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Total factor productivity growth of Turkish agricultural sector from 2000 to 2014: Data envelopment malmquist analysis productivity index and growth accounting approach

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Despite the enormous diversification Turkey has made, agriculture still remains the backbone of its economy. Most of the successes Turkey's economy has chalked came in the last 15 years; after 2000. The agricultural contribution to both gross domestic product and employment fell within this period. The answer to the state of the sector is not found in its contribution to gross domestic product or employment but the progress in its total factor productivity growth. This is defined as that part of agricultural output growth that is not explained by changes in factors of production. Like all scientific procedures, there is no one way of estimating total factor productivity growth. Considering the advantages and disadvantages methods possess over one another, it is always logical to apply more than one technique on the same data set to establish a range within which the results can be established. We settled on Data envelopment analysis malmquist productivity index and the growth accounting approach. We gathered data on agricultural output and ten inputs at the national, from 2000 to 2014. They were simultaneously applied on our data. The total factor productivity of Turkish agricultural sector grew at 28.8%, with an annual growth rate of 2%.

Key words: Data envelopment analysis, growth accounting, malmquist productivity index, total factor productivity growth.

INTRODUCTION

Turkey as a region has been a serious agriculturally oriented economy before and after its independence in 1923. It still remains a vital part of its economy, even though a lot of diversifications have taken place (Öztürk,

2012). With the exception of its contribution to industry, there has been a significant reduction in the contribution of Agriculture to gross domestic product (GDP), employment, foreign exchange, etc. Examining the

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Turkey's GDP Per Capita (\$)

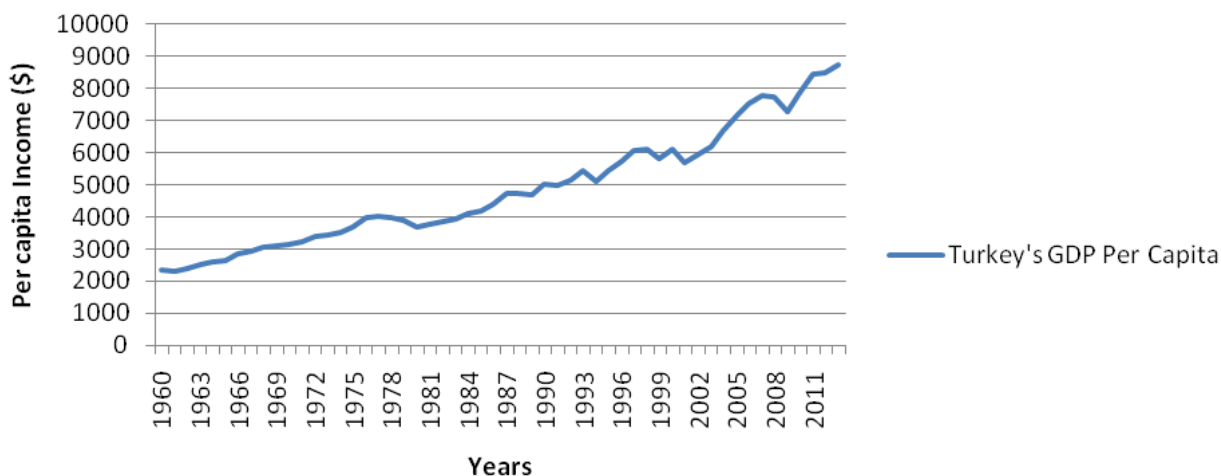


Figure 1. Turkey's GDP Per Capita. Source: Data from World Bank Development Indicators (WDI) (2014).

growth of Turkish GDP per capita (\$) since 1960 in Figure 1. The graph exhibits a clear categorization of the growth trend as revealed by the steep slope; before 2000 and post 2000. While an average annual growth in GDP per capita was \$89 between 1970 and 1999, the period between 2000 and 2013 recorded \$200 per annum. Within this unprecedented growth period (2000 till date), agriculture's contribution to GDP has been declining. However for a sector that still employs 21.1% of the country's labor force and contributes a lot to the industrial sector, it is important to investigate how it has performed during this period of unprecedented growth. In our opinion, this dwindling contribution of agriculture is not a cause for alarm, but the status of factor contribution to agricultural output is rather very vital. This informed our choice to access the total factor productivity growth (TFPG) of the agricultural sector within that period. TFPG indicates that part of output growth which is not resulting from the increase or decrease in factors of production (inputs) (Fadejeva and Melihovs, 2009). Existing TFPG studies also points to this same trend.

Using slow growth accounting approach (SGAA), Atiyas and Bakış (2013) found out a tremendous TFPG of 3.8% in the economy of Turkey which before then barely crossed the 1% mark. Their work is diagrammatically represented in Figure 2. From the two Figures 1 and 2, it can be seen that a lot of positive gains have occurred in post 2000 Turkey. It is therefore logical to investigate the status of agriculture within that same period.

There are so many different methods used in the estimation of TFPG. The choice of any method, among many things, depends on the researcher, the objectives of the study and the nature of the available data.

However, considering the pros and cons of each method, it is logical if possible to apply more than one method on a single data and compare the results. In the language of productivity and efficiency measurement, our data considered a single firm case (the whole of Turkey's agricultural sector). With this, so many TFP methods cannot be applied on it, especially most of the frontier approaches. The two methods found to be simultaneously applicable and mathematically and theoretically related are Data envelopment analysis malmquist index (DEAMPI) and the Solow growth accounting approach (SGAA). The results from both methods give a range within which the growth of TFP of Turkish agriculture can be accessed. There have been previous researches on this topic in Turkey. These researches vary a lot from the present study. While some are regional, others have targeted certain enterprises within the agricultural sector. Furthermore, the comparison with these two techniques has not been done. The main difference however, is the fact that none of them considered as many variables as ours.

Literature relating to Turkey

Basarir et al. (2006) found that even though annual agricultural growth rates was between 1.30 and 3.40% over 1961 to 2001 period, technical change growth rates ranged from -0.15 to 5.53%. Candemir and Deliktas (2007) also used data from 1999 to 2003 to estimate both productive efficiency and TFPG of Turkish state agricultural enterprises. While technical efficiency grew by 1.5%, there was a technical regress of 2.7%, leading

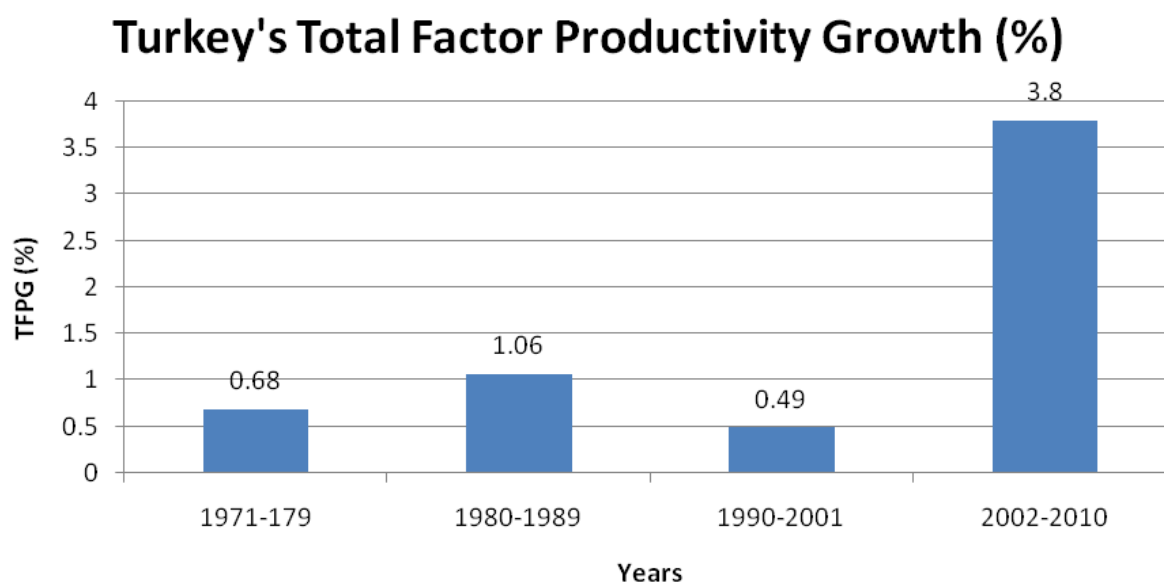


Figure 2. Total Factor Productivity Growth. Source: Atiyas and Bakış (2013, p.12).

