Discussion Paper Series

The KENYA INSTITUTE for PUBLIC POLICY RESEARCH and ANALYSIS

Technical Efficiency of Kenya's Sugar Factories: An Agenda for Enhancing Competitiveness

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Nicholas Waiyaki
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DP/84/2007

THE KENYA INSTITUTE FOR PUBLIC POLICY RESEARCH AND ANALYSIS (KIPPRA)

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Productive Sector Division
Kenya Institute for Public Policy
Research and Analysis

KIPPRA Discussion Paper No. 84
December 2007

The KENYA INSTITUTE for PUBLIC POLICY RESEARCH and ANALYSIS

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Published 2007

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ISBN 9966 777 32 6

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KIPPRA acknowledges generous support from the European Union (EU), the African Capacity Building Foundation (ACBF), the United States Agency for International Development (USAID), the Department for International Development of the United Kingdom (DfID) and the Government of Kenya (GoK).

Abstract

This paper provides estimates of technical efficiency in Kenya sugar factories. It examines factors that affect technical efficiency by applying a stochastic production frontier approach over the period 1996-2005 using firm level panel data. The findings show a mean average efficiency for the sugar factories of 81 per cent. Results on efficiency of individual firms show that Mumias sugar factory is technically efficient while Muhoroni is only 48 per cent efficient. The over-all efficiency level of the firms has improved over time from 75 per cent in 1996 to 83 per cent in 2005. The findings shed some light on the possible sources of inefficiency in the sugar industry. If a firm is publicly owned, its privatization is likely to improve technical efficiency to a great extent. A firm's technical efficiency also tends to be positively related to adoption of appropriate technology. Continued efforts to update technologies and equipment are critical in pursuit of greater technical efficiency in the sugar industry. The findings also indicate that the sugar factories do not enjoy economies of scale (or scope) in production. Based on the findings, the recommendations argue for increased productivity through research, modernization of sugar factories, privatization and expansion of product base.

Abbreviations and Acronyms

ACP	African Caribbean and Pacific
COMESA	Common Market for Eastern and Southern Africa
COLS	Corrected Ordinary Least Squares
DEA	Data Envelopment Analysis
DMUs	Decision Making Units
EAC	East Africa Community
EPA	Economic Partnership Agreement
EU	European Union
FTA	Free Trade Area
FTE	Factory Time Efficiency
GDP	Gross Domestic Product
GoK	Government of Kenya
KESREF	Kenya Sugar Research Foundation
KNTC	Kenya National Trading Corporation
KRA	Kenya Revenue Authority
KSA	Kenya Sugar Authority
KSB	Kenya Sugar Board
OLS	Ordinary Least Squares
SDF	Sugar Development Fund
SFA	Stochastic Frontier Analysis
SONY	South Nyanza
TE	Technical Efficiency
USA	United States of America
WTO	World Trade Organization

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Acknowledgements

We are grateful to KIPPRA research staff for their valuable comments given at KIPPRA inhouse seminars during which the draft paper was presented and discussed. In particular, the paper benefited from useful comments offered by both the discussants and reviewers who included Dr Samuel Mwakubo, Fred Owegi, David Muthaka and Moses Njenga. We are also deeply indebted to Christopher Hugh Onyango and Eliud Moyi for their useful insights and comments on the paper. However, we retain responsibility for any error.

1. Introduction

1.1 Background

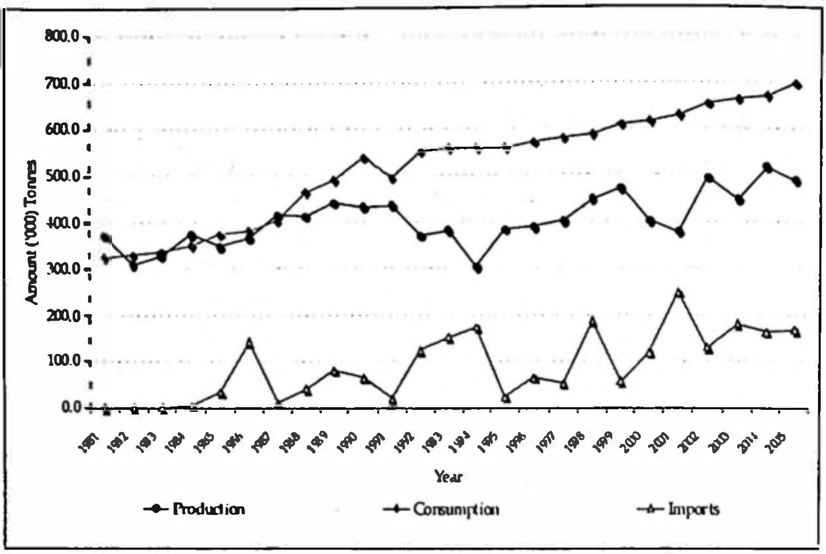
The sugar industry is crucial in the Kenyan economy mainly in terms of employment creation and income generation. Sugarcane directly supports 200,000 smallscale farmers, who supply about 80 per cent of cane milled by the local sugar companies. An estimated six million Kenyans directly or indirectly derive their livelihood out of the sugar industry. Domestic sugar production saves the country about Ksh 20 billion on average in foreign exchange annually (Kenya Sugar Board, 2004).

The development of the sugar industry in Kenya started with private investments at Miwani in 1922. The government has played a central role in the establishment, ownership, management and control of the sugar industry since independence in 1963 with the objective of import substitution, self sufficiency in sugar production, employment creation and poverty reduction. To facilitate effective and efficient development of the sugar industry, Kenya Sugar Authority (KSA) was established in 1973 as a regulatory body in the sugar industry and was thereafter replaced by the Kenya Sugar Board in 2001 (Kenya Sugar Board, 2004).

Despite these investments, sugar factories have not performed well compared to other sugar factories in the world. Average sugar production cost in Kenya between the year 1996 and 2005 was about US$ 420 per tonne and sold at about US$ 580 tonne. Over the same period, the world average production cost was US$ 150 per tonne and sold at an average price of US$ 220 per tonne in the world market. Although opportunities exist for the industry to prosper, the country has not achieved self-sufficiency in sugar as expected, and consumption continues to outstrip supply. Total sugar production grew from 368,970 tonnes in 1981 to 488,100 tonnes in 2005. Domestic sugar consumption increased even faster, rising from 324,054 tonnes to 695,600 tonnes over the same period (Government of Kenya, 2006). Consequently, since 1984, Kenya has remained a net importer of sugar, with imports rising from 4,000 tonnes that year to an all time high of 249,336 tonnes in 2001 (Figure 1.1).

In view of the growing competition in the world sugar market and the high production costs experienced in Kenya, efficiency is an important issue to consider at the farm, factory and marketing levels in an effort to improve sugar industry competitiveness.

Figure 1.1: Sugar production, consumption and imports in Kenya (1981-2005)



One of the most commonly used measures for analyzing performance of firms is labour productivity, but it only gives a partial picture of performance. A different approach taken in the literature in measuring performance of firms has been to estimate production functions in order to assess total productivity. This paper applies a stochastic production frontier approach to estimate firm specific technical efficiency in sugar factories in Kenya over the period 1996 to 2005 using panel data.

The study focuses on sugar processing at the factory level and does not attempt to do a value chain analysis of the sugar sub-sector. However, it is acknowledged that there are critical issues at the farm, transport and marketing level which need to be addressed in the process of improving the sugar industry competitiveness.

1.2 Problem Statement

The Kenya government and private investors have made efforts to invest in the sugar sub-sector with the aim of making the sugar industry competitive, creating employment and generating income. Although great potential exists for sugar cane growing and sugar production in Kenya, domestic demand continues to outstrip supply. As a result, sugar imports have risen from 4,000 tonnes in 1984 to as high as 249, 336 tonnes in 2001. This leads to loss of foreign exchange and lost opportunities for the country in terms of employment and revenue. Consumers have also had to cope with shortages and high prices of sugar, which is an important item in their commodity basket.

Despite the huge investment in sugar factories by both the government and private sector, and the existing great potential for the sugar industry, Kenya's sugar factories have not been able to produce sugar competitively. Companies such as Miwani and Ramisi have closed down while others have continued to operate below designed capacities and produce sugar at a higher than world average production cost.

Due to stiff competition from world market forces, the government has been protecting the sugar sub-sector. However, the European Union (EU) market reforms calls for reduction in production costs of sugar for the African, Caribbean and Pacific (ACP) countries. At the same time, border protection options are being eliminated by regional integration policies. Consequently, sugar from the surplus areas will freely get to deficit and high cost countries such as Kenya. The low priced sugar from the Common Market for Eastern and Southern Africa (COMESA) Free Trade Area (FTA) is a threat to Kenya's sugar industry and economy at large. Protection measures are short term and there is need for a long term solution, which is to make Kenya's sugar competitive globally. Technical efficiency is crucial in ensuring competitiveness of the local sugar factories.

1.3 Objectives of the Study

The objectives of this study are to:

(i) Measure relative technical efficiency in sugar factories

(ii) Examine the factors that influence technical efficiency of the factories

1.4 Justification and Scope of the Study

The world sugar market is becoming increasingly competitive and only efficient sugar producers will be able to survive in the market. Consequently, Kenya sugar is experiencing stiff competition from the world market particularly from African, Caribbean and Pacific (ACP) countries and the COMESA countries. There is, therefore, need to look into ways of enhancing the technical efficiency of the factories with the aim of achieving competitiveness of Kenya's sugar factories.

