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TOTAL FACTOR PRODUCTIVITY GROWTH IN TURKISH AGRICULTURE: 1992-2012

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Abstract

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Agricultural sector has an important role in Turkey. Since it provides capital to other sectors, meets the raw material needs of them and contributes to the labor employment in the country. The main purpose of this study is to measure agricultural technical efficiency and Total factor productivity using Data Envelopment Analysis (DEA) and the DEA-based Malmquist TFP index in Turkey in the periods 1992–2012. Value of agricultural production is taken as output. Land, tractors, labour, fertiliser and livestock are taken as input. The results were derived by imposing the assumption of constant returns to scale using an input-oriented DEA. A general specification encompassing all available input and output data was employed to obtain the average TFPC for the sector over the 1992–2012 periods. The average total factor productivity growth in the general model specification is -5.6%. These patterns are largely on the account of technological change as opposed to technical efficiency.

Key words: productivity, efficiency, malmquist, agriculture, Turkey

JEL Classification: Q10, O47, D24

Introduction

Productivity growth in agriculture has been the subject matter for researchs over the last fifty years. Development economists and agricultural economists have examined the sources of productivity growth over time and of productivity differences among countiries and regions over this period. Productivity growth in agricultural sector is considered essential if agricultural sector output is to grow at a sufficiently rapid rate to meet the demands for food and raw materials arising out of steady population growth (Coelli and Rao, 2003).

Agricultural sector has an important role in Turkey. Since it provides capital to other sectors, meets the raw material needs of them and makes contribution to the labor employment in the country. According to the data of the year 2012, agricultural sector provided employment to the 25% of the total labor in the country and constitutes the 9.1% of the gross domestic product (Turkstat, 2013).

One of the criterias which are using in determining the productivity performance is the change of the total factor productivity (TFP). The change in TFP has two components, namely technical efficiency change (TEC) and technological change (TC). Improvements in the indexes of TEC and TC constitute the primary tool to reach high economic performance level for an economic unit and thus to have a high compatibility power (Armagan et al., 2010).

There are different methods that can be used to measure the changes in the TFP and its components. The most widely-used two methods are Stochastic Production Frontier Analysis and Data Envelopment Analysis (DEA). Stochastic frontier approach applies parametric econometric methods, while DEA applies non-parametric mathematical methods. However, both approaches use Malmquist productivity index to measure the change in the TFP. In their research, Coelli and Rao (2003) calculated TFP change (TFPC) in the agricultural sector in 93 developed and developing countries between 1980–2000 and found TFPC as 1.021 and technical efficiency change as 1.009 and technological change as 1.002. In the same research Turkey's TFPC as 1.009 and TEC as 1.005 and TC as 1.004. Same researchs which used Malmquist produc-

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tivity index method for calculating TFPC for Turkey are listed below (Table 1).

The focus of this paper is technical efficiency and TFP. The main purpose of this study is to measure agricultural technical efficiency and TFP using DEA and the DEA-based Malmquist TFP index in Turkey in the period 1992–2012. The paper continues with the following structure. The Methodology section outlines the DEA and Malmquist total factor analysis models. The Data section gives information about the data set used in the study. Empirical results derived from these models and discussions are presented in the Results section. The final section summarises the findings of this research.

This study uses the output-oriented model of DEA-Malmquist with DEAP 2.1 software.

Material and Method

This paper applies the method of DEA and computes the input-oriented model of Malmquist index to measure Turkey's TFP growth.

The Malmquist index, pioneered by Caves et al. (1982) and based on distance functions, has become extensively used in the measure and analysis of productivity after Fare et al. (1994) showed that the index can be estimated using DEA, a non-parametric approach that uses linear programming to estimate distances. It aims at establishing linear partial space which can absorb extreme data and be observed without any limitation on the production technology, instead of the regression plane that would best fit to the data center or the best production level (Charnes et al., 1978).