to TFPG of -1.2%. In the South Marmara region of Turkey, Tipi and Rehber (2006) estimated MPI of 3.1% from 1993 to 2002. Analyzing data for the Turkish agricultural sector from 1992 to 2012, Ozden (2014) concluded there has been a TFP regress of -5.6%. Telleria and Aw-Hassan (2011) analyzed data for 12 countries within West Asia and North Africa (WANA) from 1961 to 1997. Turkey is a member of WANA. They concluded that Turkey's TFP of its agricultural sector grew by 12% within the period of study. Atiyas and Bakış (2013) using GAA, revealed that Agricultural TFPG grew by 6.75% from 2002 to 2006, and -1.5% from 2007 to 2011. This gave an average annual TFPG of 2.62% for 2002 to 2011 year period. Candemir et al., (2011) attempted to measure the technical efficiency as well as the TFPG of hazelnut production and sales in Turkey. They considered 2004 to 2008 time period. Using DEA, they found that the mean technical efficiency across this period varied between 0.841 and 0.938. Technical efficiency change was 1.3%, technical change was -3% and the TFPG (Malmquist Index) was 1.7%. Furthermore, Shahabinejad and Akbar (2010) set out to measure agricultural productivity growth in the Developing Eight (D-8) of which Turkey is a member. They considered the period from 1993 to 2007. Employing DEA, they estimated the TFPG and decomposed it into technical and efficiency change (TECH and EFFCH) components. Over the period, the countries as a whole managed a little below 1% TFPG with a 1.5% growth in Technology (TECH). This was offset by a negative growth of 0.4% in technical efficiency (EFFCH). They therefore concluded that EFFCH is a constraint to TFPG while TECH fostered

the growth in TFPG. At the level of individual countries, our country of interest, Turkey, was the second highest in terms of TFPG behind Malaysia. Malaysia recorded 2.9% growth followed by 2% for Turkey. However, unlike most of the countries, Turkey recorded a positive growth in both EFFCH and TECH. Pamuk (2008) used secondary data to estimate TFPG of Turkish agriculture from 1880 to 2000. He grouped the period into two; before and post-World War Two (WW2), that is 1880 to 1950 and 1950 to 2000. He estimated 0.3% growth for 1880 to 1950 and 1.1% for 1880 to 1950.

Rungsuriyawiboon and Lissitsa (2006) measured agricultural productivity growth in the European Union and Transition Countries. Turkey was considered among countries under transition countries despite the fact that it became an associate member of EU since 1964. The period under study was 1992 to 2002. They grouped countries into three; those that joined the union before 1995, those that joined in 2004 and the transition countries. For group comparison, they further choose three countries from each group for the analysis. The order of grouping the countries were Austria, Germany and UK; Hungary, Poland and Slovenia; Russia, Turkey and Ukraine. DEA was used to estimate the Malmquist TFPG. The 9 countries' growth rates were; Austria (2.78%), Germany (2.82%), UK (0.30%), Hungary (1.62%), Poland (2.59%), Slovenia (7.21%), Russian (5.32%), Turkey (1.70%) and Ukraine (5.33%). Zeroing in on Turkey, they explained that Turkey's TFPG was attributed significantly to 'frontier-shift' effect than 'catch-up' effect. This was due to the fact that, of the 1.7% TFPG, EFFCH was only 0.18%, compared with 1.51%

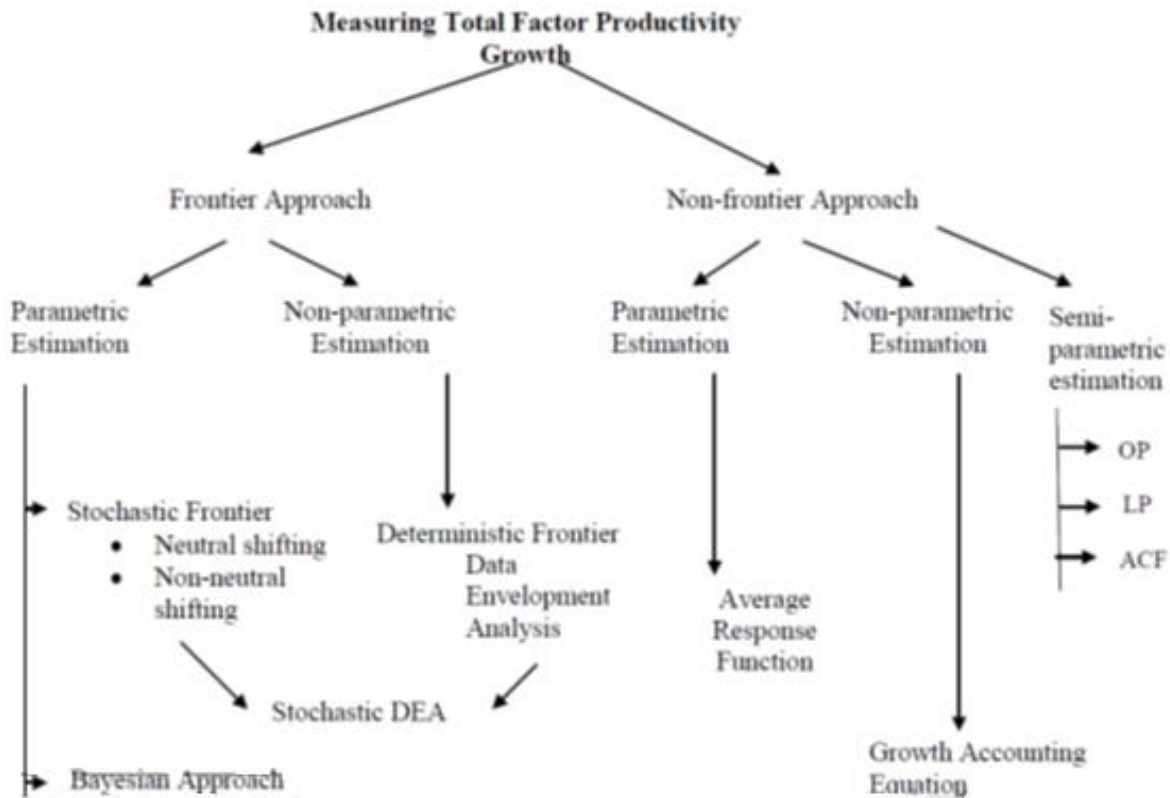


Figure 3. Measurement of Total Factor Productivity – Approaches. Notes: OP – Olley and Pakes approach; LP – Levinsohn and Petrin approach; ACF – Akerberg, Caves and Frazer model. Source: Adapted from Kathuria et al. (2013, p.6) who also adapted from Mahadevan (2003).

growth in TECH.

