AN EMPIRICAL ASSESSMENT OF TECHNICAL EFFICIENCY IN THE KENYA SUGAR INDUSTRY: DATA ENVELOPMENT ANALYSIS (DEA) APPROACH

BY

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X50/10799/2018

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Research Paper Submitted to the School of Economics in Partial Fulfillment of the Requirements for the Award of the Degree of Master of Arts in Economics of the University of Nairobi.

August, 2020

DECLARATION

This research paper is my authentic work and has never been presented for the award of a Master's Degree in any other university**.**

Signed……………………………………… Date…………………………………….

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This paper has been submitted with my approval as the university supervisor

Signed …………………………….. Date………………………………………

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ACKNOWLEDGEMENT

I would like to appreciate my supervisor Professor Kulundu for his support and scholarly advice to make this paper better. His inputs without any doubt improved the quality of this paper. I also acknowledge the University of Nairobi for this opportunity to conduct this research. I acknowledge and thank my fellow MA students who read through the paper and recommended areas for improvement. In addition, I would like to appreciate staffs at the university graduate library, particularly Jack and Martin whose support is highly appreciated.

Finally, I also acknowledge staffs at the Sugar Directorate for providing me with the data and advice that was valuable during data analysis.

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LIST OF ACRONYMS AND ABBREVIATIONS

SSA- Sub-Sahara Africa

GDP- Gross Domestic Product

KALRO- Kenya Agriculture and Livestock Research Organization

AFA- Agricultural Finance Authority

COMESA- Common Markets for Eastern and Southern Africa

TC/HA- Total cane per hectare

SRI- Sugar Research Institute

DEA- Data Envelopment Analysis

SFA- Stochastic Frontier Approach

OTE- Overall Technical Efficiency

PTE- Pure Technical Efficiency

SE- Scale Efficiency

POL%C- Pol percentage of cane

CRS- Constant Returns to Scale

VRS- Variable Returns to Scale

IRS- Increasing Returns to Scale

DRS- Decreasing Returns to Scale

ABSTRACT

The sugar industry in Kenya has been struggling and falls behind competitively produced sugar from COMESA and non-COMESA countries like Brazil. The key challenges facing the industry include high cost of production, low farm productivity, firm inefficiency, sub-optimal firm production, mismanagement, and corruption among others. Using data envelopment analysis (DEA), this study estimated the technical efficiency levels of sugar firms in Kenya. Moreover, this study used panel regression to estimate the factors affecting technical inefficiency in the sugar firms. Data on sugarcane production by all firms from 2009 to 2018 was used. Using variable return to scale (VRS) assumption and output orientation, this study decomposed technical efficiency into pure technical efficiency (PTE) and scale efficiency (SE). This study found an average overall technical efficiency of 84.21%, average pure technical efficiency (PTE) of 89.95%, and scale efficiency of 94.74% in the sugar industry. Private firms had higher efficiency levels than state owned firms but the difference was not significant. Moreover, this study found state ownership, cane quality, labour, and product diversification to have significant effects on inefficiency levels. However, age, skill level, and capital-labour ratio were all insignificant in affecting firm inefficiency levels.

CHAPTER ONE: INTRODUCTION

1.1 Background Information

As other developing countries, the agricultural sector is a significant contributor to Kenya's economy. According to the Economic Survey (2019), Kenya's leading exports are primary agricultural commodities such as tea, horticulture, coffee, and sugar confectionery among others. The Kenya Economic Report (2019) approximates the agricultural sector's contribution to GDP at 31.5%. The agricultural sector not only earns the country foreign exchange as exports but also is a source of employment. It provides employment directly to farmers across the country and indirectly to workers employed in various agricultural processing companies. Moreover, agriculture enhances industrialization through forward and backward linkages by providing raw materials used in other industries and using products from other sectors. Among the agricultural produce, tea and horticulture are the leading export earners. With the huge contribution of agriculture to GDP, enhancing efficiency and productivity in the sector can lead to higher economic growth. Increase in agricultural productivity is closely linked to economic growth.

According to KALRO (2017), agriculture contributed to 1.17% of Kenya's GDP growth between 2010 and 2016. Vision 2030 sets a target of an increase in agricultural output by 7% annually in order to achieve a growth rate of 10% annually. The agricultural sector is the leading source of employment in rural areas with over 80% of the total rural workforce employed in the sector (KALRO, 2017). To achieve an annual increase in agricultural output of 7% set by Vision 2030, it is necessary to increase the efficiency and productivity in all agricultural subsectors.

Sugarcane is classified as a temporary industrial crop in Kenya alongside pyrethrum, cotton, and tobacco. Among the temporary industrial crops, sugarcane is the most produced crop. However, sugarcane production lags behind other agricultural products that are exported like tea and cut flowers. The sugar sector directly affects small scale sugar farmers and indirectly those employed in sugar related industries or those doing small scale and medium businesses in sugar producing areas. Food, Policies, & Fao (2013) approximate that there are 250,000 small-scale farmers in the sugar industry who supply slightly over 92% of the total cane processed at the factories. The nucleus sugar estates owned by the firms supply only 8% of the processed cane.

