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Abstracts:

The primary aim of this paper to assess the output loss due to inefficient management of Sugar industry in Sudan. An industrial firm is scale inefficient if there is under utilization of production inputs. In this paper we employed nonparametric Data Envelopment Analysis (DEA) to estimate scale efficiency of the major sugar producers in Sudan: Kenana sugar company and Sudan sugar company (SSC) manufacturers: Sennar, Assalaya, New Halfa, and Al-Genied. The finding of the paper indicate Kenana and Al-Genied manufacturers exhibit constant return to scale, whereas the other three sugar manufacturers of SSC: Sennar, Assalaya, and New Halfa exhibit increasing return-to-scale. Increasing return to scale implies inefficient utilization of available input mix. The average output loss due to scale inefficiency for SSC during the periods 2009, 2010, 2011, and 2012 are respectively 6%, 12%, 14%, and 16% of the benchmark company output level of Kenana. This result implies that for SSC company to increase its efficiency level, needs to manage cane production in Assalya, Sennar, and New Halfa projects on commercial basis, as in Al-Genied, by renting the agriculture land with its infrastructure to private firms to produce sugar cane on commercial basis.

Keywords: DEA, Sugar industry, Sudan

1- INTRODUCTION

The efficiency of a manufacturing firm (or a unit) has two components: technical efficiency and allocative efficiency. Technical efficiency (TE) measures the ability of the firm to produce maximal potential output from a given input. Allocative efficiency (AE) measures the ability of the firm to utilize the cost-minimizing input ratios or revenue-maximizing output ratios. A firm needs to be technically efficient in order to be allocatively efficient, and attaining both efficiency levels require economic efficiency (Coelli, 1996). Studies on efficiency measurement decomposed technical efficiency further into pure technical and scale efficiency. Scale efficiency measures the optimality of the firm's size where average and marginal products are equal (Forsund *et al.,* 1980). Scale inefficiency takes two forms- either increasing or decreasing returns to scale. A firm displaying increasing returns to scale (IRS) is too small for its scale of operation. Unit costs decrease as output increase. In contrast, a firm with decreasing returns to scale (DRS) is too large for the volume of activities that it conducts as a result unit costs increase as output increases.

This paper is motivated by the increasing interest in identifying the inefficiency sizes and sources in operating industrial units . Analysis of Sugar industry inefficiency in Sudan at the current time is topical issue, as it matters how to increase the efficiency of sugar manufacturing in the country to compete with regional and international competitors. In the empirical research Data Envelopment Analysis (DEA) is the most common analytical tool to assess efficiency performance of productive units, based on inputs and outputs. In the sugar industry case we may consider the inputs number of labors, machines working hours, irrigated land area, whereas the output can be sugar output, and sugar cane production. DEA can be either input- or output-orientated. The input-orientated DEA method defines the frontier by seeking the maximum possible proportional reduction in input usage, with output levels held constant, for each firm. The output-orientated DEA method seeks the maximum proportional increase in output production with input levels held fixed. The two measures provide the same technical efficiency scores when constant returns to scale (CRS) technology applies, but are unequal when variable returns to scale (VRS) is assumed (Färe *et al.,* 1994).

2- Data:

The data employed in this study includes inputs and outputs for each production unit (a manufacture in our case) during the sample period 2006/2007 – 2011/2012. The inputs include number of labors, machinery working hours, and irrigated area for sugar cane plantation (feddans). The output variables include sugar cane production (tons), and refined sugar output. Table (1) below illustrates productivity analysis during the sample period 2005/06 – 2011/12 for the main major producers of sugar in the country. While there is no significant difference in the extraction rate of refined sugar between producers, however there is a significant difference between SSC and Kenana in the productivity of working machine hours and labor productivity, as the average productivity of Kenana is about four times that of SSC. However, with regard to productivity of Cane production Al-Genied producer out perform all producers in the group including Kenana. This result will be a focal point in our findings of efficiency performance in the coming section.

Table (1): Productivity and extraction rates

producer	Average Productivity per working machine hour	Average productivity per labor	Average productivity per feddan	Average extraction rate
Sennar	20.48	16.18	36.96	0.098
Gunied	17.67	21.02	46.40	0.096
Assalya	20.8	20.8	39.02	0.094
NHalfa	16.39	15.42	37.90	0.092
Average SSC	18.835	18.355	40.07	0.095
Kenana	89.62	80.67	43.5	0.10

3- Methodology:

The DEA models differ according to difference in the shape of the efficient frontier. In this paper we employed two DEA models. We use the CCR (Charnes, Cooper, and Rohdes, 1978), and BCC (Banker, Charnes, and Cooper, 1984). The CCR and BCC models differ as the former evaluates scale as well as technical inefficiencies simultaneously, whereas the latter evaluates pure technical efficiency. In other words, for a DMU to be considered as CCR efficient, it should be both scale and pure technically efficient. For a manufacturing unit to be BCC efficient, it only needs to be pure technically efficient. As a result, the ratio of CCR efficiency score over the BCC score gives the scale efficiency index. The main objective of a DEA study is to project the efficient manufacturing unit onto the most efficient frontiers of the manufacturing units in the sample, under the assumptions of constant return to scale and change in return to scale. There are two directions, input-oriented approach that aims at reducing the input amounts by as much as possible at a given level of output, and the output-oriented, approach that maximizes output levels at a given input level.

In vector notation the input-oriented CCR model, with a real variable θ and a non-negative vector $\lambda = (\lambda_1,..\lambda_n)^T$ of variables can be expressed as:

$$\min \theta \qquad (1)$$

subject to:

$$\theta x_0 - \lambda X \geq 0 \qquad (2)$$

$$y_0 - \lambda Y \leq 0 \qquad (3)$$

$$\lambda \geq 0 \qquad (4)$$

Where y_0 and x_0 are respectively the output and the input levels related to the specific manufacturing unit under investigation, and Y and X are matrices denoting output and input variables. The objective function in equation (1) specify the minimum value of the scalar θ (the ratio of inputs to outputs) that satisfy the constraint in (2) whereas the constraints in equation (3) stipulate the minimization of inputs within a feasible region, and equation (4) imposes non-negativity constraint of the input and output weights.

The linear programming problem stated above has a feasible solution at θ =1, $\lambda_0 = 1$, $\lambda_i = 0$ (i≠0). Hence the optimal θ, denoted by θ^*, is not greater than 1. On the other hand, since X>0, and Y>0, the constraint (4) forces λ to be nonzero because y_0>0. Putting all this together, we have $0 < \theta^* \leq 1$.

The input-oriented BCC model evaluates the efficiency of manufacturing units by adding to the constraints in (2) – (4), the new constraint $e\lambda = 1$, and solving for the minimum objective function in equation (1).

Illustration of the two basic models of technical efficiency measurement, CCR and BCC, can be shown in figure (1).

Figure (1)

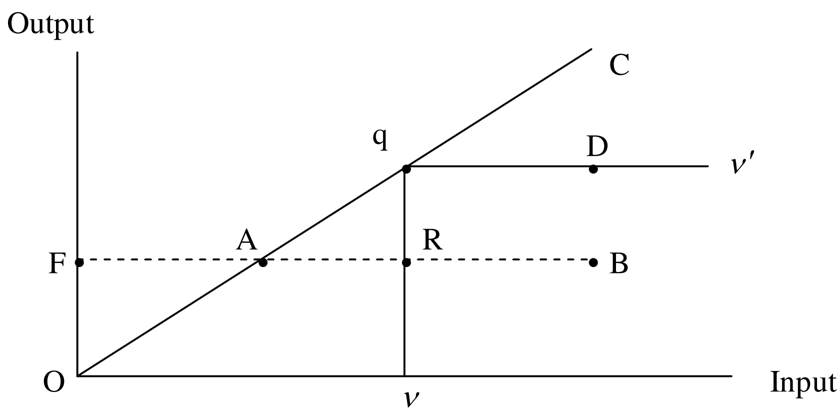


Figure 1, exhibits the units, A, R, B, q, and D each with one output and one input. The efficient frontier of the CCR model is the line (OAC), that passes through the origin. The frontier of the BCC model consists of the lines connecting v, R, q and D. The production possibility set is the area enclosing the frontier lines. At point B, a manufacturing unit is CCR and BCC inefficient. But at point q, a manufacturing unit is CCR and BCC efficient. Generally, the CCR-efficiency does not exceed BCC-efficiency. The inefficiency score of the point B inside the frontier according to CCR model is computed as ratio FA/FB (reflecting how close point B would be to point A, along the radial line OC). Thus, according to CCR model a manufacturing unit should reduce its inputs by $(1-\theta_i)$ in order to be at the efficiency frontier at point A. However, when the BCC model (variable return to scale technology) is taken into account, the overall technical efficiency reveal pure technical efficiency, which is given by the ratio $FR/FB = \sigma_i$, which measures the scope for efficiency improvement at current scale of operation. It is important to note that scale efficiency can be affected by poor management within the organization or disadvantageous operating environment. Thus, scale efficiency which is $\pi_i = \theta_i / \sigma$ measures the extent to which a producer can take advantage of return-to-scale by altering its size towards optimal scale. The fraction of output lost due to scale inefficiency can be computed as $(1-\pi_i)$. Scale efficiency equal one unit at any point along the CCR frontier line OC, at which production technology exhibits constant return to scale. Scale inefficiency can arise due to variable (increasing or decreasing) return to scale. On the other hand, pure technical inefficiency occurs because a manufacturing unit uses more inputs than needed (input waste). Alternatively, pure technical inefficiency can be can be caused by inefficient implementation of the production plan in converting inputs to outputs (managerial inefficiency). However scale inefficiency could be due to divergence of manufacturing unit from the most productive scale size. Therefore decomposing technical efficiency into pure technical and scale efficiencies allows us to gain insight into the main source of inefficiency.