METHODOLOGY

Efficiency and productivity measurement as well as their growth have undergone different phases in terms of methodology; from the use of index numbers, linear and quadratic programming to econometric estimation. Even though new frontiers in estimation are still being pursued, the combination of the available methods on one data set is becoming the most logical way of increasing the precision of findings. This is due to the convincing advantages and disadvantages each method possesses over the other. This study adopted the method of applying two non-parametric approaches which are popularly known in the efficiency and productivity literature as DEAMPI and SGAA, respectively. These two methods have a lot in common as far as our data is concerned. The justification for the selection of these methods is found in the explanation following Figure 3.

There are two main approaches by which TFPG can be estimated; frontier and non-frontiers approaches. Each of them has a sub classifications grouped under parametric and non-parametric approaches. The main difference between frontier and non-frontier approaches lies in the definition of the frontier. While the former establishes production frontier which corresponds to the set of maximum attainable output levels for a given combination of inputs,

the later only construct an average line using ordinary least square regression as a line of best fit (Kathuria et al., 2013). Furthermore, because the frontier approach has the best possible frontier constructed, it incorporates technical efficiency in its estimation of TFPG while the non-frontier approach assumes fully technically efficient firms (Kathuria et al., 2013; Fare et al., 1994). The sources of TFPG from the frontier approach are further divided into two; an outward shift in the defined frontier (Technical Change-TECH) and a movement towards it (Technical Efficiency Change-EFFCH). However, the non-frontier approaches only consider TECH as TFPG.

It can be seen that though, the two selected methods are under different side of the divide, they are both non-parametric methods. Because our data is a single firm case, we cannot construct a frontier for it since we need more than one firm to construct a frontier for any given year. However, under the frontier approaches it is only DEAMPI which does not require the explicit construction of a frontier, hence our choice of it from the frontier side. On the non-frontier side, there are two main approaches; PFA and GAA. The semi-parametric approach (SPA) is a combination of these two methods. Even though they all make use of the production function, GAA like the DEA approach does not have a stochastic term, making it impossible for statistical testing to be done. After settling for GAA, we further reviewed the three different indexes used under this approach. We had to choose the most appropriate one for our data. They are the Kendrick arithmetic Index (KI)

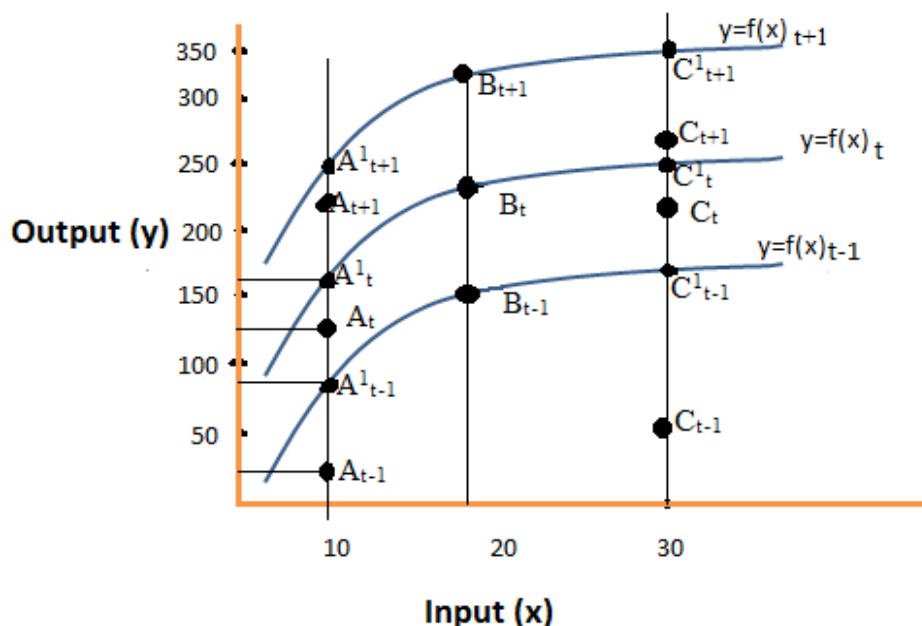


Figure 4. MPI, the case of many firms. Sources: Authors' Illustration.

(Kendrik, 1961), the Solow geometric Index (SI) (Solow, 1957) and Theil-Tornquist or Translog-Divisia Index (TLI) (Kathuria et al., 2013). The KI utilizes the income share of inputs as their weights for aggregation. This will not be possible with our data since we do not have the data on the rewards for the inputs. The SI, though with numerous assumptions fits well into our data. The data has all the requirements for its estimation. Even though Kathuria et al., (2013) considers TLI to be superior to both KI and SI, our data cannot meet its requirements for estimation. It requires current input prices for the construction of its weight. This makes it possible for the quality of inputs to be estimated.

For all GAA and PFA techniques the assumption of constant returns to scale (CRS), perfect competition and full capacity utilization are required. It is however not necessary in the case of PFA.

DEA malmquist index (DEAMPI)

Contrary to the name of the index, it was introduced by Caves et al. (1982) by using Malmquist input and output distance functions. It was however empirically applied by Fare, Grosskopf, Norris and Zhang (FGNZ) in 1994 (Kathuria et al., 2013). It is used to measure the TFPG for a group of firms or a single firm over a period of time. The difference between the two is the fact that, the former can construct a frontier for each year, while this is not possible in the single firm case. That is, more than one firm is required to construct a production frontier. In the latter case there is an implicit assumption that the firm is fully efficient for any given year, because there is no other firm for a comparison to be made.

The case of many firms

Assuming one input one output case, variable return to scale (VRS) assumption with output orientation, Figure 4 shows the TFPG

of three firms, A, B and C for three consecutive years. The present year 't', the year before 't-1' and the year after 't+1'. These three (3) firms in each year is able to construct a frontier $y=f(x)$. Each point on the graph represents productivity (Output/Input) of the firm at the point. This makes it possible for their efficiencies to be measured. That is, those points divided by the corresponding points on the frontier. Example, under VRS assumption, the efficiencies for firm A in t-1, t and t+1 are A_{t-1}/A^1_{t-1} , A_t/A^1_t and A_{t+1}/A^1_{t+1} , respectively. In order to estimate the DEAMPI for only firm A from year t-1 to t, one need to employ the concepts of distance functions as seen in equation 1. This form of presentation was referred to as Fisher ideal indexes by Caves, Christensen and Diewert (Fare et al., 1994). The index is generally defined as the geometric mean of these four indexes made up of these distance functions. For instance, $D_o^{t-1}(x^t, y^t)$ means the productivity of that firm at the current year 't' compared with the previous year's 't-1' frontier or technology. That is the one in the brackets is the firm in question and what is outside the bracket is the reference technology. $Mo(x^t, y^t, x^{t-1}, y^{t-1})$

$$= \left[\left(\frac{D_o^{t-1}(x^t, y^t)}{D_o^{t-1}(x^{t-1}, y^{t-1})} \right) * \left(\frac{D_o^t(x^t, y^t)}{D_o^t(x^{t-1}, y^{t-1})} \right) \right]^{\frac{1}{2}} \dots \dots \quad (1)$$

When these distance functions are rearranged according to Fare et al., (1994), it decomposes into technical efficiency change and technical change as follows:

$$Mo(x^t, y^t, x^{t-1}, y^{t-1}) = \frac{D_o^t(x^t, y^t)}{D_o^{t-1}(x^{t-1}, y^{t-1})} \left[\left(\frac{D_o^{t-1}(x^t, y^t)}{D_o^t(x^t, y^t)} \right) * \left(\frac{D_o^{t-1}(x^{t-1}, y^{t-1})}{D_o^t(x^{t-1}, y^{t-1})} \right) \right]^{\frac{1}{2}} \dots \quad (2)$$

The ratio outside the bracket measures EFFCH while the square

root of the one inside measures the TECH (Coelli et al., 2006).