Currently, the sugar industry is marred with various challenges. Some of the sugar factories have shut down most notably Mumias Sugar. Most of the sugar mills face frequent closures due to high debts and dwindling sugar sales. The government formed a public taskforce to examine the challenges facing the sector and develop recommendations of reforming it. Kenya sugar industry is unable to compete with sugar produced in COMESA countries such as Egypt, Sudan, Malawi, Mauritius, and Zambia. As a result, the industry has been relying on protection from sugar imports produced in the COMESA countries. The lack of competitiveness of the sugar industry can be attributed to various challenges such as inefficiency of the sugar factories and low productivity.

1.3 Structure and Overview of the Sugar Industry in Kenya

Miwani Sugar was the first sugar company established in the country in 1922 in present day Kisumu County. Ramisi Sugar Company was then established in present day Kwale County in 1927 (SRI, 2019). However, most sugar factories were established and managed by the new government after independence. Muhoroni Sugar was set up by the independence government in

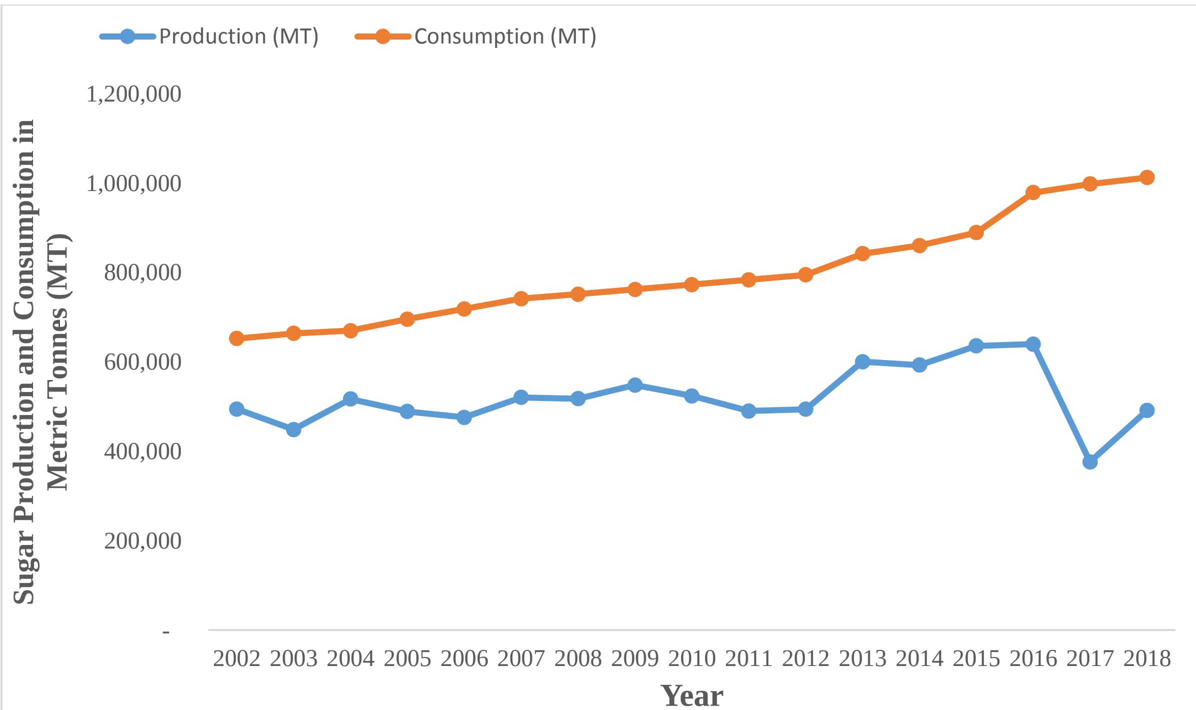
1966, while Chemelil Sugar and Mumias Sugar were established in 1968 and 1973 respectively. Thereafter, Nzoia Sugar was established in 1978 and South Nyanza, commonly known as SONY, in 1979 (SRI, 2019). These sugar factories were majorly government owned. In 1981, West Kenya Sugar Company, a private firm, was established in 1981. More private firms were later established such as Kibos Sugar in 2007, Soin factory in 2006, Butali Sugar Mills (2010), Transmara and Sukari Companies in 2011, and Kwale Sugar in 2015. The most recent entrants are Olepito Sugar Company that began operations in December 2017 and Busia Sugar that was scheduled to begin operations in 2019. According to SRI (2019), though the early sugar companies were government owned, newly established mills have been privately owned.

Sugar is mostly grown in western part of the country. According to the AFA (2018) Year Book, Bungoma County has the highest number of farmers at 68,503, followed by Kakamega (63,356), Migori (23,942), Busia (21,105), and Kisumu (20,896). Other counties where sugar is grown include Nandi, Narok, Kericho, Kwale, Homabay, Trans Nzoia, Uasin Gishu, Kisii, and Siaya. The total estimated number of sugar cane farmers is 249,841 across all sugar-growing areas in the country with 16,647 people employed in the sugar mills (AFA, 2018).

