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TECHNICAL EFFICIENCY ANALYSIS IN THE AUTOMOTIVE INDUSTRY: A STOCHASTIC FRONTIER APPROACH

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Abstract

Automotive industry can be regarded as an example of differentiated oligopoly in which a limited number of firms produce differentiated goods. The main objective of this research is to make a detailed analysis on the technical efficiency of the Turkish automotive industry for the period 1992-2012 with a stochastic frontier approach. In order to satisfy this objective, panel data related to 20 firms for the period of 1992-2012 are used; the technical efficiency levels of the firms are presented by using different models with stochastic frontier approach; and the factors that cause inefficiency are identified. As a result, the technical efficiency levels of the firms that operate in the Turkish automotive sector in the related period and the factors that cause inefficiency are estimated with a translog stochastic frontier production approach. Moreover, a positive relationship is found between the capacity utilization ratio, export intensity, foreign capital ratio, firm size and technical efficiency. On the other hand, a negative relationship is detected between the firm age and technical efficiency.

Keywords: Technical Efficiency, Production Frontier, Stochastic Frontier Approach, Time Variant Model, Turkish Automotive Industry

INTRODUCTION

Automotive industry is an industry composed of firms that produce motor vehicles. This dominating industry has a strategic importance for the countries. The main reason for this significant importance of the automotive industry is its close relations with other industries.

Motor vehicles are created with the production and assembly of approximately 5.000 parts with common quality management and efficiency approach. These parts all have different qualifications, material structure, process, technology and production site. The industry that produces these vehicles requires the most complex technology after the aerospace industry. Automotive industry uses an interdisciplinary technology that covers significant engineering fields. In addition to that, the automotive industry undertakes important tasks in the development of the country's defense industry and the increase of technology level (Şan, 2001: 72).

Automotive industry has a significant role in the development of countries as the industry creates added value, contributes to employment and undertake tasks in technological development. The industry has a driving role in the economies as the industry provides production factor from iron and steel, rubber-plastic, fabric, glass, paint, electric and electronic industries and creates a large business volume in industries like repair, maintenance, marketing, spare parts sale, financing and insurance services (Bedir, 2002: 11).

Automotive industry has a wide and differentiated product range. Cars, buses, trucks and vans constitute the major products of the industry. With regard to these main product groups, demand, production process, technical equipment, marketing and sales activities display quite different characteristics. Automotive industry is very competitive, has rapid technological developments and its production techniques show continuous changes and developments (Tanyılmaz and Erten, 2001: 7).

Automotive industry has various functions such as contributing to technological development, creating employment and added value, bringing in foreign currency through foreign trade. In this aspect, the Turkish automotive industry which has 60 years of history, becomes the driving sector of the economy. Additionally, along with the Customs Union process, the structure and perspective of the automotive sector changed. For this reason, it is important to make the structural analysis and display the economic performance of the Turkish automotive industry (Çoban, 2007: 18).

In 1996, automotive industry began to make the assembly of its own models. Within three years that follows ANADOL, the car of that period, the assembly factories that produce passenger cars (Tofaş-Fiat and Oyak-Renault) started manufacturing. TOFAŞ and OYAK-RENAULT, the two biggest automotive producers, set up their manufacturing lines in 1971 with their Italian and French licenses. In 1968, Otomarsan-Otobüs Karoseri and Motorlu Araçlar A.Ş. began to produce 0302 series buses. During 1999, the exportation of trucks continued which has an original design developed in Turkey. Later on, Japanese and South Korean automotive producers started joint ventures in Turkey. Turkish automotive producers who produce under the license of Western automotive producers, are on their way to become a center of these Western automotive producers (Ministry of Development, 2012: 2).

Today, there are 15 firms that produce various vehicles such as passenger car, bus, truck, van, minibus, bus and tractors. The capacity of these firms is approximately 1.5 million units a year. In the Turkish automotive industry, there are five firms that produce passenger cars (Renault, Tofaş, Toyota, Hyundai, Honda); ten firms that produce trucks and vans (AIOS, BMC, Hyundai, Karsan, MAN, Mercedes-Benz, Ford Otosan, Otokar, Temsa, Renault); nine firms that produce buses, minibuses and midibuses (AIOS, BMC, Karsan, Mercedes-Benz, Hyundai, Otokar, Ford Otosan, Temsa, MAN) and two firms that produce tractors (Hattat Tarım, Türk Traktör). These firms launched their production facilities in Turkey in different dates: Otokar in 1963; AIOS, BMC, Karsan and MAN in 1966; M. Benz in 1968; Tofaş in 1971, Ford Otosan in 1983, Temsa Global in 1987, Toyota in 1994, Honda Turkey and Hyundai Assan in 1997 and Hattat Tarım in 2002. The firms that have the highest level of capital in the automotive industry are BMC and Tofaş with TL 500.000.000. On the other hand, the lowest level of capital belongs to Otokar with TL 24.000.000. BMC, Hattat Tarım, Karsan, Otokar and Temsa Global are totally local firms, whereas Honda Turkey and Toyota are totally foreign capital firms.

