TECHNICAL AND SCALE EFFICIENCY OF THE TURKISH AUTOMOTIVE INDUSTRY USING DATA ENVELOPMENT ANALYSIS[1]

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Abstract

In this study, regarding to the period of 2011-2015, the technical and scale efficiencies of 14 firms as well as the changes of their total factor productivities were analyzed. In identifying the relative efficiencies of the firms, Data Enveloping Analysis were utilized, and in introducing the variation of total factor productivity in time Malmquist Total Factor Productivity Index. According to the results of analysis, under the assumption of constant return, in the years of 2011 and 2013, it was identified that only Oyak Renault reached maximum output and in the years of 2012, 2014, and 2015, Hyundai Assan and Oyak Renault. Under the assumption of variable return, it was identified that in the years of 2011, 2012, 2014 and, 2015, A.I.O.S., Hattat Tarım, Hyundai Assan, Otokar, Oyak Renault and Türk Traktör took place on the frontier of full production and in 2013, A.I.O.S., Hattat Tarım, Otokar, Oyak Renault and Türk Traktör. When scale efficiencies are examined, it was identified that in the years of 2011 and 2013, Oyak Renault made production in optimal production scale and in the years of 2012, 2014, and 2015, Hyundai Assan and Oyak Renault, while the scale efficiencies of the other firms were less than from the other aspect, it was identified that total factor productivity of Turkish automotive industry increased by 14% and that maximum increase on the basis of firm actualized in the firm A.I.O.S.

Keywords: DEA, Automotive Industry, Turkey.

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VERİ ZARFLAMA ANALİZİ YARDIMIYLA TÜRK OTOMOTİV ENDÜSTRİSİNDE TEKNİK VE ÖLÇEK ETKİNLİĞİ

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Öz

Bu araştırmada 2011-2015 dönemi dikkate alınarak, otomotiv ana sanayinde faaliyet gösteren 14 firmanın teknik ve ölçek etkinliklerinin yanı sıra toplam faktör verimliliklerindeki değişmeler analiz edilmiştir. Firmaların göreli etkinliklerinin belirlenmesinde Veri Zarflama Analizinden, toplam faktör verimliliğinin zaman içindeki değişiminin ortaya konulmasında Malmquist Toplam Faktör Verimliliği Endeksinden yararlanılmıştır. Analiz sonuçlarına göre, ölçeğe göre sabit getiri varsayımı altında 2011 ve 2013 yıllarında sadece Oyak Renault'un 2012, 2014 ve 2015 yıllarında ise sadece Hyundai Assan ve Oyak Renault'un maksimum çıktıya ulaştıkları tespit edilmiştir. Değişken getiri varsayımı altında ise 2011, 2012, 2014 ve 2015 yıllarında A.I.O.S., Hattat Tarım, Hyundai Assan, Otokar, Oyak Renault ve Türk Traktör'ün, 2013 yılında ise A.I.O.S., Hattat Tarım, Otokar, Oyak Renault ve Türk Traktör'ün tam üretim sınırı üzerinde yer aldıkları belirlenmiştir. Ölçek etkinlikleri incelendiğinde ise, 2011 ve 2013 yıllarında Oyak Renault'un, 2012, 2014 ve 2015 yıllarında ise Hyundai Assan ve Oyak Renault'un optimal üretim ölçeğinde üretim yaptıkları, diğer firmaların ise ölçek etkinliklerinin 1'den küçük olduğu belirlenmiştir. Diğer taraftan Türk otomotiv sanayinin toplam faktör verimliliğinin % 14 arttığı, firma bazında en fazla artışın A.I.O.S. firmasında gerçekleştiği tespit edilmiştir.