Improved competitiveness of the sugar industry is important considering its contribution to the Kenyan economy. The sugar sub-sector contributes about seven per cent of agriculture Gross Domestic Product (GDP). It also plays a critical role in poverty alleviation, since about six million people derive their livelihood from the sub-sector and 40, 000 people are directly employed in the industry.

This study specifically seeks to measure the technical efficiency levels in Kenya's sugar factories using panel data for the period 1996-2005. It will also examine factors that affect changes in technical efficiency of sugar firms. The study will mainly focus on operations of six sugar factories, namely: Chemilil, Muhoroni, Mumias, Nzoia, South Nyanza, and West Kenya. Other sugar factories (Miwani, Ramisi, Soin and Busia) are left out due to limited data over the study period.

Findings from the analysis will suggest some measures to make local sugar factories more efficient and competitive in sugar processing. The findings will also contribute in making more informed policy decisions and also add to the existing literature.

2. Overview of Sugar Production

2.1 General Overview

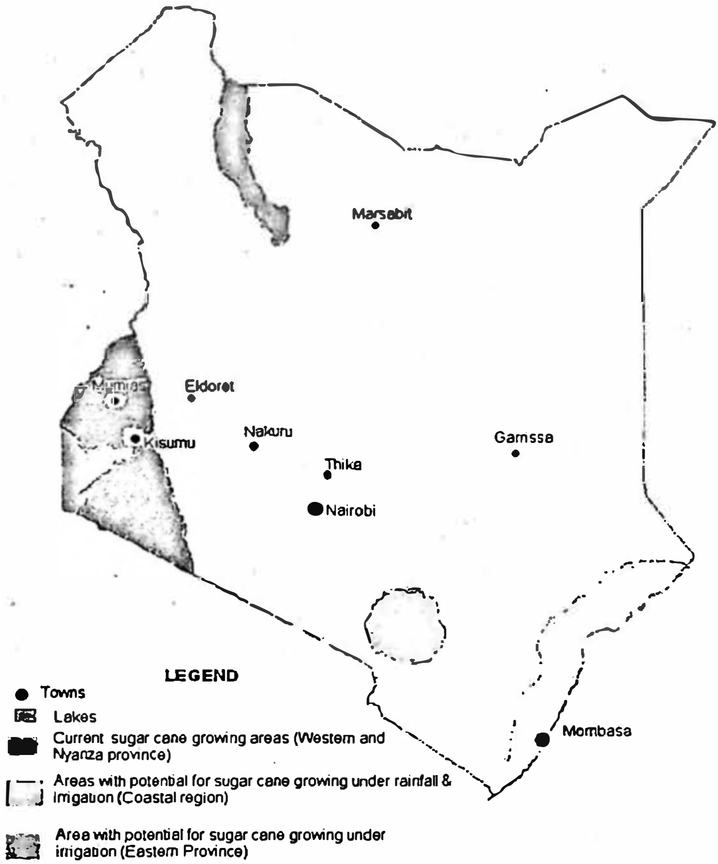
The high cost structure in the sugar industry starts at the farm level and moves up to the market through the whole production process. It is important to enhance efficiency in farming, transportation and marketing if the industry is to prosper and become competitive. Many sugar cane producers are largely small scale farmers who account for about 80 per cent of sugar cane supply and are unable to utilize economies of scale to reduce their production costs. The high cost of inputs, and particularly fertilizer, is a big concern. Other challenges include the cost and distribution of quality seed cane, land preparation, delayed harvesting and late payment to farmers.

Most of the transportation is done by private contractors who use their market power to gain higher rates from the sugar companies. The poor state of rural access roads contributes to high transport charges relative to the cost of production, and range from 20 to 36 per cent of total cost of production. The section of tarmac road is less than two per cent of the total road network while graveled and un-graveled roads make up the 98 per cent balance. At times, sugar factories have had to undertake costly repair of roads within their neighborhood, majority of which are public roads.

Prior to 1992, sugar marketing was centralized under the Kenya National Trading Corporation (KNTC), which procured and distributed sugar in the country. The government was responsible for setting producer and consumer prices but, currently, individual sugar companies are responsible for their marketing strategies. Although there are many other challenges in Kenya's sugar industry, this study focuses on the technical efficiency at firm level.

The first sugar processing plant in Kenya was Miwani Sugar Factory, which was established in 1922 as a private investment and was followed by Ramisi Sugar Company in 1927. After independence, the government established five additional companies at Muhoroni (1966), Chemelil (1968), Mumias (1973), Nzoia (1978), and Sony (1979) as state owned enterprises. In the state owned factories, the government has over 50 per cent shareholding. The latest investments are West Kenya Sugar Company (1981) established by a private investor in Western Province, and an upcoming Soin Sugar Factory in Kericho.

Figure 2.1: Sugar cane growing zones and potential areas in Kenya



The sugar sub-sector is a major enterprise in the Western and Nyanza provinces and is a major source of livelihood in the regions. All the running sugar factories in Kenya are scattered within the western part of the country (Western and Nyanza provinces). However, potential for sugar cane growing exists on some parts of Eastern and Coast provinces. In the warm coastal zone, sugar cane grows even faster both under rainfall and irrigation. Unfortunately, Ramisi, the only sugar factory that was established in Coast Province, closed down. Similarly, although there is potential for sugar cane growing under irrigation in Eastern Province (Kibwezi and Makueni), no effort has been made to exploit this potential.

2.2 Sugar Processing in Kenya

There is generally limited on-farm and off-farm processing of agricultural produce in Kenya and this translates to low income for farmers and fewer jobs for Kenyans. There are compelling reasons for encouraging agro-processing. First, it improves rural incomes by adding value to produce, saves on transport cost and creates opportunities for the use of by-products as inputs in other farm operations such as animal feeds, manure, and fuel. Second, it provides an opportunity for reducing farm losses through the conversion of perishable commodities into more durable products. Third, it would help create jobs in the rural areas, thereby contributing to reduction of both poverty and rural urban migration (Government of Kenya, 2004).

Sugar factories in Kenya require adequate sugar cane as raw material for continuous working at a steady crushing rate. This has been a problem since sugar cane production is undertaken mainly under rain-fed conditions and has led to sugar cane shortages at times. Although irrigated agriculture has been proposed as a remedy to climatic uncertainties, only Chemelil factory has sugar cane grown under irrigation. The factories utilize two sugar-processing technologies to extract the cane juice. The diffusion technology is used at Mumias Sugar Company and milling technology is applied in all the other sugar factories.

An efficient factory should operate for at least 22 hours a day non-stop. However, Kenyan factories do not achieve this mainly due to stoppages occasioned by breakdowns in equipment, lack of cane, congestion in the process house and other operational difficulties. The international standard for Factory Time Efficiency (FTE) is 91.7 per cent. FTE is a measure of the factory's ability to sustain operations against the theoretical available time, excluding stops due to cane supply. The miller must operate efficiently at minimal cost to be competitive. Kenyan sugar factories are operating at high cost compared to efficient sugar producers world wide. They experience sugar loss in their processing and also suffer from low capacity utilization.

Capacity utilization is the factory's actual cane processing rate divided by the designed or rated capacity multiplied by 100. It is closely related to Factory Time Efficiency (FTE), but in addition takes into account the availability of cane and factory through-put. In Kenya, the normal

Table 2.1: Sugar cane to sugar ratio, overall recovery rate, loss and capacity utilization for Kenyan sugar factories

Item	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Sugar cane/ Sugar ratio	10.60	11.00	10.77	9.97	9.54	9.75	9.35	9.66	9.37	9.86
Overall recovery %	72.68	68.08	70.75	77.45	73.39	70.70	80.26	79.21	78.12	79.71
Sugar loss %	27.32	31.92	29.25	22.55	28.66	29.28	20.24	21.40	21.89	20.90
Capacity utilization %	68.40	63.10	66.50	67.10	-	45.71	66.55	53.58	59.73	60.18

Source: Kenya Sugar Board; Yearbook of Sugar Statistics (2005)

Kenya, the normal standard capacity is taken as 85 per cent. However, from Table 2.1, it can be noted that the average capacity utilization over the period 1996-2005 is about 60 per cent. This brings about high cost of production resulting from idle capacity of about 40 per cent.

The high sugar cane/sugar ratio experienced by the sugar factories implies inefficiency and need to be lowered from the current average of ten tonnes of sugar cane to one tonne of sugar to about six tonnes of sugar cane to one tonne of sugar. The factories experience low overall recovery, which refers to the percentage of all the sugar in the cane entering into the mill that ends up in the bag as refined sugar. Kenya sugar factories, with exception of Mumias Sugar Company, do not achieve the standard overall recovery of 82 per cent (Kenya Sugar Authority, 1999).

2.3 Regulatory and Institutional Framework

In order to promote and foster development of the sugar industry, the Kenya Sugar Authority (KSA) was established under an order of the agriculture Act, Cap 318 through legal notice No. 32 of 1973. The initial mandate of KSA was to serve as an advisory body to the Government on sugar industry development. Over time, the government empowered the authority with executive responsibilities on sugar matters. By the time Kenya Sugar Authority was established as an advisory body to the government, all the sugar factories were running effectively.