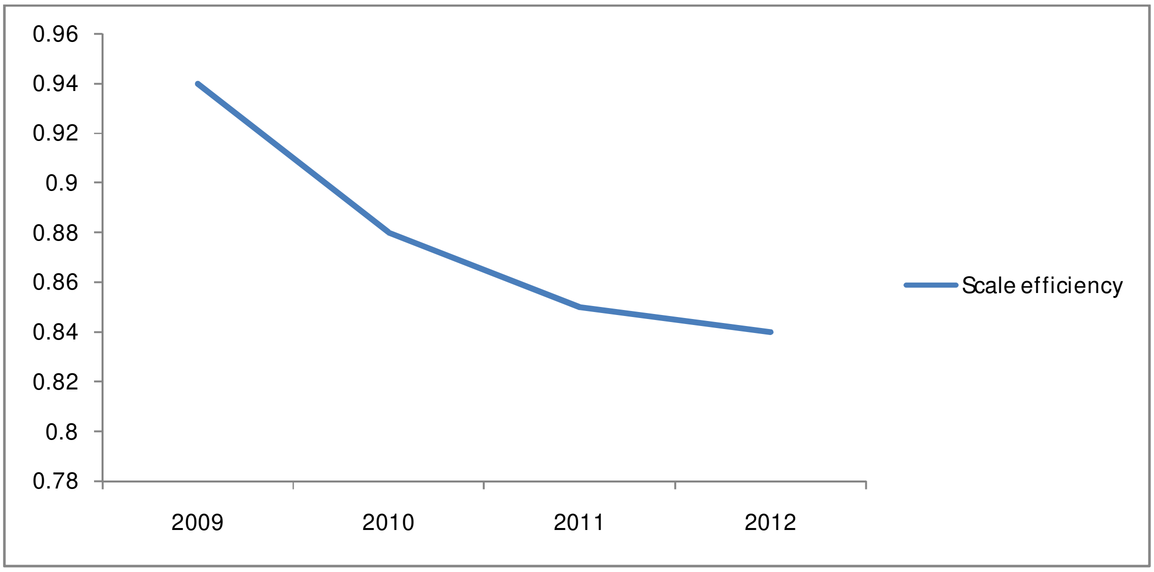
4- Results:

Results in tables (A1-A4) indicate Kenana and Al-Genied manufacturers exhibit constant return to scale (i.e scale efficient), whereas the other three sugar manufacturers of SSC: Sennar, Assalaya, and New Halfa exhibit increasing return-to-scale. Increasing return to scale implies inefficient utilization of available input mix, so that production inputs are not properly utilized. Table (2) indicates that the average output loss due to scale inefficiency for SSC during the periods 2009, 2010, 2011, and 2012 are respectively 6%, 12%, 14%, and 16% of the benchmark company output level of Kenana. This result implies that the increasing output loss due to managerial inefficiency (figure 2) of SSC since 2009 requires urgent need to change the mode of management in the company. It seems controversial that Al-Genied manufacturer, even though under the management of SSC, its technical efficiency level is the same as that of Kenana manufacture. Since sugar cane in Al-Genied manufacture is produced by private farmers, whereas in the other SSC manufactures cane production is produced by the SSC manufactures, then the efficiency difference is due to the difference in the cane production efficiency (higher productivity). As a result, for the inefficient SSC manufactures need to adopt the same model of Al-Genied manufacture by allocating cane production to private sector. This is because even when manufacturing of sugar is efficient, while cane production is inefficient, the overall efficiency of sugar production falls bellow the efficiency level. However, when sugar manufacturing is below the efficiency level, and cane production is efficient, the overall efficiency level rise to higher level. A policy implication of this result is that cane production in the other SSC manufacturers (Assalya, Sennar, and New Halfa) need to be managed on commercial basis by renting the agriculture land with its infrastructure to private firms to produce sugar cane on commercial basis.