***Anahtar Kelimeler*:** VZA, Otomotiv Endüstrisi, Türkiye

Introduction

The globalization process, which has gained momentum in almost every area since the 1990s, has also increased the importance of rational and effective use of available resources. When a problem is addressed in terms of companies that are economic decision makers, maximization of costs and maximization of production are profit maximization, which is the ultimate goal, depending on the intermediate purposes. When it is considered from the sectorial point of view, it can be said that one of the sectors where the effect of globalization is most seen is the automotive industry. For this reason, the automotive industry is perceived as a prototype in terms of globalized products. The first assembly production experiment in the Turkish automotive industry, which dates back to the beginning of the 20th century, was made by Ford Motor Istanbul in 1929. The Turkish Automotive Industry, which produced a total of 10,000 vehicles in the 1960s, has reached 1.8 million vehicle production capacities today. According to the data of the year 2015, approximately 50000 people are employed in the Turkish automotive main industry, 1.5 million vehicles are produced and about 1 million of these vehicles are exported. The export revenue of the industry is about 14 billion dollars (Çoban, 2007; OSD, 2016).

Maritz and Shieh (2013) have researched performance of automobile industry in Taiwan with data envelopment analysis for 2007-2009 period. In this paper, inputs are number of employee, operating cost and gross asset, output is operating income. The results showed that average total efficiency was 0.89 in 2007-2009 period. Tran and Ngo (2014), have analyzed the efficiency and productivity change of the Vietnamese automobile industry during the 2004-2007 periods, using the Malmquist - Data Envelopment Analysis approach. In this study, inputs are the number of labor and total capital resources (payments to labor (salaries and benefits), payments for tools and materials, and payments for the firm's construction). Outputs are also value of productions and turnovers. This analysis findings have showed that efficiency of the Vietnamese automobile firms were low. Tatlı and Bayrak (2016) have analyzed production efficiency for 15 automotive manufacturer firms listed in Borsa Istanbul according to period of 2010-2014 with both static and dynamic Data Envelopment Analysis. When equity, personnel costs, raw material costs and R&D investments as inputs have been used, there have been total turnover, total export and profit as outputs in the study. According to dynamic data enveloping analysis results; only four firms have been observed as ineffective of decision making units both by CRS and VRS models; whereas the other 11 firms as effective of decision making units for the period of all years. Kumar et al. (2017), have analyzed

efficiency of automobile manufacturing companies in India using Data Envelopment Analysis. In this study, total expenses and employees benefits expenses have used as inputs. Also gross asset and total operating income have been taken place in this analysis as outputs. Results showed that three firms were fully efficient.

In this study, in the scale of both firm and industry, it was aimed to identify the technical and scale efficiency as well as the resource of variations occurring in efficiency in Turkish automotive industry. In the analyses, in which the data of the period 2011-2015 were used, 14 firms being in active in main automotive industry were considered. The dataset regarding to these firms were compiled from OSD statistics. In determining the relative efficiencies of the firms, data enveloping analysis (DEA), which is an approach of non-parametric mathematical linear programming based on frontier estimation, was utilized. DEA is also known as non-parametric programming. By means of this method, at the present days, efficiency analysis has been carried out in many different areas (For detailed information, see Kök and Çoban, 2002; Kök and Deliktaş, 2003; Çoban, 2007; Çoban et al., 2009). In order to examine the variation in total factor productivity of both firms and industry, Malmquist Total Factor Productivity Index (Malmquist TFP Index), added to literature by Malmquist (1953). This method measures the variation in total factor productivity between two data points belonging to the different times and is used in accordance with productivity analyses (For detailed information, see; Lorcu, 2010; Chen, 2011; Çoban et al., 2015; Ara, 2016).

Methodology

Variables and Data

In this study, the technical and scale efficiencies of 14 firms being active in main Turkish automotive industry as well as the resource of the variations in productivity were dealt with. The firms under consideration are A.I.O.S., Ford Otosan, Hattat Tarım, Honda Türkiye, Hyundai Assan, Karsan, M.A.N. Türkiye, M. Benz Türk, Otokar, Oyak Renault, Temsa Global, Tofaş, Toyota, and Türk Traktör. The data used in the analyses, in which the period 2011-2015 were considered, were obtained from General and Statistical Information Bulletin of Automotive Manufacturers. In the analyses, in which Version 2.1 of DEAP program (A Data Envelopment Analysis (Computer) Program), the variables of capital and labor as input and amounts of production as output. The reason for choosing this period is to reach the full data for this period. inputs and outputs are also determined from the production function (Q = f (K, L)). K refers to capital, L refers to labor and

Q refers to production in the production function. Capital, labor and production are shown respectively 1000 TL, number of employees and number of vehicles. The descriptive statistics regarding the variables concerned take place in Table 1.

