Arabian Journal of Business and Management Review
ISSN: 2223-5833
Bushara and Abu Sin, Arabian J Bus Manag Review 2016, 6:3
DOI: 10.4172/2223-5833.1000211
Research Article Open Access

Evaluation of Total Factor Productivity of Sudanese Sugar Company Farms: A Non-parametric Analysis 1999-2007

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Abstract

This study analyzes productivity growth in Sudanese Sugar Schemes over the period 1999-2007. The application and specification of the output-based Malmquist total factor productivity index, data variables and sources, results, and some policy implications for the Sudanese sugar farms are discussed and presented The Malmquist productivity index was used to measure the technical and economic or allocative efficiency. Data Envelopment Non-parametric analysis (DEA) a model of output-oriented total factor productivity (TFP) was used in the analysis. This model provided meaningful results regarding technological and economic behavior relationships over time, using balance panel data on Sudanese Sugarcane Schemes. Efficiency change contributed to the total factor productivity progress and technical change to its regress to the Sudanese Sugarcane Schemes by 0.2% and 12.5%, respectively. The results indicated that the Sudanese Sugar Schemes had an annual average increase in TFP of 12.7%. The regression analysis results showed that expenses were negatively and significantly related to TFP.

Keywords: Total factor productivity; Malmquist productivity index; Sugar farms; Sudan

Introduction

The sugar industry in Sudan was established in the early 1960s and currently, it is one of the most important hard currency earners that, contribute substantially to the national economy in terms of investment volume contribution to the total value of the national investment activities. The sugar commodity also, plays a significant role in the national Economy with locally produced sugar filling the gap of the sugar consumption and improving trade balance by refreshing the national economy.

The sugar schemes in Sudan play significant roles in rural community development, and wealth distribution. Data Envelopment Non-parametric analysis (DEA) is a mathematical programming approach for estimating the relative technical efficiency (TE) of production activities [1-4]. The DEA technique permits an assessment of the performance or TE of an existing technology relative to DEA [5]. According to Özpeynirci et al. [6] DEA is a methodology that computes efficiency values for decision making units in a given period by comparing output with input. Therefore, improvements in total factor productivity could occur as a result of either improvement in technical efficiency or improvement in technology. The use of the Malmquist productivity index enables the determination of what portion of sector or firm productivity change was due to each of these two factors. However Domazlicky et al. [7] refers to a technical property of production that examines change in output subsequent to a proportional change in all input (if output changes by same proportion change=constant return to scale, if it is less than that proportional change=decreasing return to scale, if output increase by more than that proportion, there are increasing return to scale (IRS). Decreasing return to scale (DRS) is associated with problem management, it is also known as dis-economies of scale. The objectives of this study were (i) to measure performance changes of the Sudanese sugar industry, (ii) to work out the total factor productivity index for each of the four Sudanese sugar scheme farms and (iii) to determine the efficiency levels for eleven intervals in the period from 1999-2007.

Materials and Methods

The Malmquist index uses a distance function. The advantages of this distance functions is that they allow the description of a multi-input, multi-output production technology without the need to specify a behavioral objective such as cost minimization or profit maximization. Distance function of production technology may be defined using the output set, P(x), which represents the set of all output vectors, (y) which can be produced using the input vector (x) therefore,

$$P(x)=\{y: x \text{ can produce } y\} \quad (1)$$

The output distance function is defined on the output set, P(x), as:

$$d_o(\chi, y) \min \{\delta : (y/\delta)\ \varepsilon\ p(\chi)\} \quad (2)$$

The distance function, $d_o(x,y)$, will take a value which is less than or equal to one if the output vector`, y, is an element of the feasible production set, P(x). Furthermore, the distance function will take a value of unity if y is located on the outer boundary of the feasible production set, and will take a value greater than one if y is located outside the feasible production set.

Malmquist TFP index

It measures the total factor productivity (TFP) change between two data points by calculating the ratio of the distances of each data point relative to a common technology. Following (Fare, Grosskopf et al.) [8] the Malmquist (output-orientated) TFP change index between periods (the base period) and period t is given by

$$m_o(y_s, x_s, y_t, x_t) = \left[\frac{d_o^s(y_t, x_t)}{d_o^s(y_s, x_s)} \times \frac{d_o^t(y_t, x_t)}{d_o^t(y_s, x_s)}\right]^{1/2} \quad (3)$$

Where the notation $d_o s$ (x,y) represents the distance from the

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Received January 14, 2016; **Accepted** February 05, 2016; **Published** February 12, 2016

Citation: Bushara MOA, Abu Sin AMMM (2016) Evaluation of Total Factor Productivity of Sudanese Sugar Company Farms: A Non-parametric Analysis 1999-2007. Arabian J Bus Manag Review 6: 211. doi:10.4172/2223-5833.1000211

period t observation to the period s technology. A value of Mo greater than one will indicate Positive TFP growth from period s to period t, while a value of less than one indicates a TFP decline. Note that equation (3) is, in fact, the geometric mean of two TFP indices: the first is evaluated with respect to period s technology and the second with respect to period t technology.