The Sugar Act of 2001 established the Kenya Sugar Board (KSB) in 2001 to replace KSA with a revised mandate. Unfortunately, by this time, the sugar factories were already in problems, with Ramisi and Miwani out of operation. KSB is the current regulatory body with the mandate to regulate, develop and promote the sugar industry; coordinate activities within the industry; and to facilitate equitable access to benefits and resources of the industry (Kenya Sugar Board, 2004). However, there have been concerns by stakeholders regarding some provisions of the Sugar Act 2001 as it has several shortcomings. As a result, the Sugar Amendment Bill 2006 has been published by the government. The bill proposes extensive amendments to the present legislation. KSB is run by a board empowered by the Sugar Act of 2001 with wide and strong mandate.

The board participates in formulation and implementation of overall policies, plans and programmes. It acts as an intermediary between the industry and the government; facilitates flow of research and extension services; monitors the domestic market; facilitates arbitration of disputes; provides advisory services to growers; facilitates equitable mechanism for pricing; and facilitates export of local sugar. The board also represents the industry in relevant organizations; oversees formulation of standards; licenses sugar millers; manages the industry statistics; promotes and encourages appropriate technology; and promotes efficiency and development of the industry. The government has majority shareholding in most of the local factories. It has the role of negotiating agreements in the World Trade Organization, COMESA and other relevant bodies. It is, therefore, represented in the Kenya Sugar Board by the Ministry of Finance, and Ministry of Agriculture. There are many stakeholders in the sugar industry and thus not all of them are represented in the board.

The Kenya Sugar Research Foundation (KESREF) was inaugurated in 2001 and has the mandate to coordinate research in the sugar industry. It started as a National Sugar Research Station under the Ministry of Agriculture and was later converted into a foundation. Its major role is to liaise with stakeholders in coming up with research priority setting; carry out research on all matters affecting the sugar industry; and transfer technology to farmers. KESREF draws most of its finances from the Sugar Development Fund (SDF), just like the Kenya Sugar Board. Since inception, it has had inconsistent cash inflows and, given the inadequate funds, the foundation has tended to concentrate its research on cane aspects such as diseases, nutrients and cane variety testing. It has not had meaningful research on field and factory mechanization, sugar processing, cane and sugar transport, marketing and economics of sugar trade. These are important aspects of research in the sugar industry and, thus, there is a clear need to increase sugar research funding.

Regulation of the sugar industry is not specifically under one body and this leads to inconsistencies and delays in policy decisions. The ministries of Agriculture, Trade and Industry, East Africa Community, and Finance all have roles to play. Whereas the Ministry of Trade and Industry is key in trade matters, especially in trade negotiations as regards WTO, COMESA and EPAs, the sugar industry regulating body (Kenya Sugar Board) is under the Ministry of Agriculture. At the same time, the Ministry of East Africa Community spearheads EAC negotiations and

Kenya is bound to apply EAC duty rates under the EAC Custom Union. Finally, the Ministry of Finance through the Kenya Revenue Authority (KRA) has the mandate to implement some of the policy decisions mainly concerning issues of import duties. To improve on the policy environment, the Ministry of Agriculture in consultation with other stakeholders is in the process of developing a sessional paper for the sugar industry.

The industry stakeholders include but not limited to: farmers, Government of Kenya, all millers, out growers institutions, Kenya Sugar Research Foundation (KESREF), and interest groups such as Sugar Campaign for Change. Others include farm workers, transporters, exporters, importers, traders, financial institutions and consumers.

2.4 Sugar Production Worldwide

More than 100 countries produce sugar, 76 per cent of which is made from sugar cane and the balance from beet. Prior to 1990, about 40 per cent of sugar was made from beet but this has decreased to 24 per cent as cane sugar producers have made considerable gains in expanding their sugar markets due to lower cost of cane sugar production. About 71 per cent of the world sugar is consumed in the country of origin while the balance is traded on world markets.

Brazil, European Union, India and China are the leading sugar producers and account for about 50 per cent of world sugar. In sub-Saharan Africa, the major producers are South Africa (2.6 million tonnes) and Sudan (0.7 million tonnes). Others are Zimbabwe, Mauritius, and Swaziland with each producing 0.5 million tonnes per year while Kenya ranks sixth with an average production of 0.44 million tonnes (Kenya Sugar Board, 2005). Kenya has to increase its annual sugar production in order to bridge the gap between local demand and supply and also to benefit from desired sugar export trade. However, a bigger challenge for Kenya is on how to produce efficiently to be competitive in the market.

Currently, Kenya's sugar production cost is high compared to other producers. Kenya's local sugar was selling at about US$ 623 per tonne in 1996 and US$ 673 per tonne in 2005, against the world average price of US$ 296 and US$ 276 in the same years, respectively (Kenya Sugar Board, 2005). The ten lowest cost sugar cane producers in the world are

Australia, Brazil, Colombia, Guatemala, Fiji, Malawi, Swaziland, Thailand, Zambia and Zimbabwe (Odek *et al.*, 2003).

Total field cost of sugar production in Kenya is US$ 420 per tonne, while it only costs US$ 168.6 per tonne in Swaziland. In Sudan, the average cost of sugar production is US$ 230 per tonne at Kenana factory and sells at US$ 345 per tonne. The cost of sugar production in Swaziland is one of the lowest in the world. In the year 2005, Swaziland sugar was selling at US$ 265.5 per tonne as compared to average world prices of US$ 275.6 per tone, and US$ 673 per tonne for Kenya in the same year (Table 2.2). This is due to efficient and effective management of Swaziland sugar industry at all levels of production. The average total field cost for the African EU-ACP sugar protocol holders is US$ 197.2 and 314.9 for Caribbean EU-ACP sugar protocol holders (Annex 1). Sugar production cost in Kenya is one of the highest and the world price of sugar has always been below Kenyan cost of production. It is necessary to put in place some measures that will enable Kenya sugar millers to enhance efficiency in their operations so as to be competitive.

Table 2.2: Comparison of Kenya sugar with the world average sugar production and prices

Year	Kenya raw sugar price (US$/ tonne)	World Raw sugar price (US$/ tonne)	World White sugar price (US$/ tonne)	Kenya production in tonnes '000	World production in tonnes '000
1996	623	296	367	389	123,490
1997	604	276	316	402	126,558
1998	618	218	255	449	127,758
1999	535	161	201	471	133,638
2000	560	203	222	402	130,238
2001	595	214	249	377	137,455
2002	495	175	228	494	141,492
2003	534	189	215	448	146,500
2004	556	213	240	517	146,080
2005	673	276	291	489	149,700
Average	579	222	258	444	136,291

Source: Kenya Sugar Board; Year Book of Statistics 2005

3. Literature Review

3.1 Theoretical Literature

Technical efficiency is the ratio of actual output to the maximum output attainable with given amounts of inputs (Coelli *et al.*, 1999). On the other hand, competitiveness is simply the capacity to sell one's products profitably. To be competitive, a firm must be able to undercut the price or offer products of better quality (or with better service) than its competitors. Understanding the capacity to produce profitably and sell is a primary goal of both theory of the firm and trade theory.

A firm strives to maximize profits subject to various constraints that determine the amount it produces and sells, and consequently its competitiveness. Efficiency and profit maximization can be looked at as two sides of the same coin. The definition of economic efficiency also requires a competitive market, since neither the individual production unit nor the sector can attain efficiency if different producers face different prices or if some economic agents can influence prices and returns of other economic agents.

As long as profitable opportunities exist, firms and industries will strive to increase their production and sales. Existence of profits suggests efficiency in a firm and increase in competitiveness. By implication, a firm that maximizes profit also maximizes revenue and minimizes costs. Theory of the firm goes on to explain that to make profits and expand sales, firms must be able to bring unit costs below market determined prices. Technical Efficiency (TE) is a fundamental factor in cost reduction and profitability. Standard trade theory translates these lessons to an international context to identify the cause of world trade.

Technical Efficiency (TE) is a form of productive efficiency and is concerned with the maximization of output for a given set of resource inputs. Productive efficiency is the efficient resource input mix for any given output; the combination that minimizes cost of producing that level of output or equivalently, the combination of inputs that for a given monetary outlay maximizes level of production. The measures of productive efficiency are based on the "best practice" production function proposed by Farrell (1957). Farrell illustrated the idea of TE measurement by a simple example involving firms that use two inputs (x1 and x2) to produce a single output (q). Farrell assumed constant returns to scale and proposed a measure of TE based on an input-saving orientation. In the study, a unit isoquant is defined by describing the minimum combinations of inputs needed to produce a unit of output. Every combination of inputs along the isoquant is considered technically efficient and any points above are technically inefficient.

Technical efficiency is measured as the distance from observed input combination and the best combination point (technically efficient). It takes a value between zero and one in which case a value of one implies that a firm is fully efficient. With an output-increasing orientation, TE is obtained by comparing the observed output with that which could be produced by a fully efficient firm, given the same bundle of inputs. TE measure can also be output-orientated. The input-oriented technical efficiency measures address the question of "by how much can input quantities be proportionally reduced without changing the output quantities produced?" On the other hand, the output oriented technical efficiency is about "by how much can output quantities be proportionally expanded without altering the inputs quantities used?" The output and input oriented measures are equivalent measures of technical efficiency only when constant returns to scale exist.

