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Performance analysis in the coal bagging plant of Garp Lignite Corporation

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Abstract: Companies can contribute to a country's economy by means of efficient production in each of their units. The aim of this study was to examine the change in operational performance of the coal bagging plant of Garp Lignite Corporation in Turkey using the Malmquist total factor productivity index. The results showed that there was a decrease in the productivity of the bagging plant. This decrease could be due to the rapid growth of the market share of natural gas in heating and energy in recent years, the reduced demand for lignite, overuse use of energy as a result of the necessity to keep the plant active even when no bagging is performed, the current labor-intensive bagging process, and the difficulty in working continuously with qualified staff hired depending on the demand for coal. In conclusion, it is recommended that a fully automated coal bagging plant be built in the corporation.

Subjects: Automation Control; Control Engineering; Mining Engineering; Technology

Keywords: coal bagging; productivity; Malmquist total factor productivity index

1. Introduction

Mining industry, which has great importance due to its direct contributions to a country's economy and the inputs it gives to other sectors of economy, particularly to the manufacturing sector, also requires large investments, involves risks and uncertainties in both investment and production stages in geological, topographical, technological, and economic terms, and includes many hazards in terms of work safety. For this reason, in order for investments to be met as soon as possible and to make contributions to a country's economy, productivity, low-cost manufacturing, product quality, continuity of production, use of scientific methods, and environmentally friendly production are extremely important.

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PUBLIC INTEREST STATEMENT

There has been a constant decrease in the production of the coal bagging plants from the year 2006 to the present day. Approximately, 26% of the energy demand of Turkey is met by the domestic sources, while the rest of this demand is met by various foreign sources. Consumption of the domestic lignite in residential heating is restricted in Turkey because it leads to air pollution due to its low calorific value and high sulfur content. Natural gas has replaced coal in recent in Turkey. Other causes of the observed decline in the coal industry are that this sector requires continuous investment, long-term planning, search and preparatory work, the climate change in recent years, efficient production, and rapid marketing. The aim of this study was to examine the change in operational performance of the coal bagging plant of Garp Lignite Corporation in Turkey.

Significant changes have occurred in both production (e.g. high production rate, work safety, low operating costs, high quality, and standardized products) and in the structure of the labor force. Developments in science and technology, and demand for the increase in staff qualifications and the quality of the products, have given priority to productivity that is one of the performance indicators. Productivity involves achieving production in higher quantity and quality with less cost and less equipment.

Companies can contribute to a country's economy by means of efficient production in each of their units. The existing operation processes should be automated professionally in order for corporations in the mining sector to operate in a modern and low-cost process with higher productivity and that their technology should meet the highest standards. The aim of this study was to examine the change in operational productivity of the bagging plant of Garp Lignite Corporation (GLC). Approximately, 85% of the lignite production in GLC is from opencasts and 15% is from underground mining plants. The annual production capacity is about 6.3 million tons, and 1 million tons of this figure is from underground production. The efficiency change of the bagging plant of the corporation between the years 2006 and 2012 was evaluated using the Malmquist total factor productivity index (MPI). Sensitivity analyses were made in order to make the year 2012, which was found to be inefficient, efficient and some recommendations were made in order to provide the corporation with guidelines for the next several years.

2. Methodology

Parametric efficiency measurements assume that the production functions of fully efficient units are known. Since the production function is never known in practice, Farrell (1957) suggested that the function could be estimated from sample data. The first proposal was evaluated by Charnes, Cooper, and Rhodes (1978).

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 (Muñiz, 2002).

In order to calculate the technical efficiency (TE) for k^{th} DMU (the DMU in question), the following linear programming (LP) model is used.

$$\min \theta_k \tag{1}$$

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

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

$$\lambda_j, s_{ij}^{+}, s_{rj}^{-} \geq 0 \qquad (j = 1, 2, ..., n). \tag{4}$$

In the model that is established for efficiency measurement to be performed under input minimization, the aim is to keep outputs constant but inputs at a minimum level (1).

