Efficiency Analysis in the Automotive And Automotive Supply Industries: An Application With Data Envelopment Analysis

Otomotiv ve Otomotiv Yan Sanayi Sektöründe Etkinlik Analizi: Veri Zarflama Analizi ile Bir Uygulama

Hilal OK ERGÜN [*] Zekiye AKTAŞ [**]

Makale Geliş Tarihi / Received :26.10.2023
Makale Kabul Tarihi / Accepted :07.12.2023

ABSTRACT

In this study, the relative performance of firms traded in the automotive and automotive supplier industry sectors on the Borsa Istanbul (BIST) is evaluate using data envelopment analysis (DEA). It examines that 8 automotive and 11 automotive supplier firms's data and examined. The inputs of the analysis are employee count, total assets, and total equity, and the outputs including net sales and net profit. The analysis employs scale CCR and BCC models to identify relatively efficient firms as of 2022 and set reference benchmarks for non-efficient ones. This study is distinct for separately analyzing the automotive and supply industry industries, recognizing their complementary activities and differing from other studies in terms of the period considered. According to the findings, in the automotive industry, 3 firms are efficient based on the CCR model, and 6 firms demonstrate efficiency according to the BCC model. Additionally, 5 firms exhibit improving scale efficiency among those initially deemed non-efficient. In the automotive supply industry, 8 firms are efficient in input-oriented analyses and 9 in output-oriented analyses utilizing the BCC model. The CCR model confirms efficiency for 8 firms, while the scale efficiency of 3 initially non-efficient firms is seen to improve.

Anahtar Kavramlar:. *Automotive Industry, Automotive Supply Industry, Data Envelopment Analysis*.

ÖZET

Bu çalışmada BIST'te otomotiv ve otomotiv yan sanayi sektörlerinde işlem gören firmaların göreceli performansı veri zarflama analizi (VZA) ile araştırılmıştır. Otomotiv sektöründe 8, yan sanayi sektöründe ise 11 firma verileri incelenmiştir. Analizin girdileri personel sayısı, aktif ve öz kaynak toplamı iken; çıktıları net satış ve net kardır. Analiz kapsamında CCR ve BCC modelleri çözümlenerek 2022 yılı itibariyle görece etkin firmalar belirlenmiş ve etkin olmayan firmalar için referans firmalar tespit edilmiştir. Çalışma yaptıkları faaliyetler açısından birbirlerinin tamamlayıcı olan otomotiv ve yan sanayi sektörlerinin etkinliklerini ayrı ayrı ele almakta ve dönem itibariyle diğer çalışmalardan ayrışmaktadır. Elde edilen bulgulara göre, otomotiv sektöründeki firmalar için girdiye ve çıktıya yönelik yapılan analizlerde CCR modeline göre 3, BCC modeline göre 6 firmanın etkinliği saptanmıştır. Ayrıca etkinliği tespit edilemeyen 5 firmanın da ölçek etkinlik durumunun artan olduğu sonucuna varılmıştır. Otomotiv yan sanayinde faaliyet gösteren firmalar açısından girdiye yönelik analizlerde BCC modeline göre 8, çıktıya yönelik analizlerde 9 firmanın etkinliği tespit edilmiştir. CCR modeli kapsamında ise girdi ve çıktıya yönelik analizlerde benzer bulgular elde edilmiş ve 8 firmanın etkinliği saptanmıştır. Bununla birlikte etkinliği tespit edilemeyen 3 firmanın da ölçeğe göre etkinlik durumunun artan olduğu sonucuna varılmıştır.

Keywords:. *Otomotiv Sektörü, Otomotiv Yan Sanayi Sektörü, Veri Zarflama Analizi*.

[*] *Dr.Öğr.Üyesi, Trabzon University, Beşikdüzü Vocational School, hilalok@trabzon.edu.tr, ORCID No: 0000-0002-1454-3677*
[**] *Dr.Arş. Gör. , Karadeniz Technical University, Social Sciences Institute, zekiyetemizer@ktu.edu.tr, ORCID No: 0000-0002-4912-0412*

INTRODUCTION

The automotive and automotive supply industry constitute locomotive industrys within Türkiye. They stand among the prominent industrys within the manufacturing industry, given their potential to provide employment opportunities and create added value. Furthermore, considering the contributions of the automotive industry to associated industries, its impact on the national economy is undeniable.

The automotive and automotive supply industry industry is expanding day by day from the point of production and export volume. As of the year 2021, it is observed that many firms operating in the automotive and automotive supply industry industrys are listed among Türkiye's Top 500 Industrial Enterprises (ISO, 2023). The advancement of the automotive industry has provided opportunities for the emergence of the automotive supply industry industry, which has rapidly developed. The automotive supply industry industry is characterized by providing material supply to the automotive industry and possesses high capacity and a significant export potential. In this context, our country significantly contributes to the automotive industry (Uludağ Exporters' Associations, 2021: 1).

In light of the information provided above, the goal of this paper is to measure the relative impact level of firms operating in the automotive and automotive supply industry industrys in Türkiye. The study examines 8 firms operating in the automotive industry listed on Borsa Istanbul (BIST) and 11 firms operating in the automotive supply industry. Data envelopment analysis (DEA) is utilized for performance measurement of the firms. The study also encompasses firms operating in the automotive supply industry, distinguishing itself from the literature available up to the examined period. This aspect underscores the originality of the study. In this context, it is anticipated that the study will contribute to the existing literature.

The study is structured into four sections. The first section provides an introduction to the topic. The second section, dedicated to the literature review, examines previous studies within the scope of the automotive industry. The third section presents the methodology, encompassing analysis and findings. Finally, the fourth section encapsulates the analysis and findings.

1. LITERATURE REVIEW

In domestic and foreign literature, studies measuring the performance of automotive industry firms in terms of efficiency, particularly employing the Data Envelopment Analysis (DEA) method, have been identified. Below are some of the studies that address the automotive industry from an efficiency perspective.