3.2 Empirical Literature

In literature, there is growing body of research on efficiency measurement methods. Two streams of research can be identified as non-parametric Data Envelopment Analysis (DEA) and Stochastic Frontier Analysis (SFA), which is a derivative of parametric linear regression. Farrell (1957) suggested a deterministic method of measuring technical efficiency of a firm in an industry by estimating a frontier production function. Using data on USA agriculture, Farrell defined cost efficiency and decomposed it into its technical and allocative parts using linear programming techniques rather than econometric methods.

Based on Farrell (1957) model, several procedures have been developed in the literature to estimate technical efficiency. Some of the earliest extension of Farrell's work is by Aigner and Chu (1968), who considered the idea of a deterministic production frontier using a parametric frontier function of Cobb-Douglas form. The most recent of these procedures are the stochastic frontier models developed by Aigner *et al.* (1977), Meeusen and Van den Broeck (1977) and Battese and Corra (1977).

Charnes *et al.* (1978) proposed DEA, which is based on production possibility sets constructed by the observed cases referred to as Decision Making Units (DMUs). The production possibility set is a convex space consisting of all DMUs and their linear combinations in input-output space. The position of each DMU in this space is identified by finding DMU specific input and output weights that maximize the combined output-input ratio for every DMU. This is achieved through linear optimization. Efficiency is measured as the vertical (output orientation) or horizontal (input orientation) euclidian of DMUs to the efficiency frontier. The efficiency frontier is the envelop section of the production possibility set with a non-negative slope. Since the efficiency frontier is constructed only from a few efficient DMUs, it is sensitive to outliers, but very flexible with regard to the frontier's shape. In contrast, stochastic Frontier Analysis (SFA), which is adopted in this study is a parametric approach whereby the production frontier is estimated simultaneously from all cases.

Until 1980, most of the empirical applications in the literature measuring technical efficiency through stochastic frontier production function approach have been in agricultural economics and operational research. One of the early studies in literature is by Pitt and Lee (1982), who analyzed technical efficiency of Indonesian weaving industry using panel data. They estimated a stochastic frontier production function by the method of maximum likelihood and the predicted technical efficiencies were then regressed upon some variables, including size, age and ownership structure of each firm, and were shown to have a significant effect on the degree of technical inefficiency of the firms.

Unlike Pitt and Lee (1982), who used panel data on their analysis, most studies examining efficiency in manufacturing industries by applying stochastic production function approach have used cross-sectional datasets. Cheng and Tang (1987), using data on Taiwanese electronics sector for 1980, and Hill and Harris (1991) are two examples of studies measuring technical efficiency using stochastic production frontier approach with cross-section datasets. Harris (1991) used a frontier production function approach to estimate efficiency in Northern Ireland manufacturing sector for the years 1987-1988 using cross-sectional data from a survey of 140 manufacturing companies. The mean technical efficiency in Northern Ireland was approximately 80 per cent. Futhermore, he also found that foreign-owned firms were more productive than domestic firms and that increasing returns to scale was an important factor in technical efficiency.

Although many empirical studies have investigated the sources of technical inefficiency in different industries using the two-stage analytical method, other studies by Kumbhakar *et al.* (1991), Reifschneider and Stevenson (1991), Huang and Lui (1994), and Battese *et al.* (1996), have questioned the theoretical consistency of the two-stage analytical technique. They have proposed the use of stochastic frontier specifications that incorporate models for the technical inefficiency effects and simultaneously estimate all the parameters involved.

Sheehan (1997), using sample data from annual census of production covering 404 companies, examined technical efficiency in firms in Northern Ireland for the period 1973 to 1985 utilizing a stochastic production function. Results indicated that average technical efficiency increased from 65 per cent in 1973 to 79 per cent in 1985. Moreover, foreign ownership was an important factor in determining average efficiency levels in the manufacturing sector of Northern Ireland.

Lundvall and Battese (1998) applied stochastic production frontier on unbalanced panel data of 235 Kenyan manufacturing firms in food, wood, textile and metal sectors to estimate technical efficiency in relation to size and age of firms. They found that size effect is significant in both the textile and wood sub-sectors, but only age is significant in the textile sub-sector. Pooling data from the four sub-sectors reveals that enterprise size is a significant determinant of efficiency while its age is not. This implies that there are important size efficiency relationships in some sub-sectors, and age efficiency relationship in others. Moreover, technical efficiency under Kenya manufacturing conditions changes over time. The importance of age and size of an enterprise in the progression towards thresholds of best practice suggests that technical efficiency is the result of a learning process, which is also critical for enterprise growth.

Marcos and Galvez (2000), in their study of the Spanish manufacturing industry, applied stochastic production frontier on panel data for 855 Spanish firms in 15 manufacturing sectors to examine technical efficiency for the period 1990 to 1994. Results indicated that Spanish firms were on average 60 per cent efficient. In their study on technical efficiencies of firms in the Indonesian garment industry, Battese *et al* (2001) used stochastic frontier models for firms in five different regions of Indonesia for the period 1990 to 1995 and found that there are substantial efficiency differences among the garment industry firms across the five regions.

Kim *et al* (2005) used a time-varying stochastic frontier model to examine technical efficiency of firms in South Korea iron and steel industry and tried to identify factors contributing to the industry's efficiency growth. Data for 52 iron and steel firms for the period 1978 to 1997 was used. The results showed that if a firm is government-owned, its privatization is likely to improve its technical efficiency to a great extent. According to the results, a firm's technical efficiency tends to be positively related to its production level. Another important source of efficiency growth identified by their empirical findings is adoption of new technologies and equipment. The findings indicate that continued efforts to update technologies and equipment are critical in pursuit of efficiency in iron and steel industry.

Singh (2006) estimated relative efficiencies of individual sugar mills of Uttar Pradesh in India. The study used cross-sectional data for the period 2002-2003 from a sample of 36 sugar mills and applied Data Envelopment Analysis (DEA) to assess efficiencies of individual sugar mills. Research findings from the study show that several sugar mills have been able to make efficient use of their inputs but they suffer from disadvantageous plant sizes. The regression results indicate that net sugar recovery and plant size have a significant positive impact on the overall technical efficiency and scale efficiency.

3.3 Synthesis of Literature

Measurement of technical efficiency borrows heavily from theory of the firm, whereby it is the firm's strategic objective to maximize profits. A firm has to maximize revenue and minimize cost so as to maximize profits. It is noted from the literature that Data Envelopment Analysis (DEA) and Stochastic Frontier Analysis (SFA) are common approaches for estimating technical efficiency. DEA is attractive because it does not require any parametric assumption(s) about the functional relationship between inputs and outputs. However, it suffers from the criticism that it takes no account of the possible influence of measurement errors and other noise in the data (Coelli, 1995).

Stochastic Frontier Analysis (SFA) approach uses econometrics to estimate a stochastic frontier function, and estimates inefficiency component of the error term. The disadvantage of this approach is that it imposes an explicit and possibly restrictive functional form on technology (Coelli, 1995). Despite fundamental differences in their approach, both DEA and SFA provide a single aggregate efficiency measure. However, SFA is chosen for this study because it permits the estimation of determinants of inefficiency, which is a focus of this study.

4. Methodology

The discussion in this section confines its exploration to estimation of technical efficiency under the assumption that producers produce only a single output because they do actually produce a single output or because it is possible to aggregate their multiple output into single output index. Firms are also assumed to be efficient based on profit maximization motive.

4.1 Conceptual Framework

A firm is fully efficient if and only if none of its inputs or outputs can be improved without worsening some of its other inputs or outputs. Modern efficiency measurements begin with Farrell (1957), who drew upon the work of Koopmans (1951) to define a simple measure of firm efficiency, which could account for multiple inputs. Farrell proposed that the efficiency of a firm consists of technical efficiency and allocative (factor price) efficiency.

The concept of technical efficiency entails a comparison between observed and optimal values of output and inputs of a production unit (Sadoulet and Janvry, 1995). The comparison takes the form of the ratio of observed to maximum potential output obtainable from the given input, or the ration of the minimum potential to observed input required to produce the given output, or some combination of the two. Technical efficiency reflects the ability of a firm to obtain maximum output from a given set of inputs, while allocative efficiency reflects the ability of a firm to use inputs in optimal proportions, given their respective prices. Therefore, a productive entity is technically inefficient when, given its use of inputs, it is not producing the maximum output possible or, given its output, it is using more inputs than is necessary. Similarly, a production unit is allocatively inefficient when it is not using the combination of inputs that would minimize the cost of producing a given level of output (Sadoulet and Janvry, 1995). These two measures are then combined to provide overall measure of economic efficiency.

According to Coelli *et al* (1999), productivity refers to the ratio of output(s) that a firm produces to the input(s) and is distinct from technical efficiency. Coelli *et al* (2005) further demonstrate that a technically efficient firm may still be able to improve its productivity by exploiting scale economies. Kim *et al* (2005) defines technical efficiency as the ratio of actual output to the maximum output attainable (often called a frontier) with the given amount of inputs. Firms operate either on the frontier, in which case they are technically efficient, or beneath the frontier, in which case they are technically inefficient. Another concept that is used in empirical studies is the technical change, which involves advances in technology and can be represented by an upward shift in the production frontier or an inward drift on the isoquant map.