Table 1: Descriptive Statistics of 2 Input and 1 Output Variables

Years	Variables	N	Minimum	Maximum	Mean	Std. Deviation
2011	Production Unit	14	1610	330994	87922	124947
	Capital	14	24000	500000	185638	141567
	Employees	14	256	9581	3030	2902
2012	Production Unit	14	1134	310602	79549	112277
	Capital	14	24000	500000	185638	141567
	Employees	14	184	9527	3035	2827
2013	Production Unit	14	1300	331694	83289	116070
	Capital	14	24000	627235	220314	184749
	Employees	14	88	9444	3024	2685
2014	Production Unit	14	1051	318246	87061	113021
	Capital	14	24000	627235	234606	195478
	Employees	14	108	9762	3120	2780
2015	Production Unit	14	1743	339240	100717	133133
	Capital	14	24000	627235	234606	195478
	Employees	14	190	10676	3482	3103

Analysis Method

In this study, as analysis method, DEA as well as was Malmquist TFP index were utilized. DEA is the non-parametric mathematical programming approach to frontier estimation. This method is a linear programming-based technique used to measure the relative effectiveness of organizational units in which a large number of inputs and outputs are involved. This technique, which was developed by Charnes, et al. in 1978, has become popular in a short time and used in many different areas. Because in this technique, multiple input and output factors can be evaluated at the same time and there is no need for a previously known analytical function between inputs and outputs. In addition, this technique provides an easy approach to linear

programming, the source of ineffectiveness and the alternative approaches to decision makers (For detailed information, see Farrell (1957); Boles (1966); Afriat (1972); Banker et al. (1984); Seiford and Thrall (1990); Lovell (1993); Ali and Seiford (1993); Lovell (1994); Charnes et al. (1995) and Seiford (1996)).

DEA is based on empirical production (efficiency) frontier, depending on the level of input and output belonging to decision units. For the decision units taking place on this production frontier, $\theta_0=1$ will be and, for the other decision units, they will form a set of reference. Non-effective decision units will remain under this frontier. In other words, that the value of technical efficiency index, calculated by means of DEA, equals to 1 means that firm provides full technical efficiency, which it is less than 1 means that firm cannot produce maximum output with the existing set of input. In this framework, that technical efficiency indices obtained under the assumption of variable returns to scale take the different values points out that firm does not production in optimal production scale.

Malmquist TFP index, first introduced by Malmquist (1953) and defined based on distance functions, is a technique measuring variation in total factor productivity between two data points belonging to the different times, and commonly used, calculating the rates of the distances of each data point to a common technology. Distance functions are the functions defining production technologies, which include a number of input, based on only the information of quantity (Fare et al., 1994). Input- distance function defines production technology, depending on the input vector, which proportionally contracts the most. Similarly, output-distance function defines production technology, depending on the input vector, which proportionally expands the most, when input vector is given (Çakır and Perçin, 2012).

TFP= TC*TEC (1)

An improvement in technological change (TC) is considered a shift in the best-practice frontier; in fact an improvement in Technical efficiency change (TEC) is called “catch up” term. The technical efficieny change (TEC) is decomposed into the scale change (SEC) and pure efficiency change (PTEC) components.

