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Development of the Productivity in European Aggregate Production

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Abstract: Aggregate industry is one of the indispensable sectors of country economies due to the employment potential and the intense input-output relations with other sectors, especially with the construction sector. In this study, the productivity growth of the countries producing aggregates in Europe over the years 2012 to 2014 is investigated. Data were analyzed using the MPI (Malmquist Productivity Index), which can evaluate the multiple and different unit parameters simultaneously and examine the improvement of the decision making units over time. According to the results, the greatest development was obtained in Latvia and Turkey among the evaluated countries.

Introduction

Having an important place in human life, the mining sector is one of the factors that have played a key role in developed countries' current level of prosperity. Together with agriculture in particular, mining is one of the two main production areas that provide the raw material needs of society. The economic strength of developed countries that use natural resources efficiently is especially based on this situation.

The mining sector possesses a special importance because of its direct contribution to the economy and the inputs it provides to other areas of the economy. Having the highest capacity for creating added value and employment, the mining industry prevents migration to the city and accelerates regional development, as it is usually conducted in close proximity to rural areas. Therefore, the sector needs to be given a special importance in designing both economic and social development policies. If appropriate plans and policies are followed, mining sector will make an important contribution to economic indicators such as employment and manufacturing industry and it will be a driving force for a country's manufacturing sector. Despite the high consumption and the amount of raw materials of many goods used in daily life to be purchased from mining, the importance of the sector is not sufficiently recognized. As a result of the failure to produce the raw materials /inputs provided by mining directly to many sectors, the country will be faced with additional imports and unemployment of thousands of people working in this sector, and consequently the national economy will be faced with loss (Ernst and Young, 2011; Kulaksız, 2012).

Due to its employment potential and intense input-output relationships with other sectors, particularly with the construction sector, the aggregates industry is one of the indispensable sectors of Turkey's economy.

Aggregates and other aggregate-derived construction products such as cement are a part of daily life. In parallel with the increasing population and rapid urbanization, the need for aggregates and their derivatives is increasing. Water, consumed most per person in the world, is followed by aggregates. Aggregates are defined as a combination of crushed rock or sand and gravel that are classified according to size after extraction from quarries and that are used in many manufacturing industries, especially in the construction industry, such as paint, paper, fodder and fertilizers. Aggregates can be produced in quarries, but they can also be obtained from the sea in some countries. Recycled aggregates can be produced by reprocessing previously used in construction materials including construction and demolition residues. Manufactured aggregates are obtained through industrial processes on blasts, electric furnace slags or China clay residues. Demand for aggregates is met by stone crushing (46%), sand and gravel (41%), recycling (8%), and sea and manufacturing (5%) (UEPG, 2015; Anonymous, 2016a)

European aggregates production (39 countries) is 3766 million tonnes/year. Total production is carried out by 16824 companies and 28099 quarries. According to 2014 data from the European Aggregates Association production in Europe is 5 tonnes per capita per year while this figure in Turkey is about 6 tonnes. The aggregates sector has a significant position among the non-energy extractive industries. Aggregate mining has a very important place in the development of the economy and quality of life in Turkey. Turkey ranks as the third biggest aggregates producers in Europe with an annual production capacity of 477 million tonnes. Employing approximately 25000 people, the aggregates sector has an important place in the mining industry (UEPG, 2015; Anonymous, 2016 a).

The aim of this study is to examine the efficiency changes of countries in Europe that produce aggregates by using the Malmquist total factor productivity index (MPI), which is based on Data Envelopment Analysis (DEA).

Materials and Methods

The need for a single criterion in weighting the different ratios calculated in efficiency measurements to be conducted in cases of multiple sets of input-output led to the emergence of data envelopment analysis approach. DEA was first developed by Charnes, et al. (1978) in order to measure the relative efficiency of economic decision making units that are similar to each other in terms of the goods or services they produce.