An equivalent way of writing this productivity, index is

$$m_o\left(y_s,\, x_s,\, y_t,\, x_t\right)=\frac{d_o^{\,t}\left(y_t,x_t\right)}{d_o^{\,s}\left(y_s,x_s\right)}\left[\frac{d_o^{\,s}\left(y_t,x_t\right)}{d_o^{\,t}\left(y_t,x_t\right)}\times\frac{d_o^{\,s}\left(y_s,x_s\right)}{d_o^{\,t}\left(y_s,x_s\right)}\right]^{1/2} \quad (4)$$

where the ratio outside the square brackets measures the change in the output oriented measure of [9] technical efficiency between periods s and t. That is, the efficiency change is equivalent to the ratio of the Farrell technical efficiency in period t to the Farrell technical efficiency in period s. The remaining part of the index in equation (4) is a measure of technical change. It is the geometric mean of the shift in technology between the two periods, evaluated at xt and also at xs, thus the two terms in equation (4) are:

$$\textit{Efficiency change}=\frac{d_o^{\,t}\left(y_t,\, x_t\right)}{d_o^{\,s}\left(y_s,\, x_s\right)} \quad (5)$$

and

$$\textit{Technical change}=\left[\frac{d_o^{\,t}\left(y_t,\, x_t\right)}{d_o^{\,t}\left(y_t,\, x_t\right)}\times\frac{d_o^{\,s}\left(y_s,\, x_s\right)}{d_o^{\,t}\left(y_s,\, x_s\right)}\right]^{1/2} \quad (6)$$

This decomposition is illustrated below where we have depicted a constant return to scale technology involving a single input and a single output. In each period the firm is operating below the technology for that period. Hence there is technical inefficiency in both periods. Using equations (5) and (6) we obtain

$$\textit{Efficiency change}=\frac{y_t\ /\ y_c}{y_s\ /\ y_a} \quad (7)$$

$$\textit{Technical change}=\left[\frac{y_t\ /\ y_b}{Y_s\ /\ y_a}\times\frac{y_s\ /\ y_a}{y_s\ /\ y_b}\right]^{1/2} \quad (8)$$

In an empirical application one must calculate the four distance measures which appear in equation (3) for each firm in each pair of adjacent time periods. This can be done using either mathematical programming or econometric techniques. One issue that must be stressed is that the returns to scale properties of the technology are very important in TFP measurement [10]; used a simple one-input, one-output example to illustrate that a Malmqujst TFP may not correctly measure TFP changes when VRS is assumed for the technology Hence it is important that CRS be imposed upon any technology that is used to estimate distance functions for the calculation of a Malmquist TFP indirectly otherwise the resulting measures may not properly reflect the TFP gains or losses resulting from scale effects.

Following [4,8,11,12] and given that suitable panel data are available; we can calculate the required distances using DEA-like linear programming. For the i-th firm we must calculate four distance functions to measure the TFP change between two periods. This requires the solving of four linear programming (LP) problems. Fare et al. [8] assumed a constant return to scale (CRS) technology in their analysis. The required LPs are:

$[d^t_o(y_t,x_t)]^{-1}=\max_{\phi,\lambda}\phi,$

$St-\phi y_a+y_t\lambda\geq 0,$

$x_a-x_t\,\lambda\geq 0,$

$\lambda\geq 0,$ (9)

$[d^s_o(y_s,x_s)]^{-1}=\max_{\phi,\lambda}\phi,$

$St-\phi y_a+y_s\lambda\geq 0,$

$x_a-x_s\,\lambda\geq 0,$

$\lambda\geq 0,$ (10)

$[d^t_o(y_s,\, x_s)]^{-1}=\max_{\phi,\lambda}\phi,$

$St-\phi y_a+y_a\lambda\geq 0,$

$x_a-x_t\,\lambda\geq 0,$

$\lambda\geq 0,$ (11)

and

$[d^t_o(y_t,\, x_t)]^{-1}=\max_{\phi,\lambda}\phi,$

$St-\phi y_a+y_a\lambda\geq 0,$

$x_a-x_t\,\lambda\geq 0,$

$\lambda\geq 0,$ (12)

However, in LPs 11 and 12 where production points are compared to technologies from different time periods, the parameters need not be greater than or equal to one as it must be when calculating Farrell output-orientated technical efficiencies. The data point could lie above the feasible production set. This will most likely occur in LP (12) where a production point from period t is compared to technology in an earlier period, s. If technical progress has occurred, then a value of Ø<l is possible. Note that it could also possibly occur in LP 11 if technical regress has occurred, but this is less likely.