Economic efficiency is defined as a situation where there is no possibility of bringing some or all people to a better position in their own value judgments, without bringing other people to a worse situation in again their own value judgments through the redistribution of some part of the resources and goods (Yaylalı, 2004: 488-489). Farrell has introduced a new definition in 1957 that evaluates efficiency and effectiveness on a micro level instead of a macro approach. In order to measure efficiency, Farrell put forward the necessity of determining a piecewise linear production frontier instead of a regression line based on average performance values economically. Farrell suggests that the overall efficiency of decision making units equals the multiplication of the two components (Farrell, 1957: 254). In line with that, Economic Efficiency = Technical Efficiency x Allocative Efficiency. In order to calculate the technical efficiency of a firm, the nonparametric approach of Data Envelopment Analysis and the parametric approach of Stochastic Frontier Approach are used. Data envelopment analysis approach calculates inefficiency as the distance to the production frontier and does not include any term error as it is a deterministic technique (Büyükkılıç and Yavuz, 2005: 49). On the other hand, scholastic frontier approach is a good efficiency measurement approach with panel data. It is the most favorable approach especially in determining the factors that affects the efficiency of a private firm or a specific period of time (Grosskopf, 1993: 189).

The main objective of this research is to make a detailed analysis on the technical efficiency of the Turkish automotive industry for the period 1992-2012. In this regard, the technical efficiency levels of the firms operating in the Turkish automotive industry are presented for the specific period and the factors that cause inefficiency are identified.

The research is composed of five main sections. The second section explains the methodology of the study. The third section covers the data and variable definitions, as well as the literature review. Fourth section summarizes and interprets estimation results. The fifth and the final section reveals research results.

METHODOLOGY

This section analyzes Stochastic Frontier Approach which is used to measure technical efficiency.

Most of the topics covered by Economics can be defined within the production function framework. It is important for the production functions to directly reflect the production frontier and provide a structure that estimates the frontier econometrically. The crucial points of the method are the inefficiency of stochastic frontier approach management and the structure that estimates the frontier with a single econometric test. In today's economy, where the performance measures of the firms gain importance, it is a significant feature of the method to introduce the econometric estimation methods to the determination of technical efficiency through the related features of stochastic frontier method (Tutulmaz, 2012: 124).

Stochastic production frontier approach assumes that the firms at data input level can produce a maximum output of a certain amount. There may be two reasons for the firms to fail in producing at levels defined by production frontier. At the outset, there may be some factors such as the unexpected and unpredictable issues in the production process, changes in input quality and pace of workers. Secondly, as the firm cannot work fully effective, it can stay below the maximum expected production level. These two factors and the stochastic production frontier can be estimated in line with certain assumptions on the form of the production limit. The method is based on input-output data at the firm level and production frontier adaptation. Pace of technologic change is measured by the shift ratio of production frontier. Technical efficiency level is defined as the ratio between the firm's output and the output realized by using the current inputs (Taymaz, 2001: 102).

Stochastic frontier approach which is also defined as an econometric approach, establishes a functional relationship between disclosed variables such as expense, profit, production and explanatory variables such as input, output and environmental factors, taking into consideration the margin of error in the model (Berger and Humphrey, 1997: 178).

Stochastic production frontiers are developed by Aigner, Lovell, Schmidt (1977), Meeusen and Van den Broeck (1977), independent of each other. In general, the production frontier of the firm i among n number of firms can be defined as follows:

$$y_i = f(x_i, b) + v_i - u_i \qquad (1)$$

y_i, the natural logarithm of the firm i's production,

x_i, input vector of the firm i,

β, unknown parameter vector that should be estimated,

v_i,i.i.d. random variables,

u_i, non-negative random variable that measures technical efficiency.

The above model has a cross sectional format. Schmidt, Robin C. Sickles (1984) stated the below issues on cross sectional formats:

- The maximum likelihood method used in cross sectional models requires strong assumptions related to the distribution of efficiency element. It has not been fully enlightened how sensitive the results are against these assumptions.
- The maximum likelihood method requires the technical efficiency element to be completely independent from explanatory variables. However, as the technical efficiency is a concept related to input usage, the case does not seem to be a very realistic assumption.
- The technical efficiency rates are not consistent at firm level.