Constraint (2) sets involve comparison of the outputs kept constant in data envelopment analysis (DEA) carried out under input minimization. With this constraint, r^{th} output of each j DMU will not be greater than the maximum linear combination of the units constituting the efficient frontier. The constraints where minimization is sought for the inputs in inefficient DMUs are shown in the Equation (3). Equation (5) represents the constraints to be negative (Kasap, 2011).

In order for a DMU to be considered efficient,

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

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

N—the number of DMUs involved in comparison,

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 DMUs,

$k = (1,2,\ldots,n)$—set of DMUs taken into consideration,

$r = (1,2,\ldots,s)$—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 process,

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 r^{th} output amount produced by decision unit *j*,

Y_{rk}—the r^{th} output amount produced by decision unit *k*,

X_{ij}—the i^{th} input amount used by decision unit *j*,

X_{ik}—the i^{th} input amount used by decision unit *k*.

As a form of static analysis, DEA performs analyses using data from DMUs in a single period. However, a DMU that is 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 TE, 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 (Coelli, Rao, & Battese, 1998). This study used the output distance function because it was suitable for the analysis that was conducted to investigate the efficiency changes of the DMUs in the considered years.

Grifell-Tatjé 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.[1]

Since the production in the coal bagging plant is performed depending on the demand by the market for coal, an input-oriented analysis was considered to be more appropriate.

The input distance function is

$$D_i(x,y) = \max\left\{\theta:(\frac{x}{\theta},y) \in \mathrm{L(y)}\right\} \tag{5}$$

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

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

where $D_i(x, y)$ represents the distance of t period to $t+1$ period technology. An MPI value greater than one indicates that there is an expansion of total factor productivity from t period to $t+1$ period while an MPI value smaller than one shows a contraction in total factor productivity (Färe, Grosskopf, & Lovell, 1994).

MPI considers changes in productivity according to two separate components: TE change and technological change. TE change provides an assessment of the process in which DMUs approach the efficient frontier, whereas technological change (TC) provides the change of the efficient frontier over time (Grifell-Tatjé & Lovell, 1995; Mahadevan, 2002).

When Equation (6) is revised,

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

where the ratio outside the square brackets measures the change in the output-oriented measure of Farrell TE between periods t and $t+1$. In other words, the efficiency change is equivalent to the ratio of the TE in period $t+1$ to the TE in period t. The remaining part of the index in Equation (2) is a measure of technical 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 (Coelli & Rao, 2005).

$$\mathrm{MPI} = \mathrm{TE} \times \mathrm{TC}. \tag{8}$$

Non-parametric LP 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 using non-parametric linear programs with this method. Four distance functions must be calculated to measure the changes TFP between the two periods for any i^{th} input and this requires the solution of four LP problems. The LPs required under the assumption of constant returns to scale are

$$\begin{aligned}
\left[D_i^{t+1}\left(x_j^{t+1},y_j^{t+1}\right)\right]^{-1} &= \max\theta_k & \left[D_i^{t}\left(x_j^{t},y_j^{t}\right)\right]^{-1} &= \max\theta_k \\
&\sum_{j=1}^{n}\lambda_{jk}^{t+1}\cdot y_{rj}^{t+1} \ge y_{rk}^{t+1}\cdot\theta_k & &\sum_{j=1}^{n}\lambda_{jk}^{t}\cdot y_{rj}^{t} \ge y_{rk}^{t}\cdot\theta_k \\
&\sum_{j=1}^{n}\lambda_{jk}^{t+1}\cdot x_{ij}^{t+1} \le x_{ij}^{t+1} & &\sum_{j=1}^{n}\lambda_{jk}^{t}\cdot x_{ij}^{t} \le x_{ij}^{t} \\
&\lambda_{jk}^{t+1} \ge 0 & &\lambda_{jk}^{t} \ge 0
\end{aligned} \tag{9}$$

