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Productivity changes of forest enterprises in Turkey: A non-parametric Malmquist approach

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The aim of this study is to determine the total factor productivity changes between the years 2006 and 2010 at the state forest enterprises bound to Isparta Regional Forest Directorate located at the Western Mediterranean Region in Turkey. The Malmquist productivity index (MPI) as a non-parametric approach was used in the study. The MPI is evaluated based on the data envelopment analysis. The technical efficiency change, the technological change, pure technical efficiency change, scale efficiency change and the total factor productivity change were evaluated according to three inputs and two outputs. According to the results of the study, majority of enterprises were detected to be unsuccessful in management activities and productivity due to appropriate measures. Such lack seen in success can be defined as a recession in technical efficiency. The results also showed that increase in the last period for technological change is not enough.

Key words: Malmquist productivity index, forest enterprise, data envelopment analysis, linear programming, Turkey.

INTRODUCTION

There are four different factors described in the economic theory: 1) land, 2) entrepreneur, 3) capital and 4) workforce. Productivity is a measure of output from a production process, per unit of these factors (inputs). An increase in productivity is characterized by a shift of the production function and a consequent change to the output/input relation. The formula of total factor productivity can be written as:

Total factor productivity = Output quantity / Input quantity (Saari, 2006).

Besides the parametric methods (econometric methods) used to measure the changes seen in the total factor productivity, the methods that are non parametric are also used in the recent years. In the measures of the productivity, the non parametric methods are based on linear programming models. The data envelopment analysis (DEA) is one that fore comes among these. The DEA is a non-parametric technique that is based on linear programming and that evaluates and measures subjective efficiency/productivity that is based on a multiple decision making unit depending on multiple inputs and outputs (Liu et al., 2000).

However, the DEA can only measure these aspects for a certain defined period and cannot compare the differences among different periods. By such means, the Malmquist total factor productivity index (MPI) was developed to realize evaluation based on the distance functions of DEA. This index is densely used in the measurements applied in enterprises in means of measuring the changes in productivity. Moreover, these studies can be seen in the forestry and forest industries as well (Hailu and Veeman, 2000a, b, 2001; Nyrd and Baardsen, 2003; Hseu and Shang, 2005; Yao and Liu, 2009; Kao, 2010). The forest resources of Turkey which possesses approximately 21.2 million hectares is bound to 27 regional forest directorates and is administrated and directed by 218 state forest enterprises (OGM, 2011). By such means, the changes seen in the productivity of these enterprises related to the inputs benefitted from and the outputs gained within the scope of the service and product they provide is regarded to be of great importance. The changes seen in productivity can be
defined as the changes seen among enterprises and the changes seen through years in a single enterprise. The purpose of this study is to determine the changes in the total factor productivity between the years 2006 and 2010 of six states forest enterprises located at the Western Mediterranean Region in Turkey and that are bound to Isparta Regional Forest Directorate.

MATERIALS AND METHODS

Malmquist productivity index

In spite of the numerous models developed to evaluate productivity and efficiency, the comparison of enterprises with sets of input and outputs totaling more than one, the unrequited functional form in analysis and so on, have provided the non-parametric linear programming methods to step ahead. However, non-parametric linear programming methods realize analysis with data related to a specific period but cannot observe and evaluate the changes of productivity that may derive in time. Therefore, the MPI that also consists of the time aspect was used in this study. MPI was first developed in 1952 by Sten Malmquist and was used and developed by many researches through time (Cooper et al., 2007). This index is used to observe the development of a decision making unit within the total factor productivity between two periods. This development constitutes of two aspects and these are called as “catch-up” and “frontier-shift.” Whilst the frontier shift refers to the change seen around the efficiency borders of the decision making unit the catch-up term expresses the changes seen in technical efficiency of the unit.