The issues identified in cross sectional models can be resolved by using panel data. Panel data contains much more information than a single cross sectional data. As the firm is observed more than one time in panel data, more information can be obtained on the firm's efficiency. As a natural result of this, some of the strong distribution assumptions that are used in cross sectional data will result in a more statistically meaningful technical efficiency estimate together with the use of panel data (Kumbhakar and Lovell, 2000: 95).

Taking into account the panel data set, the frontier production function which contains n number of firms in the T time period can be stated as follows (Kalirajan and Shand, 1999: 159):

$$y_{it} = \beta_o + x_{it}\beta + v_{it} - u_{it} \qquad (2)$$

The decrease, increase and constant state of means that the technical efficiency will relatively decrease, increase or remain constant in time.

Panel data models can be analyzed in two different groups: time variant and invariant efficiency models.

Within T time period, under the assumption that i number of firms are in production, time invariant Cobb-Douglas production frontier technical efficiency can be defined as follows (Kumbhakar and Lovell, 2000: 97-98):

$$\ln y_{it} = \beta_o + \sum_n \beta_n \ln x_{it} + v_{it} - u_{it} \qquad (3)$$

At this point, represents symmetrical error term and represents technical inefficiency. It has been assumed that production technology remains constant in time; none of the changes originate from technical amendments. This model structurally shows similarities with cross sectional production frontier model. The only difference between the models is the inclusion of time index for input, output and error term. The model displays similarities with producer effects and traditional panel data models without time effect. The only difference is that, the producer effects should not be negative as they represent technical inefficiency. With the same methods, the parameters of the model and technical efficiency can be estimated. The parameters of the above model can be estimated with fixed effect, random effect and maximum likelihood models.

Time variant efficiency models have first been developed by Cornwell, Schmidt and Sickles (1990) and Kumbhakar (1990). Time variant efficiency model can be defined as follows:

$$\ln y_{it} = \beta_{0t} + \sum_{n} \beta_n \ln x_{nit} + v_{it} - u_{it} = \beta_{it} + \sum_{n} \beta_n \ln x_{nit} + v_{it} \qquad (4)$$

β_{0t}: common production frontier constant for all producers within t periods

$\beta_{it} = \beta_{0t} - u_{it}$: constant for the producer i within t periods

As in all other models, the foremost aim is to estimate the parameters that present the structure of production technology. Second aim is to get the technical efficiency estimation specific to the producer. It is impossible to obtain IxT number of fixed terms, N number of slope parameters and . Therefore, the number of parameters subject to estimation will be more than the number of observation. Thus, Cornwell, Schmidt and Sickles (1990) assume to be a function of time and used the below described second order function for (Kumbhakar and Lovell, 2000: 108):

$$\beta_{it} = \Omega_{i1} + \Omega_{i2} t + \Omega_{3} t^2 \qquad (5)$$

At this point, s are the parameters that determine the relationship between the efficiency and time. This functional form and the model that is defined in the above equation are estimated by using panel data methods.

Battese and Coelli (1992) formulated the time variant efficiency model for N number of firms in T time period, under the assumptions that the effects specific to firms systematically change during time and inefficiency effects are directly affected from the number of variables (Battese and Coelli, 1992: 154):

$$y_{it} = f(x_{it}; \beta) \exp(v_{it} - u_{it}) \quad i = 1, 2, \ldots, n \qquad (6)$$

$$u_{it} = \{\exp[-\eta(t - T)]\} u_i$$

y_{it}: the production of i number of firms within t periods,

$f(x_{it}; \beta)$: applicable vector function,

x_{it}: input factors used by i number of firms within t periods,

η: unknown parameters.

In the above model, time variant efficiency model does not cover inefficiency effects or factors that cause inefficiency. However, it is possible to discuss the effects of these factors on efficiency. Instead of regression model estimation, Battese and Coelli (1995) suggest simultaneous equation modeling to eliminate the mentioned circumstances. Therefore, the variables that are assumed to cause efficiency effects are included in the stochastic model and a specific model is constructed (Kök and Deliktaş, 2003: 279-280).