TEC = PTEC*SEC (2)

In this study, output oriented efficiency measurement was taken into consideration. Output oriented efficiency measurement, with a particular

input vector can be produced under the use of a particular production technology shows the ratio of the maximum output level of the output level of the observed (Coelli et al., 2005). If the Malmquist TFP index value is greater than 1, it indicates an increase in productivity, If index values is smaller than 1; it indicates a decrease in efficiency. If the index is equal to 1, shows that there is no change in productivity

Empirical Results

Output oriented DEA results belonging to the period 2011-2015 take place in Appendix 1. According to Appendix 1, under the assumption of constant returns to scale, in the years of 2011 and 2013, it is seen that the technical efficiency indices of the firms out of Oyak Renault are less than 1 and in the years of 2012, 2014, and 2015, the firms out of Assan and Oyak Renault. This determination means that in the relevant years, in the firms out of Oyak Renault and Hyundai Assan, some part of production factors remain idle and, thus, these firms cannot reach maximum output.

Under the assumption of variable return, when the values of technical efficiency are examined, while it was identified that in the years of 2011, 2012, 2014 and 2015, A.I.O.S., Hattat Tarım, Hyundai Assan, Otokar, Oyak Renault and Türk Traktör took place on the full production frontier, index values of the other firms were less than 1. When the scale efficiencies of the firms are examined, in the years of 2011 and 2013, that the values of **crste** and **vrste** index of the firms out of Oyak Renault are different from each other and in the years of 2012, 2014 and 2015, the firms out of Hyundai Assan and Oyak Renault and, thus, that their scale efficiencies are less than 1 express that these firms do not make production in optimal production scale.

In the framework of data enveloping analysis, in order to measure the variations in efficiency, the results of Malmquist TFP index take place in Table 2.

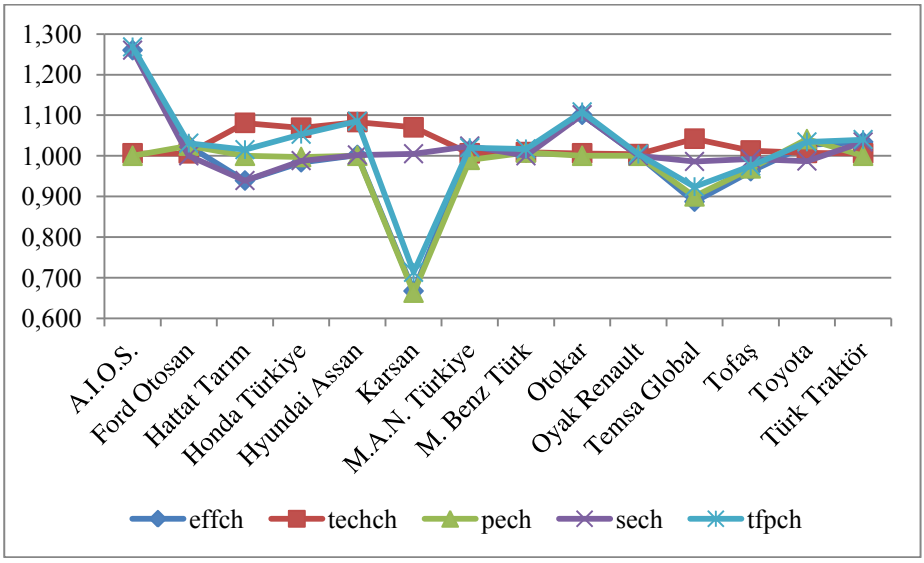
Table 2: Malmquist Index Summary of Firm Means

Firms	effch	techch	pech	Sech	tfpch
A.I.O.S.	1,260	1,006	1,000	1,260	1,268
Ford Otosan	1,025	1,006	1,025	1,000	1,031
Hattat Tarım	0,939	1,081	1,000	0,939	1,015
Honda Türkiye	0,984	1,069	0,997	0,988	1,053
Hyundai Assan	1,002	1,083	1,000	1,002	1,085
Karsan	0,667	1,070	0,663	1,005	0,713
M.A.N. Türkiye	1,014	1,006	0,990	1,024	1,020
M. Benz Türk	1,008	1,009	1,008	1,000	1,017
Otokar	1,101	1,006	1,000	1,101	1,108
Oyak Renault	1,000	1,004	1,000	1,000	1,004
Temsa Global	0,887	1,042	0,900	0,986	0,924
Tofaş	0,962	1,013	0,969	0,992	0,975
Toyota	1,027	1,007	1,041	0,987	1,034
Türk Traktör	1,034	1,006	1,000	1,034	1,040
Mean	0,985	1,029	0,966	1,020	1,014