The MPI, which can detect and evaluate the changes of productivity based on input and outputs between two enterprises or between two periods of an enterprise, expresses the reasons of the changes of productivity as based on technological change (TC) and technical efficiency change (TEC) (Färe et al., 1994). The TEC is expressed as the productivity of catching up production limits (the catch-up effect) and the TC is expressed as the change of placement of production limits (the frontier-shift or boundary shift). Such effects constitute the main aspects of the total factor productivity change (TFPC) and the multiplication of the change of technical efficiency and technological change evaluates the change of the total factor productivity, which provides the MPI (Rezitis, 2006). In the MPI method application, all indexes starting from the second year are evaluated according to the previous year. TEC evaluated below the assumed constant returns for each decision making unit provides, TC, Pure technical efficiency change (PTEC) evaluated below the assumed variable returns to scale, the scale efficiency change (SEC) and finally the total factor productivity change (TFPC) concluding with five different indexes. The multiplication of TEC and TC provides us the TFPC and the multiplication of PTEC and SEC provides us TEC.

In order to prevent the effect of the scale through time over the productivity change the enterprises are accepted to be realizing their activities below the assumed constant returns to scale thus, the MPI in which the input and output functions are defined can be defined with $P^T_0$ production technology which transfers the input $x^t \in R^n$ to the output $y^t \in R^m$ as

$$P^T = \{(x^t, y^t): x^t, y^t \text{ produced}\}$$

to evaluate DEA with $t$ time period ($t=1,2..., T$) (Rezitis, 2006). The output distance function in the $t$ period according to the set of production facilities $(P^t)$, the output vector $(y^t)$ and the input vector $(x^t)$ can be expressed as follows:

$$D^t(x^t, y^t) = \inf \left\{ \theta \left( x^t, \frac{y^t}{\theta} \right) \in P^t \right\} \quad (1)$$

Where, the $\theta$ expresses the rational increase seen in all outputs. In order to define the MPI, the distance functions are defined related to the two different periods:

$$D^{t+1}(x^{t+1}, y^{t+1}) = \inf \left\{ \theta \left( x^{t+1}, \frac{y^{t+1}}{\theta} \right) \in P^{t+1} \right\} \quad (2)$$

$$D^{t+1}(x^t, y^t) = \inf \left\{ \theta \left( x^t, \frac{y^t}{\theta} \right) \in P^{t+1} \right\} \quad (3)$$

Equation (2) evaluates the maximum rational change in $t$ period related to the outputs due to technology. Similarly, Equation (3) evaluated the maximum rational change in the $t+1$ period. The MPI based on the outputs in a $t$ period is thus expressed as follows (Caves et al., 1982):

$$MPI^t = \frac{D^{t+1}(x^{t+1}, y^{t+1})}{D^t(x^t, y^t)} \quad (4)$$

and for $t+1$ as:

$$MPI^{t+1} = \frac{D^{t+1}(x^{t+1}, y^{t+1})}{D^{t+1}(x^{t+1}, y^{t+1})} \quad (5)$$

By evaluating the geometric averages of the indexes stated earlier by Färe et al. (1994), the MPI is then defined as follows:

$$MPI(t; x^{t+1}, y^{t+1}, x^t, y^t) = \left[ \frac{D^{t+1}(x^{t+1}, y^{t+1})}{D^t(x^t, y^t)} \right]^\frac{1}{m} \quad (6)$$

Or

$$MPI(t; x^{t+1}, y^{t+1}, x^t, y^t) = \left[ \frac{D^{t+1}(x^{t+1}, y^{t+1})}{D^{t+1}(x^{t+1}, y^{t+1})} \right]^\frac{1}{n} \quad (7)$$

According to Equations 6 and 7; if the $MPI(x^{t+1}, y^{t+1}, x^t, y^t) > 1$ the productivity has increased from $t$ period to $(t+1)$ period; if the $MPI(x^{t+1}, y^{t+1}, x^t, y^t) = 1$ the productivity has not changed from the $t$ period to the $(t+1)$ period and finally if the $MPI(x^{t+1}, y^{t+1}, x^t, y^t) < 1$ then the productivity has decreased from the $t$ period to the $(t+1)$ period.