Malmquist productivity index measures the change in the TFP between two data point, by calculating the relative distances of each data point of the regions according to the common technology. Distance functions can be treated as input-oriented functions and output-oriented functions. Input-oriented distance function means the production technology that considers the minimum proportional shrinkage of the input vector, when the output vector is the data. As for the output-oriented distance function considers the maximum proportional increase of the output vector, when the input vector is the data. Distance function can be defined as the opposite of the maximum proportional increase in the output vector, when the input vector is the data. If the (X^t,Y^t) data is above the production level of t period, the distance is $D_0^t(X^t,Y^t) = 1$ and there is full efficiency, with the expression of Fare et al. (1994). If $D_0^t(X^t, Y^t) \leq 1$, the production is accepted to be inefficient in t period. Distance function measures the change in the technical efficiency and productivity in different periods. The distance function for the period (t+1) can be written as follows (Fare et al. 1994):

$$D_0^t(x_{t+1}, y_{t+1}) = \min\left[\Phi : (x_{t+1}, y_{t+1} / \Phi) \in R^t\right] \quad (1)$$

This index measures the maximum proportional change to be obtained in the y^{t+1} output with x^{t+1} dataset under the technology of t period. Similarly, mixed distance function can be defined as $D_1^{t+1}(X^t, Y^t)$ for t+1 period. This function measures the maximum proportional change that will appear at the yt output to be obtained with xt input set, in comparison to the t+1 technology (Eq. 2).

$$M_0^t = \frac{D_0^t(x^{t+1}, y^{t+1})}{D_0^t(x^t, y^t)} \quad (2)$$

The index shown on Eq. 2 measures the productivity changes caused by the change in technical efficiency between t+1 nd t periods, under t technology. On the other hand, TC from between t+1 and t period can also be measured under the technology of the t+1 period. In this case, Malmquist productivity index can be written as follows:

$$M_1^{t+1} = \frac{D_1^{t+1}(x^{t+1}, y^{t+1})}{D_1^{t+1}(x^t, y^t)} \quad (3)$$

The change in the efficiency is the proportion of the technical efficiency in (t+1) period to the technical efficiency in (t) period (Eq. 4).

$$Efficiency\_Chance = \frac{D_1^{t+1}(y^{t+1}, x^{t+1})}{D_0^t(y^t, x^t)} \quad (4)$$

Table 1
Studies for Turkey's TFPG

Paper	Years	Countries	Mean			Turkey		
			EC	TC	TFPC	EC	TC	TFPC
Fulginiti and Perrin (1997)	1961-1985	18 LDC	1.005	0.979	0.984	1.022	1.001	1.023
Nin et al. (2003)	1961-1994	20 LDC	1.000	0.988	0.988	0.992	0.987	0.980
Galanopolulos et al. (2004)	1993-1999	27 Europe	0.992	1.028	1.020	1.003	1.028	1.031

In Eq. 5, the change in the technology between two periods (xt+1 and xt) is explained.

$$Technical\_Change = \left[\left(\frac{D_0^t(y^{t+1}, x^{t+1})}{D_1^{t+1}(y^{t+1}, x^{t+1})} \right) \times \frac{D_0^t(y^t, x^t)}{D_1^{t+1}(y^t, x^t)} \right]^{\frac{1}{2}} \quad (5)$$

Here (EC) is the change index in the technical efficiency under constant return to scale. While this index is defined as the effect of catching-up the best production level for each observation between two periods (*t* and *t+1*), (TC) index is defined as frontier effect (slide of production border curve or innovation). The change in the TFP is defined as the multiplication of the change in the technical efficiency and technology (Mahadevan 2002). Here, if M_0 index is bigger than 1, it means that the TFP has increased or improved between t period and *(t+1)* period. If it is smaller than 1, it means that the TFP has decreased from *(t)* until *(t+1)*.

The Malmquist index of TFPC is the product of TEC and TC.

$$TFPC = TEC \times TC \quad (6)$$

The Malmquist productivity change index, therefore, can be written as:

$$M_0 (y^{t+1}, x^{t+1}, y^t, x^t) = TEC \times TC \quad (7)$$

If the sum of the production elasticities in the linear programming approach is 1, it is considered that there is Constant Return to Scale (CRS). In this case, the scale efficiency is considered to be equal to the pure efficiency. In case, there is a difference between the technical efficiency indexes of CRS and VRS (Variable Return to Scale) for any economic unit, it indicates that the economic unit suffers scale inefficiency and the scale inefficiency can be calculated through the difference between the CRS and VRS technical efficiency levels (Coelli et al., 1998). The technical efficiency index under variable return to scale is the multiplication of the efficiency index under variable return to scale and the index of scale efficiency. Efficiency indexes are between 1 and 0. Moving from 1 towards 0 indicates the presence of higher inefficiency, while 1 means full efficiency.