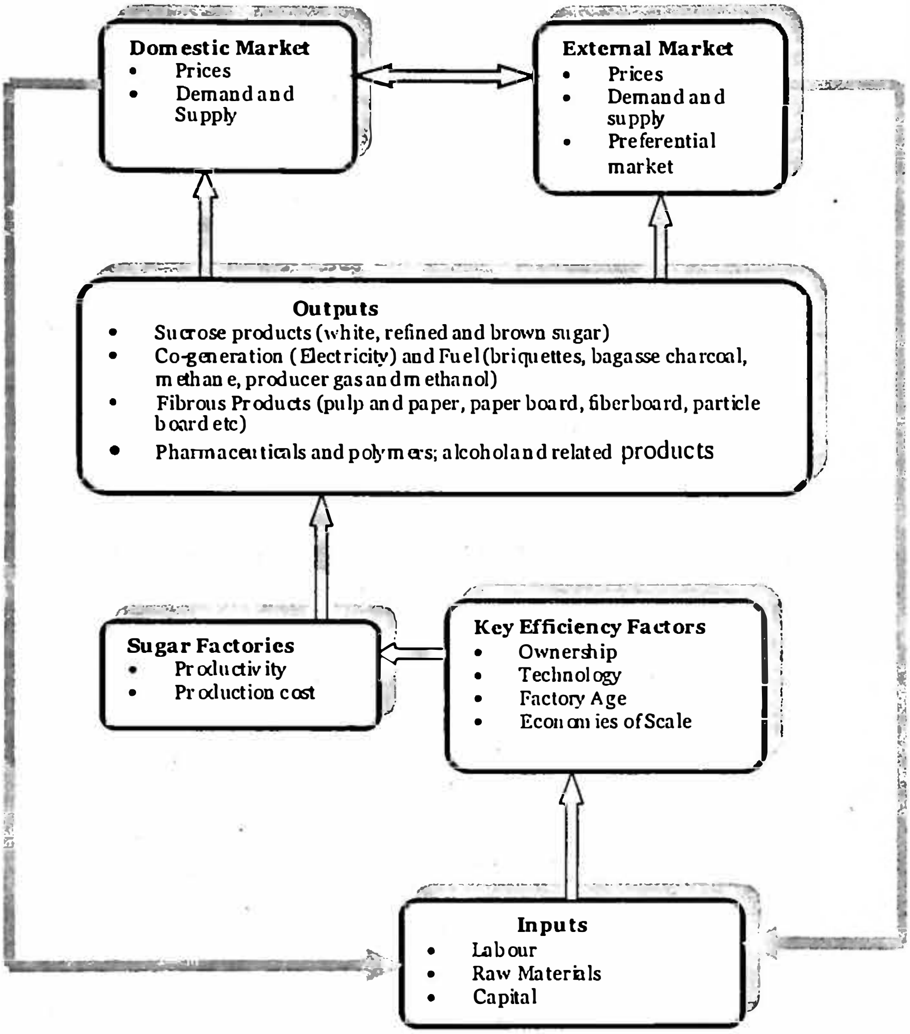
In estimating production functions, it is often wrongly assumed that all producers are technically efficient. However, the pioneering work of Koopmans (1951) provided a definition of technical efficiency suggesting that not all producers were technically efficient. Since then, modelling of production functions take caution that not all firms might be operating efficiently. Thus, there is the alternative approach that starts with the presumption that not all producers are technically efficient and involves the estimation of production functions, which is known as stochastic production frontier analysis (Harris, 1991; Sheehan, 1997; and Marcos and Galvez, 2000). The same approach is adopted for this study.

As reflected in Figure 4.1, the efficiency of the firms is dependent on both production and efficiency factors. The key inputs considered in the study for sugar production are labour, raw material and capital. To achieve maximum output and technical efficiency, firms need to fully utilize the available inputs. Any factory operating below its designed capacity contributes to direct monetary loss as equipment and manpower is kept under-utilized. Ability to fully utilize capital enables the firm realize higher productivity and is also cost saving. The higher the capacity utilization level, the higher the efficiency and productivity.

Labour is an important factor in determining efficiency levels (Mahadevan, 2000). The sugar factories in Kenya utilize both the skilled and unskilled labour. The number of unskilled labour, mainly casual workers, considerably fluctuates and a huge part of the firm's total budget is spent on salaries, this has implications on production costs.

Apart from West Kenya factory, all sugar factories have invested in sugar cane production since their efficiency is dependent on continuous working with a steady crushing rate, which requires smooth supply of raw material. They run small nuclear estates to provide between 20 and 30 per cent of cane requirement, whereas the farmers within their localities provide the rest of cane required.

Figure 4.1: Sugar processing in Kenya



Source: Authors' conceptualization

Beside the inputs, there are efficiency factors that impact on factory performance (Figure 4.1). These include factory ownership, technology, factory age and economies of scale. Ownership is considered to capture effects of privatization on technical efficiency. It can also be used to analyze the impact of local and foreign ownership with the expectation that foreign owned firms tend to be more efficient.

The importance of technological capabilities in promoting manufacturing performance has been emphasized by several analysts (Bell and Pavit, 1993; Lall and Teubal, 1998). It is hypothesized that technological capabilities have a positive impact on technical efficiency. There are two kinds of technologies (mill and diffuser), which are applied by Kenya's sugar factories. Diffusion as compared to mill technology requires less mechanical energy, but uses larger quantities of water and steam. Whereas a mill can be upgraded to crush as much as twice the amount of cane per hour, a diffuser is fairly fixed in its processing capacity.

Inputs in the sugar industry are sourced both from the domestic and external market. By combining various inputs, a sugar factory can have different outputs. Some of these may include sucrose products (sugar), electricity, fuel, fibrous products, pharmaceuticals and polymers. Efforts to improve production efficiency and economic viability in the sugar industry have traditionally focused on maximizing sugar cane yield per hectare of agricultural land and sugar produced per tonne of sugar cane. The challenge for the sugar industry in Kenya is to increase profitability and income for the actors in the sugar sub-sector. This challenge can be partly met through diversification of sugar cane products.

A firm's technical efficiency tends to be positively related to its market share (Kim *et al*, 2005). However, size of the firm has ambiguous effects on efficiency. First, it may be negatively linked to efficiency if large firms experience diseconomies in production due to problems of management and supervision. A positive effect can be predicted on the grounds of scale economies and the availability of financial resources to invest in skills and technologies (Little *et al*, 1987). This study has focused specifically on economies of scale rather than size (Figure 4.1).

Kenya produces about 400, 000 tonnes of raw sugar annually, while average annual consumption of sugar is about 600, 000 tonnes, necessitating importation to meet the demand. Similarly, the high production cost by local millers encourages imports, which pose a threat to the local sugar industry. Sugar import has a negative effect on technical efficiency since it denies the firms benefits of scale economies. Previous studies have found export orientation to improve efficiency at firm level (Cheng and Tang, 1987; Caves and Bartonne, 1990) largely because it exposes firms to international competition. This leaves firms with only one desirable option of being competitive in a liberalized market.

4.2 Analytical Framework

Early studies of technical efficiency were based on deterministic frontier model suggested by Aigner and Chu (1968), but this model cannot account for random factors that may move production off the frontier. Subsequently, various stochastic production frontier models were introduced to take these factors into account. For example, Aigner *et al* (1977) and Meeusen and Van den Broeck (1977) proposed the estimation of a stochastic frontier production function. These models allow for technical inefficiency, while acknowledging that random shocks are beyond the control of producers. In their estimations, noise is accounted for by adding a symmetric error term (u_i) to the non-negative term to provide a simple form of stochastic production frontier as follows:

$$\ln y_i = X_i \hat{a} + v_i - u_i \quad \text{...(1)}$$

Where:

y_i = output of firm i

X_i = column vector of inputs

$\hat{a}$ = vector of unknown parameters to be estimated

v_i = unrestricted error component

u_i = non-negative random variable, which captures production inefficiency.

The total error term, v_i - u_i, has an asymmetric distribution. The v_i random term is assumed to be independent and identically distributed as a normal random variable with mean zero and variance $ó^2_v$.

The stochastic frontier model was first extended to cover panel data by assuming time invariant inefficiency. However, the assumption of time-invariant inefficiency ($u_{it} = u_i$) is restrictive and not appropriate when the data covers a relatively long period of time. For example, technical efficiency of a firm can change as the firm acquires new information and technology over time. Several models of time-varying inefficiency were later introduced to take this possibility into consideration. This is, for example, by Cornwell *et al* (1990), Kumbhakar *et al* (1991), and Battesse and Coelli (1992 and 1995).

This study is based on the model developed by Battesse and Coelli (1995), which allows for firm-specific patterns of efficiency change and specifies inefficiency as in equation 2:

$$u_{it} = z_{it}\,\ddot{a} + \mathring{a}_{it} \quad \text{...} (2)$$

Where z_{it} is a vector of explanatory variables associated with technical inefficiency of firm i at time t. ä is an unknown vector of coefficients to be estimated. $\mathring{a}_{it}$, is unobservable random variables, which are assumed to be normally independent and identically distributed, obtained by truncation of the normal distribution with mean zero and unknown variance $ó^2$ such that u_{it} is non-negative. Since u_{it} is a non-negative random variable, technical efficiencies lie between zero and unity, where unity indicates that a firm is technically inefficient.