Table (2): Output loss

	2012	2011	2010	2009
Sennar	0.22	0.27	0.16	0.11
Gunied	0.00	0.00	0.00	0.00
Assalya	0.16	0.12	0.14	0.06
N.Halfa	0.27	0.19	0.21	0.07
Average SSC	0.16	0.14	0.12	0.06
Kenana	0.00	0.00	0.00	0.00

Figure (2): Scale efficiency of SSC



5- Concluding remarks:

The findings in this paper indicate Kenana and Al-Genied manufactures exhibit constant return to scale (i.e scale efficient), whereas the other three sugar manufacturers of SSC: Sennar, Assalaya, and New Halfa exhibit increasing return-to-scale. Increasing return to scale implies inefficient utilization of available input mix, so that production inputs are not properly utilized. The average output loss due to scale inefficiency for SSC during the periods 2009, 2010, 2011, and 2012 are respectively 6%, 12%, 14%, and 16% of the benchmark company output level of Kenana. This result implies that the increasing output loss due to managerial inefficiency of SSC since 2009 necessitates an urgent need to change the mode of management in the company. Since sugar cane in Al-Genied manufacture is produced by private farmers, whereas in the other SSC manufactures cane production is under SSC management, then the efficiency difference is due to the difference in the cane production efficiency (higher productivity). As a result, the inefficient SSC manufacturers need to adopt the same mode of cane production as in Al-Genied by separating the management of cane production from sugar manufacturing management. A policy implication of this result is that cane production in SSC manufacturers: Assalya, Sennar, and New Halfa, need to be managed on commercial basis by renting the agriculture land with its infrastructure to private firms to produce sugar cane on commercial basis.

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Appendix

Table (A1): Technical efficiency

	CCR	BCC	RTS	Scale efficiency
2012				
Sennar	0.78	1.00	I	0.78
Gunied	1.00	1.00	C	1.00
Assalya	0.82	0.98	I	0.84
N.Halfa	0.73	1.00	I	0.73
Average SSC	0.83	0.99		0.84
Kenana	1.00	1.00	C	1.00
2011				
Sennar	0.73	1.00	I	0.73
Gunied	1.00	1.00	C	1.00
Assalya	0.88	1.00	I	0.88
N.Halfa	0.81	1.00	I	0.81
Average SSC	0.85	1.00		0.85
Kenana	1.00	1.00	C	1.00

Note: I=increasing return to scale; C=constant return to scale
D=decreasing return to scale.

Table (A2): Technical efficiency

	CCR	BCC	RTS	Scale efficiency
2010				
Sennar	0.84	1.00	I	0.84
Gunied	1.00	1.00	I	1.00
Assalya	0.83	0.97	I	0.86
N.Halfa	0.79	1.00	I	0.79
Average SSC	0.86	0.99		0.88
Kenana	1.00	1.00	C	1.00
2009				
Sennar	0.89	1.00	I	0.89
Gunied	1.00	1.00	I	1.00
Assalya	0.89	0.95	I	0.94
N.Halfa	0.88	0.95	I	0.93
Average SSC	0.91	0.97		0.94
Kenana	1.00	1.00	C	1.00

Note: I=increasing return to scale; C=constant return to scale
D=decreasing return to scale.

Table (A3): Technical efficiency

	CCR	BCC	RTS	Scale efficiency
2008				
Sennar	0.79	1.00	I	0.79
Gunied	0.94	1.00	I	0.94
Assalya	0.84	0.94	I	0.90
N.Halfa	0.84	0.90	I	0.94
Average SSC	0.85	0.96		0.89
Kenana	1.00	1.00	C	1.00
2007				
Sennar	0.87	0.99	I	0.88

Gunied	0.93	1.00	I	0.93
Assalya	0.88	1.00	I	0.88
N.Halfa	0.85	0.91	I	0.94
Average SSC	0.88	0.97		0.91
Kenana	1.00	1.00	C	1.00

Note: I=increasing return to scale; C=constant return to scale
D=decreasing return to scale.

Table (A4): Technical efficiency

	CCR	BCC	RTS	Output loss
2006				
Sennar	0.84	0.98	I	0.14
Gunied	0.93	1.00	I	0.07
Assalya	0.89	0.93	I	0.04
N.Halfa	0.83	0.88	I	0.05
Average SSC	0.87	0.94		0.07
Kenana	1.00	1.00	C	0.00
2005				
Sennar	0.84	0.99	I	0.15
Gunied	0.98	1.00	I	0.02
Assalya	0.90	0.92	I	0.02
N.Halfa	0.76	1.00	I	0.24
Average SSC	0.87	0.97		0.10
Kenana	1.00	1.00	C	0.00

Note: I=increasing return to scale; C=constant return to scale
D=decreasing return to scale.