The first step in non-parametric approach to measurement of efficiency, which is used for comparative efficiency analysis, is to determine enveloped surfaces (efficient frontier) that cover the linear combinations and efficient observations of the decision making units (DMUs) which carry out the same production activities. Then the efficiency scores and radial distances (from the center) of inefficient units within the enveloped surface are calculated (Muniz, 2002; Aydagün, 2003; Kasap, 2008).

The most important advantage to this method is that the sources of inefficiency can be analyzed and quantified for every evaluated unit. With this feature, the method guides decision makers on how much to reduce their inputs and/or how much to increase their output so that inefficient units can become efficient.

In order to calculate the Technical Efficiency (TE) for kth DMU (the decision making unit evaluated), the following linear programming model is used.

$$\max \theta_k \quad (1)$$

$$\sum_{j=1}^{n} \lambda_j \cdot Y_{rj} - s_{rj}^{-} = \theta_k . Y_{rk} \; ; r = 1,2,...,s \quad (2)$$

$$\sum_{j=1}^{n} \lambda_j \cdot X_{ij} + s_{ij}^{+} = X_{ik} \; ; i = 1,2,..,m \quad (3)$$

$$\lambda_j , s_{ij}^{+} , s_{rj}^{-} \geq 0 \quad \forall i, r, j \quad (4)$$

In the model that is established for efficiency measurement to be performed under output maximization, the aim is to keep inputs constant but outputs at a maximum level (Eq. 1).

The constraints where maximization is sought for the outputs in inefficient DMUs are shown in the equation (2). With this constraint, rth output of each j DMU will not be greater than the maximum linear combination of the units constituting the efficient frontier. Constraint (Eq. 3) sets involve comparison of the inputs kept constant in non-parametric linear programming carried out under output maximization. It will be possible to measure ith input of each j DMU with a level of input lower than the one formed with weighted linear combination of the ith input used by all of the units.

In order for a DMU to be considered efficient,

- optimal θ_k has to be equal to 1, and
- all slack variable scores have to be zero ($s_{ik}^{+}, s_{rk}^{-} = 0$).

The symbols used in the formulation of non-parametric linear programming are defined below:

n the number of decision-making units involved in comparison (European countries),

s the number of outputs gained from the production,

m the number of inputs used in the production,

$j = (1,2,\ldots,n)$ set of all decision-making units,

$k = (1,2,\ldots,n)$ set of decision-making units evaluated,

$r = (1,2,\ldots,s)$ set of all outputs,

$i = (1,2,\ldots,m)$ set of all inputs,

$y \in R^{+}_{s}$ vector of outputs $(y_1, y_2,\ldots,y_s) = s\times n$

$x \in R^{+}_{m}$ vector of inputs $(x_1, x_2,\ldots,x_m) = m\times n$

λ the vector of density variables giving inputs-outputs weight averages = $k\times 1$

λ_{jk} the relative (compared to other units, *j*) weight value of "*k*" decision unit measured for efficiency in input-oriented,

θ_k the scaler variable (efficiency score) trying to decrease all inputs of k DMU, which is considered to obtain the best frontier,

Y_{rj} the rth output amount produced by decision unit j,

Y_{rk} the rth output amount produced by decision unit k,

X_{ij} the ith input amount used by decision unit j,

X_{ik} the ith input amount used by decision unit k,

t the year evaluated,

t+1 the next year evaluated.

As a form of static analysis, Data Envelopment Analysis performs analyses using data from decision making units in a single period. However, decision making unit that was identified to be efficient before may lose its efficiency and reference quality. In this respect, in efficiency evaluation process, the MPI was developed to examine the changes that may occur over time.