Several estimation techniques exist to estimate or calculate the efficiency frontiers. These are mathematical programming techniques or econometric estimation methods. Deterministic parametric methods employ either mathematical programming techniques (Aigner and Chu, 1968) or econometric estimation techniques. Stochastic Frontier production functions employ only econometric techniques. Ordinary Least Squares (OLS) could be used but its estimator of intercept coefficient is biased downwards. A solution to this problem is to correct for the bias in the intercept term using a variant method suggested by Winstonne (1957). The resulting estimator is often known as Corrected Ordinary Least Squares (COLS). A better solution is to make some distributional assumptions concerning the two error terms and estimate the model using the Maximum Likelihood Methods (Coelli *et al*, 2005).

In this study, the stochastic production frontier, using regression techniques (Maximum Likelihood Methods), is employed to estimate technical inefficiency in sugar production at the factory level. Because the Maximum Likelihood Estimators have many desirable large sample (i.e. asymptotic) properties, they are often preferred to other estimators (Coelli *et al*, 2005).

4.3 Data Requirements

Secondary data on six sugar factories (Mumias, Sony, West Kenya, Nzoia, Chemelil and Muhoroni) in Kenya for the period 1996-2005 is used in the analysis. Other factories (Miwani, Ramisi, Soin and Busia) have been left out because of missing data for the study period. The study uses published panel data obtained mainly from the Kenya Sugar Board; yearbooks of statistics, and the Kenya National Bureau of Statistics; and, economics surveys.

The most important advantage of using panel data as opposed to cross section data is that it leads to better efficiency estimates as each producer is observed more than once over a period of time, and it contains more observations. Cross section techniques cannot measure changes, particularly technological changes, that are key determinants of efficiency. Secondly, given that the inefficiency term and residual are unobservable, there are substantive identification issues that need to be addressed. With cross-sectional data, it is not possible to separate the residual from inefficiency without making parametric assumptions about the distribution of the residual and inefficiency term, which is unattractive. With the panel data, it is possible to model time varying inefficiency through the stochastic frontier analysis model. In short, panel data can enrich empirical analysis in ways that may not be possible if we use only cross-section or time series data (Gujarat, 2004)

4.4 Model Specification

The model consists of two equations, production frontier (equation 3) and inefficiency (equation 4). Labour, raw materials and capital are the explanatory variables for production amount (tonnes of sugar) in the stochastic production frontier. The other set of variables explain technical efficiency differences across the factories. The variables are identified from the literature depending on dataset availability. They include factory ownership, technology, age and economies of scale.

$$\ln(pdn_{it}) = \hat{a}_0 + \hat{a}_1 \ln(lab_{it}) + \hat{a}_2 \ln(rawm_{it}) + \hat{a}_3 \ln(cap_{it}) + v_i - u_i \ldots \quad (3)$$

Where:

pdn = output (sugar production in tonnes)

lab = total number of workers in a factory

rawm = raw material inputs (tonnes of sugar cane crushed annually)

cap = capital captured as productive capacity (designed factory capacity)

The inefficiency model as specified by Battese and Coelli (1995) is:

$u_{it}=ä_0+ä_1own_{it}+ä_2tech_{it}+ä_3AGE_{it}+ä_4SCALE_{it}+W_{it}$........................(4)

Where:

own= dummy variable equaling 1 for state owned firm, 0 otherwise

tech= dummy variable equaling 1 for diffuser technology, 0 for mill technology

AGE = age of a factory (in years)

SCALE= firm's production as a share of the total production

W= unobserved random variables

A significant positive coefficient means a positive contribution to increasing inefficiency.

4.5 Variables in the Model

The model has a production equation 3 and inefficiency equation 4 and each is specified with different variables.

4.5.1 Production equation

Production

This is the factory output used in the model as the dependent variable and is measured in tonnes of sugar produced by a factory annually. In technical efficiency, firms will strive to maximize their output intuitively to lower production costs.

Raw materials

This is measured as tonnes of sugar cane crushed per year. A short supply of raw materials contributes to unplanned stoppage time and reduces the factory capacity utilization which, in turn, negatively affects technical efficiency.

Labour

Labour includes both the total number of permanent employees and casual workers in a factory for the particular year. Generally, labour is expected to have a positive impact on technical efficiency.

Capital

This is measured as factory design capacity in tonnes of sugar cane crushed per hour by a factory. Capital is expected to have a significant positive impact on the overall technical efficiency.

4.5.2 Inefficiency equation

Factory ownership

The sugar factories are classified as private if government ownership is less than 50 per cent or public if the private ownership is less than 50 per cent. This is captured by a dummy D equaling 1 for the public sugar factory and 0 otherwise. D is included in equation (4) to capture any effects of privatization on technical efficiency.

Type of processing technology

This is captured by a dummy equaling 1 for diffuser technology and 0 otherwise (mill technology). All the sugar factories in Kenya use the milling technology, except Mumias Sugar Company which uses the diffusion technology. Technology type is expected to positively impact on efficiency.

Age of factory

This is the age of a factory captured to test whether technical efficiency is related to the age of equipment and experience. The variable AGE is defined as the number of years since the inception of the factory. Age of the firm may capture both the elements of equipment age and also some elements of accumulated knowledge through learning by doing. Therefore, the expected sign of Age's coefficient is somewhat ambiguous.

Economies of scale

Scale is measured by firm's production as a share of the total production in all the sugar factories (in percentages). Sugar production may show economies of scale and, therefore, scale is captured to test the existence of economies of scale in the industry. According to Kimuyu (1996), where there are scale economies, large enterprises will be inherently more efficient than smaller ones.

5. Results and Discussion

5.1 Descriptive Statistics

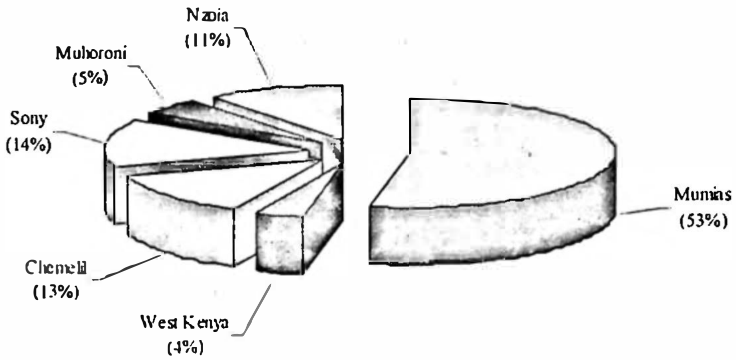
The total number of observations was 60, covering six sugar factories for the ten year period (1996-2005). From the statistics, it is evident that the gap between the highest and lowest local sugar producer is wide. Total production in the year 2005 was 488,997 tonnes compared to 516,803 tonnes in 2004, which is a drop of 5.4 per cent. The maximum value in production is 260,746 tonnes against a minimum of 1,238 tonnes. Labour statistics shows a lowest of 401 persons and maximum of 18,212. Mumias Sugar Company is leading in these two and also in the amount of cane crushed annually.

The total area under sugar cane in 2005 was 144,765 hectares, out of which Mumias region has the largest coverage of 51,296 hectares. It is followed by South Nyanza and Nzoia with 22,970 and 20,319, respectively. Chemilil, Muhoroni and West Kenya zones, each has on average about 13,000 hectare under cane. This has been the scenario over the years and, thus, Mumias has been receiving the highest quantity (about 50%) of sugar cane. In year 2005, Mumias Sugar Company received 2,359,129 tonnes(49%) of sugar cane out of the 4,800,820 total cane delivered to the factories. South Nyanza and Nzoia received 692,777 and 611,249, respectively (Kenya Sugar Board, 2005).

Mumias Sugar Company has been the major sugar producer in Kenya over the years (Figure 5.1). The findings show that the company produces over 50 per cent of local sugar and this can be related to the availability of sugar cane. For example, the company produced 260,746 tonnes (53%) of sugar in 2005, out of the total local production of 488,100 tonnes. The company is more efficient compared to other local sugar companies in the sense that it is able to produce 53 per cent of local sugar after receiving less than 50 per cent of the total sugar cane harvested in 2005. All the other sugar producers in Kenya combined produce less than 50 per cent of the local sugar. Mumias high production is followed by South Nyanza and Chemelil sugar companies with 14 and 13 per cent, respectively (Figure 5.1). South Nyanza Sugar Company is in the process of expanding factory capacity from the current 2,400 TCD (Tonnes of Sugar cane Crushed per Day) to 6,500 TCD in the effort to produce high quantity of sugar efficiently.

The number of employees has kept on fluctuating particularly for Mumias, which had the highest labour force of 18,212 in 1999 and the

Figure 5.1: Factories average share of sugar production



lowest of 2,833 in years 2004 and 2005. This is occasioned by engagement of casual labourers. South Nyanza, Chemilil, Muhoroni and West Kenya Sugar companies have had a relatively stable number of workforce. However, whereas the number of employees at Muhoroni has reduced by half over the ten year period, Nzoia company labour force has been on the rise, making it the company with the highest number of employees in years 2004 and 2005.