Gichovi (1983) opines that sugar production under the independence government was driven by the self-sufficiency policy. Under this policy, import substitution was encouraged through domestic production to ensure that the country produced enough food for domestic consumption and save foreign exchange. To achieve the self-sufficiency policy, the government directly invested into the industry through the establishment and management of five sugar mills. However, more than fifty years since independence and the establishment of the self-sufficiency policy, it has failed with sugar consumption being way greater than production. Currently, the self-sufficiency policy is manifested in the government protection of domestic sugar mills from cheap sugar from COMESA countries. The Kenyan government has been applying for reprieves from COMESA to bar cheap sugar from these countries to allow it to reform the industry. With the reprieve coming to an end in 2020, time is running out to reform Kenya's sugar industry.

1.4 Performance of the Sugar Sector

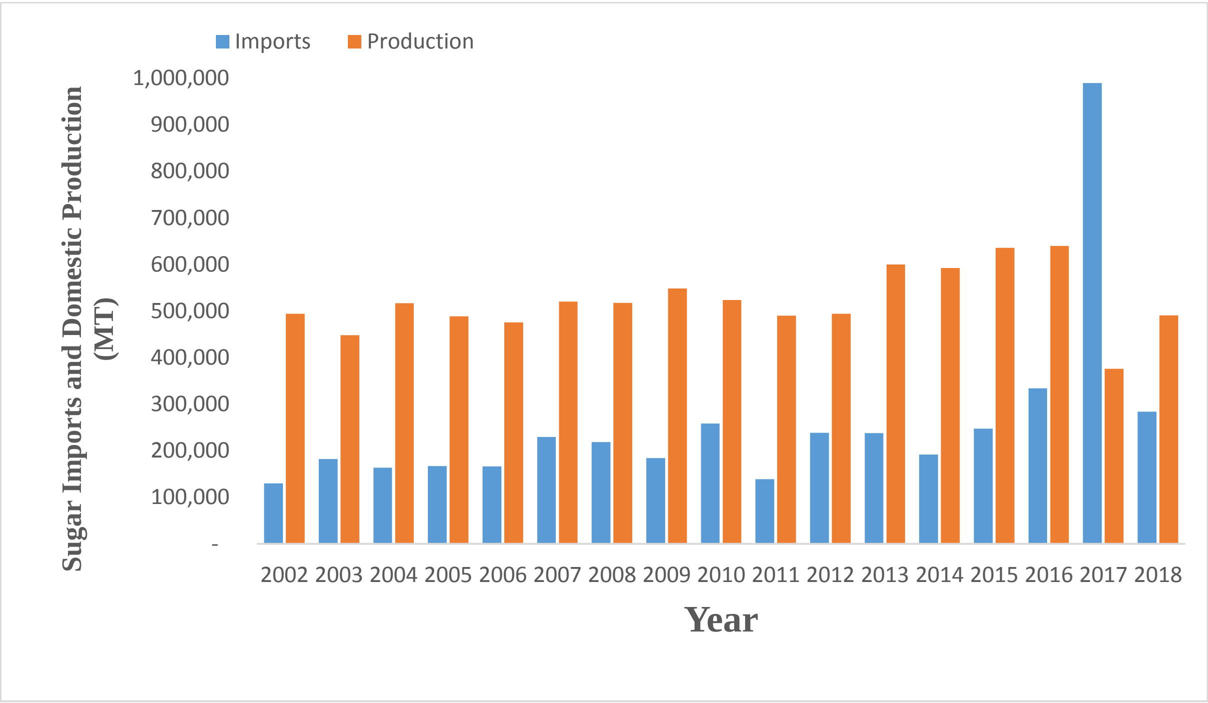
Figure 1: Sugar Production and Consumption (Metric Tonnes), 2002-2018



Source: AFA 2018 Year Book of Sugar Statistics

Figure 1 shows the disparity in sugar consumption and production in Kenya from 2002 to 2018. The figure confirms the failure of the self-sufficiency policy that led to the development of the sugar sector during post-independence. The country is far from meeting domestic sugar consumption which has been steadily rising while production has been fairly constant and declining in some years such as 2017. With sugar consumption unable to keep up with demand, the country has been forced to turn to imports to meet the deficit.