The MPI, which was obtained by adding the functions of distance to the Farrell (1957) measure of technical efficiency, measures the variation in two units' total factor productivities as the proportion of the distances from a common technology. Distance function is used to define multi-input and multi-output production technologies without specifying objectives such as cost minimization or profit maximization. The input distance function considers a production technology by looking at a minimal proportional contraction of input vector, given an output vector, while the output distance function characterizes it a maximal proportional expansion of the output vector, given an input vector. This study used the output distance function because it was suitable for the analysis, which was conducted to investigate the efficiency changes of the decision making units in the years evaluated (Tarım, 2001; Cingi and Tarım, 2000; Coelli et al. 1998).

Grifell-Tatje and Lovell (1995) showed that using the assumption of variable returns to scale when calculating the distance functions required for MPI would not accurately measure the changes (gain or loss of productivity) in Total Factor Productivity (TFP) index. For this reason, the index needs to be calculated under the assumption of constant returns to scale.

The output distance function is

$$D_i(x,y) = \min\left\{\theta : (x, \frac{y}{\theta}) \in L(x)\right\} \quad (5)$$

If y vector is an element of the possible production set ofL(x) efficient frontier, the distance function $D_o(x,y)$ will have a value smaller than or equal to one. According to the output between t period and the subsequent (t+1) period and within the framework of distance function, MPI is calculated as

$$MPI = \sqrt{\frac{D_i^t\left(y^{t+1}, x^{t+1}\right)}{D_i^t\left(y^t, x^t\right)} \times \frac{D_i^{t+1}\left(y^{t+1}, x^{t+1}\right)}{D_i^{t+1}\left(y^t, x^t\right)}} \quad (6)$$

Where $D_o^t(x^{t+1}, y^{t+1})$ represents the distance of t period to t+1 period technology. An MPI value greater than 1 indicates that there is an expansion of total factor productivity from t period to t+1 period while an MPI value smaller than 1 show a contraction in total factor productivity.

The MPI evaluates changes in productivity according to two separate components: technical efficiency change and technological change. Technical efficiency (TE) change provides an assessment of the process in which decision-making units approach the efficient frontier whereas technological change (TC) provides the change of the efficient frontier over time. The aim of this study is to determine the productivity changes of the European aggregates producer countries over the years evaluated.

When Equation 6 is revised:

$$MPI = \underbrace{\frac{D_i^{t+1}\left(y^{t+1}, x^{t+1}\right)}{D_i^t\left(y^t, x^t\right)}}_{\text{Technical Efficiency Change}} \times \underbrace{\sqrt{\frac{D_i^t\left(y^{t+1}, x^{t+1}\right)}{D_i^{t+1}\left(y^{t+1}, x^{t+1}\right)} \times \frac{D_i^t\left(y^t, x^t\right)}{D_i^{t+1}\left(y^t, x^t\right)}}}_{\text{Technological Change}} \quad (7)$$

where the ratio outside the square root measures the change in the output-oriented measure of Farrell technical efficiency between periods t and t+1. In other words, the efficiency change is equivalent to the ratio of the technical efficiency in period t+1 to the technical efficiency in period t. The remaining part of the index in Equation (7) is a measure of technological change. It is the geometric mean of the shift in technology between the two periods, evaluated at x^{t+1} and also at x^t.

$$MPI = TE \times TD.$$

Non-parametric linear programming method is the most popular method that is used to estimate the distance functions that are required to form MPI. When there is a suitable panel data set, the required distances can be calculated by using non-parametric linear programs by means of this method. Four distance functions must be calculated to measure the changes TFP between the two periods for any i^{th} firm and this requires the solution of four Linear Programming (LP) problems. The LPs required under the assumption of constant returns to scale (Table 1).