In the study conducted by Yıldız (2006), the efficiency and effectiveness levels of 13 firms operating in the automotive industry that were profitable in the year 2004 were tested using the DEA method. A two-stage process was followed in the analysis. In the first stage of the analysis, where the number of personnel, total assets, and paid-in capital were used as inputs, and sales were used as outputs, the second stage considered sales as the input variable and net period profit and operating profit as the output variables. According to the obtained findings, FM-İzmit Piston and Karsan exhibit high levels of efficiency, although their effectiveness levels are at a low level. On the other hand, Ditaş and Tofaş maintain high levels of effectiveness but have lower efficiency

levels. Anadolu Isuzu, Otokar, Brisa, Kordsa, Uzel, Ford, Good-Year, and Doktaş firms, however, demonstrate both effectiveness and efficiency levels at a lower tier. In this study, where a firm with high performance in terms of efficiency and effectiveness could not be identified, emphasis has been placed on the need to reduce the input quantity utilized, especially in terms of increasing sales. Additionally, it is underscored that efforts should be directed towards increasing both the operating profit and the net period profit.

In the study conducted by Bakırcı (2006), the impact of 13 firms operating in the automotive industry, which were included in the ISO 500 list in 1999 and 2004, was measured using the DEA method. The study determined net assets, equity, and the number of personnel as input variables, while net sales, pre-tax profit, and exports were identified as the outputs. According to the analysis results, in both periods, Mercedes and Erkunt were found to operate at full efficiency. In the transition to the year 2004, despite efforts to increase efficiency by Man, Temsa, Anadolu Honda, and Nursan, the efficiency of BMC, Hema, Kale Oto, Tırsan, and Mako decreased. Additionally, the study highlighted that the issue in particularly non-efficient firms stemmed from excessive investment in inputs, and it concluded that achieving full efficiency could be attained through reducing inputs.

In Çoban's study (2007), the economic performance of firms operating in the automotive industry was evaluated in terms of both productivity and efficiency. The calculation of the productivity index was based on labor productivity, and the DEA method was utilized for efficiency measurement. In the productivity analysis, data for 17 firms operating in the automotive industry from 1990 to 2004 were used, while the data for the year 2004 of these firms were used in the efficiency analysis. In the Data Envelopment Analysis (DEA) method, technical efficiency indices were calculated by considering the production quantities, capital, and the amounts paid to labor as wages and bonuses for the year 2004. The analysis results revealed that among the firms with the highest labor productivity between 1990 and 2004 were Oyak Renault, Toyota, Tofas, Hyundai Assan, and Honda. On the other hand, the firms with the lowest labor productivity were identified as MAN Türkiye, M. Benz Türk, Askam and BMC. As for the technical efficiency, which constitutes another aspect of performance, Hyundai Assan, Oyak Renault, and Toyota ranked at the top.

In the study conducted by Özdemir and Düzgün (2009), the efficiency levels of 34 firms operating in the automotive industry and listed in the ISO 500 were measured using the DEA method. The study utilized 2006 data and classified automotive firms based on their capital structures (domestic, public, foreign, and mixed). The inputs for the analysis were net assets, equity, and the number of employees, while the outputs were revenue, pre-tax profit and exports. According to the obtained outputs, among the 34 firms included in the sample, only 6 (Oyak Renault, Karsan, SE Otomotiv, Teklas, Yazaki Wiring and Cevher Jant) have achieved full efficiency in managing their inputs and outputs. Considering the diversity in their capital structures, no significant difference was found in the efficiency levels of the firms.

Lorcu (2010) formed the sample of the study from among the 500 firms published by the Istanbul Chamber of Industry (ISO), comprising 14 firms active in the automotive and supply industry. The total factor productivities of the respective firms were examined within the time frame of 2003-2007. In the study, the number of employees and net assets were chosen as input variables,

while exports, pre-tax profit, and gross value added were considered as output variables. According to the analysis results, there was no significant increase in technical efficiency over the years 2003-2007. However, between 2003 and 2004, there was a respective increase of 1.3% and 9.1% in both technical and technological efficiency. Similarly, a positive change of 10.5% was observed in average total factor productivity from 2003 to 2004.

In the study conducted by Yılmaz and Karakadılar (2010), a sample was selected comprising 9 domestically produced passenger cars and 10 imported passenger cars intended for sale in Türkiye. The objective was to ascertain whether a significant difference in efficiency existed between domestically manufactured and imported vehicles. Data Envelopment Analysis was employed in the study, with inputs being the on-road price of the car model and the maintenance service cost paid per 10,000 km. The outputs included the volumetric dimensions of the car, engine horsepower, and the time taken to accelerate from 0 to 100 km/h. In consequence of the analysis, it was observed that the average efficiency scores of domestically produced (0.973) and imported vehicles (0.972) were very close to each other. Despite the greater demand for imported vehicles, domestically produced vehicles were found to have higher relative productivity. This suggests that domestically produced models impose less economic burden on consumers compared to imported vehicles, which is another finding obtained from the study.

In Nandy's study (2011), the efficiency levels of 14 different automotive firms in India for the period of 2007-2008 were investigated utilizing Data Envelopment Analysis. The input variables in the analysis were selected as raw material expenses/total expenses, labor cost/total expenses, sales and administrative expenses/total expenses. As for the output variables, net profit margin and pre-tax profit were chosen for the analysis. According to the CCR and BCC models, 8 firms (Amtek Auto Ltd., Bajaj Auto Ltd., Bharat Forge Ltd., Bosch Ltd., Cummins India Ltd., Exide Industries Co. Ltd., Hero Honda Motors Ltd., and Maruti Suzuki India Ltd.) operate at full efficiency. The most non-efficient firms in both models are Escorts Ltd. and Tata Motors Ltd., respectively.

In the study conducted by Maritz and Shieh (2013), the efficiency of firms operating in the automotive industry in Taiwan was investigated for the years 2007-2009. The sample included 6 firms. The study utilized the DEA method, with total assets, operating expenses, and the number of employees representing the input variables; while operating profit represented the output variable. Regarding the findings obtained from the analysis, Kuozui Motors exhibited the most successful performance in regard of overall efficiency, pure technical efficiency, and scale efficiency across all years. On the other hand, Sanyang was identified as the least successful firm. The average overall efficiency of the automotive industry was found to be 89%.

In the study by Tran and Ngo (2014), the efficiency and productivity of 11 firms operating in the automotive industry in Vietnam from 2004 to 2007 were investigated using DEA and the Malmquist method. The input variables in the study were the number of employees and capital resources, while the output variables were production quantity and revenue. According to the outputs obtained, one firm in 2004, 3 firms in 2005-2006 and 4 firms in 2007 continued their activities at the optimum scale. There was only one firm that remained efficient throughout all the years. Total factor productivity increased by 3.5 times between the years 2004 and 2007.