The below model is suggested by Battese and Coelli (1995) that allows technical inefficiency and panel data usage (Battese and Coelli, 1995: 326).

$$y_{it} = x_{it}, b + \left(v_{it} - u_{it}\right) \; i = 1, 2, \ldots, n \; t = 1, 2, \ldots, T \qquad (7)$$

In this model, represents the production of i number of firms in the t year, is the (1xK) input vector of i number of firms in the year t, represents unknown parameters vector that needs to be estimated, i.i.d (independent and identically distributed) is the random variable that is assumed to exist and shows distribution, is the random variable that measures non-negative technical efficiency and shows distribution. The following equation is defined: where defines the (1xP) variable vector that effects the efficiency of a firm, represents (1xP) parameter vector that is estimated compliant with this matrix. The technical efficiency of i number of firms in the year t is calculated with the following equation:

For the frontier model defined with this equation, null hypothesis is tested against the alternative hypothesis.

$$LR = -2\left[\ln\left[L\left(H_0\right) / L\left(H_1\right)\right]\right] = -2\left\{\ln\left[L\left(H_0\right)\right] - \ln\left[L\left(H_1\right)\right]\right\} \qquad (8)$$

DATA AND LITERATURE SUMMARY

There are many sources in the literature that analyzes the efficiency and/or effectiveness of the Turkish Automotive industry by using different analysis methods (Data Envelopment Analysis, Fuzzy Data Envelopment Analysis, Malmquist Total Factor Efficiency Index etc.). Yılmaz et al. (2002) analyzed the effectiveness of 9 firms operating in the industry as of 2001; Bakırcı (2006) studied the efficiency of 13 firms that operating in the industry as of 1999 and 2004; Karaduman (2006) investigated the technical efficiency levels and total factor effectiveness changes of 17 firms operating in the industry in the 2001-2005 period; Yıldız (2006) explored the efficiency of 13 firms in the industry as of 2004; Çoban (2007) analyzed the efficiency and effectiveness of 17 firms operating in the industry in the 1990-2004 period; Ayan and Perçin (2008) observed the efficiency of 37 firms registered to Istanbul Chamber of Industry by using Data Envelopment Analysis; Özdemir and Düzgün (2009) investigated the efficiency of 34 firms that operate among the 500 biggest firms in the industry; Lorcu (2010) explored the technical efficiency level and total factor productivity changes of 14 firms in the 2003-2007 period; Toloo and Ertay (2014) analyzed the efficiency of 73 distributors that sold automotive in Turkey in 2010 by using CE-DEA approach.

When the literature is reviewed, it is possible to come across many researches that measure effectiveness and technical efficiency in the automotive industry by using Stochastic Frontier Approach. Some of these researches are mentioned below.

Kang (1997) analyzed the technical efficiency of firms that operate in the US truck industry as of 1976, 1980 and 1982 by using Stochastic Frontier approach. The study points out that the technical efficiency increased from 86.52% to 90.44% within the given period and the firms which have higher amount of capital ratio are much more effective than the others.

Lieberman and Dhawan (2005) analyzed the technical efficiency of Japanese and US automotive producers in the period 1965-1997 by using stochastic frontier approach. The study argues that the factors causing inefficiency can be stated as follows: added value/sales ratio, design quality, number of vehicles produced, factory capacity and cumulative production.

Khalifah et al. (2008) examined the total factor effectiveness of the firms operating in the Malaysian automotive industry in the period 2000-2004 by using Stochastic Frontier Approach and panel data composed of 510 firms. The research points out that the changes in the technical efficiency have a positive impact on total factor effectiveness growth. Moreover, it has been discussed that the firm size and foreign capital have positive impact on efficiency as well.

Narayanan and Vashisht (2008) investigated the competitiveness of the Indian automotive industry and analyzed the periods 1988-1989 and 2005-2006 by using stochastic frontier approach and data that belongs to 226 firms. The study argues that market share, capacity utilization and the share of R&D in expenditures have a positive impact on technical efficiency. On the other hand, the share of wages, taxes and fuel in expenditures have a negative impact on technical efficiency.

Yaşar and Paul (2009) analyzed the efficiency and effectiveness of the firms operating in the Turkish automotive industry by using translog production function with the support of Least Squares Method, Stochastic Frontier Approach and Quantile Regression Methods. The research highlighted the positive impact of foreign direct investments on effectiveness and efficiency. The study argued that the firms which have higher foreign capital tend to be more effective and technically efficient.

Mazumder and Adhikary (2010) explored the technical efficiency of Indian automotive industry in the period 2006-2006 by using stochastic frontier approach and time invariant efficiency model. The study finds out that the technical efficiency is inversely proportional with the firm's age. Additionally, it has been found out that the market share and the degree of automation of the firm have a positive impact on technical efficiency.

Khalifah (2013) observed the technical efficiency of the firms operating in the Malaysian automotive industry in the period 2000-2004 by using micro panel data and Stochastic Frontier Approach. It has been questioned if the factors that cause technical inefficiency are vertical integration degree, firm size, workforce quality, export intensity and the foreign ownership. It has been found out that foreign ownership and net export intensity are not significant determinants of technical efficiency and the other factors have positive impact on technical efficiency.