Table 1.The distance functions.

$$\left[D_i^{t+1}\left(x_j^{t+1}, y_j^{t+1}\right)\right]^{-1} = \max\theta_k \quad (8)$$
$$\sum_{j=1}^{n} \lambda_{jk}^{t+1} \cdot y_{rj}^{t+1} \geq y_{rk}^{t+1}.\theta_k$$
$$\sum_{j=1}^{n} \lambda_{jk}^{t+1} \cdot x_{ij}^{t+1} \leq x_{ij}^{t+1}$$
$$\lambda_{jk}^{t+1} \geq 0$$

$$\left[D_i^{t}\left(x_j^{t}, y_j^{t}\right)\right]^{-1} = \max\theta_k$$
$$\sum_{j=1}^{n} \lambda_{jk}^{t} \cdot y_{rj}^{t} \geq y_{rk}^{t}.\theta_k$$
$$\sum_{j=1}^{n} \lambda_{jk}^{t} \cdot x_{ij}^{t} \leq x_{ij}^{t}$$
$$\lambda_{jk}^{t} \geq 0$$

$$\left[D_i^{t+1}\left(x_j^t, y_j^t\right)\right]^{-1} = \max\theta_k \quad (9)$$

$$\sum_{j=1}^{n} \lambda_{jk}^{t+1} \cdot y_{rj}^{t+1} \geq y_{rk}^{t}.\theta_k$$

$$\sum_{j=1}^{n} \lambda_{jk}^{t+1} \cdot x_{ij}^{t+1} \leq x_{ij}^{t}$$

$$\lambda_{jk}^{t+1} \geq 0$$

$$\left[D_i^{t}\left(x_j^{t+1}, y_j^{t+1}\right)\right]^{-1} = \max\theta_k$$

$$\sum_{j=1}^{n} \lambda_{jk}^{t} \cdot y_{rj}^{t} \geq y_{rk}^{t+1}.\theta_k$$

$$\sum_{j=1}^{n} \lambda_{jk}^{t} \cdot x_{ij}^{t} \leq x_{ij}^{t+1}$$

$$\lambda_{jk}^{t} \geq 0$$

Determining these defined distance values by using Equations (8) and (9) for all time periods and firms requires the solution of $n(3t-2)$, where n represents the number DMUs and t shows the number of periods, linear programming models (Tarım, 2001; Fare, et al., 1994). Since there were 33 European countries and 3 years (as periods of time) in this study, a total of 231 linear programming models were solved so that the analyses could be carried out.

Application

This study examined the efficiency changes of the European countries that produced aggregates over the years 2012 to 2014. Thirty three European aggregates producing countries were evaluated in order to access accurate data in the input-output sets within the three years. Because a large part of the demand for aggregates was met with crushed rock and sand-gravel, they were evaluated as outputs. The total amount of production was also evaluated as output, as it reflected other manufacturing ways. The amount of aggregates production per capita was evaluated as output because it reflected production quantities based on country populations and the amount of demand that may arise. Exports and imports were evaluated as output and input respectively, since they could represent their impact on national economies. In addition, the amount of countries' reserves could be evaluated as input but there is a variety of rocks that are used as raw materials for aggregates and there is no regular data on this subject. Then, the total number of quarries of the countries was evaluated as input (Table 2).

Input data for some parameters used in the analysis:

n Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherland, Norway, Poland, Portugal, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey, UK,

s Sand gravel production, Crushed rock production, Total production, Imports, Aggregate Amount Per Capita,

m Total Number of Extraction Sites, Export

k = (1,2, ….33)

j = (1,2, ….33)

r = (1, 2, 3, 4, 5)

I = (1,2)

DEAP 2.1 software package designed by Coelli (1996) was used to examine the efficiency changes of the countries engaged in the production of aggregates in Europe.

Table 2. The data evaluated in this study.