5.2 Regression Results

The estimated coefficients of equations (3) and (4) are presented in Table 5.1. The estimated coefficients are statistically significant at 5 per cent significant level except for labour. Raw materials have turned out to be very significant in explaining sugar production. A casual look at the statistics portrays that factories receiving highest quantity of sugar cane lead in sugar production.

The positive coefficient of ownership in the efficiency equation indicates that the sugar factories tend to be less efficient under government ownership than in private ownership. The positive and statistically significant estimate of coefficient for age clearly shows that aged equipment negatively affects efficiency in the sugar factories and that learning by doing (experience) has only limited effect. The estimated coefficient of scale is positive and statistically significant, which reflects that the sugar factories have not shown economies of scale.

The production frontier has two significant factors, which influence production positively. Raw material and capital have turned out to be very important factors in influencing production. The estimated

Table 5.1: Estimation results using stochastic frontier model

	Coefficient (â)	S.E	Z	P>z	(95% confidence)	Interval
Stochastic production frontier						
Pdn						
Rawm	0.6781482	0.0151314	44.82	0.000	0.6484913	0.7078052
Cap	0.4275125	0.035387	12.08	0.000	0.3581553	0.4968696
Lab	0.0005927	0.0127546	0.05	0.963	-0.024406	0.0255912
Lnsig2v						
_cons	-6.471601	0.414599	-15.61	0.000	-7.2842	-5.659002
Inefficiency results						
Lnsig2u						
Own	0.3028832	0.1473872	2.06	0.045	0.0075127	0.5982536
Tech	0.4413334	0.2968744	1.49	0.143	-0.153616	1.036283
Age	0.2684328	0.1164881	2.3	0.025	0.0349854	0.5018801
Scale	0.2727734	0.1059388	2.57	0.013	0.0604673	0.4850796
Cons	-2.757214	0.8913135	-3.09	0.003	-4.543446	-0.970981
Sigma_v	0.0393287	0.0081528			0.0261973	0.0590423
Log likelihood = 39.772644						
Prob > chi2 = 0.0000						

The estimated coefficient of labour is positive but it is statistically insignificant. The poor performance of the labour variable in this model may be due to high level of aggregation. For instance, total number of employees in a factory was captured but combines both the skilled and unskilled labour, thus making it hard to reflect on labour quality. The result shows that labour input is highly under-utilized.

5.3 Sources of Inefficiencies

The regression of the predicted inefficiencies on the inefficiency factors (equation 4) gives statistically significant coefficients at the 5 per cent level as displayed in Table 5.1.

Ownership

Taken at face value, the regression estimates suggest that if a sugar factory is privatized, its production might increase by 30 per cent of its potential output with the same amount of inputs. The results are consistent with the general view that privately held firms are superior to publicly held firms. This is because private firms are motivated to minimize transaction costs, which is good for the firm and for society, while government owned firms or enterprises have a perverse incentive to maximize transaction costs. Private firms take advantage of size but also will recognize that there is a limit to the benefits of size. On the other hand, government owned enterprises have little incentive to recognize that bigger is not always better. The results are consistent with the experience of Mumias sugar factory, which is largely privatized and also in line with the experience of the West Kenya sugar factory, which is a private investment. The two factories have shown a high level of efficiency (Annex 2) over the study period. Among the six factories, the most inefficient are the state-owned.

Age

The age coefficient is positive and statistically significant. The study findings, therefore, indicate that age contributes positively to technical inefficiencies such that old factories are more inefficient. This is consistent with the expectations from theory that if factory age is to capture the element of equipment age, then the older firms cannot be considered to be more efficient than the young ones.

· Older firms could have aged and outdated equipment or even developed inefficient production routines and practices, leading to the negative impact of age on efficiency. Mumias sugar factory is relatively old (32 years) compared to factories such as Sony and Nzoia, which are 26 and 27 seven years old, respectively, but is more efficient probably due to its recent effort to upgrade equipment (Annex 2).

Technology

Adoption of appropriate technologies is identified as an important source of technical efficiency in the empirical findings. Interpreting the technology coefficient at the face value indicates that a shift from diffuser to mill technology would increase production by 44 per cent. This confirms the superiority of the mill technology due to its flexibility in expansion. However, Mumias sugar factory has adopted the diffuser as part of its new technology and has been more efficient compared to all other factories that use mill technology. This is due to the fact that, in the process of adopting the new technology, most of the old equipment in Mumias have been replaced with new ones, which are more efficient. On the other hand, factories such as Muhoroni and Chemilil, which are older than Mumias and use the mill technology are less efficient since they may not have made effort to update the same tcchnology.

The findings indicate that firms using similar technologies can achieve efficiency levels that vary due to some other factors such as technical change. It may be argued that installation of new sugar processing equipment will require a relatively long lead time and additional retrofitting of other equipment, which may initially lead to efficiency losses rather than gains. However, the study findings indicate that efficiency gains from new technologies and equipment tend to outweigh any efficiency losses. Therefore, continued efforts to update technologies and equipment are critical in pursuit of efficiency in the sugar industry. Modernization of factories and especially in terms of adoption of new technologies is costly for most of the Kenya sugar factories as they have been operating at a loss and under huge debts. For instance, modernization would require expansion of factories and more so replacement of old equipment, thus calling for injection of huge resources.

Scale economies

The positive coefficient of scale is due to the fact that it captures the size effects, which can be ambiguous. Specifically in this case, positive coefficient indicates that the sugar factories experience diseconomies in production, meaning they suffer from disadvantageous plant size. This could be due to size effects, which cause problems of management and supervision. The existing evidence from developing countries does not suggest any strong links between efficiency and size in either direction (Little *et al*, 1987).

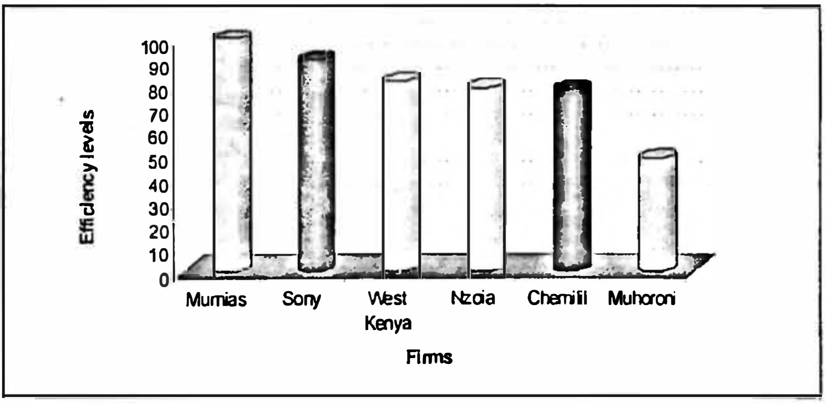
5.4 Efficiency of Individual Firms

The efficiency of the six sugar factories can be evaluated using estimates of technical efficiency based on the frontier model. Figure 5.2 shows the overall firm efficiency levels for all the firms under study.

It can be noted that there are substantial efficiency differences among the sugar factories. The study findings indicate that Mumias is the most efficient sugar processing firm in Kenya, producing at an average of about 100 per cent efficiency as compared to other sugar factories. It is followed by South Nyanza Sugar Company (Sony) and West Kenya, which are producing at an average efficiency level of 90.7 and 81.4 per cent, respectively.

Table 5.2 shows relative average efficiencies and inefficiencies level for all the firms under the study. It can be noted that Mumias, which is privatized and West Kenya, which is a private investment are among the first three most efficient sugar factories. The least

Figure 5.2: Firms relative efficiency levels (1996-2005)



efficient factory is Muhoroni, producing on average around 48 per cent efficiency level. This means that Muhoroni sugar factory can actually improve it production by about 52 per cent without employing any extra resources.

A comparison of the factories performance in the periods 1996 to 1998 and 2003 to 2005 (Table 5.2) indicates that all the sugar factories have reduced their levels of inefficiencies, except for Chemilil. The factory has increased inefficiency level from an average of 18 per cent in the period 1996-1998 to 34 per cent in the period 2003-2005. Generally, this confirms that technical efficiency for the Kenya sugar factories changes over time. Increased efficiency could be attributed to the general improvement in economic performance and the government's effort to improve the management of the sugar factories over time. Government effort to ensure timely payment to farmers, coupled with favourable weather may also have contributed to the increased efficiency. At the same time, there have been efforts to acquire new equipment in some factories.

Mumias sugar factory has been the best all over and has maintained high efficiency levels. Mumias has invested a lot in technology and acquisition of new equipment over time. Nzoia sugar factory has shown the highest improvements in efficiency levels, having reduced inefficiency from 41 per cent to 5 per cent within the two periods possibly due to management change. West Kenya, which is a private investment and the most new among the six firms, has also reduced inefficiency with time from 16 per cent to about 6 per cent over the period. From Annex 4a, it can be noted that, overall, average efficiency for the firms has improved over time from about 75 per cent in 1996 to 83 per cent in 2005.