Data Set

The present study is based on data exclusively drawn from the TURKSTAT (1992-2012). The following are some of the main features of the data series used.

Output (Y): Value of agricultural production is taken as output.

Input Series: Given the constraints on the number of input variables that could be used in the DEA analysis, we have opted to consider only five input variables. Details of these variables are given below (Coelli and Rao, 2003).

Land (x_1): This variable covers the arable land, land under permanent crops as well as the area under permanent pasture. Arable land includes land under temporary crops (double-cropped areas are counted only once), temporary meadows for mowing or pasture, land under market and kitchen gardens and land temporarily fallow. Land under permanent crops is the land cultivated with crops that occupy the land for long periods and need not be replanted after each harvest. This category includes land under flowering shrubs, fruit trees, nut trees and vines but excludes land under trees grown for wood or timber.

Tractors (x_2): This variable covers the total number of wheel and crawler tractors, but excluding garden tractors, used in agriculture. It is important to note that only the number of tractors is used as the input variable with no allowance made to the horsepower of the tractors.

Labour (x_3): This variable refers to economically active population in agriculture. Economically active population is defined as all persons engaged or seeking employment in an economic activity, whether as employers, own-account workers, salaried employees or unpaid workers assisting in the operation of a family farm or business. Economically active population in agriculture includes all economically active persons engaged in agriculture, forestry, hunting or fishing.

Fertiliser (x_4): We use the sum of Nitrogen (N), Potassium (P_2O_2) and Phosphate (K_2O) contained in the commercial fertilizers consumed. This variable is expressed in thousands of metric tons.

Livestock (x_5): The livestock input variable used in the study is the sheep-equivalent of five categories of animals used in constructing this variable. The categories considered are: cattle, sheep and goats. Numbers of these animals are converted into sheep equivalents using conversion factors: 8.0 for cattle; 1.0 for sheep and goats. Chicken numbers are not included in the livestock figures (Table 2).

Results

This section presents the empirical results. The Malmquist TFP index was obtained by applying the DEA technique to the model specification in data set. The results were derived by imposing the assumption of constant returns to scale using an input-oriented DEA. The Malmquist TFP index represents the productivity of the production point (x^{t+1},y^{t+1}) relative to the production point (x^t,y^t). Having specified an input-oriented Malmquist productivity change index, the estimated indices are interpreted as follows: a score of less than production unit indicates productivity progress in the sense that the producer delivers a unit of output in period t+1 using fewer inputs. In other words, the production unit in period t+1 is more efficient relative to itself in period t. Similarly, a score greater than unity implies productivity regress and a unit score indicates constant productivity (Hollingsworth et al., 1999). Table 3 shows the mean, minimum, maximum of the Malmquist productivity index for the model for the 1992–2012 period. On average the agricultural sector registered a 5.6% negative productivity progress over the sample period. In general, this indicates that Turkey's agriculture registered productivity loose (Table 3).

Table 4 reports the Malmquist TFP index summary of annual means for the model. It shows the annual means of TEC, TC, pure efficiency change, scale efficiency change and TFPC over the study period (1992–2012). Given an

Table 3
TFP results from the DEA Malmquist model, 1992–2012

Mean *(Geometric)*	0.944
Minimum	0.725
Maximum	1.018

Table 2
Descriptive statistics about data set, 1992–2012

	y	x_1	x_2	x_3	x_4	x_5
Mean	2.4752E+10	901994	40018750	8062900	2046614	128299778
Std.	2128469852	131471	932501	878938	358987	13760707
Median	2.493E+10	933153	39933000	7975000	1919966	125048500
Min.	2.1952E+10	692454	38757000	6954000	1507337	111350400
Max.	2.833E+10	1073538	42033000	9259000	2758769	150101912