This study that intends to analyze the technical efficiency of the firms operating in the Turkish automotive industry uses panel data related to the period 1992-2012. Due to the impossibility of obtaining reliable data on the firms operating in the Turkish automotive industry before 1992, panel data related to the period 1992-2012 is used. The information on the firms operating in the Turkish automotive industry is obtained from the Automotive Industry General and Statistical Bulletin reports published by Automotive Manufacturers Association annually.

Turkish automotive industry, one of the significant industries in the country, produces a differentiated product range composed of tow truck, truck, van, midibus, minibus, car, bus and tractor etc. There are 20 firms in the sector in the period 1992-2011. The firms are included in the analysis in line with the fact that they produce or not in the given years. These firms launched their production facilities in Turkey in different dates: T. Traktör in 1954, Ford in 1959, Uzel in 1962, Otokar in 1963, Askam (Chrysler) in 1964, M.Benz Türk in 1965, A.I.O.S, B.M.C., Karsan, M.A.N. and Otoyol in 1966, Tofaş and O. Renault in 1971, Temsa in 1987, General Motors (Opel) in 1990, Traksan and Toyota in 1994, Honda Turkey and Hyundai in 1997 and Hattat Tarım in 2002. Among these firms, some end their production facilities in different dates: Traksan in 1997, General Motors (Opel) in 2001, Askam (Chrysler), Otoyol and Uzel in 2009. Other than these firms, all other firms in the industry continued their production facilities within the given years and they are included in the analysis of all the periods.

In order to determine the input and output variables to be used in the analysis of technical efficiency, the studies in the literature and the cost sheet of the firms are used. Amount of turnover is used in the study as the output variable. Turnover variable (Q) is the sum of domestic and foreign sales of the products produced in the relevant year. Production amount is one of the significant indicators that show the performance of the automotive firm. The firms that have production facilities in the automotive industry are producing numerous and different types of cars, buses, trucks, tractors etc. Therefore, while we compare the firms, we do not take the production amount as the output variable since different products have different costs and not all of the firms produce the same product. As physical quantities may result in incomplete and incorrect analysis, turnover variable is used instead of production amount.

In the study, total payments made for raw materials and sub-industry which constitutes the cost items (K) and payments made to the employees (L) are used for input variables. When the capital is regarded as a production tool, the capital of the firms that have production facilities in the industry are considered to be raw material and sub-industry. The other production factor used in the production activity is workforce. The workforce that produces in the automotive industry is classified as: worker, officer, engineer and administrative engineer. As the output variable is evaluated as monetary units in the study, the input variable has also been expressed in monetary units in line with this.

EMPIRICAL FINDINGS

The Stochastic Frontier Approach model is implemented in this study by using FRONTIER 4.1 program developed by Timothy James Coelli in 1996.

By using the time variant efficiency model mentioned in the theoretical section, technical efficiency levels and changes in the technical efficiencies within the period 1992-2012 have been aimed to be measured.

The stochastic frontier function used in the study can be stated as follows:

$$\ln Y_{it} = \beta_0 + \beta_1 \ln\left(K_{it}\right) + \beta_2 \ln\left(L_{it}\right) + \beta_3 t + 0.5\left[\beta_{11}\left(\ln K_{it}\right)^2 + \beta_{22}\left(\ln L_{it}\right)^2 + \beta_{33} t^2\right] + \beta_{12}\left(\ln K_{it}\right)\left(\ln L_{it}\right) + \beta_{13}\left(\ln K_{it}\right) t + \beta_{23}\left(\ln L_{it}\right) t \qquad (9)$$

Y_{it}: the turnover of i number of firms in the year t,

K_{it}: the total payments i number of firms made for raw materials and sub-industry in the year t,

L_{it}: the payments i number of firms made to employed in the year t,

t: Time variable (1992-2012)

$\ln$: Natural logarithm Parameters to be estimated

The variables that cause inefficiency are discussed to be capacity utilization rate, export intensity, foreign capital rate, firm age and firm size in line with the literature review. With these variables, the inefficiency effect model can be formulated as follows:

$$\mu_{it} = \delta_0 + \delta_1 CUR_{it} + \delta_2 EI_{it} + \delta_3 FCR_{it} + \delta_4 FA_{it} + \delta_5 FS_{it} \qquad (10)$$

The expectations on the variables in the above mentioned inefficiency effect model can be described as follows. It is expected that a positive correlation exists between capacity utilization rate and technical efficiency. In a sense, it is expected that among the firms that operate in the