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

$$\left[D_i^{t}\left(x_j^{t+1},y_j^{t+1}\right)\right]^{-1} = \max\theta_k \quad \sum_{j=1}^{n}\lambda_{jk}^{t}\cdot y_{rj}^{t} \ge y_{rk}^{t+1}\cdot\theta_k \quad \sum_{j=1}^{n}\lambda_{jk}^{t}\cdot x_{ij}^{t} \le x_{ij}^{t+1} \quad \lambda_{jk}^{t}\ge 0 \tag{10}$$

Determining these defined distance values using Equations (9) and (10) for all time periods and years requires the solution of $n(3t-2)$, where n represents the number DMUs and t shows the number of periods, LP models (Färe et al., 1994). Since there were 7 years analyzed and 12 months (as periods of time) in this study, a total of 238 LP models were solved so that the analyses could be carried out.

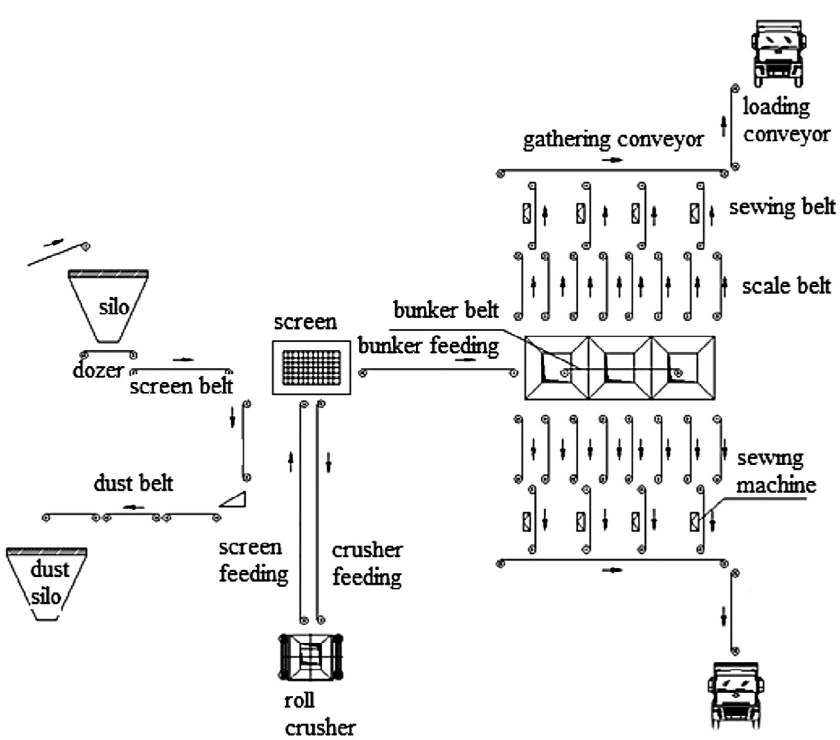
3. Application

There are currently three bagging plants in GLC: Tunçbilek, BEKE and 1B. BEKE and 1B plants are not used because the capacity of Tunçbilek bagging plant is compatible with the amount of production. The total capacity of Tunçbilek Bagging Plant has now reached 6,000 tons/day.

The plant offers pure and dust-free products to customers by washing the run of mine coal coming from the GLC casts in the coal washing plants and bagging it. As can be seen in Figure 1, the coal coming to the bagging plant is first poured into the dumbs with a capacity of 100 tons, it is then sent to the screen through belt conveyors, and it is screened at +18–100 mm in size. The coal +100 mm in size are fed to the crushers as screen oversize and then back to the screen, while the coal −18 mm in size is sent to the dust silo. On the other hand, the coal +18–100 mm in size coal is fed to the coal-bunkers of bagging unit by belt conveyors.