Yaylalı and Çalmaşur (2014) utilized the 1992-2001 period data of 19 firms in the automotive industry. In the paper, turnover was used as output and capital and labor variables were used as inputs. As for that the results of the analysis, although there was no change in the total factor productivity of Askam and Renault for one period, the total productivity of all firms in general increased during the relevant period. M.A.N., M. Benz and Uzel have the highest productivity compared to the firms in the industry. In addition, A.I.O.S., B.M.C., Ford, Karsan, M.A.N., M. Benz and Renault operate with increasing returns to scale, while other firms operate with decreasing returns to scale.

In the study of Nurcan and Kaya (2015), the efficiency levels of 17 firms operating in the global automotive industry with brand value in the period 2011-2013 were investigated by DEA. For the analysis, total equity, total assets and number of employees were determined as inputs and net income and gross profit variables were determined as outputs. According to the results of the BBC model, Suzuki, Fiat S.P.A., Audi, Jaguar Land Rover, Hyundai and Peugeot achieved full efficiency for three years. General Motors was the least efficient firm in the 2011-2013 time period. Moreover, the efficiency ratio of the global automotive industry was 70% in 2011 and 74% in 2012. In 2013, the efficiency level remained below in both years.

Tatlı and Bayrak (2016) investigated the production efficiency of firms traded in the automotive industry in BIST by using static and dynamic DEA.The period considered is 2010-2014 and the number of firms is 15. Equity, personnel costs, raw material costs and R&D investments are the inputs of the analysis, while total turnover, exports and net profit variables are the outputs. As for that the static DEA method, CCR and BCC models yielded similar results. According to the CCR model, in the 2010-2014 time period, Ford, Tofaş, Karsan, Katmerciler, Tümosan, Parsan, Ditaş Doğan and F-M İzmit Piston reached the full efficiency level in terms of both input and output. In the BCC model, these firms include Balatacılar Balatacılık and BoschFren Sistemleri. In addition, both method (static and dynamic DEA) revealed that Isizu, Türk Traktör, Ege Endüstri and Jantsa did not work efficiently, while the remaining 11 firms reached the full efficiency limit.

In the study of Gedik et al. (2017), the efficiency of 7 automotive firms in the ISO-500 was investigated with the Malmquist total factor productivity method. In the paper, the data of the relevant firms in the 2014-2016 time period were used. While the inputs of the analysis were equity capital, number of employees and net assets; profit before tax, exports and net sales were preferred as output variables. As a consequence of the analysis, it was specified that there was a 0.8% decrease in technical efficiency, 0.1% decrease in technological efficiency and 0.8% decrease in total factor productivity in 2014-2015. In the 2015-2016 time interval, an increase of 22% was found only in technical efficiency.

In the study conducted by Çoban et al. in 2018, the efficiency and factor productivity of 14 firms operating in the automotive main industry listed on BIST were revealed by utilizing DEA and Malmquist Total Factor Productivity Index, respectively. The period considered is 2011-2015. Capital and number of personnel are the inputs of the analysis, while production quantity is the output. The findings of the constant returns to scale assumption indicate that only Renault achieved full efficiency in 2011 and 2013. In the remaining years, the fully efficient firms were Hyundai Assan and Renault. According to the variable return assumption, A.I.O.S., Hattat Tarım, Hyundai Assan, Otokar, Renault and Türk Traktör were fully efficient in the remaining years except 2013,

and Otokar, Renault, A.I.O.S, Hattat Tarım and Türk Traktör were operating fully efficiently in 2013. The Malmquist Total Factor Productivity index results show that the total factor productivity of the automotive industry has increased by 14% over the years, with A.I.O.S. being the firm that has increased its productivity the most.

In the study of Jiang et al. (2018), the efficiency levels of automotive firms operating in China between 2012-2016 were investigated with Malmquist Total Factor Productivity and DEA. The number of firms included in the sample is 77. In the study, tangible assets, intangible assets, number of employees and operating expenses were used as input variables. Operating profit was determined as the output variable of the analysis. According to the consequences of the analysis, total factor productivity for the automotive industry decreased between 2012 and 2015. In 2016, there was a 0.5% increase in factor productivity. In 2016, 81.8% of firms in the new energy vehicles industry and 90% of firms in the traditional vehicles industry were not efficient.

Güral and Buğatekin (2018) tested the efficiency of the 100 best-selling car models in Türkiye in 2017 with DEA. In the study aimed to guide consumer purchases, different input and output variables were included, especially in contrast to domestic studies. In the study, selling price and fuel consumption were set as input variables, while top speed, cylinder volume, horsepower, maximum torque, trunk volume, and acceleration time from 0 to 100 km were set as output variables. The outputs show that only 20 out of 100 firms were not fully efficient in 2017. Moreover, the efficiency of the Fiet Egea is low compared to other car models.

In the study by Şahin and Akkoyuncu (2019), the efficiency of the automotive industry was analyzed and the end-of-period data of 16 firms operating in the industry continuously throughout 2015-2018 were used. DEA and Malmquist total factor productivity index were used to determine efficiency. In analysis, equity capital, total assets, and number of employees were considered as inputs, while turnover and net profit were considered as outputs. As for thato DEA results, the two fully efficient firms for four years were Ford and Izmit-Piston. Doktaş was efficient in all years except 2011, while Parsan was the least efficient firm among the selected years. From 2015 to 2018, the average efficiency level of the automotive manufacturing industry showed a downward trend. According to the Malmquist total factor productivity index, although there was a negative outlook in efficiency in 2016 compared to the previous year, there was a positive change in 2017 compared to 2016 and in 2018 compared to 2017.

Papouskova et al. (2020) examined the efficiency of 5 automobile manufacturers with two plants in the Czech Republic and three plants in Germany in 2018 using DEA. In the study, the number of personnel, total cost, equity and fixed assets were determined as input variables of the study, while total sales, after-tax earnings and the number of vehicles produced were determined as output variables. According to the BCC model, BMW, Hyundai, PSA, VW and Skoda Auto were operating effectively, while according to the CCR model, only Hyundai could not achieve efficiency. In the study, a general evaluation was made that in order to ensure full efficiency in the CCR model, the number of vehicles produced should be increased by 3.58%, total sales should be reduced by 6.7% and equity capital by 12.27%.