Turkish automotive industry within the given periods, the firms that have high level of capacity utilization tend to show high technical efficiency. It is also anticipated that the firm size variable has a positive relationship with technical efficiency. In other words, it is predicted that operating in a larger scale has a positive impact on technical efficiency. Moreover, the studies in the literature points out that there is a negative correlation between firm age and technical efficiency. In this context, it is anticipated that a negative relationship can be detected between firm age and technical efficiency. There is no preliminary forecast in our study regarding the effect of export intensity and foreign capital rate on technical efficiency. These variables are not considered to be significant variables that will have an impact on the firms' technical efficiencies. Stochastic frontier approach is usually implemented in two stages. In the first stage, the functional structure is estimated and in the second stage the error term is modeled (Kök and Yeşilyurt, 2006: 49).

In the study, the following functions are estimated respectively which are used widely: Cobb-Douglas production function, Cobb-Douglas production function where no technical change is presumed, Hicks production function where there is no technical change, Hicks-neutral production function and translog production function. All the estimation results obtained from all functional patterns are listed in Table 1.

As per the estimation results in Table 1, in the Cobb-Douglas production function and the Cobb-Douglas production function where is no technical change, the sum of elasticity of output with respect to labour input ( ) and the elasticity of output with respect to capital input ( ) defines the returns to scale. In each function, it is possible to state that there is decreasing returns to scale in the Turkish automotive industry (=0581+0.279=0.860, =0.600+0.356=0.956). In the Hicks production function with no technical change, and parameters remain statistically insignificant at 5% significance level. In the translog production function, the sum of and parameters does not directly provide return to scale. In the translog production function, the elasticity of output with respect to labour input for firm i in period t is defined as the elasticity of output with respect to capital input is stated as and the return to scale is calculated as. The Cobb-Douglas production function with technical change points out that there is a positive technological improvement as the parameter is marked positive. In the translog production function, the change in the technical change rate is calculated with the following formula: . In all models, the predicted parameter is statistically significant at 5% significance level. γ shows total variation to industry specific variation. is positive in translog production function and is statistically significant at 5% significance level (0.440). In a sense, industry specific technical efficiency is significant in the explanation of the total variation of produced outputs. η represents technical inefficiency effects. In the translog production function, parameter is found to be negative and statistically significant at 5% significance level. This shows that technical efficiency increase in time (-0.199). In addition to that, as the parameter in the translog production function is marked positive, it is stated that the inefficiency effects distribution is non zero.

Table 1: Estimation Results Obtained from Functional Patterns

Variable (Coefficient)	Cobb-Douglas with technical change	Cobb-Douglas with no technical change	Hicks with no technical change	Hicks with neutral technical change	Translog with non-neutral technical change
Constant (b_0)	3.685* (6.771)	2.933* (4.410)	0.939 (0.934)	-2.582 (-1.097)	-6.980 (-1.675)
LnK (b_1)	0.581* (14.516)	0.600* (15.551)	0.762 (1.245)	0.750* (2.768)	0.923 (1.954)
LnL (b_2)	0.279* (5.454)	0.356* (9.746)	0.357 (0.509)	0.840* (2.476)	1.336* (2.150)
t (b_3)	0.926* (3.849)			-0.030* (-0.493)	-0.376 (-1.399)
$0.5LnK^2$ (b_{11})			0.060* (2.287)	0.071* (2.816)	0.070* (2.842)
$0.5LnL^2$ (b_{22})			0.078* (2.138)	0.075* (2.571)	0.062 (1.620)
$0.5t^2$ (b_{33})				0.006* (2.196)	-0.003 (-0.061)
LnKxLnL (b_{12})			-0.142* (-2.791)	-0.165* (-3.149)	-0.178* (-3.291)
LnKt (b_{13})					0.004 (0.313)
LnLt (b_{23})					0.021 (0.910)
s^2	0.890* (2.342)	0.529* (11.934)	0.524* (12.002)	0.995* (2.624)	0.851* (2.806)
G	0.438 (1.800)	0.006 (1.363)	0.004 (0.264)	0.522* (2.885)	0.440* (2.201)
m	0.819 (1.658)	0.115* (3.115)	0.100 (1.793)	1.371* (2.315)	1.199* (2.115)
h	-0.160* (-3.160)	0.069* (2.256)	0.048 (1.204)	-0.221* (-3.524)	-0.199* (-2.804)
Log-Likelihood Function	-381.252	-385.927	-381.706	-381.467	-372.661

The values in parentheses indicate the values of t.