Note: effch, technical efficiency change (relative to a CRS technology); techch, technological change; pech, pure technical efficiency change (i.e., relative to a VRS technology); sech, scale efficiency change; tfpch, total factor productivity (TFP) change.

According to Table 2, in the period dealt with, total factor productivity of Turkish automotive industry increased in the rate of 14%. In this scope, although there is a decrease in the technical efficiency and pure efficiency, an increase occurred in the technology and scale efficiency. When considered on the basis of firm, in 11 (79%) of a total of 14 firms, it was identified that total factor productivities increased. A.I.O.S, with the increase of 27%, became a firm, whose total factor productivity increases the most. This firm was followed by Hyundai Assan 8.5(%), Honda Türkiye (5.3%) and Türk Traktör 3.4(%). As seen in the Figure 1, the firms, whose total factor efficiencies decrease became Karsan, Temsa Global and Tofaş.

Figure 1: Malmquist Index Summary of Firm Means



When annual average in total factor productivity of Turkish automotive industry is considered, the analysis results taking place in Table 3.

Table 3: Malmquist Index Summary of Annual Means

Years	effch	techch	pech	sech	tfpch
2012	0,938	0,960	0,932	1,006	0,900
2013	1,027	1,077	0,972	1,056	1,106
2014	0,803	1,094	0,810	0,992	0,879
2015	1,219	0,990	1,185	1,028	1,207
Mean	0,985	1,029	0,966	1,020	1,014

Note: effch, technical efficiency change (relative to a CRS technology); techch, technological change; pech, pure technical efficiency change (i.e., relative to a VRS technology); sech, scale efficiency change; tfpch, total factor productivity (TFP) change.

When Table 3 is examined, in the years of 2012 and 2014, it was identified that total factor productivity of Turkish automotive industry decreased by 10 % and 12% compared to the previous period. In spite of this, in the years of 2013 and 2015, it increased by 11% and 12%, respectively, compared to the previous period. When the general averages are taken into consideration, as seen in Table 2, total factor productivity increased 145.

Conclusions

In this study, at the level of both firm and industry, the technical and scale efficiencies as well as variations in total factor productivity in Turkish automotive industry were analyzed. In the period of 2011-2015, in the analyses, in which 14 firms being in active in the main industry are considered, DEA index as well as TFP index were utilized.

According to DEA results, under the assumption of constant returns to scale, in the years of 2011 and 2013, it was identified that only Oyak Renault reached maximum output and in the years of 2012, 2014 and 2015, Hyundai Assan and Oyak Renault. In the assumption of variable return, it was identified that in the years of 2011, 2012, 2014, and 2015, A.I.O.S., Hattat Tarım, Hyundai Assan, Otokar, Oyak Renault, and Türk Traktör took place on the full production frontier and in the year of 2013, A.I.O.S., Hattat Tarım, Otokar, Oyak Renault, and Türk Traktör. It was identified that index values of the other firms are less than 1. In this scope, when the scale efficiencies are examined, in the years of 2011 and 2013, it was identified that Oyak Renault made production at the level of optimal production and in the years of 2012, 2014 and 2015, Hyundai Assan, and Oyak Renault, while the scale efficiencies of the other firms are less than 1.

According to the results of Malmquist TFP index analysis, total factor productivity of Turkish automotive industry increased by 14%. In this scope, it was identified that total factor productivity of 79% of the firms considered in the analyses increased, while maximum increase actualized in the firm A.I.O.S. The firms, whose total factor efficiencies fall, are Karsan, Temsa Global and Tofaş. When all automotive industry is considered, in the years of 2012 and 2014, total factor efficiency increases by 12% and 14%, respectively, compared to the previous period and in the years of 2013 and 2015, by 11% and 21%, respectively.