Kara et al. (2020) examined the economic-financial profitability, efficiency-productivitiy and export competitiveness levels of firms operating in the automotive industry in BIST between 2007

and 2017. Ratio analysis, DEA and Malmquist Total Factor Productivity methods were used in the study. Ratio analysis outputs showed that the financial profitability of all firms except Karsan was above the economic profitability. Moreover, according to the ratio analysis, the firm that uses its equity capital most effectively was Ford Otosan. When the results were evaluated in terms of efficiency, Otokar was the only firm that reached full efficiency and operated at an optimum scale between 2007-2017. The period when technical efficiency was high was between 2009 and 2014. Although the total factor productivity of the industry has followed a decreasing trend over the years, Anadolu Isuzu and Tümosan have been the firms that increased their average factor productivity the most in the industry.

In the study of Mirzaei and Zareian (2022), the performances of automotive and parts manufacturing firms traded on the Tehran Stock Exchange were evaluated with DEA. In the study based on the period 2010-2019, financial data of 28 firms were used. Among the components that make up intellectual capital; human capital, structural capital, used capital and innovative capital are the input variables of the analysis. Profitability from assets, equity capital, sales and earnings per share were determined as output variables. The analysis results showed that 26 out of 28 firms worked fully effectively between 2010 and 2019, and output was created in proportion to the intellectual assets owned.

The sample of Bardi (2023) study was created with 14 automotive firms whose stocks were traded on BIST and operating in the Metal Goods, Machinery, Electrical Devices and Transportation Vehicles industry. The period 2016-2021 was considered and the activities of the firms were determined using the DEA and MTFV index. Additionally, the C5.0 decision tree algorithm was used in the study. According to the CCR model, Federal Mogul, Bosch Fren, Ege Endüstri and Ford Otosan were the firms operating at the optimum scale during 2016-2021. Ege Endüstri also had the highest reference value. According to the MTFP index, the change in technical efficiency decreased by 1.8% and the change in technology decreased by 5.9% on average annually during 2016-2021. The results of the decision tree algorithm show that the return on assets ratio has the highest impact on the determination of firm efficiency.

In the studies in the literature, it has been observed that, in general, in the studies conducted in Türkiye, especially the efficiency of automotive industry firms has been evaluated within the framework of certain criteria (ISO 500 list, passenger cars and imports, and capital structure characteristics). In this regard, the paper analyzes the efficiency of firms in the automotive and automotive supply industry industrys, which are complementary to each other in terms of their activities, separately for the year 2022 and the results are presented comparatively. This difference adds a unique value to the study. The study will reveal the efficient and non-efficient firms in the automotive and supplier industries in 2022.

2. METHODOLOGY

In the study, data envelopment analysis, a linear programming-based technique that allows the comparison of inputs and outputs with different measurement units, was used to determine the relative performance of decision units (Demirci, 2018: 29). Data envelopment analysis, which was first introduced by Charnes-Cooper-Rhodes in 1978, is a non-parametric method and has a static feature.

In data envelopment analysis, models can be constructed for input and output. In order to produce the targeted output efficiently, an input-oriented model should be established at the point of searching for the lowest level of input. Here, in order for the decision unit to be considered efficient, there should be no possibility of decreasing the input without raising any input or reducing the output from other decision units. In order to search for the maximum amount of output with certain inputs, an output-oriented model should be established. In order for a decision unit to be considered efficient in an output-oriented model, none of the other decision units should have the possibility of increasing the output without increasing the input or decreasing the output (Charnes et al., 1981: 669 as cited in: İşbilen-Yücel, 2017: 6). In other words, while input-oriented models involve using a minimum level of input to obtain a certain output, output-oriented models involve using a certain amount of input to obtain a maximum level of output.

Data envelopment analysis models can be constructed with increasing and constant returns to scale assumptions. The constant returns to scale assumption is known as the CCR model proposed by Charnes, Cooper and Rhodes and measures aggregate efficiency. The assumption of variable returns to scale, known as the BCC model, was developed by Banker, Charnes and Cooper and is utilized to measure technical efficiency. The production limits of BCC and CCR models differ (Demirci, 2018: 48). If there is a constant return to scale in efficiency measurement, performing input or output-oriented measurement will not change the efficiency score. However, if there is variable returns to scale, the efficiency scores of input and output oriented models may not be the same (İşbilen-Yücel, 2017: 11)

2.1. Scope and Data of the Study

In this study, data from 8 firms in the automotive industry and 11 firms in the automotive sub-industry industry were used. The data of the study were acquired from the Stockeys pro database and the analysis was carried out through the Win4deap 2.1 program

In this paper, the relative activities of firms operating in the automotive and sub-industry in BIST in 2022 were investigated with data envelopment analysis. CCR and BCC models were estimated within the scope of the analysis. In this section, the scope of the study, data, decision-making units, inputs and outputs, and findings obtained from the analysis are generally included.

2.2. Decision-Making Units

In data envelopment analysis, the selection of decision-making units is particularly important when measuring efficiency. Especially the homogeneity and number of decision-making units are two important factors (Demirci, 2018: 75). There are various approaches in the literature in specified the number of decision-making units. One of these approaches is that the number of decision-making units should be at least one more than the sum of the number of inputs and outputs (in case of m inputs and p outputs, at least m+p+1) (Bakırcı, 2006: 168 as cited in: İşbilen-Yücel, 2017: 7). By utilizing 3 inputs and 2 outputs, the number of decision-making units is appropriate in terms of the number of firms in both sectors.

The decision-making units of the study are the firms operating in the automotive and sub-industry industry in BIST. In this context, there are 8 firms in the automotive industry and 11 firms in the automotive sub-industry. The abbreviated trade names of the relevant firms and their symbolized forms included in the study are presented in Table 1.

Table 1. Decision-Making Units

	Firm	*Symbol*
Automotive Industry	Anadolu Isuzu Otomotiv	ASUZU
	Doğuş Otomotiv	DOAS
	Ford Otomotiv	FROTO
	Karsan Otomotiv	KARSN
	Otokar Otomotiv	OTKAR
	Tümosan Motor	TMSN
	Tofaş Türk	TOASO
	Türk Traktör	TTRAK
Automotive Supply Industry	Balatacılar Balatacılık	BALAT
	Bosch Fren Sistemleri	BFREN
	Brisa Bridgestone	BRISA
	Table 1(Contunied): Decision-Making Units	
	Ditaş Doğan Yedek Parça İmalat	DITAS
	Ege Endüstri	EGEEN
	Federal-Mogul İzmit Piston	FMIZP
	GoodYear Lastikleri	GOODY
	Jantsa Jant Sanayi	JANTS
	Katmerciler Araç Üstü Ekipman	KATMR
	Kordsa Teknik Tekstil	KORDS
	Parsan Makina Parçaları	PARSN

2.3. Inputs and Outputs

In determining the inputs and outputs, the studies in the literature were utilized and the details of the inputs and outputs used are presented in Table 2. According to the table, the inputs of the analysis are number of employees, total assets and equity. The outputs are net profit and net sales.