*Significant at the five percent level.

Hypothesis tests are used in the study to determine functional pattern. In the light of the results listed in Table 1, the hypothesis test on which model to be preferred is given in Table 2.

Table 2 shows log-likelihood values obtained from functional patterns, the test statistics acquired from these values and critical values at the distribution table designed by Kodde and Palm in 1986. Hypothesis test number 1 tests if the Cobb-Douglas production function is an adequate specification to analyze the technical efficiency of firms (allβij=0). For the related hypothesis the following calculation is used: LR = -2{-381.252 – (-372.661)}=17.182. As this value is bigger than the critical values in the table (17.182>11.911), Ho hypothesis is rejected. For the related industry, when the function at 5% significance level is compared with translog production function, it has been found out that it is not an adequate specification. This result shows that the input and output elasticities are not constant among the firms (Lundvall and Battese, 2000).

Hypothesis test number 2 intends to test if the Cobb-Douglas production function without technical improvement is adequate to analyze the technical efficiency of firms operating in the Turkish automotive industry (all βij=0 and$\beta 3$=0). As the test statistics is bigger than the critical value, the H0 hypothesis at 5% significance level is rejected and it has been found out that there is technical improvement in the production function.

Hypothesis test number 3 tests the Hicks production function with technical improvement ($\beta 3$=$\beta 33$=$\beta 13$=$\beta 23$=0). It has been decided that there is technical improvement at 5% significance level.

In hypothesis test number 4, it has been tested whether there is Hicks neutral technology or not and it has been argued that the production function at 5% significance level does not reflect the Hicks neutral technology ($\beta 13$=$\beta 23$=0). In other words, it has been asserted that technical change has not only been impacted from mean output but also derives from the changes in the marginal rate of technical substitution.

Hypothesis test number 5 tests if the inefficiency effect exists for the firms in the industry (γ=$\delta 0$= $\delta 1$= $\delta 2$= $\delta 3$= $\delta 4$= $\delta 5$=0). It has been decided that there is inefficiency effect model at 5% significance level. It has been agreed that there is technical change, inefficiency changes in time and the production function is in the structure of translog production function. Thus, it has been decided that translog production function which is an alternative hypothesis can be used for the inefficiency effects analysis of production function.

Table 2. Hypothesis Tests

Null Hypotheses	Test Statistic[a]	Critical Value[b]	Decision
(1) Cobb-Douglas production function (all β_{ij}=0)	17.182	11.911	H_0 Reject
(2) Cobb-Douglas production function with no technical change (all βij=0 and β_3=0)	26.532	13.401	H_0 Reject
(3) No technical change ($\beta_3=\beta_{33}=\beta_{13}=\beta_{23}=0$)	18.090	8.761	H_0 Reject
(4) Hicks-neutral production function ($\beta_{13}=\beta_{23}= 0$)	17.612	5.138	H_0 Reject
(5) No inefficiency ($\gamma=\delta_0= \delta_1= \delta_2= \delta_3= \delta_4= \delta_5=0$)	11.031	10.371	H_0 Reject

a: The test statistic is computed by the formula (LR = -2[ln[L(Ho)/L(H1)]] = -2{ln[L(H0)] –ln[L(H1)]}).

b: Critical value of the test statistic at the five percent level of significance (Table 1, Kodde and Palm 1986).

In Table 3, the results of inefficiency effects can be observed. All parameters except δ0, δ2 and δ5 are statistically significant at 5% significance level. At the table, it can be observed that the increase in capacity utilization rate, trade intensity, foreign capital rate and firm size increase efficiency level (decrease inefficiency level) and the increase in firm age decrease efficiency level (increase inefficiency level). An increase of 0.01 in the capacity utilization rate increases the efficiency level by 1.427. An increase of 0.01 in export intensity increases the efficiency level by 0.136. An increase of 0.01 in foreign capital share increased the efficiency level by 0.161. An increase of 0.01 in the firm size increases the efficiency level by 0.346.

Table 3. Estimation Results for Inefficiency Effects

Parameter	Variable	Coefficient	t-ratio
(β_0)	Constant	-8.852*	-8.888
(β_1)	LnK	1.110*	23.294
(β_2)	LnL	1.492*	11.038
(β_3)	T	-0.604*	-24.909
(β_{11})	0.5LnK^2	0.065*	2.723
(β_{22})	0.5LnL^2	0.057*	3.247
(β_{33})	0.5t^2	-0.009*	-3.638
(β_{12})	LnK x LnL	-0.182*	-3.426
(β_{13})	LnK x t	0.013*	2.055
(β_{23})	LnL x t		5.399
(δ_0)	Constant	0.036	1.831
(δ_1)	CUR	-1.427*	6.387
(δ_2)	EI	-0.136	-0.593
(δ_3)	FCR	-0.161*	-10.465
(δ_4)	FA	0.003*	2.816
(δ_5)	FS	-0.346	-0.481
	σ^2	0.504*	12.875
	Γ	0.446*	24.800

*Significant at the five percent level.