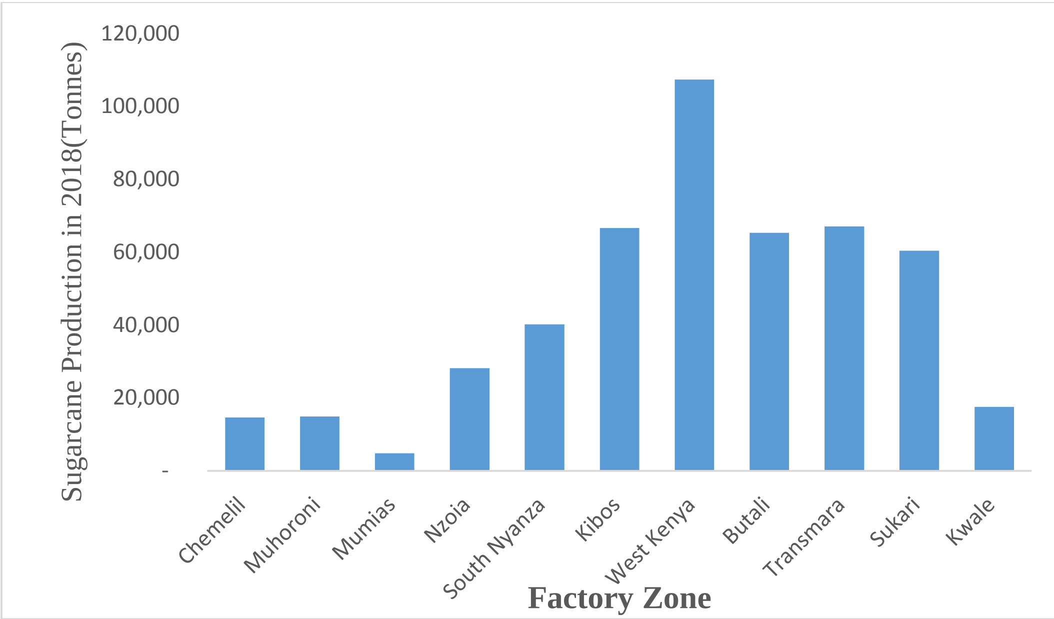
Figure 2: Domestic Sugar Production and Imports (Metric Tonnes), 2002-2018



Source: AFA 2018 Year Book of Sugar Statistics

Figure 2 shows domestic sugar production and imports. Since 2002, sugar imports have been nearly half the domestic production. In 2017, sugar imports were nearly triple the production level, while in 2018 imports were more than half production amounts.

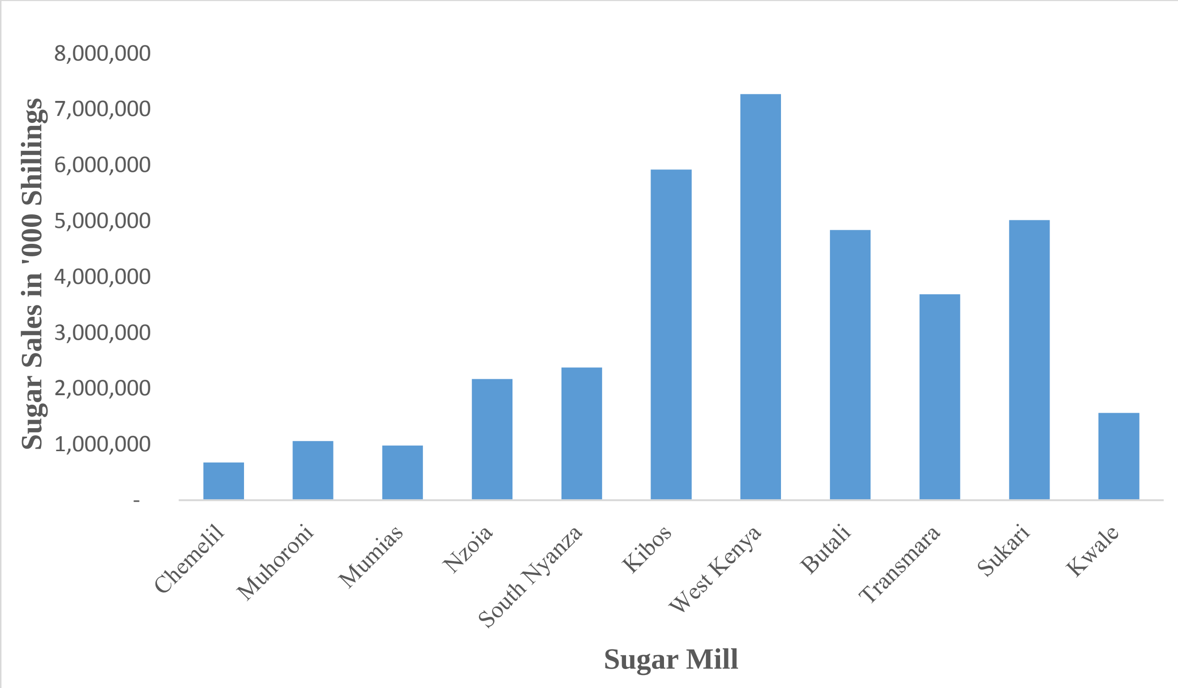
Figure 3: Sugarcane Production per Factory Zone, 2018 (Tonnes)



Source: AFA 2018 Year Book of Sugar Statistics

From figure 3, farmers from private sugar zones produced more sugarcane with West Kenya sugar zone being the highest. Sugar zones belonging to government owned sugar mill such as Chemelil, Muhoroni, and Mumias lagged behind in sugarcane production. The sugarcane production statistics includes sugarcane produced by factory owned nucleus estates and small-scale farmers.

Figure 4: Sugar Sales by All Sugar Mills in 2017/2018



Source: AFA 2018 Year Book of Sugar Statistics

From figure 4 above, private sugar companies like West Kenya, Kibos, Butali, Sukari, and Transmara had higher sales than government owned mills SONY, Nzoia, Muhoroni, Chemelil, and Mumias. Most sugar firms, especially the government owned, are struggling financially riddled with huge debts, low production, and sales, as a result, are frequently out of operations.