Table 2. Inputs and Outputs

Inputs	*Symbol*	*Reference*	*Outputs*	*Symbol*	*Reference*
Number of employees of Firm	INPUT1	Soylu(2022),Nurcan and Kaya(2016), Bakırcı(2006), Özdemir and Düzgün (2009), Şahin and Akkoyuncu(2019),Çoban vd.(2018),Yıldız(2006)	Net Sales of Firm	OUTPUT1	Sevinç and Eren(2019), Bakırcı(2006), Özdemir and Düzgün(2009), Şahin and Akkoyuncu(2019),Yıldız (2006)
Total Value of Firm Assets	INPUT2	Nurcan and Kaya (2016),Bakırcı(2006), Özdemir and Düzgün(2009), Şahin and Akkoyuncu (2019), Yıldız(2006)	Net Profit of Firm	OUTPUT2	Sevinç and Eren(2019), Özdemir and Düzgün(2009),Şahin and Akkoyuncu(2019), Yıldız(2006)
Total Value of Firm Equity	INPUT3	Nurcan and Kaya (2016), Bakırcı(2006), Özdemir and Düzgün(2009), Şahin and Akkoyuncu(2019)			

2.4. Findings

2.4.1. Efficiency Scores

In the study, total and technical efficiency scores were calculated with BCC and CCR models for input and output in determining efficiency scores.

Table 3 presents the scale efficiency results of the firms in the automotive industry for the year 2022 with the input-oriented BCC and CCR model.

Table 3. Efficiency Scores Regarding Input and Output Oriented BCC and CCR Model (Automotive Industry)

	Input Oriented				***Output Oriented***			
Firm	***CCR***	***BCC***	***Scale Efficiency***	***Efficiency Status by Scale***	***CCR***	***BCC***	***Scale Efficiency***	***Efficiency Status by Scale***
ASUZU	0,406	0,684	0,594	Ascending	0,406	0,525	0,774	Ascending
DOAS	1,000	1,000	1,000	-	1,000	1,000	1,000	-
FROTO	1,000	1,000	1,000	-	1,000	1,000	1.000	-
KARSN	0,250	0,902	0,277	Ascending	0,250	0,517	0,483	Ascending
OTKAR	0,677	1,000	0,677	Ascending	0,677	1,000	0,677	Ascending
TMSN	0,522	1,000	0,522	Ascending	0,522	1,000	0.522	Ascending
TOASO	1,000	1,000	1,000	-	1,000	1,000	1,000	-
TTRAK	0,998	1,000	0,998	Ascending	0,998	1,000	0,998	Ascending
Average	0,732	0,948	0,759		0,732	0,880	0,807	

When the findings of the input-oriented analysis in Table 3 are analyzed, it is found that 3 firms, namely DOAS, FROTO and TOASO, are efficient according to the CCR model, and 6 firms, namely DOAS, FROTO, OTKAR, TMSN, TOASO and TTRAK are efficient in accordance with the BCC model. While scale efficiency is detected in DOAS, FROTO and TOASO, ASUZU, KARSN, OTKAR, TMSN and TTRAK have ascending efficiency at scale.

When the output-oriented results are analyzed, it is determined that 3 firms, namely DOAS, FROTO and TOASO, are efficient are efficient in accordance with the CCR model, and 6 firms, namely DOAS, FROTO, OTKAR, TMSN, TOASO and TTRAK are efficient according to the BCC model. While DOAS, FROTO and TOASO are scale efficient, ASUZU, KARSN, OTKAR, TMSN and TTRAK have ascending efficiency.

As a consequence of the input-oriented analysis show that the firms with the lowest efficiency scores are KARSN according to the CCR model and ASUZU according to the BCC model. KARSN is the firm with the lowest efficiency according to both models as a consequence of the output-oriented analysis.

When the analysis results for input-oriented and output-oriented approaches are considered together, it is concluded that the same firms are efficient within the scope of CCR, BCC, and scale efficiency. However, in the input-oriented BCC model, the efficiency scores are higher than the

average output-oriented efficiency scores. In general, the average results of the BCC model are higher than those of the CCR model.

Table 4 presents the efficiency findings of the firms in the automotive supply industry according to the BCC and CCR model for input and output for the year 2022.

Table 4. Efficiency Scores Regarding Input and Output-oriented BCC and CCR Model (Automotive Supply Industry)

Firm	*Input Oriented*				*Output Oriented*			
	CCR	*BCC*	*Scale Efficiency*	*Efficiency Status by Scale*	*CCR*	*BCC*	*Scale Efficiency*	*Efficiency Status by Scale*
BALAT	0,054	1,000	0,054	Ascending	0,054	1,000	0,054	Ascending
BFREN	1,000	1,000	1,000	-	1,000	1,000	1,000	-
BRISA	1,000	1,000	1,000	-	1,000	1,000	1,000	-
DITAS	1,000	1,000	1,000	-	1,000	1,000	1,000	-
EGEEN	1,000	1,000	1,000	-	1,000	1,000	1,000	-
FMIZP	1,000	1,000	1,000	-	1,000	1,000	1,000	-
GOODY	1,000	1,000	1,000	-	1,000	1,000	1,000	-
JANTS	1,000	1,000	1,000	-	1,000	1,000	1,000	-
KATMR	0,222	1,000	0,222	Ascending	0,222	0,248	0,892	Ascending
KORDS	1,000	1,000	1,000	-	1,000	1,000	1,000	-
PARSN	0,578	1,000	0,578	Ascending	0,578	0,624	0,927	Ascending
Average	0,805	1,000	0,805		0,805	0,897	0,898	

When the findings of the input-oriented analysis in Table 4 are analyzed, it is found that 8 firms, namely BFREN, BRISA, DITAS, EGEEN, FMIZP, GOODY, JANTS and KORDS, are efficient according to the CCR model while all firms examined in the study are efficient with respect to the BCC model. Hence, the average value score has been calculated as fully efficient (1.000). Furthermore, scale efficiency has been identified in all 8 firms, which are BFREN, BRISA, DITAS, EGEEN, FMIZP, GOODY, JANTS, and KORDS. The efficiency by scale is ascending for the companies BALAT, KATMR, and PARSN.