Table 5.2: Relative inefficiencies and efficiencies levels of sugar firms (1996-2005)

Years	Mumias	Sony	West Kenya	Muhoroni	Nzoia	Chemilil
Overall efficiencies (%)	100.00	90.75	81.47	48.23	78.72	78.27
Overallinefficiencies (%)	0.00	9.25	18.53	51.77	21.28	21.70
Average inefficiencies (%): 1996-1998 and	0.00	9.50	15.91	55.18	41.61	18.49
2003-2005	0.00	5.91	6.10	32.24	5.24	33.54

6 Conclusions and Recommendations

6.1 Conclusions

This paper has explored the technical efficiency levels in the sugar factories in Kenya and the factors that affect these levels using a stochastic production frontier approach over the period 1996-2005 and using panel data. The estimation results of production frontier equation are that raw materials and capital are significant and positive factors in sugar production. The findings shed some light on the possible sources of inefficiency in the sugar industry, which include ownership, technology, age and economies of scales. The findings indicate that these factors are statistically significant in influencing technical efficiency levels.

The mean average inefficiency level for the six sugar factories within the study period is 20.4 per cent. This means that there is a scope for further increasing sugar output by 20.4 per cent without increasing the levels of inputs. Results on efficiency of individual firms show that Mumias sugar factory is the most efficient while Muhoroni is the most inefficient firm, with an average inefficiency level of 51.8 per cent. The overall efficiency level for the firms has improved over time from 75 per cent in 1996 to about 83 per cent in 2005. Mumias sugar factory has turned out to be very efficient because it is only compared with other local firms. It may be important to do an analysis that compares these local firms with foreign sugar factories to see how competitive they are globally.

6.2 Policy Recommendations

Research

There is need to increase local sugar production and supply through increased sugar cane production and productivity. Strengthening of research and adoption of irrigated cane production and improved cane varieties are key issues in the effort to ensure efficiency and competitiveness in sugar production. For instance, there is need to intensify research for early maturing, high yielding, high sucrose content varieties with ratooning ability and developing appropriate low cost irrigation technologies. The sucrose content of sugar cane grown in Kenya is much lower than that found in sugar exporting countries such as Brazil and Sudan. The average yields in tonnes per hectare have gone down since 1996 from 90.86 to 71.46 tonnes in 2005. This declining trend can be seen across all the sugar growing zones and, thus, calls for research on sugar cane varieties and expansion of areas under the crop. Development of low cost irrigation technology is necessary in expansion of sugar production to Tana River delta, Ramisi areas, Nzoia and Nyando, among other areas.

Sugar research need to be extended to field and factory mechanization, sugar processing, cane and sugar transport, and marketing. There is limited use of modern technology, which would increase production at lower cost. Research in sugar industry is being coordinated by the Kenya Sugar Research Foundation (KESREF), which draws most of its finances from the Sugar Development Fund (SDF). The Fund is shared with the Kenya Sugar Board as the sugar apex body and KESREF only gets a small percentage of it. It is necessary to increase KESREF funding to meet the research demands.

Factory modernization

There is an urgent need to modernize and optimize capacities utilization in existing sugar factories. Obsolete factories (e.g. Muhoroni and Miwani) require rehabilitation. This calls for the government to allocate funds on modernization and, where possible, rehabilitation of the state-owned sugar firms. All the sugar factories should regularly update their technologies and equipment for them to remain efficient and competitive. Optimum utilization of these firms requires steady supply of sugar cane and other required raw materials, and prudent labour management. They should undergo a restructuring programme, review staffing norms and competitively source personnel. This is important to ensure that all factories operate either at or near full capacity throughout and in order to reduce incidences of large fluctuations in sugar production.

Privatization

The government should privatize all state-owned sugar factories to inject professionalism in the management and increase efficiency in the sugar industry. Mumias Sugar Company can be looked at as an example of what privatization can achieve in the industry. Part of the shareholding may be transferred to farmers while the rest is sold to interested investors, preferably through the Nairobi Stock Exchange. This could be done after rehabilitation and modernization of the factories. Privatization is one way in which the government is able to mobilize financial resources for use in its core business. Privatization also takes away from government also takes away from government what is not its core function and thus the government is left to do what it does best.

Diversification

The sugar factories need to expand their product base to be more efficient and competitive. The challenge for the sugar industry in Kenya is to increase profitability and income for the actors in the sugar sub-sector. This challenge can be partly met through diversification of sugar cane products. Although sugar processing in Kenya has been costly, the factories may find it profitable venturing into other sugar cane products. Some of the possible co-products that can be profitably produced and marketed include sucrose products (white sugar, refined sugar and brown sugar); electricity (co-generation); fuel (briquettes, bagasse charcoal, methane, producer gas and methanol); fibrous products (pulp and paper, paper board, fiberboard, and particle board); pharmaceuticals; and polymers.

6.3 Suggestions for Further Research

This study is limited to addressing technical efficiency in Kenya's sugar industry at factory level, with the assumption that technical efficiency contributes positively to competitiveness. However, the study acknowledges the importance of efficiency at all other levels of production in an effort to enhance competitiveness. There is need for further research on efficiency at the farm level, transportation and also at marketing level if the sugar industry is to be competitive. Another crucial area of further research is on the cost of sugar production at various levels (farm, transportation, factory and marketing). A better approach will be to undertake a value chain analysis on the entire Kenya sugar industry, emphasizing on cost, efficiency and competitiveness. This calls for an extensive and intensive research with critical comparative analysis of Kenya sugar industry with some of the world best sugar industries.

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Annex

Annex 1: Raw sugar production costs for Kenya, Swaziland and selected regions: Average for 1993 to 1998

Country/Region	Total field cost(US$/tonne)	Total factory cost (US$/tonne)	Total cost including overheads (US$/ tonne)
Swaziland	168.6	77.7	265.5
Africa Sugar Protocol (SP) quota holders	197.2	105.7	340.0
Caribbean SP quota holders	314.9	174.1	537.9
Pacific SP quota holders	181.7	67.9	266.2
ACP SP quota holders	221.6	116.0	374.6
Kenya	420.0	496.2	600.0

Source: Odek, O., Kegode P. and Ochola S. (2003)

Annex 2: Efficiency results

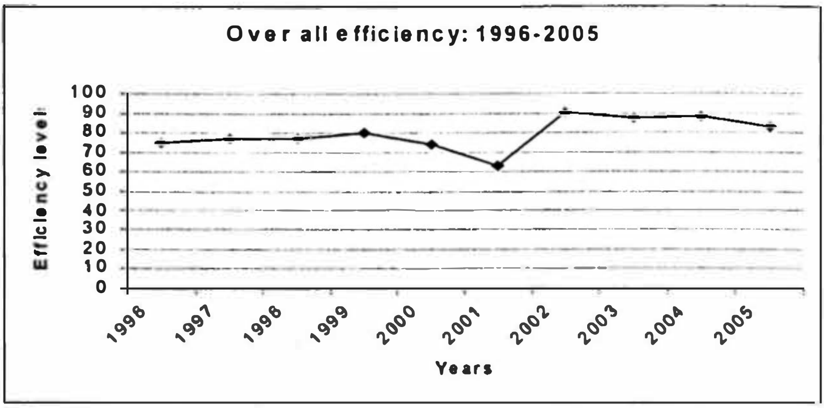
Years	Inefficiencies						Overall efficiency (%)
	Mumias	Sony	West Kenya	Muhoroni	Nzoia	Chemilil	
1996	1.17E-08	0.050117	0.156517	0.482814	0.617909	0.175453	75.30
1997	1.53E-08	0.101282	0.095126	0.667716	0.294131	0.220464	77.02
1998	1.54E-08	0.133605	0.225698	0.504935	0.336302	0.158889	77.34
1999	1.56E-08	0.105308	0.23619	0.47481	0.171665	0.220133	79.86
2000	1.67E-08	0.16773	0.544464	0.617775	0.208728	0.021808	73.99
2001	1.56E-08	0.111865	0.291903	1.258766	0.239369	0.288977	63.49
2002	1.91E-08	0.077999	0.120393	0.202566	0.102819	0.08121	90.25
2003	1.95E-08	0.045994	0.086647	0.192314	0.08264	0.347986	87.41
2004	2.22E-08	0.038785	0.059063	0.363767	0.02005	0.226074	88.20
2005	2.22E-08	0.092614	0.037433	0.411048	0.054575	0.432091	82.87
Over all Ineff.	1.733E-08	0.09253	0.185343	0.517651	0.212819	0.217309	20.43
Over all Eff.	1.000E+00	0.90747	0.814657	0.482349	0.787181	0.782691	79.57

Annex 3: Summary statistics: Production frontier and Inefficiency variables

Variable	Means	Std. Dev	Min	Max	Measurement units
pdn	73018.15	75302.51	1238	260746	Tonnes of sugar produced annually
rawm	26.33333	6.382356	15383	2326353	Tonnes of sugar cane crushed annually
lab	3442.383	4236.122	401	18212	Total number of employees
cap	720212.8	650538.2	34	350	Capital (designed capacity)
age	1051.048	889.8551	15	39	Age of factory in years
scale	141.6227	91.85391	167.1	5169.5	Factory's share of total production in Kenya (%)
own	0.666667	0.475383	0	1	Private ownership: 0 Public ownership: 1
tech	0.166667	0.375823	0	1	Mill technology: 1 Diffuser technology: 0

Annex 4: Efficiency levels

Annex (4a): Over all efficiency over time



Annex (4b): Firm's efficiency over time