The coal +18–100 mm in size that is sent to the coalbunkers in the plant is sent to the scales through belt scales under the bunker (eight on the right side and eight on the left side). The scales

Figure 1. Flow diagram of unit 1 of Tunçbilek bagging plant (units 1, 2, and 3 are equivalent).



are electronic and weigh the amount of coal as 25 kg. When the coal in a scale reaches 25 kg, the system stops the scale-feeding belt and the coal is poured from the scale into the filling reduction. After a worker places an empty coal bag to the reduction, the coal in the scale is poured into the reduction by means of a switch and, from here, it is filled into the empty coal bag.

It takes approximately 12 s for a reduction to fill a coal bag. In order to increase production, on each coal-filling reduction are mounted two scales. When the worker responsible for the coal-filling reductions unloads the coal in one of the scales into an empty coal bag by means reduction, the other scale is loaded with coal. This increases coal-filling rate.

The worker responsible for the coal-filling reductions hooks 25 kg bags in 50 × 75 cm dimensions on the coal-filling reductions. The bags loaded with coal are sent to the sewing belt and a worker sews these bags with a sewing machine. After that, the bags are loaded to trucks through the loading line.

3.1. Efficiency change in the GLC coal bagging unit

The Malmquist TFP index was used to estimate the efficiency change in the GLC The aim of this study was to examine the change in operational productivity of the bagging plant of the GLC. When the conditions required for obtaining significant activity measurement results were considered, it was appropriate to choose seven years (2006–2012) as the DMUs in accordance with the number of inputs and outputs that were taken into consideration.

There would be differences in the yearly efficiency scores because the demand for coal increases in certain months of the year and, out of the raw ore lignite production in GLC, approximately 80% is from opencasts and 20% is from underground mining plants. Therefore, the periods of time that should be taken into consideration for the efficiency measurement method used were determined as months.

The amount of coal fed to the bagging units, the number of workers hired in the bagging units, and the amount of energy used in the bagging units were considered as the input, and the amount of bags of coal that were produced was considered as the output (Table 1).

While outputs can be kept constant in order to increase productivity in the non-parametric efficiency analysis, inputs can be kept constant in order to increase outputs as well. Although the Malmquist TFP index examines the efficiency changes of DMUs without input minimization or output maximization, because it is based on the non-parametric efficiency analysis, an increase in productivity was possible by reducing the amount of the coal fed to the plant, which was considered as an input. However, reducing the amount of the coal fed to the plant was not option so that the plant could operate at full capacity. Determining the inputs that are compatible with the structure of the models used is critical for obtaining accurate results. For this reason, the amount of coal that was fed to the plant were negated (1/the amount of the coal fed) and included in the analysis.

There are currently 24 coal-filling reduction and 24 sewing machines in the GLC coal bagging unit, which requires assigning 48 workers. Together with these 48 workers, there should be a total of 80 workers in a shift including eight loaders, four cleaners, three electricians, two welders, four

Table 1. The inputs and outputs of the bagging units

	Type	Unit	Description
Inputs	Coal that is fed	Tons	The quantity of coal that is fed to the bagging units
	Labor	Number/day	The average number of workers in the unit at a certain time
	Energy	kwh	The amount of energy used
Outputs	Bagged coal	Tons	The quantity of coal that is bagged

maintenance workers, one technician, one shift superintendent, four truck drivers, two loader operators, one sweeper operator, one shunter, and sewing machine worker. Therefore, the unit needs a total of 240 workers for the three shifts in a day. On the other hand, there could also be variations in the coal-filling reduction, which is operated according to the daily demand for bagged coal. This, consequently, causes a change in the number of workers in the plant at a specific time.

The amount of electric power used in the coal bagging units depends on production and, therefore, energy consumption increases depending on the number of units that are run when the amount of bagged coal increases.

According to the considered data, there was a difference between the quantity of the coal fed and the quantity of the coal bagged. The coal losses normally occur because improperly sewed, torn, or incorrectly loaded coal bags are sent back to the coal-washing plant.