Table 4
Malmquist TFP index summary of annual means for the DEA model, 1992–2012

Year	Technical efficiency change	Technical change	Pure efficiency change	Scale efficiency change	Total factor productivity change
1993	1.000	0.725	1.000	1.000	0.725
1994	1.000	0.839	1.000	1.000	0.839
1995	1.000	0.912	1.000	1.000	0.912
1996	1.000	0.899	1.000	1.000	0.899
1997	1.000	0.923	1.000	1.000	0.923
1998	1.000	0.924	1.000	1.000	0.924
1999	1.000	0.957	1.000	1.000	0.957
2000	1.000	0.942	1.000	1.000	0.942
2001	1.000	0.970	1.000	1.000	0.970
2002	1.000	1.018	1.000	1.000	1.018
2003	1.000	0.995	1.000	1.000	0.995
2004	1.000	1.001	1.000	1.000	1.001
2005	1.000	0.983	1.000	1.000	0.983
2006	1.000	0.964	1.000	1.000	0.964
2007	1.000	0.968	1.000	1.000	0.968
2008	1.000	0.984	1.000	1.000	0.984
2009	1.000	0.992	1.000	1.000	0.992
2010	1.000	0.978	1.000	1.000	0.978
2011	1.000	0.977	1.000	1.000	0.977
2012	1.000	0.974	1.000	1.000	0.974

Note: 1993 refers to the change between 1993 and 1992, and so on TFPC = (TEC) x (TC).
TEC = (pure efficiency change) x (scale efficiency change).

input-oriented Malmquist TFP index, the mean TFPC of 0.944 indicates that on average, over the sample period, there was a 5.6% productivity loose. Look in gat the mean TEC (1.000) and the mean technical or technological change (0.944), productivity gains were largely the result of technical or technological change. This is because the mean TEC (1.000) is greater than the mean technical or technological change of (0.944). Additionally, since the over all TEC is the product of pure technical efficiency and scale efficiency, such that Technical Efficiency=(Pure Efficiency) (Scale Efficiency), pure efficiency change was 1.000 (100%) where as scale efficiency changes 1.000 (100%), this implies that the relative source of technical efficiency was either scale efficiency or pure efficiency. Figure 1 presents the behavior of the TFP index and the TEC. It shows trends of the TFP index vis-a-vis the TEC and TC over the sample period. Figure 1 shows that overall, over the study period, the TFP gain was accounted for more by technical or technological progress than technical efficiency. Note that 1992 represents the base year and equals the value of unity. The graphs indicate that TFP progress is driven more by technological gain than technical efficiency. There might be other drivers of productivity growth which have not been in corporated in the analysis. This is because technological change may not necessarily translate into TFP growth. Empirically, however, TFP growth is not necessarily caused by technological change.

Conclusion

This study employed input and output data to empirically measure TFP of the agricultural sector in Turkey. An input oriented data envelopment analysis (DEA) estimation technique was employed to measure the Malmquist TFP indices for the Turkish agriculture. A general specification encompassing all available input and output data was employed to obtain the average TFPC for the sector over the 1992–2010 period. The results show that the agricultural sector posted impressive total factor productivity growth rates over the study sample. The average total factor productivity growth in the general model specification is -5.6%. These patterns are largely on the account of technological change as opposed to technical efficiency.

A total factor productivity growth in Turkish agriculture is seen in other studies including Turkey, except for Nin et al. In these studies, Turkey is compared with other countries, and for that reason results are relatively. However, in this study, Turkish agriculture was compared with itself and it was concluded that there was a loss of total factor productivity in the last 20 years.

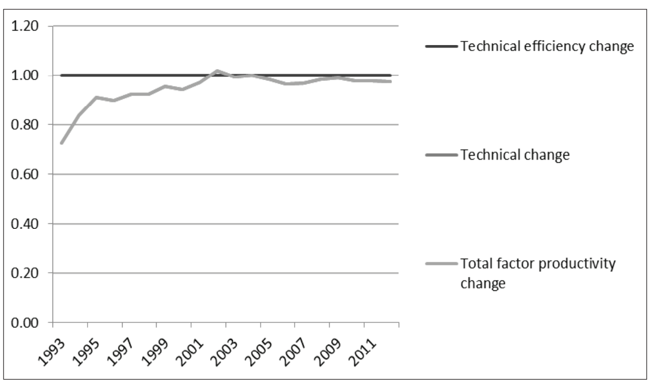

Fig. 1. Malmquist TFP index versus TEC and TC, 1992–2012

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