From the equation 2, it can be seen that, the EFFCH ratio is the ratio of the technical efficiency in the current year to the previous year. This ratio indicates how closer or otherwise the firm in question is to its frontier as the years pass. The rest of the equation can be seen as a ratio of efficiencies made up of references to technologies in different years. A geometric mean of these gives the TECH, which indicates the shift or change in technology between the two periods under study (Coelli et al., 2006). The product of these two indexes gives the malmquist productivity index (MPI). That is:

$$TFPG = EFFCH \times TECH \tag{3}$$

In all the indexes, EFFCH, TECH and MPI have the same interpretation. An index above one indicates a positive change or growth, below means negative and one means stagnant or no growth (Fare et al., 1994). Even though further decompositions were later developed, they are not relevant to this study. The software we used for this analysis is data envelopment analysis program (DEAP Version 2.1) by Tim Coelli. Applying this formula to Figure 4, the MPI for firm A from the year t-1 to t is algebraically represented as follows:

$$Mo(x^t, y^t, x^{t-1}, y^{t-1}) = \frac{A_t/A_t^*}{A_{t-1}/A_{t-1}^*} \left[\left(\frac{A_t/A_{t-1}^*}{A_t^*/A_{t-1}^*} \right) * \left(\frac{A_{t-1}/A_t^*}{A_{t-1}^*/A_t^*} \right) \right]^{0.5} \tag{4}$$

Mathematically, it demands the solving of four different distance functions in the DEA format. Even though there are six (6) distance functions, there are actually four unique ones and the other two are repeated. Since they are output distance functions, we need to take the inverse of each of them.

$$[D_o^t(x^t, y^t)]^{-1} = Max_{\emptyset, \gamma} \emptyset,$$

St:

$$\begin{aligned} -\emptyset y_t + Y_t \gamma &\geq 0, \\ x_t - X_t \gamma &\geq 0, \\ \gamma &\geq 0, \end{aligned}$$

$$[D_o^{t-1}(x^{t-1}, y^{t-1})]^{-1} = Max_{\emptyset, \gamma} \emptyset,$$

St:

$$\begin{aligned} -\emptyset y_{t-1} + Y_{t-1} \gamma &\geq 0, \\ x_{t-1} - X_{t-1} \gamma &\geq 0, \\ \gamma &\geq 0, \end{aligned}$$

$$[D_o^t(x^{t-1}, y^{t-1})]^{-1} = Max_{\emptyset, \gamma} \emptyset,$$

St:

$$\begin{aligned} -\emptyset y_{t-1} + Y_t \gamma &\geq 0, \\ x_{t-1} - X_t \gamma &\geq 0, \\ \gamma &\geq 0, \end{aligned}$$

$$[D_o^{t-1}(x^t, y^t)]^{-1} = Max_{\emptyset, \gamma} \emptyset,$$

St:

$$\begin{aligned} -\emptyset y_t + Y_{t-1} \gamma &\geq 0, \\ x_t - X_{t-1} \gamma &\geq 0, \\ \gamma &\geq 0, \end{aligned}$$

Whiles \emptyset represents efficiency, γ represents the weight of individual firms. Unlike normal efficiency estimation where \emptyset is restricted to between 0 and 1, it may be greater than 1 in some of the linear programming since the firms are compared with the frontiers of different years (Coelli et al., 2006). These four linear programming are sufficient for only one firm. This means that if there are ten firms to be considered forty of such linear programming must be solved.

The case of a single firm

Let's us assume now that we are dealing with only one firm 'A' with its available data for the current year 't', the previous year 't-1' and the following year 't+1' as represented in Figure 5. In order to construct a frontier or a production function, data on several firms are required, which is not possible in this case. The other option is to adopt an existing production function or frontier. Even though several studies have been done estimating the production function of Turkish Agriculture, none of them considers as many inputs as we have done in this study. This therefore means that there is no production function for which the firm can be compared to, other than itself. That is, unlike the case of firm A in Figure 4, there is no A_{t-1}^* , A_t^* and A_{t+1}^* . This logically means that technical efficiency will be 1. This further implies that the first part of the MPI which measures the EFFCH will be 1, indicating no change in technical efficiency. However, the technical change component is measurable, considering the fact that the firm is using the same amount of inputs to produce more in year t and t+1. It is only in the improvement of technology that this will be possible. This value multiplied by 1 (EFFCH) will give the MPI for that firm.

The solow growth accounting (SGAA)

Though Robert Solow (1957) is widely considered as the originator of this approach, its origins could actually be traced back to Tinbergen (1942) (Kathuria et al., 2013). Despite the fact that GAA has a lot of differences with other known TFPG techniques, especially index numbers, it still has a strong relationship with them. MPI which has become the most widely used index for TFPG measurement has a mathematical relationship with GAA which makes it comparable to other Malmquist index results from DEA and SFA. However as explained earlier, the nature of our data (that is, the single firm case scenario, with no defined frontiers for each year), it is difficult to employ the SFA method. However, DEA does not need a functional specification (Diewert and Nakamura, 2006). In GAA, aggregate output growth is decomposed into input or factor growths as well as the growth in the residual term which represents TFPG. That is, the portion of output growth not explained by input or factor growth (Atiyas and Bakış, 2013).

According to Diewert and Nakamura (2006), the multi factor productivity measurement procedures can be classified into four: (1) The rate of growth over time of TFP, (2) The ratio of the output and the input growth rates, (3) The rate of growth in the revenue/cost ratio controlling for price change and (4) The rate of growth in the margin after controlling for price change. As can be observed, the third and fourth are in monetary terms requiring the use of rewards for inputs (wage, rent, interest etc.), the first two however do not. Considering the fact that our data is a single firm case with no price information, the first and the second procedure will be adopted.

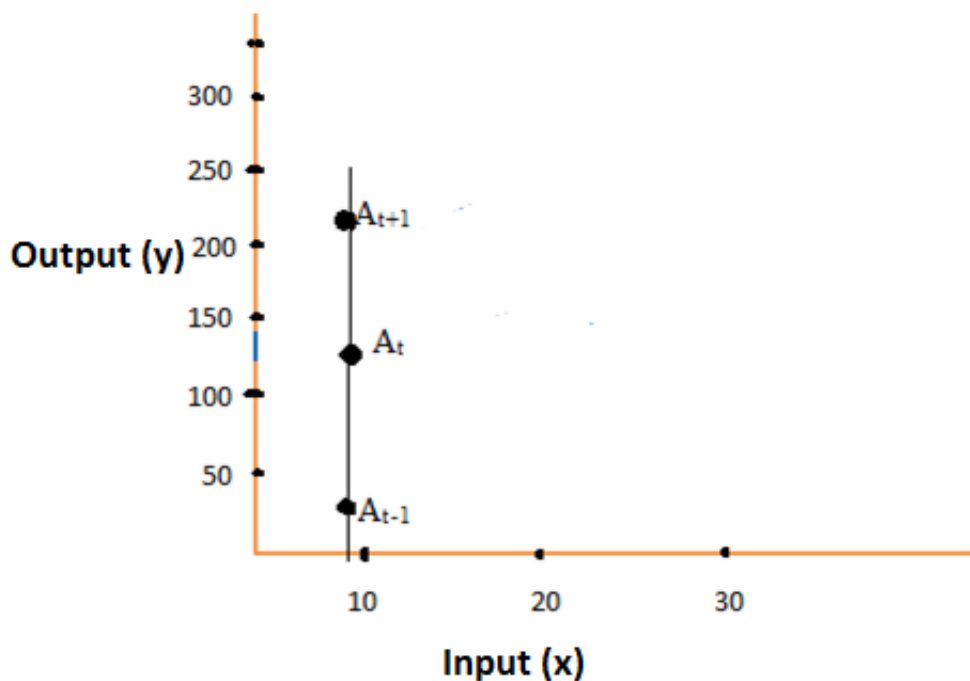


Figure 5. Malmquist Index, the case of one firm. Source: Authors' Illustration.