The sets and parameters used in the efficiency analyses are defined below:

n—seven years of the coal bagging plant (2006–2012),

s—the number of outputs gained from the production (the quantity of bagged coal produced in the bagging units),

m—the number of inputs used in the production (the quantity of coal fed to the bagging units, the number of workers in the bagging units, the quantity of energy used in the bagging units),

$k \in \{1,2,....,7\}$—set of DMUs taken into consideration,

$j \in \{1,2,....,7\}$—set of all DMUs,

$r \in \{1\}$—set of all outputs,

$i \in \{1,2,3\}$—set of all inputs,

t—12 months in a year (January, February, ..., December).

The efficiency change of the bagging units between the years 2006 and 2012 was evaluated using the Malmquist TFP index. DEAP 2.1 written by Coelli (1996) was used in the analyses.

According to the productivity change within the seven-year period of the coal bagging unit in Table 2, there was a decrease in the mean Malmquist TFP (0.990 < 1). TC was effective on the scores of the inefficient ones among 2007, 2008, 2009, 2011, and 2012. In other words, there was a change in the efficiency frontier of the plant over the years. While there was a decrease in production due to the demand for coal, inefficiency occurred because there was no linear decrease in the quantity of the coal fed, the number of workers and the amount of energy consumed.

According to the 2012 Malmquist TFP index components, the sources of the inefficiency were both the overuse of the inputs taken into consideration and the inputs components not being in appropriate

Table 2. The yearly Malmquist TFP index components of the coal bagging unit

Years	Technical efficiency change (TE)	Technological change (TC)	Malmquist TFP change (MPI)
2006	1.001	1.092	1.093
2007	1.000	0.966	0.966
2008	1.000	0.969	0.969
2009	1.000	0.998	0.997
2010	1.000	1.000	1.000
2011	1.001	0.967	0.967
2012	0.989	0.956	0.945
Mean	0.999	0.992	0.990

scales and the efficient frontier were exposed to change in time (technological efficiency = 95.6% < 100%). While there was a decrease in the Malmquist TFP change from 2006 to 2010, the 100% score in the year 2010 indicates that there was no change in that year in comparison with the preceding year. On the other hand, the decrease in the Malmquist TFP change beginning from the year 2010 continued (96.7% in 2011 and 95.6% in 2012).

The reasons for the inefficiency in this year could be due to the following: wearing down of the bagging units in time, overconsumption of energy due to the continuous running of all equipment although the demand for coal was homogeneous in all months and the quantity of the coal that was fed was little, keeping the number of workers in this year constant, whereas the number of workers was determined depending on the production in the other years despite the homogeneity of demand; the greatest increase in the quantity of incorrectly bagged coal was in the year 2012, whereas there was a decrease in that quantity from 2006 to 2010.

There has been a constant decrease in the production of the coal bagging plants from the year 2006 to the present day. Approximately, 26% of the energy demand of Turkey is met by the domestic sources while the rest of this demand is met by various foreign sources. Consumption of the domestic lignite in residential heating is restricted in Turkey because it leads to air pollution due to its low calorific value and high sulfur content. The use of imported coal for heating emerged as an alternative in order to avoid the intense air pollution, especially in big cities toward the end of the 1970s. Natural gas has replaced coal in recent years with the increase of the natural gas network in Turkey. Other causes of the observed decline in the coal industry are that this sector requires continuous investment, long-term planning, search and preparatory work, efficient production, and rapid marketing.

In addition, the climate change in recent years has also affected the demand for coal. There has been a decrease in coal consumption due to relatively shorter and milder winter seasons.

Tunçbilek coal bagging plant was originally established as a single unit at the beginning. In 2008, two more identical units were added to Tunçbilek coal bagging plant. In 2007, all of the eight coal-filling reductions in the first unit in performed continuous production and 75% of the production was in the coal sales season. The energy consumed in the plant depends on production and, therefore, energy consumption increases in parallel to production. Because the three units of Tunçbilek coal bagging plant were simultaneously run in 2009, the amount of energy consumed was high in this year.

As in the case with the amount of energy, the number of workers varies depending on the production. For this reason, the loss of the qualified staff trained in bagging coal and new workers producing too much improperly bagged coal in the orientation process can be effective on inefficiency.