2012	**Max**	**Min**	**Average**
Sand gravel production (million tonnes)	245	0	36.15
Crushed rock production (million tonnes)	390	0	50.24
Total production (million tonnes	564	1	95.45
Imports (tonnes)	25160776	0	3012806
Aggregate Amount Per Capita (tonnes)	16.37	0.99	5.84
Total Number of Extraction Sites	3145	10	798
Export (tonnes)	23457644	4102	3169825

2013	**Max**	**Min**	**Average**
Sand gravel production (million tonnes)	228	0	33.58
Crushed rock production (million tonnes)	390	0	48.76
Total production (million tonnes)	546	2	92.67
Imports (tonnes)	21825199	0	3086532
Aggregate Amount Per Capita (tonnes)	15.72	1.98	5.93
Total Number of Extraction Sites	3034	10	778
Export (tonnes)	22724647	1432	2934820

2014	**Max**	**Min**	**Average**
Sand gravel production (million tonnes)	240	0	33.91
Crushed rock production (million tonnes)	430	0	50.79
Total production (million tonnes)	564	2	95.24
Imports (tonnes)	22579753	0	3189090
Aggregate Amount Per Capita (tonnes)	15.72	1.95	6.12
Total Number of Extraction Sites	2960	10	798
Export (tonnes)	24404781	1716	3045039

The results obtained are given in Table 3 and Figure 1. When Malmquist total factor productivity index components are evaluated, a decrease of approximately 2% according to the average MPI (1-0.980 = 0.02) can be observed.

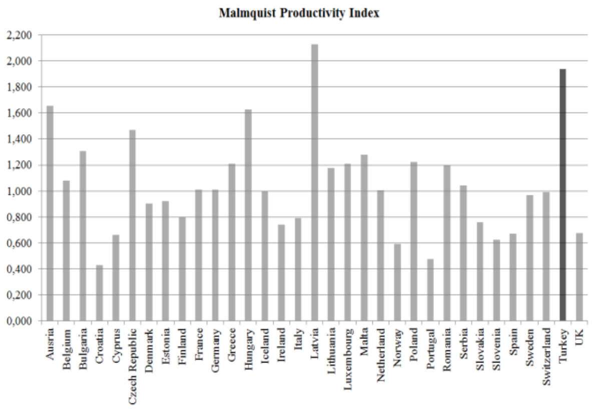

Fig.1 Malmquist Productivity Index.

An increase was obtained in the efficiency changes of Austria, Belgium, Bulgaria, Czech Republic, France, Germany, Greece, Hungary, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Romania, Serbia and Turkey because their MPI values were greater than 1.000. The Technical Efficiency scores of these countries equal to or greater than 1.000, which implies that they were able to produce outputs in quantities in line with their capacities. On the other hand, when the technological changes of these countries were analyzed, we found that the scores received by the Czech Republic, Germany, Hungary, Lithuania, Romania and Serbia were less than 1.000. The scores of Technological Change below 1.000 indicate that the input-output components in these countries' production processes changed in a negative way. However, we could assume that those scores would not have a negative impact on the MPI because they were very close to 1.000 (e.g. 0.998).

Among the countries evaluated, the biggest development was realized in Latvia with a MPI score of 2128, followed by Turkey with a MPI score of 1937. According to data from 2013, Latvia ranked 28th in Europe in terms of production capacity, while Turkey ranked 3rd with its high production capacity after Russia and Germany.

Although, Latvia has a low capacity of aggregates production, it showed a considerable growth between 2009 and 2010. In that period, a total of 300,000 m³ increase was observed in 21 dolomite quarry production. In terms of the years evaluated in the analyses, it can be seen that while the production volume was 2 million tonnes in 2012, the amount of production reached around 14 million tonnes in 2013 and 2014. Since 2009, new investments have been made in Latvia taking into consideration the materials demand of the construction industry. Moreover, the fact that Latvia has an ideal location in terms of logistics, it offers low production costs and skilled work force has contributed to the development of the aggregates sector (Anonymous, 2016 b).

Table 3. Malmquist productivity index components.