When examining the results for output-oriented analysis, it is found that 8 firms, namely BFREN, BRISA, DITAS, EGEEN, FMIZP, GOODY, JANTS and KORDS, are efficient with respect to CCR model; and 9 firms, namely BALAT, BFREN, BRISA, DITAS, EGEEN, FMIZP, GOODY, JANTS and KORDS, are efficient according to the BCC model. Scale efficiency has been identified in all 8 firms, including BFREN, BRISA, DITAS, EGEEN, FMIZP, GOODY, JANTS and KORDS. The efficiency by scale is ascending for the companies BALAT, KASHMIR, and PARSN.

According to the consequence of input and output analysis, BALAT has the lowest efficiency score. However, when the consequence of the input-oriented and output-oriented analyses are compared, it is concluded that the same firms are efficient according to the CCR model. As a result, the average efficiency scores obtained for input-oriented analysis using the BCC model are higher than the average efficiency scores for output-oriented analysis. In phrase of scale efficiency scores, it is concluded that the average scores are higher in the findings obtained for output-oriented analysis compared to the input-oriented findings.

2.4.2. References Sets

In data envelopment analysis, the units identified as efficient can serve as references for the non-efficient units.

Table 5 contains the reference firms and density values for the companies operating in the automotive sector considered in the study within the context of the input and output-oriented BCC and CCR models.

Table 5. Reference Sets

Firms	*Input Oriented*				*Output Oriented*			
	BCC		*CCR*		*BCC*		*CCR*	
	Reference Set	*Density*	*Reference Set*	*Density*	*Reference Set*	*Density*	*Reference Set*	*Density*
ASUZU	DOAS	0,059	DOAS	0,081	DOAS	0,033	DOAS	0,093
	TMSN	0,941	TOASO	0,038	TOASO	0,144	TOASO	0,200
					TMSN	0,823		
KARSN	TMSN	-	DOAS	0,014	OTKAR	0,249		
					TTRAK	0,029	FROTO	0,054
		-	FROTO	0,013	TMSN	0,723		
OTKAR	-	-	FROTO	0,067	-		DOAS	0,056
						-	FROTO	0,098
TMSN	-	-	DOAS	0,065	-	-	FROTO	0,008
			FROTO	0,004			DOAS	0,125
TTRAK		-	DOAS	0,079	-	-	FROTO	0,127
			FROTO	0,126			DOAS	0,079

Table 5 shows the reference sets and density values of ASUZU and KARSN according to the BCC model and ASUZU, KARSN, OTKAR, TMSN, TTRAK according to the CCR model. Accordingly, the findings regarding the reference set for ASUZU company in both the input and output-oriented BCC and CCR models exhibit similarity with DOAS, TOASO, and TMSN being included in the reference set. In the context of input-oriented analysis for KARSN company, according to the BCC model, TMSN is included in the reference set, and according to the CCR model, DOAS and FROTO are included in the reference set. For output-oriented analysis, according to the BCC model, OTKAR, TTRAK, and TMSN are included in the reference set, and according to the CCR model, FROTO is included in the reference set.For the OTKAR company, in both input-oriented and output-oriented analyses, it is determined to be efficient according to the BCC model, and therefore, it does not have a reference set. However, in the input-oriented CCR model, FROTO is included in the reference set, and in the output-oriented CCR model, DOAS and FROTO are included in the reference set.TMSN and TTRAK companies are found to be efficient according to the BCC model in both input-oriented and output-oriented analyses, so they do not have reference sets. Similarly, according to the CCR model, DOAS and FROTO are included in the reference set for TMSN and TTRAK companies.

Table 6 includes the reference firms and density values of the firms operating in the automotive supply industry discussed in the study within the scope of for input and output- oriented BCC and CCR models.

Table 6. Reference Sets Regarding Input-oriented BCC and CCR model(Automotive Supply Industry)

Firms	*Input Oriented*				*Output Oriented*			
	BCC		*CCR*		*BCC*		*CCR*	
	Reference Set	*Density*	*Reference Set*	*Density*	*Reference Set*	*Density*	*Reference Set*	*Density*
BALAT	-	-	FMIZP	0,016	-	-	FMIZP	0,301
							GOODY	0,005
KATMR	BALAT	0,752	JANTS	0,010	FMIZP	0,465	JANTS	0,046
			BFREN	0,097	JANTS	0,343	EGEEN	0,264
	JANTS	0,248	EGEEN	0,058	GOODY	0,192	BFREN	0,437
			GOODY	0,056			GOODY	0,253
PARSN	BALAT	0,067	EGEEN	0,384	JANTS	0,676	EGEEN	0,664
	JANTS	0,933	BRISA	0,194	BRISA	0,324	BRISA	0,336

Table 6 includes the reference sets and density values of KATMR, PARSN firms according to the BCC model and BALAT, KATMR and PARSN firms according to the CCR model. Reference sets of active firms are not included in the table.

BALAT company is found to be non-efficient in both input-oriented and output-oriented analyses according to the BCC model, and therefore, it does not have a reference set. In the input-oriented CCR model, FMIZP is included in the reference set, and in the output-oriented CCR model, FMIZP and GOODY companies are included in the reference set.

In the input-oriented analysis for KATMER company, according to the BCC model, BALAT and JANTS companies are included in the reference set. In the CCR model, the reference set consists of JANET'S, BFREN, EGEEN, and GOODY companies. In the output-oriented analysis, according to the BCC model, FMIZP, JANTS and GOODY firms; According to the CCR model, JANTS, BFREN, EGEEN and GOODY firms are included in the reference set. In the context of the analysis pertaining to inputs and outputs within the framework of the CCR model, it has been specified that the reference sets consist of the same firms; however, there is a disparity in the density values.

Within the scope of the input-oriented analysis of PARSN firm using the BCC model, the reference set consists of the BALAT and JANTS firms, whereas in the CCR model, the reference set comprises the EGEEN and BRISA firms. In the context of the output-oriented analysis, according to the BCC model, the reference set includes the JANTS and BRISA firms, while in the CCR model, the reference set consists of the EGEEN and BRISA firms. In the context of the analyses related to inputs and outputs of the firm, it has been determined that, according to the CCR model, the reference sets consist of the same firms; however, there are variations in the density value.

Table 7 indicates the number of firms operating in the automotive and automotive supply industry according to the input and output-oriented BCC and CCR model.