When the MPI is examined, it can be observed that four distance functions related to two sequential periods are required to be evaluated. For the $D^t(x^t, y^t)$ evaluation the linear programming model is used:

$$[D^t(x^t, y^t)]^t = \max_{\theta^t} \theta$$

subject to:

$$\sum_{j=1}^m \gamma^t_j y^t_j \leq 0, \quad m = 1,..., M$$

$$y^t \geq 0$$

$$x^t \geq 0$$

$$x^t \neq 0$$

$$y^t \neq 0$$
\[ \sum_{j=1}^{J} \lambda_{j,t} x_{j,n}^{t} \leq x_{n}^{t}, \quad n = 1, \ldots, N \]
\[ \lambda_{j,t} \geq 0, \quad j = 1, \ldots, J \]

The computation of \( D_{t+1}(x_{t+1}^{t}, y_{t+1}^{t}) \) is exactly like the equation (aforestated), where \( t+1 \) is substituted for \( t \). For the evaluation of \( D_{t}(x_{t+1}^{t}, y_{t+1}^{t}) \) the linear programming model is used:

\[
\begin{align*}
[D_{t}(x_{t+1}^{t}, y_{t+1}^{t})] & = \max_{\theta} \theta \\
\text{Subject to:} \\
\sum_{j=1}^{J} \lambda_{j,t} y_{j,n}^{t} & \leq 0, \quad n = 1, \ldots, M \\
\sum_{j=1}^{J} \lambda_{j,t} x_{j,n}^{t} & \leq x_{n}^{t}, \quad n = 1, \ldots, N \\
\lambda_{j,t} & \geq 0, \quad j = 1, \ldots, J \\
\end{align*}
\]

The formula aforestated is used to evaluate \( D_{t+1}(x_{t}^{t}, y_{t}^{t}) \). But the \( t \) and \( t+1 \) superscripts are reversed.

The MPI applies evaluation constant returns to scale (CRS). When the models are applied with convexity constraint

\[ \sum_{j=1}^{J} \lambda_{j,t} = 1 \]

it is possible to evaluate the distance function of the variable returns to scale (VRS) (Färe et al., 1994). Thus:

\[
\begin{align*}
TEC & = \frac{D_{t+1}(x_{t+1}^{t}, y_{t+1}^{t})}{D_{t}(x_{t}^{t}, y_{t}^{t})} \\
PTEC & = \frac{D_{t+1}(x_{t+1}^{t}, y_{t+1}^{t})|_{VRS}}{D_{t}(x_{t}^{t}, y_{t}^{t})|_{VRS}} \\
SEC & = \left[ \frac{D_{t+1}(x_{t+1}^{t}, y_{t+1}^{t})|_{CRS}}{D_{t}(x_{t}^{t}, y_{t}^{t})|_{CRS}} \times \frac{D_{t}(x_{t}^{t}, y_{t}^{t})|_{VRS}}{D_{t}(x_{t}^{t}, y_{t}^{t})|_{VRS}} \right] \\
\end{align*}
\]

Thus:

\[ M(x_{t+1}^{t}, y_{t+1}^{t}, x_{t}^{t}, y_{t}^{t}) = TCE \times TEC \]
\[ M(x_{t+1}^{t}, y_{t+1}^{t}, x_{t}^{t}, y_{t}^{t}) = TCE \times PTEC \times SEC \]

Data

The main units and institutions that realize the forestry activities in Turkey are the forest enterprises. Thus, the units that decide on the economic, social and technical means of the activities are the forest enterprises authorized. Moreover, all accounts and the storage of records are also realized by these enterprises (Dasdemir, 1996). Therefore, the DMUs have been decided to be the forest enterprises. The enterprises have to be comparable to gain assessment relative to each other in means of productivity (Geray, 1982). Therefore, the six forest enterprises that are located in the West Mediterranean Region of Turkey have been included into the study as they have similarity among themselves by means of economic, technical and social means (Figure 1). These enterprises realize their activities bound to Isparta Regional Forest Directorates.

For the MPI measurements between 2006 and 2010 years of the forest enterprises, three inputs and two output factors values have been considered. Such factors have been determined in accordance with the studies previously applied (Kao and Yang, 1992; Kao et al., 1993; Dasdemir, 1996; Turker and Turker, 1999; Senturk, 2007; Safak, 2009; Kao, 2010). The data sources, the balance sheets of the enterprises, the income charts, the production and sales charts, the administrative and fiscal records are supplied from the branch offices of the directorates that bind the enterprises and the marketing processes.