As a result of the data envelopment analysis in the studies related to the automotive sector in the literature, some firms were effective and some firms were found ineffective. Therefore, this study shows similar results with Maritz and Shieh (2013), Tran and Ngo (2014), Tatlı and Bayrak (2016) and Kumar et al. (2017) studies in the literature.

In order to increase the efficiency of the automotive sector in Turkey, firms should give importance to the technological development. Because technological developments are an important factor in increasing the productivity of both labor and capital factor. In addition, giving importance

to R & D activities is an important factor that enhances the development and effectiveness of both the company and the market. In this sector increasing export-oriented production plays an important role on the effectiveness of firms. One of the important factors affecting the effectiveness of the firms is the time they are in the market.

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Appendix 1: Output Oriented DEA Results: 2011-2015

	2011			2012			2013			2014			2015		
Firms	crste	vrste	Scale	crste	vrste	scale	crste	vrste	scale	crste	vrste	scale	crste	vrste	scale
A.I.O.S.	0,166	1	0,166 irs	0,195	1	0,195 irs	0,188	1	0,188 irs	0,307	1	0,307 irs	0,419	1	0,419 irs
Ford Otosan	0,823	0,894	0,921 drs	0,807	0,876	0,921 drs	0,781	0,848	0,921 drs	0,709	0,769	0,922 drs	0,909	0,986	0,922 drs
Hattat Tarım	0,353	1	0,353 irs	0,271	1	0,271 irs	0,412	1	0,412 irs	0,286	1	0,286 irs	0,275	1	0,275 irs
Honda Türkiye	0,247	0,275	0,898 irs	0,517	0,575	0,9 irs	0,329	0,35	0,942 irs	0,191	0,212	0,9 irs	0,232	0,271	0,855 irs
Hyundai Assan	0,993	1	0,993 irs	1	1	1	0,86	0,874	0,984 irs	1	1	1	1	1	1
Karsan	0,431	0,476	0,905 irs	0,235	0,243	0,969 irs	0,243	0,256	0,95 irs	0,023	0,025	0,941 irs	0,085	0,092	0,924 irs
M.A.N. Türkiye	0,024	0,033	0,737 irs	0,018	0,025	0,738 irs	0,019	0,027	0,728 irs	0,016	0,021	0,773 irs	0,026	0,032	0,809 irs
M. Benz Türk	0,08	0,081	0,995	0,079	0,08	0,995	0,079	0,08	0,99 irs	0,082	0,082	0,996	0,083	0,083	0,995
Otokar	0,125	1	0,125 irs	0,124	1	0,124 irs	0,197	1	0,197 irs	0,138	1	0,138 irs	0,183	1	0,183 irs
Oyak Renault	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Temsa Global	0,047	0,048	0,987 irs	0,027	0,027	0,999	0,031	0,032	0,977 irs	0,025	0,026	0,95 irs	0,029	0,031	0,934 irs
Tofaş	0,736	0,93	0,792 drs	0,696	0,826	0,843 drs	0,677	0,737	0,918 drs	0,587	0,7	0,839 drs	0,63	0,82	0,768 drs
Toyota	0,661	0,692	0,955 irs	0,648	0,675	0,96 irs	0,664	0,72	0,922 irs	0,89	0,977	0,911 irs	0,736	0,813	0,905 irs
Türk Traktör	0,743	1	0,743 irs	0,771	1	0,771 irs	0,702	1	0,702 irs	0,872	1	0,872 irs	0,849	1	0,849 irs
Mean	0,459	0,673	0,755	0,456	0,666	0,763	0,442	0,637	0,774	0,438	0,629	0,774	0,461	0,652	0,774

Note: crste = technical efficiency from CRS DEA; vrste = technical efficiency from VRS DEA; scale = scale efficiency = crste/vrste; irs = increase return scale; drs = decrease return scale.