1.5 Challenges Facing the Sugar Industry

The low productivity at the farm level is one of the major challenges facing the sugar industry (Njuguna &Kyalo, 2018). When compared to other COMESA countries producing sugar, Kenya's sugarcane yield per hectare is among the lowest. Njuguna & Kyalo (2018) explain that Kenya has average a yield of 66 TC/HA which is considerably lower than South Africa (94 TC/HA), Sudan (100 TC/HA), Malawi (113 TC/HA), and Egypt (126.4 TC/HA). AFA (2018) data reveals even a lower 10-year average from 2009-2018 yield of 59.52 TC/HA. The low productivity of sugarcane in Kenya can be attributed to the low yielding and longer maturity cane variety (CO421) that is still used by many farmers despite other higher yielding varieties introduced by the Sugar Research Institute (SRI). In contrast, other COMESA countries have adopted new cane varieties that are resistant to droughts and diseases, have high sucrose content, and shorter maturity period. The low productivity problem is buttressed by reliance on rainfall. Whereas other countries such as the Mauritius, Malawi, and Sudan have adopted irrigation, majority of sugarcane farmers in Kenya depend on rainfall for production. Kwale Sugar International is currently investing in sub-surface and drip irrigation system. But such investment is capital intensive and requires large scale production to take advantage of economies of scale.

Besides low farm productivity, some sugar factories are inefficient and operate at low productive levels. Inefficient firms usually face a lot of stoppages for maintenance due to the use of outdated machinery and technology. Moreover, inefficiency increases the already high production costs even higher. Inefficiency leading to factory closures cause late harvests that consequently result in a reduction in sucrose content (Odek, Kegode & Ochola, 2003). The reduction in sucrose content due to late harvests causes low firm productivity, and increases production costs due to longer crushing periods to produce the same amount of output as before. Moreover, the current taxation system in the country where all farm inputs are taxed has contributed to higher sugarcane production cost compared than other COMESA countries (Odek, Kegode & Ochola, 2003). According to Njuguna & Kyalo (2018), the average production cost of a tonne of sugarcane in Kenya is $22.5 almost twice compared with $13 per tonne in the COMESA region. As a result, any inefficiencies among the sugar mills increases production costs further resulting in higher sugar prices and consumer welfare loss.

Other problems bedevilling the sugar sector include poor cane husbandry due to inadequate extension officers to help farmers to improve their yields, political interference, mismanagement of the sugar mills, and corruption (Wanyande, 2001). Mismanagement of sugar mills through collision with sugar cartels to create artificial sugar shortages to pave way for sugar importation has adversely affected farmers in the sector (Anti-Corruption Kenya, 2010).

1.6 Statement of the Problem

With Kenya's cane yield per hectare among the lowest compared to other COMESA countries that produce sugar, Kenya sugar firms must ensure high production efficiency levels. The demand of sugar is very high in Kenya with the country still unable to meet the self-sufficiency objective, which was the main purpose of establishing the industry 50 years ago. Inefficiency, particularly operating at low optimal levels, among some sugar mills is one of the causes of low sugar production in the country.

Compared to other sugar producing countries in COMESA, Kenya has a very high average production cost of a tonne of sugar. Production inefficiency increases production costs through longer crushing hours. Besides, inefficiency causes delays in cane crushing that may lower the quality of cane and, therefore, increase the quantity of cane required to produce a specific level of sugar. Increasing efficiency levels can help lower the firms' production costs.

The sugarcane sector is riddled by corruption and gross mismanagement, especially among the state-owned sugar firms. Mismanagement has led to high debt levels, delays in cane payment to farmers and consequently, the closure of some of the sugar mills. Consequently, there is a need for analysing the effects of the level of mismanagement of the sugar firms by examining their managerial efficiency.

Various studies such as (Gicheru, Waiyaki, & Omiti, 2008) and (Irungu, Wambugu & Githuku, 2009) have examined the level of technical efficiency of sugar mills in Kenya. However, these studies failed to estimate the various components of technical efficiency such as pure technical efficiency (PTE) and scale efficiency (SE). Moreover, this study examines how variables like ownership structure, age, sucrose content, product diversification, labour, skill level, and capital-labour ratio affect firms' overall technical inefficiency (OTIE).

1.7 Research Questions

This research paper seeks to answer the two research questions below:

1. What is the level of overall technical efficiency (OTE), pure technical efficiency (PTE), and scale efficiency (SE) of sugar firms in Kenya?
2. What are the determinants of overall technical inefficiency (OTIE) of sugar mills in Kenya?

1.8 Study Objectives

The general objective of this paper is to examine technical efficiency levels in sugar mills in Kenya. The specific objectives are:

1. To estimate OTE (overall technical efficiency), PTE (pure technical efficiency), and SE (scale efficiency) of sugar factories in Kenya.
2. To examine the determinants of overall technical inefficiency (OTIE) levels in the sugar factories.