Presentation

With only slight modification, the presentation follows the same procedure and assumptions used by Solow himself. In his 1957 landmark paper, he modified the production function by redefining the time trend which measures TECH. That instead of $Y = F(K, L, t)$, he represented it by $Y = A(t)F(K, L)$. Where Y is the output and K and L represent capital and labor inputs, and the 't' in the function represent neutral TECH. The 'A' measures the TFP, while its multiplicative factor, $A(t)$ measures the cumulated effect of shifts over time that is, TFPG (Solow, 1957). Even though the use of translog production could have been possible, we are forced by the nature of our data to assume a Cobb-Douglas production function as would be explained in the data section of this paper. It has to be noted that Solow also fitted Cobb-Douglas production function on his data covering 1909 to 1949. Considering a Cobb-Douglas production function with a constant return to scale (CRS) assumption:

$$Y = A_t * K_t^\alpha * L_t^{(1-\alpha)} \tag{5}$$

The parameters α and $(1-\alpha)$ are the fractional exponents which represent the capital and labor share of output, respectively. The sum of these parameters also defines the scale of operation. When they sum up to one it indicates CRS, below one, decreasing return to scale (DRS), and greater than one increasing return to scale (IRS). Since CRS is imposed on the formulation, their summation must be equal to one, that is $\alpha + (1-\alpha) = 1$. Basically, there are two ways of calculating the α and $1-\alpha$, that input shares; by regression analysis or extraction from the national or available data (Atiyas and Bakış, 2013). The former was used in the present analysis.

Linearizing (taking logarithm) Equation 5;

$$\ln Y = \ln A_t + \alpha \ln K_t + (1 - \alpha) \ln L_t \tag{6}$$

There is an implicit assumption in equation 5 that technology or TFP (A) is constant over time, after $\ln Y$ is regressed on $\ln K$ and $\ln L$. The intercept after the regression represents $\ln A$. Differentiating with respect to time;

$$\frac{1}{y} \frac{dY}{dt} = \frac{1}{A} \frac{dA}{dt} + \alpha \frac{1}{K} \frac{dK}{dt} + (1 - \alpha) \frac{1}{L} \frac{dL}{dt} \tag{7}$$

Mathematically, since the derivative of a logarithmic function is the rate of change of that function, $\frac{1}{y} \frac{dY}{dt}$ represents the rate of growth

of Y , so that $\frac{1}{A} \frac{dA}{dt}$, $\frac{1}{K} \frac{dK}{dt}$ and $\frac{1}{L} \frac{dL}{dt}$ represent the rate of growth of

Technology or TFP (A), capital (K) and labor (L), respectively. For analysis sake, let us represent the growth rates of output, TECH, capital and labor as G_Y , G_A , G_K , and G_L respectively.

$$G_Y = G_A + \alpha G_K + (1-\alpha)G_L \tag{8}$$

Normally, from the available data G_Y , G_K and G_L are known. According to Solow, this makes it possible for the G_A to be estimated as a residual, hence the name Solow residual (Atiyas and Bakış, 2013). Equation 8 allowed a non-constant technology or TFP. When G_Y is regressed on G_K and G_L , the resulting constant G_A measures the TFPG for the entire years under study (Atiyas and Bakış, 2013). For annual estimation, we use the first of Diewert and Nakamura (2006)'s classification aforementioned; the rate of growth over time of TFP becomes:

$$TFP = \frac{Y_t}{x_t} = A_t \tag{9}$$

From the assumed Cobb-Douglas production function in equation 5, Y_t is the aggregate agricultural output, X_t is the aggregated inputs used and A_t still remains the TFP.

$$TFPG = \left(\frac{Y_t}{X_t} \right) / \left(\frac{Y_{t-1}}{X_{t-1}} \right) = \frac{A_t}{A_{t-1}} \tag{10}$$

Model presentation

$$\ln Y = \ln A + \alpha_1 \ln x_1 + \alpha_2 \ln x_2 + \alpha_3 \ln x_3 + \alpha_4 \ln x_4 + \alpha_5 \ln x_5 + \alpha_6 \ln x_6 + \alpha_7 \ln x_7 + \alpha_8 \ln x_8 + \alpha_9 \ln x_9 + \alpha_{10} \ln x_{10} \dots \tag{11}$$

$$\alpha_1 + \alpha_2 + \alpha_3 + \alpha_4 + \alpha_5 + \alpha_6 + \alpha_7 + \alpha_8 + \alpha_9 + \alpha_{10} = 1 \dots \tag{12}$$

Differentiating with respect to time;

$$\frac{1}{y} \frac{dy}{dt} = \frac{1}{A} \frac{dA}{dt} + \alpha_1 \frac{1}{x_1} \frac{dx_1}{dt} + \alpha_2 \frac{1}{x_2} \frac{dx_2}{dt} + \alpha_3 \frac{1}{x_3} \frac{dx_3}{dt} + \alpha_4 \frac{1}{x_4} \frac{dx_4}{dt} + \alpha_5 \frac{1}{x_5} \frac{dx_5}{dt} + \alpha_6 \frac{1}{x_6} \frac{dx_6}{dt} + \alpha_7 \frac{1}{x_7} \frac{dx_7}{dt} + \alpha_8 \frac{1}{x_8} \frac{dx_8}{dt} + \alpha_9 \frac{1}{x_9} \frac{dx_9}{dt} + \alpha_{10} \frac{1}{x_{10}} \frac{dx_{10}}{dt} \tag{13}$$

Representing each variable growth rate by the letter ‘G’ with the same input shares of output:

$$G_Y = G_A + \alpha_1 G_1 + \alpha_2 G_2 + \alpha_3 G_3 + \alpha_4 G_4 + \alpha_5 G_5 + \alpha_6 G_6 + \alpha_7 G_7 + \alpha_8 G_8 + \alpha_9 G_9 + \alpha_{10} G_{10} = 1 \tag{14}$$

When the growth rate of agricultural output is regressed on the 10 inputs used, the intercept value G_A will estimate the average percentage growth in TFP per annum, that is growth rate of TFP. When multiplied by 14, the resultant will be TFPG for the entire 15 years.

Like Cobb and Douglas, the data for the entire period under study is first used to estimate the share of each input to total agricultural output. That is from α_1 to α_{10} . This is done by running a regression on equation 11, with a CRS constraint. Since the variables are already in their logarithmic form, the growth rates (that is the G’s in equation 14) is calculated by subtracting the previous year’s value from the year under consideration. That is, $\frac{1}{y} \frac{dy}{dt} = \ln Y_t - \ln Y_{t-1} = G_Y$. The resulting G_A from the regression gives the TFPG per annum. Stata/MP 14.0 was used in this analysis with some calculation by Microsoft excel.