On the other hand, an increase of 0.01 in the firm age decreases the efficiency level by 0.003. In the table, the fact that the t values of the capacity utilization rate (CUR), foreign capital rate (FCR) and firm age (FA) are above 2 as the absolute value, shows that these variables are statistically significant at 5% significance level. Moreover, export intensity (EI) and firm size (FS) variables are statistically insignificant at 5% significance level.

Table 4 lays out the technical efficiency values derived from the translog production function in the Turkish Automotive industry in the period 1992-2012.

In Table 3, the results of inefficiency effects can be observed. All parameters except δ0, δ2 and δ5 are statistically significant at 5% significance level. At the table, it can be observed that the increase in capacity utilization rate, trade intensity, foreign capital rate and firm size increase efficiency level (decrease inefficiency level) and the increase in firm age decrease efficiency level (increase inefficiency level). An increase of 0.01 in the capacity utilization rate increases the efficiency level by 1.427. An increase of 0.01 in export intensity increases the efficiency level by 0.136. An increase of 0.01 in foreign capital share increased the efficiency level by 0.161. An increase of 0.01 in the firm size increases the efficiency level by 0.346.

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Table 4 lays out the technical efficiency values derived from the translog production function in the Turkish Automotive industry in the period 1992-2012.

Table 4. Mean Technical Efficiency Values of the Industry as of the Period 1992-2012

Year	Number of Firms	Mean Technical Efficiency	Year	Number of Firms	Mean Technical Efficiency
1992	15	0.924	2003	17	0.916
1993	15	0.934	2004	17	0.914
1994	17	0.931	2004	17	0.910
1995	17	0.932	2006	18	0.914
1996	17	0.934	2007	18	0.911
1997	17	0.935	2008	15	0.928
1998	18	0.937	2009	15	0.923
1999	18	0.963	2010	15	0.921
2000	18	0.932	2011	15	0.920
2001	17	0.922	2012	14	0.988
2002	17	0.919	1992-2012		**0.926**

As observed in Table 4, the mean technical effectiveness level has been calculated as 0.926 in the industry. When the mean technical efficiency levels are analyzed in years, the lowest mean technical efficiency level belongs to the year 2004 and the highest mean technical efficiency level belongs to the year 2012. There are 17 firms operating in the industry in the year 2004 when the efficiency level at its lowest levels. On the other hand, there are 14 firms operating in the industry in the year 2012 when the efficiency level at its highest levels.

CONCLUSION

In this study, the technical efficiencies of the firms operating in the Turkish automotive industry in the period 1992-2012 are estimated by using stochastic frontier approach. The study benefited from the model developed by Battese and Coelli (1995) which allows the use of technical inefficiency and panel data in the course of time. The mean technical efficiency of the industry has been found as 0.926 within the given period of time.

The study makes estimations for Cobb-Douglas production function, Cobb-Douglas production function where no technical change is presumed, Hicks production function where there is no technical change, Hicks neutral production function and translog production function. As a result of the hypothesis tests, it has been decided to use the translog production function for the analysis of inefficiency effects.

Capacity utilization rate, export intensity, foreign capital rate, firm age and firm size are evaluated to be the factors which may lead to the inefficiency of the firms in the industry in line with the literature review. It has been determined that there is a positive and statistically significant relationship between capacity utilization rate and technical efficiency of a firm. Accordingly, a firm’s technical efficiency increases in line with the increase in the capacity utilization rate of the firm. Similarly, there is a positive and statistically significant relationship between foreign capital rate and technical efficiency of a firm. Consequently, the greater proportion of foreign capital rate has a positive impact on technical efficiency. Hence, it can be argued that the technical efficiency of foreign capital firms is much more higher compared to domestic capital firms. It has been found that there is a negative and statistically significant relationship between the firm age and the technical efficiency of a firm. This shows that the technical efficiency of a firm decrease when the firm’s age increase in time.

The results obtained in this study are limited to the review period of data, the input-output variables and analysis method used. Different periods, variables and methods can lead to differentiation of the analysis results. This study analyzed the technical efficiency of Border Stochastic Approach. In future studies, technical activities can be analyzed by different methods. It may also be the subject of analysis in the detection efficiency.

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