1.9 Justification of the Study

The study results will help to inform policy formulations and reforms in the industry. For instance, results on OTE can be used to estimate how much the sugar mills can increase their output without extra capital investments in inputs. By decomposing the OTE scores into PTE and SE, this study will illustrate the levels of managerial inefficiency of the firms as well as estimate the scale of operation. In 2019 the government formed a taskforce to develop appropriate reforms with the aim of privatizing five government-owned factories. The study will inform this privatization policy by examining efficiency scores among private and public sugar firms.

CHAPTER TWO: LITERATURE REVIEW

2.0 Literature Review

This chapter reviews theoretical literature that explains firms' objective of maximizing profits by increasing their efficiency levels. This chapter also examines empirical literature of related studies done on technical efficiency in sugar firms. The last section of the chapter is an overview of the literature.

2.1 Theoretical Literature Review

This study's theoretical underpinning is based on the producer theory where firms' objective is to maximize their profits. All the sugar mills aim to maximize their profits by employing a combination of inputs that will produce the maximum possible output subject to their cost constraints. Firms maximize profits if they produce maximum output from their set of inputs, that is, if they are technically efficient. Consequently, this study analyses the overall technical efficiency levels of the sugar firms and decompose it its various components.

Society (2017) defines efficiency of a firm as a means of producing the possible maximum output from a specific set of inputs. A technically efficient firm is one that operates on its production frontier, defined as the highest output a firm can attain from a particular combination of inputs (Coell, Rao, O'Donnell, & Battese, 2005). Firms that operate below the production frontier are not technically efficient. Efficiency is related but not the same as productivity which refers to the ratio of outputs to inputs (Coell, Rao, O'Donnell, & Battese, 2005). A firm that is technically efficient may still increase productivity by taking advantage of scale economies. OTE comprises of PTE, a measure of managerial efficiency or practice and scale efficiency.

2.2 Measurement of Technical Efficiency

The commonly used methods in estimating efficiency are data envelopment analysis (DEA) as well as Stochastic Frontier Analysis (SFA). The former is a linear computer programming method that is non-parametric and uses a pairwise method to compare the efficiency scores of a group of similar entities known as decision making units (DMUs). The level of technical efficiency is estimated using an efficient frontier comprised of Pareto-efficient DMUs. The DEA pair-wise linear frontier estimation was first proposed by Farrell (1957). This method was unknown until Charnes, Cooper, and Rhodes (1978) developed the term DEA. Since then numerous papers have applied the DEA methodology.

The DEA model is divided input and output orientation. In the input approach, the efficient frontier minimizes the inputs given the outputs, while in the output approach the Pareto efficient DMUs maximize output given the inputs. The earlier DEA model applied constant returns to scale (CRS) assumption. Later versions that assumed variable returns to scale (VRS) were developed (Fare, Grosskopf & Logan, 1983); (Banker, Charnes, & Cooper, 1984). The CRS assumption implies that all mills are operating at an optimal scale. In reality, however, due to heterogeneous factors such as financial constraint, government regulations, imperfect competition, firms may not function at the most optimal scale. As a result, the VRS assumption model is commonly applied.

The DEA approach and the SFA have been commonly applied in Economics and other fields to measure technical efficiency. The DEA approach applies linear programming approaches to establish a non-parametric frontier of the data. Efficiency and productivity scores can be estimated relative to the frontier. There have been questions whether firms in the frontier are at the most efficient point or whether they can still increase their efficiency scores. As a result, some authors have recommended the use of non-zero input or output slacks when using DEA to calculate technical efficiency (Coelli, Rao, O'Donnell & Battese, 2005). The SFA method can be applied as an alternative to the DEA. The SFA assumes an appropriate functional form of the association between inputs and outputs. After the appropriate functional form has been identified, econometric techniques are used to estimate the unknown parameters. The SFA method is more demanding and prone to statistical noises if the wrong functional form is chosen. In the SFA model, the output values are enveloped from above by a random (stochastic) variable, hence the name. Another disadvantage of the SFA model is that it does not predict the technical efficiencies of entities producing multiple outputs. The choice of the method used depend on the type of data available, objectives of the research, and the researcher. For this study, the DEA method was preferred.

2.3 Empirical Literature Review

Studies on the factors affecting technical efficiency in the sugar industry have differed depending on the methodology applied. For instance Ali & Jan (2017) used cross-sectional data to examine how technically efficient sugarcane farmers were in three districts of Khyber Pakhtunkwa, Pakistan. The authors interviewed 303 sugarcane farmers in the districts of Mardan, Charsadda, and Dera Ismail Khan during the 2014-2015 growing season. The authors used a stochastic frontier approach and a Cobb-Douglas production function. Using a Maximum Likelihood Estimates (MLE) to estimate the SFA model, the authors found positive and significant effect of land size, seed variety, urea use, DAP use, farmyard manure utilization, irrigation, pesticides, tractor hours, and labour on sugarcane yield. Moreover, sugarcane yield was found to be lower in Districts of Charsadda and Dera Ismail Khan than in Mardan District. The study found technical efficiency levels of the sampled farmers to be between 47% to 98% with an average of 84%. Moreover, the authors found age and experience to have positive impact on technical efficiency, while education has a significant positive effect on inefficiency implying that an increase in a farmer's formal education increased inefficiency or reduced production efficiency. The coefficients of household size, distance between home and farm, and farmers' off- farm employment had negative relations with technical inefficiency but were insignificant.