While there was a constant decrease in production, the lack of a decrease in the inputs at the same proportion and the increase in energy and labor costs day by day had a negative effect on the efficiency of GLC bagging plant.

Table 3 shows the efficiency changes that were analyzed based on the months within the seven-year period of the coal bagging unit. The study found that the obtained results were directly proportional to the demand developing according to the months. Since there is generally hardly any demand for coal in February, March, and April, the corresponding efficiency scores were around 70%. As the demand for coal generally increases gradually in May and June, the coal bagging plant starts to produce more bagged coal then. Production at full capacity generally starts in July and August. Because the religious holiday periods were in November in the years considered and there was no coal bagging work in these periods, there was hardly any efficiency change in November and December.

Table 3. Malmquist TFP monthly change of the coal bagging unit

Months	Technical efficiency change (TE)	Technological change (TC)	Malmquist TFP change (MPI)
January–February	0.933	0.832	0.777
February–March	0.860	0.815	0.701
March–April	0.683	1.121	0.766
April–May	1.100	1.097	1.206
May–June	1.374	1.136	1.561
June–July	1.028	0.951	0.977
July–August	0.892	1.094	0.976
August–September	1.184	0.977	1.157
September–October	1.091	1.039	1.134
October–November	0.946	1.078	1.020
November–December	1.060	0.844	0.895
Mean	0.999	0.993	0.990

There was a decrease in the efficiency levels in July, August, and December. However, there was an increase, albeit modest, in efficiency in May, June, September, October, and November. The highest increase was in June (56.1%).

The amount of overused energy, the number of extra workers, and losses in the bagging unit were found to be effective on inefficient months determined by the analysis results.

3.2. Sensitivity analysis

One of the advantages of non-parametric efficiency analysis is that it provides guidelines about what inefficient DMUs can do so as to become efficient. Using this feature, sensitivity analyses related to the efficiency analysis of the fully automated coal bagging plant were conducted for the

Table 4. The sensitivity analysis results of the current coal bagging unit

DMU	Efficiency value	Quantity of bagged coal produced (tons)	Quantity of coal fed (tons)		Number of workers (number/day)	Amount of energy (kwh)
	θ	%	Old	New	%	%
January	1.000	–	–	–	–	–
February	1.000	–	–	–	–	–
March	0.996	–	50,020	251,826	–	21
April	0.207	–	5,101	2,590,674	93	79
May	0.452	–	13,021	956,023	83	55
June	0.882	–	76,762	147,016	11	12
July	1.000	–	–	–		
August	0.798	–	73,982	109,123	20	20
September	0.973	–	110,736	114,194	3	3
October	1.000	–	–	–	–	–
November	1.000	–	–	–	–	–
December	1.000	–	–	–	–	–
Mean	0.859					

year 2012, which was found to be inefficient. Table 4 shows the non-parametric efficiency analysis results constant return to scale by taking the data for the 12 months of 2012 into consideration. As the efficient units (θ = 1.000 and $s_{ik}^{+}, s_{rk}^{-} = 0$) use inputs in appropriate amounts and scales in order to reach the constant amount of production, Table 4 does not present any data about these units. Table 4 shows the % decrease values in the number of workers and amount of energy needed to make March, April, May, June, August, and September, which were determined to be inefficient, efficient. Because the % increase values of the amount of the coal fed were really high, the new feeding values were presented in the same table. The reason why the values in the input of the amounts of the coal fed increased was the fact that the negations of this input, which was considered in the analysis because reducing the inputs was a requirement to increase productivity, were obtained (1/the amount of the coal fed).

Since production is performed depending on the demand by the market, when the quantity of production is kept constant and the inputs considered are increased or decreased by the quantities given in Table 4, it would be possible for the coal bagging plant to be productive.