Table 7. The Number of Firms Used as References in the BCC and CCR models

Automotive Industry	*Input Oriented*		*Output Oriented*		*Automotive Supply Industry*	*Input Oriented*		*Output Oriented*	
	BCC	*CCR*	*BCC*	*CCR*		*BCC*	*CCR*	*BCC*	*CCR*
DOAS	1	4	1	4	**BALAT**	2	-	-	-
FROTO	-	4	-	4	**BFREN**	-	1		1
OTKAR	-	-	1	-	**BRISA**	-	1	1	1
TMSN	2	-	2	-	**EGEEN**	-	2	-	2
TOASO	1	1	-	1	**FMIZP**	-	1	1	1
TTRAK	1	-	-	-	**GOODY**	-	2	1	2
					JANTS	2	1	1	1

According to Table 7, the firms GOALS and FROTO are identified as the most efficiently operating and referenced firms in the automotive industry. In the automotive supply industry, the firms BALAT, EGEEN, GOODY, and JANTS are recognized as the most efficiently operating firms and are the most frequently referenced.

Table 8 provides summary statistical information regarding the findings obtained within the scope of the analysis.

Table 8. Summary Statistical Findings

Industry		*Input Oriented*			*Output Oriented*		
		CCR	*BCC*	*Scale Efficiency*	*CCR*	*BCC*	*Scale Efficiency*
Automotive Industry	Average Efficiency Score	0,732	0,948	0,759	0,732	0,880	0,807
	Number of Efficient Firms	3	6	3	3	6	3
	Number of Non-Efficient Firms	5	2	5	5	2	5
	Efficient Firm Ratio	%37,5	%75	%37,5	%37,5	%75	%37,5
	Lowest Efficiency Score	0,250	0,684	0,277	0,250	0,525	0,483
Automative Supply Industry	Average Efficiency Score	0,805	1,000	0,805	0,805	0,897	0,898
	Number of Efficient Firms	8	11	8	8	9	8
	Number of Non-Efficient Firms	3	0	3	3	2	3
	Efficient Firm Ratio	%72,7	%100	%72,7	%72,7	%81,8	%72,7
	Lowest Efficiency Score	0,054	1,000	0.054	0,054	0,248	0,892

According to Table 8, in input and output oriented analyses, BCC model average efficiency scores were found to be higher than CCR model average efficiency scores for automotive and supply industry firms.

In the automotive supply industry industry, where the number of efficient firms was higher, the efficiency ratio was higher compared to the firms in the automotive industry. When the lowest efficiency scores were compared, it is found that the automotive supply industry industry had a lower efficiency score than the automotive industry.

CONCLUSION

The automotive industry in Türkiye is among the highly competitive industrys with its contribution to the economy and the added value it provides at the macro level. In this context, it is important to examine industry performance. In the study, the performance of BIST listed firms operating in the automotive and automotive supply industry in Türkiye was measured using data envelopment analysis. Based on the year 2022, the study analyzed 8 firms from the automotive industry and 11 firms from the automotive supply industry. In the study where the performance of the firms is measured by efficiency analysis, BCC and CCR models are used within the scope of input and output analysis. Along with the determination of the efficiency scores of the firms, the reference sets and the number of references have also been identified.

When examining the relative efficiency scores for the automotive sector, it is observed that the same results are obtained for efficient firms within the scope of both the BCC and CCR models in input and output-oriented analyses. In other words, the total and technical efficiency outcomes exhibit similarity. Accordingly, according to the CCR model, 3 firms, namely Doğuş, Ford and Tofaş; and 6 firms, namely Doğuş, Ford, Otokar, Tümosan, Tofaş and Türk Traktör, are detected to be efficient according to the BCC model. Among these firms, Doğuş, Ford, Tümosan, Türk Otomobil Fabrikası and Türk Traktör are in the reference set of other non-efficient firms. In addition, Doğuş and Ford are the most referenced firms for the automotive industry.

When the relative efficiency scores for the automotive supply industry are examined, according to the CCR model in input-oriented analyses; it has been determined that 8 firms, including Bosch Fren Sistemleri, Brisa, Ditaş Doğan, Ege Endüstri, F-M İzmit Piston, GoodYear, Jantsa Jant and Kordsa Teknik, and all automotive supply industry firms are relatively effective according to the BCC model. The findings of the CCR model for output-oriented analysis are concluded to be the same as the firms identified as efficient in the input-oriented analysis. In the BCC model, with the exception of Katmerciler and Parsan, all firms are determined to be relatively efficient. Among the firms identified as efficient in the automotive supply industry, Balatacılar Balatacılık, Jantsa Jant Sanayi, F-M İzmit Piston, Bosch Fren Sistemleri, Ege Endüstri, GoodYear, and Brisa have been included in the reference set for the non-efficient firms. Among these non-efficient firms, the companies Balatacılar Balatacılık, Ege Endüstri, and GoodYear are the most frequently referenced.

As a result, the study identifies relatively efficient and relatively non-efficient firms operating in the automotive and automotive supply industry in BIST within the scope of the relevant inputs and outputs. When the efficiency scores of automotive and automotive supply industry firms are analyzed, it is found that the average efficiency values of the firms in the automotive supply industry are higher than the efficiency scores of the firms in the automotive industry. Accordingly, firms whose efficiency cannot be determined can investigate methods to improve their performance in line with the findings. At this point, firms may be advised to focus on digital infrastructure, research and development, differentiation in production and quality.

The findings acquired as a consequence of the study are indicative of the performance of firms operating in the automotive and automotive supply industry in Türkiye as of 2022. With the

study findings, potential investors will be able to have an idea about which firms it would be more appropriate to transfer resources to in the future.

The findings of the paper may vary build on the utilize of different inputs and outputs or different reference years. In future research, different input and output variables could be employed, or variations in efficiency measurement methods could be introduced to enable comparative evaluation of the findings.