Using panel data analysis**,** Chirwa (2001) examined the effect of privatization of sugar factories on their technical efficiency levels in Malawi. The panel comprised of six sugar companies between 1970 and 1997. Chirwa (2001) used the DEA approach to estimate the efficiency levels of sugar firms prior and after privatization. The study then used panel regression to estimate how variables like privatization, competition, organizational culture, and policy environment affect firms' technical efficiency levels. The study revealed that the technical efficiency of state-owned enterprises increased after privatization and the difference pre and post privatization was statistically significant. The variation in technical efficiency (TE) due to privatization was 27.4% using CRS assumption and 31.6% when VRS was assumed. Among private enterprises that competed with privatized firms, technical efficiency increased with the difference ranging from 0.3% to 5.4% implying that privatization slightly affected private firms.

Using Stochastic Frontier Approach (SFA), Irungu, Wambugu & Githuku (2009) analysed the efficiency levels in Kenya's sugar production. The study estimated a time varying translog stochastic production frontier using panel data consisting of five sugar factories. The study estimated the technical efficiency of the sugar firms at 79.83% which suggests that the firms were on average operating away from off their efficient frontier by 20.17%. A decreasing return to scale of 0.23 was found in the industry, while technical change seemed to drive the sugar companies at an annual rate of 1.25% from their frontier. Moreover, the study found that factory age, market share, sucrose content, and capital-labour ratio had significant impact on firms' technical inefficiency levels.

Other studies like Ali & Jan (2017) showed that state ownership had a significant negative effect on technical inefficiency under both CRS and VRS assumptions. The results show that firms operating in competitive markets were the most efficient, import competition had no significant effect on efficiency, and capital intensity had a positive significant impact on efficiency scores. The impact of SAPs was positive and statistically significant when CRS assumption was applied. The authors also analysed the impact on technical efficiency using a sub-sample of only privatized firms. There was a strong evidence of the privatization coefficient significantly and positively influencing TE in all the models. Assuming a linear Herfindahl-Hirschman index (HHI), the relationship between TE and market power was found to be negative. However, in a non-linear HHI, the relationship was U shaped, declining to a minimum level then increasing. Import substitution had a negative though insignificant effect on TE, while capital intensity, and foreign ownership (multi-nationality) had positive significant effects on TE. SAPs had a positive significant effect on TE but only when a linear form was assumed.

Some studies analysed efficiency at the farm level but not the factory level. For instance, Oyugi & Lagat (2012) analysed households headed by either male or female farmers in SONY sugar out-grower zone. The study sample area included two districts of Rongo and Trans Mara. The sample consisted of 205 sugarcane farmers from the three study areas. The results found out that women headed farms had higher technical, allocative, and economic efficiency scores than farms managed by men. Using a two limit Tobit model, the study found that belonging to farmers' out-growers association had a significant positive influence on technical, allocative, and economic efficiency scores. Farmers' level of education was found to be significantly but inversely related to their level of allocative and economic efficiency. The availability of credit facilities among farmers was found to positively influence their economic efficiency. Farmers who had access to credit purchased farm inputs in a timely manner and made better management decisions thereby improving productive efficiency. The study also found out that farmers' age was insignificant in influencing all the three types of efficiency; technical, allocative and economic.

While examining the technical efficiency among farmers, Msuya & Ashimogo (2013) compared the efficiency levels of out-grower and non-outgrower sugarcane farmers in Mtibwa Sugar Estate in Morogoro Region, Tanzania. The study used a cross-sectional survey carried out from September and November 2002 and a sample of 140 outgrower and non-outgrower sugarcane farmers. The study utilized a SFA production function proposed by Aigner, Lovell, & Schmidt (1977). The authors found out that the mean technical efficiency was 76.43% for outgrower farmers and 80.65% for non-outgrowers. However, the study did not find any significant difference in the technical efficiency of outgrowers and non-outgrower farmers. The study found education to be negatively and significantly related to inefficiency for both out-grower and non-outgrower meaning farmers with higher education levels are the more efficient. The origin of the farmer (migration) and experience had a negative relationship with inefficiency which implied that migrant farmers and experienced ones were less efficient though the effect of experience was statistically insignificant. The farm area had a significant negative relationship with inefficiency for outgrower farmers which implied that the farmers with large farms were more efficient.