**Input factors**

1) Capital (TL/ha [Approx. 1TL = 0.67 US $]): The actual capital of forest enterprises are constituted by the values of the trees and the land. However, these values are not stated on the balance sheets of the enterprises (Turker, 2008). Therefore, the current assets of the enterprises are considered to be the balance sheet values of the institutions (Dasdemir, 1996);

2) Production costs (TL/ha): Refers to the total of the costs made for the production such as logs, mine poles and other relative processes (logging, transportation and etc);

3) Amount of employee (person/ha): Refers to the total amount of employee working in the field of the relative forest enterprise (workers, officers and etc).

**Output factors**

1) Amount of production (m³/ha): Refers to the total amount of production of logs, mine poles and etc;

2) Value added (TL/ha): The value added is evaluated by the net sales excluded from the first substances and the equipment expenses and depreciation (Senturk, 2007).

As seen earlier, the determined input and output factors of enterprises have been transferred to values for per hectare parted in productive forest areas. Within the data obtained, in order to remove the fluctuations due to inflation, prices have been adjusted prior to analysis. The nominal prices have been adjusted in accordance with the then current producer price index based on the Turkish Statistical Institute (2003: 100).

**RESULTS AND DISCUSSION**

The TECs due to periods can be seen in Table 1. According to the table, the highest average TEC in a period of five years has reached its peak with an increase of 11.5% during the 2007 to 2008 periods. However, the proceeding decrease can be seen in the following periods. The greatest increase in the TEC values during 2007 to 2008 was seen at Isparta forest enterprise. The reason of such an increase is the decrease seen in the...
previous year with a rate of 50.1%. In the period 2008 to 2009, the TEC values remained without change in the same enterprise and a decrease was observed in 2009 to 2010 with a rate of 26.3%. The TEC at Egirdir forest enterprise ruled towards a decrease in the first two periods but then progressed with an increase in the last two periods with a rate respectively 4.7 and 2.6%. According to the situation, it can be seen that Egirdir had caught up with the productivity limits in the recent years. According to the TEC values, the least changes were seen at Burdur, Sütçüler and Bucak forest enterprises. Whilst only 7.8% of rational decrease was seen at Burdur in the recent period, an increase with a rate of 2.9% was seen at Sütçüler in the first period. As for Bucak, a decrease was seen in the period 2007 to 2008 with a rate of 0.5% and an increase was seen in 2008 to 2009 with
the same rate of 0.5%. At Gölhisar forest enterprises no changes have been seen in the TEC values in all periods.

When the values are examined in the means of TC (Table 2), the first (2006 to 2007) and the last (2009 to 2010) periods had revealed an increase whilst the other periods were detected with a decrease. Whilst the highest TC was seen at Bucak in the period 2006 to 2007 with a rate of 23.2%, the highest TC in 2009 to 2010 was detected at Egirdir with a rate of 54.6%. The TC decreasing values at Burdur, Sütçüler and Bucak enterprises in the same period was detected as respectively 0.1, 2.6 and 22.4%. According to the averages obtained, the greatest decrease seen in the TC values was in the 2008 to 2009 period with a rate of 16.5%. The greatest decrease in the same period was detected to be seen at Gölhisar forest enterprise with a decrease rate of 30.6%. When the PTEC values are examined (Table 3), Burdur shows a decrease of 6.8% in 2009 to 2010, an increase of 81.1% can be seen at Isparta enterprise in 2007 to 2008 and similarly an increase can be seen at Sütçüler enterprise in the 2006 to 2007 periods with a rate of 2.5%. The increase seen at the Isparta enterprise with a rate of 81.1% can be explained with the decrease experienced in the previous period with a rate of 44.8%. There is no change seen in the PTEC values of other enterprises in means of the periods.

As can be seen in Table 4, the SEC values have shown an increase in the periods 2007 to 2008 and 2008 to 2009 with rates respectively 1 and 0.9% and a decrease was seen in the periods 2006 to 2007 and 2009 to 2010 with rates respectively 1.9 and 4.7%. Egirdir forest enterprise reveals differences from other enterprises by means of the SEC values. Whilst the SEC values of this

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Table 5. Annual total factor productivity change of forest enterprises from 2006 to 2010.

