shipping or local production? CO2 impact of a strategic decision: An automotive industry case study", International Journal of Production Economics, vol. 140, no. 1, 138-148, 2012.

Schmitz, J., & Platts, K. W., "Supplier logistics performance measurement: Indications from a study in the automotive industry", International Journal of Production Economics, vol. 89, no. 2, 231-243, 2004.

Wong, C. Y., Boon-itt, S., & Wong, C. W. Y., "The contingency effects of environmental uncertainty on the relationship between supply chain integration and operational performance", Journal of Operations Management, vol. 29, no. 6, 604-615, 2011.

Wad, P., "The Development of Automotive Parts Suppliers in Korea and Malaysia: A Global Value Chain Perspective", Asia Pacific Business Review, vol. 14, no. 1, 47-64, 2007.

Barnes, J., & Morris, M., "Staying alive in the global automotive industry: what can developing economies learn from South Africa about linking into global automotive value chains", European Journal of Development Research, vol. 20, no. 1, 31-55, 2008.

Vietnamese Government, "Decree No. 177/2004/QĐ-TTg on the Approvement of the Development project for the automotive industry in Vietnam toward 2010, vision 2020 (in Vietnamese)", 2004.

Business Monitor International, "Vietnam Autos Report Q4 2010", 2010.

Business Monitor International, "Vietnam Autos Report Q1 2012", 2012.

Economist Intelligence Unit, "Vietnam cars: Vietnamese car industry still stuck in reverse, claims official", 2013.

Vietnamese Government, "Conclusions of the Prime Minister at the Government regular meeting on the Development project for the automotive industry in Vietnam toward 2020, vision 2030 (in Vietnamese)", 2013.

Sturgeon, T. J., "The automotive industry in Vietnam: Prospects for development in a globalizing economy *Industrial Competitiveness Review* (pp. 46), Ministry of Planning and Investment (MPI), Hanoi, VN, 1998.

Economist Intelligence Unit, "Automotive Report Vietnam", The Economist Intelligence Unit (EIU), London, UK, 2004.

PricewaterhouseCoopers, "Vietnam's Automotive Component Industry: Ready to go global?", PricewaterhouseCoopers LLP, Hochiminh City, VN, 2007.

Thuy, N. B., "The Vietnamese Automobile Industry and Globalization", Paper presented at the The Fourth VDF-Tokyo Conference on The development of Vietnam, Tokyo, Japan, 2008.

VAMA, "Automotive market performance", Vietnam Automobile Manufacturers' Association (VAMA), Hanoi, VN, 2014.

Farrell, M. J., "The Measurement Of Productive Efficiency", Journal of the Royal Statistical Society, vol. 120, no. 3, 253-281, 1957.

Leibenstein, H., "Allocative efficiency vs. "X-efficiency"", The American Economic Review, vol. 56, no. 3, 392-415, 1966.

Charnes, A., Cooper, W. W., Golany, B., Seiford, L., & Stutz, J., "Foundation of Data Envelopment Analysis for Pareto-Koopmans Efficient Empirical Production Function", Journal of Econometrics, vol. 30, 91-107, 1985.

Seiford, L. M., & Thrall, R. M., "Recent developments in DEA: the mathematical programming approach to frontier analysis", Journal of Econometrics, vol. 46, no. 1, 7-38, 1990.

Banker, R. D., Charnes, A., & Cooper, W. W., "Some Models for Estimating Technical and Scale Inefficiencies in Data Envelopment Analysis", Management Science, vol. 30, no. 9, 1078-1092, 1984.

Russell, R. R., "Measures of technical efficiency", Journal of Economic Theory, vol. 35, no. 1, 109-126, 1985.

Tone, K., "A slacks-based measure of efficiency in data envelopment analysis", European Journal of Operational Research, vol. 130, no. 3, 498-509, 2001.

Malmquist, S., "Index numbers and indifference surfaces", Trabajos de Estadistica, vol. 4, no. 2, 209-242, 1953.

Caves, D. W., Christensen, L. R., & Diewert, W. E., "The economic theory of index numbers and the measurement of input, output and productivity", Econometrica, vol. 50, 1393-1414, 1982.

Färe, R., Grosskopf, S., Norris, M., & Zhang, Z., "Productivity growth, technical progress, and efficiency change in industrialized countries", The American Economic Review vol. 84, no. 1, 66-83, 1994.

Mukherjee, K., Ray, S. C., & Miller, S. M., "Productivity growth in large US commercial banks: The initial post-deregulation experience", Journal of Banking & Finance, vol. 25, no. 5, 913-939, 2001.

Asmild, M., Paradi, J., Aggarwall, V., & Schaffnit, C., "Combining DEA Window Analysis with the Malmquist Index Approach in a Study of the Canadian Banking Industry", Journal of Productivity Analysis, vol. 21, no. 1, 67-89, 2004.

Ngo, D. T., & Nguyen, L. T. P., "Total Factor Productivity of Thai Banks in 2007-2010: An Application of DEA and Malmquist Index", Journal of Applied Finance and Banking, vol. 2, no. 5, 27-42, 2012.

Quynh Minh, The automotive industry: Vision 2030 (in Vietnamese), In *Commercial & Industrial News Online*, Retrieved from http://baocongthuong.com.vn/co-khi-luyen-kim/34927/cong-nghiep-o-to-tam-nhin-den-nam-2030-ky-i.htm, 2013.

OICA, OICA Statistics, Retrieved from http://www.oica.net/category/production-statistics/, 2014.

AAF, ASEAN Automotive Federation Statistics, Retrieved from http://www.asean-autofed.com/statistics.html, 2014.

Berger, A. N., & Humphrey, D. B., "Efficiency of financial institutions: International survey and directions for future research", European Journal of Operational Research, vol. 98, 175-212, 1997.