Link between DEAMPI and GAA

Mathematically and theoretically GAA is actually an approximation of an index number (Diewert and Nakamura, 2006). As seen earlier, DEAMPI procedure utilizes distance functions. Adopting the Cobb-Douglas production function in Equation 5; $Y_t = A_t * K_t^\alpha * L_t^{(1-\alpha)}$, the distance function will be the ratio of the point of interest to the corresponding point on the frontier. Example for a point in year ‘t’ will be $Y_t / A_t * K_t^\alpha * L_t^{(1-\alpha)}$. Substituting the various distance function into equation 1, that is the original Malmquist index formulation;

$$M_O(x^t, y^t, x^{t-1}, y^{t-1}) = \left[\frac{\frac{Y_t}{A_{t-1} * K_{t-1}^\alpha * L_{t-1}^{(1-\alpha)}}}{\frac{Y_{t-1}}{A_{t-1} * K_{t-1}^\alpha * L_{t-1}^{(1-\alpha)}}} * \frac{\frac{Y_t}{A_t * K_t^\alpha * L_t^{(1-\alpha)}}}{\frac{Y_{t-1}}{A_t * K_t^\alpha * L_t^{(1-\alpha)}}} \right]^{1/2}$$

$$= \left[\frac{Y_t}{A_{t-1} * K_{t-1}^\alpha * L_{t-1}^{(1-\alpha)}} * \frac{Y_t}{A_t * K_t^\alpha * L_t^{(1-\alpha)}} * \frac{Y_{t-1}}{A_{t-1} * K_{t-1}^\alpha * L_{t-1}^{(1-\alpha)}} * \frac{Y_{t-1}}{A_t * K_t^\alpha * L_t^{(1-\alpha)}} \right]^{1/2} = \left[\frac{(Y_t)^2}{(Y_{t-1})^2} \right]^{1/2} = \frac{A_t}{A_{t-1}} \tag{15}$$

This gives an index of growth or contraction of TFP from year ‘t-1’ to ‘t’ used in GAA procedure. This is the same as in equation 10. According to Fare et al. (1994), this formulation in Equation 15 is equivalent to the more general formulation by Robert Solow (1957), which is the basis for the GAA to measure TFP.

According to Hulten (2000), all the productivity measurement procedures are complementary to one another. In the words of Lovell (1993): “In my judgment neither approach strictly dominates the other, although not everyone agrees with this opinion, there still remains some true believers out there”. In a commentary to this assertion, Kathuria et al. (2013) remarked that no TFPG calculation is superior to the other. The use of any technique depends on the unique situation of the researcher. According to them (Kathuria et al. (2013)), the selection can be based on factors like multiple inputs and outputs, specification of functional form, outliers, sample size, prevalence of high collinearity among inputs, noise, such as measurement error, statistical testing.

The two procedures (DEAMPI and GAA) does not consider technical efficiency, scale efficiency as well as prices. They are also both non-parametric approaches (Kathuria et al., 2013). As noted by Fare et al. (1994), when technical efficiency is not considered, especially in the single firm case, TFPG will then be synonymous to TECH. In the same vain, the TFPG in the DEA analysis is equal to TECH, because the other two components, EFFCH and SECH are all constants throughout. This clearly seen in the DEAP results in Table 2. It is for this same reason that the A(t) component in the Cobb-Douglas from which Solow proved the GAA, is simultaneously referred to as TECH and TFPG.

Data

The data used for this study are primarily secondary data from six main sources; the Statistics Division of Food and Agriculture Organization of The United Nations (FAOSTAT), International Labor Organization (ILO), The World Bank Development Indicators (WDI), International Fertilizer Association (IFA), the State Hydraulic Works of Turkey (Devlet Su İşleri-DSI) and the most valuable Turkish Statistical Institute (TUIK). The data covered a period of 15 years spanning from 2000 to 2014. It must be noted that some of the values for some years of some variables were extrapolated, especially for 2014. This was necessary because some of the official values for those variables were not released as at the data collection period.

Variables

The study considered one output and 10 inputs at the aggregate national level. Unlike agricultural output at the farm level, we felt that aggregate agricultural output at the national level requires the inter play of many inputs. The number of input used in studies reviewed ranged from 3 to 6. We recognize the challenges faced in analyzing more variables, especially some software’s inability to deal with more variables. Normally, the data is given the chance to determine which functional form fits it better, however because many inputs are considered, available software are not able to deal with the analysis if it takes a translog production form. Frontier 4.1c,

Stata 14 and R 3.0.1 programs could not cope up with the total number of independent variables (regressors) considered for the analysis. In the translog form, the total number of regressors or inputs generated is 77 against 15 cross sections, including the time trend variable. However, a Cobb-Douglas specification generated 11 regressors or inputs, including the time trend. This compelled us to choose the Cobb-Douglas production function to fit our data for the GAA.

Output

This is represented by the agricultural production index, which is defined as the relative level of the aggregate volume of agricultural production for each year in comparison with the base period 2004 to 2006. The weighted sum of seed and feed are deducted before this calculation is made. The unit of measurement is International dollar (Int. \$). The international dollar measures the same amount of good and services which can be bought with a US dollar in America as in the country under consideration. The whole data on this variable was gotten from FAOSTAT. The only year that was extrapolated was 2014 and the variable that represents it in the study is 'y', that is output (y).

Inputs

Land: This is defined as the total utilized agricultural land, that is cultivated land. This included land sowed (crops and vegetables), those under fallow, land occupied by ornamental plants and fruits, as well as those used as permanent meadows and pastures (TUIK). This is measured in thousand hectares (1000 Ha). Data on this was gotten from TUIK with the exception of the year 2000. This was complemented by the WDI which had the Figure for 2000. It is represented as 'x1'

Labor: Agricultural labor consists of economically active labor force of a country that is engaged in agricultural activities for living. This includes crop production, animal husbandry, hunting, forestry and fishing. The data considered 15 years of age and above as the active working population. The source of this data has been a little challenging. Turkey until 2005 was recording their labor force statistics based on the ordinary household labor force survey, but adopted the more harmonized European Union Labor Force Survey (EU LFS) from 2005. With the study period under review, this would mean that our data span the period between these two different surveys. This means that using any of them will mean the unavailability of data for a significant amount of years, which can be extrapolated. We settled for the EU LFS for two important reasons; its harmonized nature and the fact that we have to extrapolate for 5 years backwards instead of 10 years ahead if we had chosen the other one. The data was gotten from TUIK.

Agricultural machinery: A lot of items come under this category. However, monetizing these items would have been good but it is almost impossible especially for a national aggregated data like this. Unlike livestock units (LSU) for livestock and labor force survey (LFS) for labor, there is no known aggregation technique to include all type of machinery even though there is data on their respective quantities. Because of the aforementioned problem the data on machinery is limited to the two most important and highly used machines; tractors and combine-harvester. Their combined number is used.

Fertilizer: This data was extracted from the database of the International Fertilizer Association (IFA) of which Turkey is a member. The most highly used plant nutrients are considered;

Nitrogen (N), Potassium (K_2O) and Phosphorous (P_2O_5). The summation of the weight of each of the nutrients is represented in the study in thousand tones nutrients. However available data fell short of two years, which was then extrapolated, that is the data did not include the years 2013 and 2014.

Seed: Considering the importance of seeds as a direct input to agricultural crop production, the study considered in tones, the combined weight of all seeds in the production of all crops and plants in Turkey. These include cereals, legumes, tubers and ornamental plants. The whole data with the exception of 2014 (extrapolated) was gotten from FAOSTAT.