On the other hand, because the plant performed production depending on the demand by the market and the demand for coal has decreased over the recent years, the plant is required to be running even when there is no production, the plant cannot have enough qualified workers when necessary and developing technology has provided many advancements, it is recommended that GLC bagging plant should be upgraded to a fully automated bagging system.

4. Conclusion and recommendations

The aim of this study was to examine the change in productivity of the bagging plant of GLC between 2006 and 2012 using the Malmquist TFP index. The results indicated that there was a decrease in the productivity change according to the years examined (0.990 < 1). This decrease in productivity could be due to constant number of workers hired in the plant, constant amount of energy consumed in the plant, and losses in production despite the decrease in production as a result of the decrease in demand for coal. The analysis results based on the months within the seven-year period of the coal bagging unit revealed that there was a decrease in productivity in February, March, April, July, August, and December. However, there was an increase, albeit modest, in efficiency in May, June, September, October, and November. The highest increase was in June (56.1%). The study also found that these results were directly proportional to the demand increasing or decreasing depending on months.

The rapid growth of the share of natural gas in heating and energy in recent years has reduced demand for lignite. In addition, considering the formation and quality of coal, and economy of corporations, heating and industrial coal production have been affected adversely and, therefore, heating and industrial coal demand started to be met by coal import.

On the other hand, it seems likely for lignite to maintain its market share in the heating sector by increasing the number and quality of the plants to improve coal, preparing coal compatible with environmental protection criteria, and continuing to compete with imported coal by means of a pricing policy in market conditions. It also possible to increase the market share of lignite in the heating sector by developing smokeless boiler and stove technologies and revising legal regulations related to environmental protection in order to use low-calorie coal in the heating sector.

Considering the fact that each sector requires labor with specific qualifications, particularly regression in lignite mining has had adverse effects on qualified and experienced labor force needed by the sector. The GLC coal bagging plant has been producing bagged coal since the 2000s. Currently, the plant, which was designed according to the technology back then, requires too much labor and the plant consumes too much energy because it is required to be running even when there is no production. Also, there are inevitable production losses because the plant cannot have enough qualified workers when necessary as a result of hiring workers depending on the demand for coal.

An efficient staff policy and dealing with the problems of the staff efficiently would play a key role in increasing the productivity of the plant. However, it seems currently unlikely to develop an efficient staff policy as the coal bagging plant does not hire a constant number of workers, workers are hired depending on the need, and there is not sufficient qualified labor in general. The production capacity of the current GLC bagging plant is 6,000 ton/day. On the other hand, throughout the seven-year period (2006–2012) taken into consideration, the units have never operated at full capacity due to insufficient qualified labor force.

The study found that the maximum possible quantity of production would be 4,700 ton/day provided that the bagging units were run 24 h a day with all of their equipment. This value indicates that the plant operates approximately at 75% productivity. In fact, 28 conveyor belts, 3 vibrating screens, and 3 roll crushers are active even when there is no production. Their depreciation expenses should be taken into consideration as well as the energy they consume.

One of the advantages of non-parametric efficiency analysis, which the Malmquist TFP index is based on, is that it provides guidelines about what inefficient DMUs can do so as to become efficient. Using this feature, sensitivity analyses related to the efficiency analysis of the fully automated coal bagging plant were conducted for the year 2012, which was found to be inefficient. The analysis results showed that the months March, April, May, June, August, and September in the year 2012 were inefficient. This inefficiency was caused by the high number of workers hired and high amount of energy used in the plant despite the low amount of coal fed. Therefore, some recommendations were made so that the causes of inefficiency in 2012 can be eliminated and there is no inefficiency in the years following 2012.

Considering the fact that the existing operation processes should be automated professionally in order for corporations in the mining sector to operate in a modern and low-cost process with higher productivity and that their technology should meet the highest standards, it is recommended that a fully automated coal bagging plant be built in the corporation.

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Note

1. In the assumption of constant return to scale, a radial increase in the input vector (an increase of all the input combinations by the same percentage) causes a same proportion of increase in the output vector. In other words, variations in production scale do not affect productivity (Charnes et al., 1978).

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