REFERENCES

Bakırcı, F., (2006), "Sektörel Bazda Bir Etkinlik Ölçümü: VZA İle Bir Analiz", Atatürk Üniversitesi İktisadi ve İdari Bilimler Dergisi, 20(2), s.199–217

Bakırcı, F., (2006), Üretimde Etkinlik ve Verimlilik Ölçümü Veri Zarflama Analizi Teori ve Uygulama, Atlas Yayınları

Bardi, Ş., (2023), "Otomotiv Sektöründe Faaliyet Gösteren Firmaların Maliyet Girdi Odaklı Etkinlik Analizi", Sakarya Üniversitesi İşletme Enstitüsü Dergisi, 5(1), s.15-25

Charnes, A., Cooper, W.W., & Rhodes, E., (1981), "Evaluating Program And Managerial Efficiency: An Application Of Data Envelopment Analysis To Program Follow Through", Management Science, 27(6), s. 668-697

Çoban, A., Çoban, O. & Baysal Kurt, D., (2018), "Technical And Scale Efficiency Of The Turkish Automotive Industry Using Data Envelopment Analysis", Çankırı Karatekin Üniversitesi Sosyal Bilimler Enstitüsü Dergisi, 9 (2) , s.58-71

Çoban, O., (2007), "Türk Otomotiv Sanayiinde Endüstriyel Verimlilik Ve Etkinlik", Erciyes Üniversitesi İktisadi ve İdari Bilimler Fakültesi Dergisi, (29), s.17-36

Demirci, A., (2018), Teori Ve Uygulamalarla Veri Zarflama Analizi, Gazi Kitabevi.

Gedik, A., Koçarslan, H., & Karaer, M., (2017), "ISO 500 İşletmelerinin Malmquist-Tfv Endeksi İle Etkinliğinin Ölçülmesi: Otomotiv Sektörü Örneği", International Journal of Social Humanities Sciences Research, 4(15), s.1917–1923

Güral, Y. ve Turan Buğatekin, A, (2018), "Evaluation Of Car Performances Using Data Envelopment Analysis", ITM Web of Conferences, 22(01051), s.1-5.

ISO 500. (Erişim Tarihi: 20.08.2023), https://www.iso500.org.tr/

Jiang H., Han L., Ding Y., & He Y., (2018), "Operating Efficiency Evaluation Of China Listed Automotive Firms: 2012–2016", Sustainability, 10(1), s.1-22

İşbilen Yücel, L., (2017), Veri Zarflama Analizi. İstanbul: Der Yayınları

Kara, O., Tarakcıoğlu Altınay, A. & Erkan, B., (2020), "The Relationship Between Efficiency, Rantability And Export Competitiveness: An Implementation On Turkish Automotive Sector", Gaziantep University Journal of Social Sciences, 19(3), S.1194-1214

Lorcu, F., (2010), "Malmquist Toplam Faktör Verimlilik Endeksi: Türk Otomotiv Sanayi Uygulaması", İstanbul Üniversitesi İşletme Fakültesi Dergisi, 39(2), S.276-289

Maritz, A. & Shieh, C, (2013), "Performance Analysis Of Automobile Industry In Taiwan With Data Envelopment Analysis", International Journal of Applied Mathematics and Statistics, 38(8), s.85-95

Mirzaei, M. & Zareian M., (2022), "Benchmarking Automotive And Parts Manufacturing Companies Based On Intellectual Capital Using Data Envelopment Analysis", International Journal of Data Envelopment Analysis, 10(1), s.1-24

Nandy, D., (2011), "Efficiency Study Of Indian Automobile Companies Using Dea Technique: A Case Study Of Select Companies", The IUP Journal of Operations Management, 10(4), s.39-50

Nurcan, E. ve Kaya, N, (2016), "Dünya Otomotiv Sektöründeki Lider Firmaların Verimliliğinin Veri Zarflama Analizi İle İncelenmesi", International Journal of Social Sciences and Education Research, 2(1), s.64-75

Özdemir, A. İ. ve Düzgün, R., (2009), "Türkiye'deki Otomotiv Firmalarının Sermaye Yapısına Göre Etkinlik Analizi", Atatürk Üniversitesi İktisadi ve İdari Bilimler Dergisi, 23(1), s.148-164

Papouskova, K., Telecký, M. & Cejka, J., (2020), "Process Efficiency Analysis Of Selected Automotive Companies In Europe", Communications - Scientific letters of the University of Zilina, 22(4), s.20-27

Sevinç, A. & Eren, T., (2019), "Determination Of KOSGEB Support Models For Small- And Medium-Scale Enterprises By Means Of Data Envelopment Analysis And Multi-Criteria Decision Making Methods", Processes,7(3), s.1-27

Soylu, N., (2020), "Entelektüel Sermaye Etkinliğinin Veri Zarflama Analizi İle Değerlendirilmesi: BİST Teknoloji Şirketlerine Yönelik Bir Araştırma", Muhasebe ve Finansman Dergisi, 85, s.269-286

Şahin, İ. E. ve Akkoyuncu, H, (2019), "Türkiye'de Otomotiv Sektöründe Faaliyet Gösteren Şirketlerin Etkinlik Analizi", Selçuk Üniversitesi Sosyal Bilimler Enstitüsü Dergisi, Prof. Dr. Fuat Sezgin Özel Sayısı, s.339-347

Tatlı, H. ve Bayrak, R., (2016), "Borsa İstanbul'da Kayıtlı Otomotiv Sektöründe Faaliyet Gösteren Firmaların Etkinliklerinin Statik Ve Dinamik Veri Zarflama Analizi Yöntemiyle Değerlendirilmesi", Siyaset, Ekonomi ve Yönetim Araştırmaları Dergisi, 4(1), s.119-145

Tran, D. & Ngo, D., (2014), "Performance Of The Vietnamese Automobile İndustry: A Measurement Using DEA", Asian Journal of Business and Management, 2(3), s.184-191

Uludağ İhracatçı Birlikleri Genel Sekreterliği AR-GE Şubesi (2021). Türkiye Otomotiv Endüstrisi Raporu, (Erişim Tarihi: 20.08.2023), https://uib.org.tr/tr/kbfile/turkiye-otomotiv-endustrisi-raporu

Yaylalı, M. ve Çalmaşur, G, (2014), "Türk Otomotiv Endüstrisinde Maliyet Ve Toplam Faktör Verimliliği", Atatürk Üniversitesi Sosyal Bilimler Enstitüsü Dergisi, 18(3), s.325-350

Yıldız, A., (2006), "Otomotiv Sektörü Performansının Değerlendirmesi", Muğla Üniversitesi Sosyal Bilimler Enstitüsü Dergisi, 16, s.1-12

Yılmaz, N. ve Karakadılar, İ., (2010), "Türk Otomobil Pazarında Yerli Üretim Ve İthal Araçların Verimliliklerinin Veri Zarflama Analizi İle Değerlendirilmesi", Marmara Üniversitesi İİBF Dergisi, 28(1), s.499-521