Some points to keep in mind are that the Øs and √s are likely to take different values in the above four LPs. Furthermore, note that the above four LPs must be solved for each firm in the sample. Thus if there are 20 firms and 2 time periods, 80 LPs must be solved. Note also that as extra time periods are added, one must solve an extra three LP's for each firm (to construct a chained index). If there is T time periods, then (3T-2) LPs must be solved for each firm in the sample. Hence, if there are N firms, Nx (3T-2) LPs need to be solved for example, with N=20 firms and T=10 time periods, this would involve 20x (3x10-2)=560 LPs.

Scale efficiency

The above approach can be extended by decomposing the technical efficiency change into scale efficiency and "pure" technical efficiency components. This requires the solution of two additional LPs (when comparing two production points). These would involve repeating LPs (9) and (10) with the convexity restriction.

Data sources and variables

The time frame of this study was 1999-2008. The data used were annual cost of Sudanese sugar company farms Guneid, New Halfa, Sinnar and Assalaya. The cost had been taken In US$ for 10 years each comprising a panel data of 40 observations at 5-digit level of the international standard of industrial classification (Sic).

Basically the proposed purpose of this study was to look in to the economic performance of Sudanese sugar company farms. In general, they needed the input data capital, labor, expenses, mechanization and water (KLEMW). The information and statistics of Sudanese sugar company farms over year's panel data were not easily available. However, the following sectors of Sudanese Sugar Schemes were the main sources of information and data:-

(i) Agriculture Sector

(ii) Financial Sector

(iii) Computer Unit

(iv) Sudanese Central Bank

(v) Gunied Agriculture Division

The amount of sugar produced annually by each decision making unit (DMU) multiplied by the price to the ton according to Gunied prices as agreed upon by farmers and administration to get the value of out-put, which is divided by the harvested area in each (DMU) to get the value per feddan in United States Dollars. The input cost for all DMU according to the production function is given by:

$y=x_1, x_2, x_3, x_4, x_5$

Where y=Out put, cane tonnage/feddan in US $

x_1=Capital represent total cost in US $/feddan (1 fed.=0.42 ha) of inputs which have a direct influence on cane cost and it consists of urea, phosphorus, herbicide, gasoline, benzene and agricultural equipments as cane cutters and irrigation pipes.

x_2=Labor cost/fed. and includes wages of permanent and seasonal labour.

x_3=Expenses and represents the hired machinery, harvesting cost, agricultural operational cost, land tax, sets, personnel and cane crushing privileges.

x_4=Mechanization cost/fed. And it includes spare parts, oil lubrication, tires, batteries, oxy-acetylene and other consumable materials, wages, (permanent and seasonal jobs).

x_5=Cost of pumped water and it composed of the following electricity, canal maintenance weed control, personal privilege administration cost and Irrigation expenses.

Results and Discussion

The output oriented Malmquist indexes using the DEA like linear programming as proposed by Fare et al. [8]; for all the firms covering the period 1998-2008. The computer software DEAP [1] has been used to compute the indexes of TFP growth that decomposed into indexes of technological change and technical efficiency change (TEC). Indexes of TEC have been further decomposed into pure technical efficiency change (PTEC) and scale efficiency change (SEC). The sample consist of total 4 firms in Sudanese Sugar cane farms namely Guneid, Halfa, Sinnar and Assalaya. This performance relative to best practice or frontier.

Table 1 present the annual average Malmquist index values and their decomposition into technical change and efficiency change for Sudanese Sugarcane farms. If the value of the Malmquist index or any of its components is less than 1, this denotes deterioration in performance and value greater than 1 denotes improvement in performance. Malmquist TFP index of Sudanese Sugarcane farms fluctuated throughout the analysis period except for 2005 is decreasing by 26.2% and the productivity of Sudanese sugarcane farms increased by 62% in 1999. The productivity of Sudanese sugarcane farms increased by 12.8% on average throughout the analysis period. An examination of the components of the Malmquist TFP index for Sudanese Sugarcane farms showed that productivity decrease is mainly attributed to the deterioration in technology mainly in the year (2005-2006). Efficiency of Sudanese Sugarcane farms decreased more than technical change component throughout the analysis period except for the year (2005-2006). Cause of deterioration in efficiency may be determined by analyzing the component of efficiency change index. Pure efficiency change index values are lower than scale efficiency change index values throughout the analysis period. This result showed that lower productivity performance of Sudanese Sugarcane farms are caused by operating in wrong pure efficiency rather than increase in scale (Table 1 and Figure 1). For the whole sample scale efficiency change as a component of TFP as measured by output-oriented was main problem facing this study.