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Figure 2. Malmquist index summary of annual means.

enterprise ruled towards a decrease in the first two periods (2006 to 2007, 2007 to 2008), the last two periods ruled the vice versa showing an increase (2008 to 2009, 2009 to 2010). This situation reveals that the enterprise had gained success in means of production in the recent years realized via appropriate scales. The TFPC of all enterprises can be seen in Table 5. According to this, the TFPC values have only revealed an increase in means of average values in the period 2006 to 2007 with a rate of 0.2% whilst the worst period was in 2008 to 2009 with a decrease of 15.8%. In the period 2008 to 2009, only Egirdir forest enterprise had shown an increase with a rate of 1%. Similarly, the TFPC values of the same enterprise in the period 2009 to 2010 ruled an increase with a rate of 58.7%. When the changes seen in the MPIs are examined by means of the regional forest directorates due to periods studies have obtained the findings as follows (Figure 2):

1) The TEC value has reached its highest level in 2007 to 2008 with an increase of 11.5%. Administrative efficiency which is expressed as PTEC with a rate of 10.4% and the SEC value which shows whether the appropriate scales were applied with a rate of 1% have positive contributions to such an increase. The most important reason for the lack of TEC in other periods is the lack of administrative success of the enterprises and the over-use of resources;
2) The TC value had shown increase in the first and the last periods whilst ruled towards decrease during the other periods;
3) It was seen that the PTEC value had reached its maximum level in 2007-2008 but then was subject to decrease in the following years. Thus, according to such a finding, it can be said that the only period administrative success was only gained in the period of 2007 to 2008.
4) There is no change seen in the SEC values as was detected in the PTEC values. Therefore, it can be said that the only period production was applied with success appropriate to the directorate scales was during the 2007 to 2008 period;
5) As for the TFPC values, it can be stated that besides the increase seen in the first period with a rate of 0.2%, the following periods experienced decrease. The reason for the increase in such period was due to the contribution
of the TC values with a rate of 12.3%. However, the TEC values of the period had disaffected the TFPC values with a rate of 10.7%.

When all the averages are considered for all periods, it is possible to detect decrease in all indices. The rates of the decrease seen in the TEC, TC, PTEC, SEC and TFPC values are respectively as 1.4, 3.3, 3.3, 1.2 and 4.6%. When the averages of all the periods were examined by enterprises, the results reached were as follows (Figure 3):

1) The highest values for TEC were detected at Egirdir and Sütçüler enterprises whilst the lowest value was seen at Isparta. Therefore, it possible to state that Egirdir and Sütçüler forest enterprises had gained success in catching up the production limits;
2) The highest TC value was detected at Egirdir forest enterprise and the lowest values were at Burdur and Bucak enterprises;
3) The highest PTEC value was detected at Sütçüler, whilst the lowest value was seen at Burdur enterprise.
4) The highest SEC values were detected at Egirdir forest enterprise, whilst the lowest values were at Isparta enterprise; and
5) The highest TFP value was detected at Egirdir whilst the lowest value was seen at Burdur enterprise.

According to the explanations aforesated, the most successful enterprise by means of the TC, SEC and TFP values and located within the research area is the at Egirdir enterprise and the most successful enterprise by means of PTEC and TEC values was detected as the Sütçüler enterprise.

Conclusion

MPI as a non-parametric approach is a method applied in production measuring the production limit catch-up, causing the production limits to reach higher or lower levels, measuring the administrative activities and their success in production due to appropriate scales and thus realizes the analysis of the efficiency of production factors. Therefore, it is possible to assess the values in means of forest enterprises together with regional aspects within the scope.

As a conclusion to the applied study, a majority of the enterprises were detected to be unsuccessful in administrative activities and in the production realized with appropriate measures. Such lack in success can also be defined as a recession seen in technical efficiency. Furthermore, it is also observed that the technological changes realized in the recent periods are not sufficient. According to results, it can be concluded that policies and regulations for the production process affecting the technology or productivity are not enough. Thus, in such condition the optimization of the amount of employee, the capital and the production costs is used as input factors shall be considered.

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