Pesticide: Pesticide use by so far is the variable with most missing data which had to be extrapolated. Even though there are different type of chemical used in agriculture, they are basically grouped into five; insecticides, herbicides, fungicides/bactericides, rodenticides and acaricides. However, an allowance was made for other chemicals that are used but has no classification under these five. Data for this is found both in FAOSTAT and TUIK, but that of FAOSTAT has a lot of inconsistencies even though it covers the entire period of study. That of TUIK covers from 2006 to 2013. We used the information from TUIK but had to extrapolate for the missing data. They are measured in tones.

Livestock: The agricultural output from livestock is directly linked to the number of animals available. They are the main source of protein, especially from their meats and eggs. However, livestock comes in different shapes, breeds and sizes. Even geographically, there is vast difference between the same kind of livestock. This makes aggregation difficult. Livestock units (LU) is an aggregation procedure used to find the total number of livestock from different categories of livestock. This technique however, varies from region to region. The designated regions are North Africa, Sub-Saharan Africa, South Africa, North America, Central America, South America, Asia, Eastern Europe, Oceania Developing, USSR and OECD. The geographical classification of Turkey as a country has been a controversy. It can be classified as Near East country, Eastern Europe and an OECD member. This poses a problem on which unit to use. We consequently settled for the OECD criterion which is less geographically defined. Regions and countries that are in the tropics use the famous Tropical Livestock Unit (TLU). In order to standardize the data, we considered Global/International Livestock Unit (ILU). In this technique, all regions are compared to that of North America, with cow as the reference (referenced as 1). The livestock considered are cattle, buffalo, sheep, goats, pigs, horses, mules, camels, asses, chickens, ducks, turkeys, geese and rabbits.

There are two major limitations to this aggregation with regards to our data. Firstly, Turkey does not have official records on the number of rabbits, but FAO has a fixed estimation of 50000. Secondly Beehives are livestock, however there is no known LSU for their measurement; hence information about it is omitted from our measurement.

$$\text{Total livestock} = \sum_{i=1}^n ILU_i \quad (16)$$

n = number of species/type, ILU_i = ILU for species/type

Water products: This input complement livestock in the provision of agricultural output especially protein related products. This input is normally not considered in most studies, however it is very important to the agricultural output of some countries. We believe

Table 1. The variable representation of inputs and output in the study.

Land	Labor	Machinery	Fertilizer	Seed	Pesticide	Livestock	Water products	Irrigation	Rainfall
x1	x2	x3	x4	x5	x6	x7	x8	x9	x10

Table 2. DEA results.

1	2	3	4	5	6	7	8
YEAR	EFFCH	TECH	PECH	SECH	TFPG	% CHANGE	CPCH
2001	1.000	0.934	1.000	1.000	0.934	-6.6	-6.6
2002	1.000	1.068	1.000	1.000	1.068	6.8	0.2
2003	1.000	0.985	1.000	1.000	0.985	-1.5	-1.3
2004	1.000	1.033	1.000	1.000	1.033	3.3	2
2005	1.000	1.107	1.000	1.000	1.107	10.7	12.7
2006	1.000	0.954	1.000	1.000	0.954	-4.6	8.1
2007	1.000	0.904	1.000	1.000	0.904	-9.6	-1.5
2008	1.000	1.120	1.000	1.000	1.120	12	10.5
2009	1.000	0.846	1.000	1.000	0.846	-15.4	-4.9
2010	1.000	1.081	1.000	1.000	1.081	8.1	3.2
2011	1.000	1.074	1.000	1.000	1.074	7.4	10.6
2012	1.000	1.025	1.000	1.000	1.025	2.5	13.1
2013	1.000	1.149	1.000	1.000	1.149	14.9	28
2014	1.000	0.917	1.000	1.000	0.917	-8.3	19.7

Note: EFFCH stands for Technical Efficiency Change (TECH), TECH stands for Technical Change, PECH stands for Pure Efficiency Change, SECH means Scale Efficiency Change, TFPG is Total Factor Productivity Growth (TFPG) and CPCH stands for Cumulative percentage Change. Source: DEAP Version 2.1.

Turkey, which has almost half its border as coastline in addition to the numerous inland water systems, owes a significant amount of its agricultural output to its waters. The data comprises the total amount in tons of sea products, aquaculture and freshwater products. Data for 2001, 20013 and 20014 were extrapolated.

Irrigation: This input is captured as the number of dams constructed for irrigation purposes. Normally in efficiency and productivity analysis studies, this is captured as the proportion of arable land that is irrigated. However, we felt that in order to capture irrigation as an input to agricultural output, it should be the number of irrigation facilities used. If irrigated land is considered, there will be confliction with the total agricultural land which in itself is an input. These records were gotten from DSI database.

Rainfall: Rainfall is an important input in determining the aggregate agricultural output of any country. It is such an important input that its quantity, pattern and timing can have a disastrous effect on agricultural output as a whole. Even irrigation-dependent production needs rainwater to reinforce the dams for efficient operation. This data records the annual rainfall in millimeters (mm), all from DSI database.

The variable representation of inputs and output in the study is shown in Table 1.

RESULTS AND DISCUSSION

DEA results

As can be seen in Table 2, TFPG (column 6) and MPI for

that matter experienced some fluctuations over the entire 15 years. As explained earlier, all the efficiency related estimates are constant and recorded one throughout the entire period that is EFFCH, PECH and SECH. This is as a result of the absences of efficiency measurement as depicted in Figure 5, since there is no constructed frontier. A better picture of the trend is revealed in Figure 6; the number of positive growths is more and more significant than the negative growths. The diagram reveals a unique pattern of dividing the results into two; from 2000 to 2010 and from 2010 to 2014. From 2000 to 2010, all the negative cumulative growths are sandwiched between positives cumulative growths, with that of 2001 being the highest negative growth. This indicates that, there was a cyclical fluctuation in the environmental elements which heavily affect agriculture, or agricultural policy implementers were experimenting with some particular policies for each farming season. From 2010, growth has not only been positive, it has been significant and sustained for five consecutive years. The highest growth rate also occurred within this period in 2013. About 84% of the total cumulative growth occurred in that last 5 years, with only 16% for the whole of the first 10 years. The cumulative percentage change (CPCH), which is captured under column 8 of Table 2 the

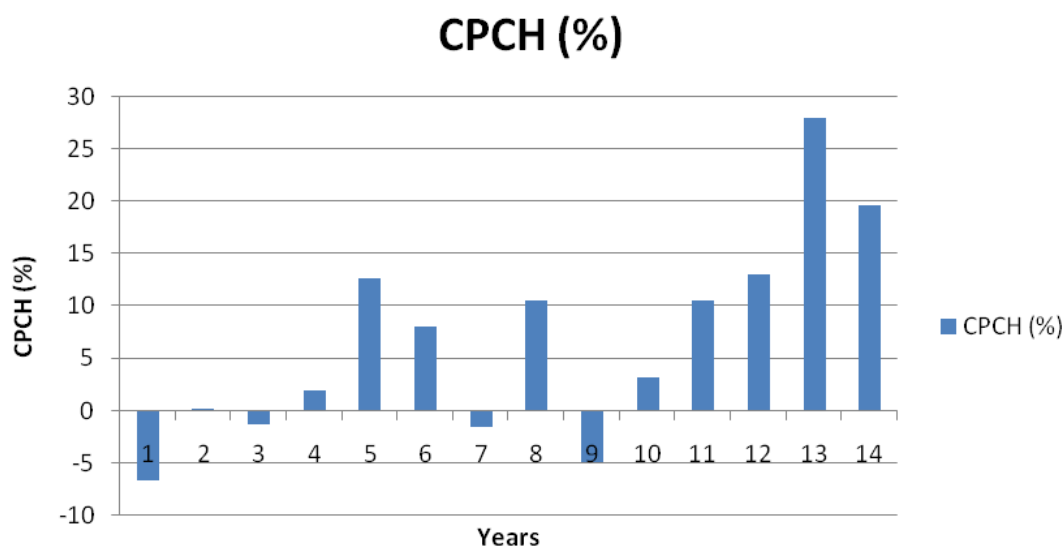


Figure 6. CPCH (%). Source: DEAP Version 2.1.

cumulative growth of any year from the year 2000. This eventually led to an overall growth of 19.7% from 2000 to 2014.