Turning to the firm by-firm results, we note that Sinnar has the highest total factor productivity change in the sample at 15.3% per year on average; almost all is due to technical change (Table 2). The interpretation was that these four sectors experienced out ward shifts in their production frontiers over the period due to technological progress for the whole sample, pure technical efficiency change as component of TFP, as measured by output – oriented Malmquist index, was the main problem facing these firms as revealed by this study, of the changes of pure efficiency were positive (Table 2).

Table 3 explained that three farms out of four run at constant return to scale, Sinnar on the other hand runs at decreasing return to scale, these results showed that output increases by less than that proportional change.

Years	EFFCH	TECHCH	PECH	SECH	TFPCH
1999	1.023	1.591	1.000	1.023	1.629
2000	1.000	1.398	1.000	1.000	1.398
2001	0.998	1.149	1.000	0.998	1.147
2002	1.002	1.152	1.000	1.002	1.154
2003	0.976	1.150	1.000	0.976	1.122
2004	0.996	1.036	1.000	0.996	1.031
2005	1.003	0.736	1.000	1.003	0.738
2006	1.027	0.995	1.000	1.027	1.022
2007	0.999	1.122	1.000	0.999	1.121
Mean	1.002	1.125	1.000	1.002	1.127

Source: (Coelli [1])

Table 1: Malmquist index components summary of annual means of Sudan Sugarcane Schemes (1998-2008) DEAP2-1.

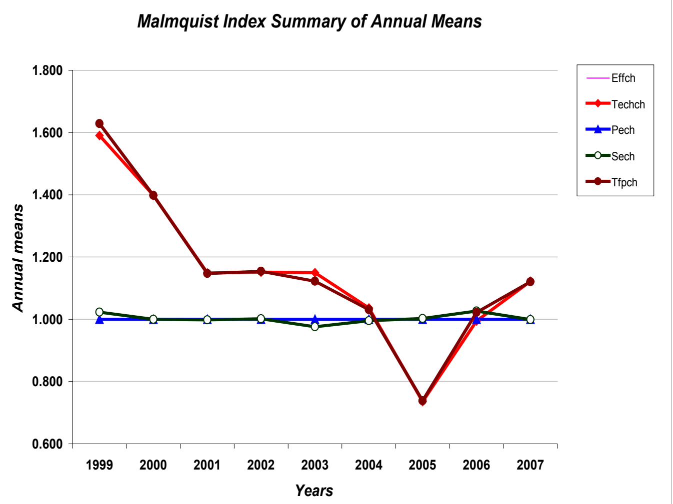

Figure 1: The Malmquist index summary of annual means.

FARM	EFFCH	TECHCH	PECH	SECH	TFPCH
Guneid	1.000	1.112	1.000	1.000	1.112
Halfa	1.000	1.124	1.000	1.000	1.124
Sinnar	1.010	1.141	1.000	1.010	1.153
Assalaya	1.000	1.122	1.000	1.000	1.122
Mean	1.002	1.125	1.000	1.002	1.127

Table 2: Malmquist index summary of firm means of sectors of Sudanese Sugarcane farms (1998-2008) (DEAP 2-1).

Firm	CRSTE	VRSTE	Scale	
Guneid	1.000	1.000	1.000	CRS
Halfa	1.000	1.000	1.000	CRS
Sinnar	0.912	1.000	0.912	DRS
Assalaya	1.000	1.000	1.000	CRS
Mean	0.978	1.000	0.978	

Table 3: Efficiency summary.

CRSTE=technical efficiency from CRS DEA; VRSTE=technical efficiency from VRS DEA; Scale=scale efficiency=crste/vrste

Conclusions

Findings in this study indicated that, the establishment and use of good quality cane significantly reduced processing time and maintenance costs. Cost minimization on some input variables by utilizing other techniques like hydroflom in irrigation, energy extraction, paper manufacturing, animal forage and feed supplements; and co-generation of electricity can add value to this industry.

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