	TE	TD	MPI
Austria	1.468	1.126	1.653
Belgium	1.000	1.078	1.078
Bulgaria	1.303	1.003	1.306
Croatia	0.446	0.962	0.429
Cyprus	0.752	0.880	0.662
Czech Republic	1.471	0.998	1.468
Denmark	0.992	0.910	0.902
Estonia	1.208	0.762	0.921
Finland	0.997	0.804	0.802
France	1.007	1.003	1.010
Germany	1.036	0.974	1.009
Greece	1.175	1.031	1.211
Hungary	1.734	0.937	1.625
Iceland	1.249	0.800	0.999
Ireland	0.851	0.870	0.740
Italy	0.813	0.974	0.793
Latvia	2.103	1.012	2.128
Lithuania	1.215	0.966	1.175
Luxembourg	1.000	1.211	1.211
Malta	1.197	1.067	1.277
Netherland	1.000	1.007	1.007
Norway	0.767	0.771	0.592
Poland	1.166	1.050	1.224
Portugal	0.495	0.966	0.478
Romania	1.196	0.999	1.194
Serbia	1.125	0.926	1.041
Slovakia	0.868	0.873	0.758
Slovenia	0.739	0.844	0.624
Spain	0.608	1.107	0.673
Sweden	1.004	0.965	0.969
Switzerland	0.966	1.026	0.991
Turkey	1.000	1.937	1.937
UK	0.628	1.076	0.676
Average	0.997	0.983	0.980

The construction sector in Turkey and aggregates production therefore, was accelerated by the following: urban transformation due to earthquake risks, constant expansion of road network across the country, the increasing need for housing, schools and other urban facilities caused by the high population growth rate, migrants from neighboring countries and mega-projects (e.g. the third bridge and the third airport in Istanbul and Izmit bay crossing projects).

Especially, the third airport project in Istanbul required by far the largest excavation, filling and ground improvement work in Turkey. This project will also include sea fillings. In addition to the cavities formed by coal pits and ground shifts, the loose soil structure of the project area will lead to work in a wide area.

The future growth rate of the industry, which is expected to grow dramatically due to the mega projects, cannot be estimated exactly. However, it is estimated that the sector will need millions of tons of raw materials. Therefore, there will very probably be a need for opening new quarries and pits, and entrepreneurs in this area will be offered serious opportunities (Aydın, 2013; Anonymous, 2016 c). In line with this result, the increases in evaluated output units in recent years and decrease in imports promoted an environment for productivity growth.

Croatia and Portugal had lowest MPI values by 0.429 and 0.478, respectively. The fact that the technological change scores of Croatia and Portugal were close to 1.000 (0.962 and 0.966, respectively), it is clear that the problem in these countries was caused by technical inefficiency. No efficiency growth was observed in these countries in the evaluated years because, apparently, they were unable to produce what they could have done with their resources.

Conclusion and Recommendations

In the modern world, the need for products to be obtained from the Earth's crust is rapidly increasing in parallel with the growing population and rapid urbanization. Considering the fact that the only thing constantly used in human life since ancient times is rock, aggregates emerge as a critical resource to grow the economy, to increase prosperity in a country and for modern life.

This study examined the efficiency changes of the European countries that produced aggregates over the years 2012 to 2014. Further it used the Malmquist Productivity Index, which can evaluate multiple and different unit parameters simultaneously and examine the productivity changes of decision making units over time.

The results showed that the overall productivity growth of the evaluated countries decreased by 2%. Nevertheless, Latvia and Turkey have achieved a large-scale productivity growth. This result could be attributed to the demand increase in the construction industry over the recent years. As a matter of fact, materials used in concrete production such as sand, gravel and crushed rock are important components that occupy around 60-75% of concrete.

In Turkey, urban transformation due to earthquake risks, constant expansion of road network across the country, the increasing need for housing, schools and other urban facilities caused by the high population growth rate, migrants from neighboring countries and mega-projects (e.g. the third bridge and the third airport in Istanbul and Izmit bay crossing projects) accelerated the construction sector and, therefore, aggregates production. There will probably be a need for opening new quarries and pits to meet the recently increasing need for aggregates. It is essential to launch campaigns to promote investments needed for the growth of the sector.

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