Growth accounting

Using the entire data, a linearized Cobb-Douglas production (Equation 11), with a CRS constraint was estimated as:

$$\ln Y = 0.89 - 1.05 \ln x_1 + 0.22 \ln x_2 - 1.04 \ln x_3 + 0.07 \ln x_4 + 0.38 \ln x_5 - 0.21 \ln x_6 + 0.86 \ln x_7 - 0.05 \ln x_8 + 1.81 \ln x_9 + 0.005 \ln x_{10} \quad (17)$$

The time derivative of the aforementioned function leads to its growth rate function which includes all the variables. However the variable of interest is the TFP.

$$G_Y = G_A - 1.05G_1 + 0.22G_2 - 1.04G_3 + 0.07G_4 + 0.38G_5 - 0.21G_6 + 0.86G_7 - 0.05G_8 + 1.81G_9 + 0.005G_{10} \quad (18)$$

After transforming the data to suit the aforementioned equation, the growth rate of agricultural output is then regressed on the growth rate of the 10 inputs. The resulting intercept, G_A which represents the TFPG is 2.7% per annum. The TFPG for the entire period under study is therefore 37.8%.

From our reviewed studies, in terms of techniques and period of study, our results can be compared with researches of Basarir et al., (2006), Atiyas and Bakış (2013), Candemir et al., (2011), Shahabinejad and Akbar (2010) and Rungsuriyawiboon and Lissitsa (2006). Basarir, et al. (2006) found an annual growth of 1.30 and

3.40% over 1961 to 2001. Atiyas and Bakış (2013) also estimated 2.62% annual growth in TFP for 2002 to 2011 year period. Candemir et al., (2011) also found a TFPG of 1.7% within 2004 to 2008. 2% growth was estimated by Shahabinejad and Akbar (2010) from 1993 to 2007. Finally, Rungsuriyawiboon and Lissitsa (2006) also recorded 1.7% growth between 1992 and 2002. All these studies seem to agree with our results which established an average annual growth between 1.4 and 2.7% over the period between 2000 and 2014 from the two techniques applied.

Conclusion

The two procedures used in measuring TFPG have a lot in common as revealed in the mathematical proof. The nature of our data restricted us from applying various methods of TFPG procedures, hence the choice of these two. They have no efficiency elements, no predefined production function and price information. The breakdown in years as revealed by the DEAMPI results show that the government, which still governs till date, until 2010 did not find its footing in terms of its agricultural policies. This explains the fluctuations and minimal growths in TFP within that period. The results show that, for whatever has been the policy from 2010, it is paying off as reflected in the sustained significant growth recorded from 2010 till date. Combining the results of the two approaches, a conclusion can be made that, the Turkish agricultural TFP has grown between 19.7 and 37.8% over the 15 year period, a significant portion of which occurred within the last 5 years. This translates into annual growth between 1.4 and 2.7%. For a definite conclusion,

considering an average of the two procedures, the TFP of Turkish agricultural sector grew at 28.8% with an annual growth rate of 2%.

Conflict of Interests

The authors have not declared any conflict of interests.

REFERENCES

- Atiyas I, Bakiş O (2013). Aggregate and Sectoral TFP Growth in Turkey: A Growth Accounting Exercise."Sabanci University and Competitiveness Forum.http://ref.sabanciuniv.edu/sites/ref.sabanciuniv.edu/files/tfp_tur_refwp.pdf
- Basarir A, Karli B, Bilgic A (2006). An evaluation of Turkish Agricultural production performance. *Int. J. Agric. Biol.* 8(4).
- Candemir M, Deliktas E (2007). Production Efficiency and Total Factor Productivity Growth in Turkish State Agricultural Enterprises. *Agric. Econ. Rev.* 8(2).
- Candemir M, Özcan M, Güneş M, Deliktaş E (2011). Technical efficiency and total factor productivity growth in the hazelnut agricultural sales cooperatives unions in Turkey. *Math. Comput. Appl.* 16(1):66-76.
- Coelli TJ, Prasada RDS, O'Donnell CJ, Battese GE (2006). *An Introduction to Efficiency and Productivity Analysis*, 2nd Edition, Springer, New York, 366 pp.
- Diewert WE, Nakamura AO (2006). The Measurement of Aggregate Total Factor Productivity Growth. In: Heckman JJ, Leamer EE, eds., *Handbook of Econometrics* 6. Amsterdam: Elsevier.
- Fadejeva L, Melihovs A (2009) Measuring Total Factor Productivity and Variable Factor Utilisation: Sector Approach, the Case of Latvia. Bank of Latvia. Working Paper, No. 3:40.
- Fare R, Grosskopf S, Norris M, Zhang Z (1994). Productivity Growth, Technical Progress, and Efficiency Changes in Industrialized Countries", *Am. Econ. Rev.* 84(1):66-83.
- Hulten CR (2000). Total Factor Productivity: A Short Biography, NBER Working Paper # 7471.
- Kathuria V, Rajesh SNR, Kunal S (2012). Productivity Measurement in Indian Manufacturing: A comparison of alternative methods. *J. Quant. Econ.* 11(1-2).
- Kendrick JW (1961). *Productivity Trends in the United States*, Princeton University Press, Princeton.
- Lovell CAK (1993). Production frontiers and productive efficiency' in Fried HO, Lovell CAK, Schmidt SS (eds.) *The Measurement of Productivity Efficiency - Techniques and Applications*, Oxford University Press, New York: pp. 3-67.
- Ozden A (2014). Total factor productivity growth in Turkish agriculture: 1992-2012. *Bulg. J. Agric. Sci.* 20(2):469-473.
- Öztürk M (2012). *Agriculture, Peasantry and Poverty in Turkey in the Neo-liberal Age*. Wageningen Academic Publishers.
- Pamuk Ş (2008). Agriculture and Economic Development in Turkey, 1870-2000. In *Agriculture and Economic Development in Europe Since 1870*, eds Lains P, Pinilla V. pp. 375-396. London: Routledge.
- Rungsuriyawiboon S, Lissitsa A (2006). Agricultural Productivity Growth in the European Union and Transition Countries. IAMO Discussion Paper No. 94. Leibniz Institute of Agricultural Development in Central and Eastern Europe. Halle, Germany.
- Shahabinejad V, Akbari A (2010). Measuring agricultural productivity growth in Developing Eight. *J. Dev. Agric. Econ.* 2(9):326-332.
- Solow RM (1957). Technical Change and the Aggregate Production Function. *Rev. Econ. Stat.* 39(3):312-320.
- Telleria R, Aw-Hassan A (2011). Agricultural productivity in the WANA region. *J. Comparative Asian Dev.* 10(1).
- Tipi T, Rehber E (2006). Measuring technical efficiency and total factor productivity in agriculture: the case of the South Marmara region of Turkey. *The Royal Society of New Zealand. New Zealand J. Agric. Res.* 49:137-145.
- World Bank (2014). *World Bank Development Indicators (WDI)- Turkey*. <http://data.worldbank.org/sites/default/files/wdi-2014-book.pdf>