Other studies have investigated the effect of liberalization on both efficiency and productivity of sugar firms. Mulwa, Emrouznejad & Murithi (2009) examined the impact of market reforms on efficiency and productivity in the sugar industry from 1980 to 2000. In 1992, due to liberalization, the role of the market in the industry increased with the entry of private stakeholders. Mulwa, Emrouznejad & Murithi (2009) used both DEA and SFA methods to investigate efficiency in pre and post liberalization for five sugar firms of Muhoroni, Chemelil, Mumias, Nzoia, and Sony. The study included a dummy variable in the regression model to test for any structural change in efficiency scores in pre and post liberalization. The authors did not find any statistical difference in the efficiency scores in pre and post liberalization using both methodologies. Five years before liberalization the firms experienced full technical efficiency but CRS. Prior to 1986, the firms operated at sub-optimal technical efficiency levels but experienced increasing return to scale for five years. Liberalization caused a mixed trend in both technical and scale efficiency levels. According to the authors, efficiency levels declined to the lowest level of 85.4% in 1998. To increase production levels, firms reacted by adopting new technologies in 1997 that led to increasing returns to scale (IRS) for three years until 2000 when the firms achieved full efficiency levels. The mean technical efficiency level was higher before liberalization at 98.1% compared to 93.1% in the post liberalization period. The authors concluded that liberalization had both negative and positive effects the firms manifested in the decline in efficiency levels and the adoption of new processing and packaging technologies. The study found similar results using both DEA and stochastic frontier approach.

Some studies examined the effect of liberalization on a single sugar mill. Mulwa (2001) investigated the effects of structural adjustment programs (SAP) on the technical efficiency of Mumias Sugar Company. The study applied the stochastic frontier approach and assumed a Cobb-Douglas production function to model the processing function of Mumias Sugar Company. Furthermore, the author introduced a structural dummy variable to the stochastic production function. The study used time-series data from 1980 to 2000. The results showed that the dummy variable was insignificant meaning the SAPs did not have a significant effect on sugar production. The technical efficiency of the firm prior to the SAPs was 88.431% and slightly increased to 89.633% in the SAPs period, hence there was no significant change in the two periods. Cane accounted for much of sugar output. Among the variables, only cane and fuel experienced increasing marginal returns, while chemicals, power, and capital experienced diminishing marginal returns.

2.4 Overview of Literature

The theoretical literature elaborates the various component of technical efficiency which comprise of PTE and SE. Efficiency may be defined as a firm's ability to maximize its output from a given combination of inputs (Society, 2017). Overall technical efficiency (OTE) shows how much a firm can scale up its output without an increase in inputs. Pure technical efficiency (PTE) estimates how efficient the management is in converting inputs into outputs. Scale efficiency (SE) provides a measure of whether the firm is functioning in an optimal or sub-optimal scale. Efficient firms produce more output and enjoy scale economies, lower production costs, higher revenues and profits as opposed to inefficient firms.

From the empirical literature, previous studies have estimated technical efficiency of sugar firms in Kenya using either DEA or SFP method. For instance, Gicheru, Waiyaki, Omiti (2007) analysed technical efficiency in the sugar manufacturing sector as a method of enhancing the industry's competitiveness. Irungu, Wambugu & Githuku (2009) using the SFP method found a average technical efficiency of 79.83% in the sugar industry, while Mulwa, Emrouznejad & Murithi (2009) found an average technical efficiency of five sugar mills to be 98.1% before liberalization of the industry and 93.1% after liberalization. This study improves the frontier of knowledge on this topic by estimating overall technical efficiency of the sugar firms and decomposing it to both PTE and SE. Moreover, this study examines how variables such as factory age, cane quality, labour, skill, product diversification, ownership structure, and capital-labour affect technical inefficiency. This study will help inform policy debates on privatization of the state-owned firms as a means of improving their efficiency.

CHAPTER THREE: METHODOLOGY

3.0 Theoretical Framework

This study will employ the DEA approach, proposed by Farrell (1957), to calculate Overall technical efficiency (OTE) and break it down to PTE and SE. The DEA, as explained earlier, is a non-parametric method that applies a pairwise approach to compare decision making units (DMU) to an efficient frontier or envelopment surface. DEA can be expressed intuitively through a ratio form of all outputs to all inputs.

Assuming N inputs and M outputs for j firms. For the i-th firm, let x_j represent column vector of inputs, and qj and column vector for output. N×1 input matrix, X, and M×1 output matrix, Q, represent production data for all *j* firms, u is M×1 vector of output weights and v is N×1 vector of input weights. DEA solves the mathematical programming challenge by finding the values of u and v that maximizes the efficiency scores of the *i*-th firm subject to the constraint that efficiency scores must be less than or equal to one.

$$\text{Maximize (u v) } \frac{u^T q_i}{v^T x_i}$$

$$\text{Subject to} \qquad \frac{u^T q_j}{v^T x_j} \leq 1 \qquad (1)$$

$$j = 1, \ldots.., n \qquad u, v \geq 0$$

Where "T" represents matrix transpose operator.

3.1 Technical Efficiency Estimation and Decomposition

The DEA model established by the Charnes, Cooper, and Rhodes (1978) was input oriented and assumed CRS. Fare, Grosskopf, & Logan (1983); Banker, Charnes, and Cooper (1984) later proposed VRS models. The CRS model allocates weights to all inputs and outputs then calculates the efficiency level of each DMU (firm) by obtaining the ratio of aggregate weighted output to total weighted inputs.

3.1.1 Overall Technical Efficiency (OTE)

The maximization problem specified in equation one has infinite solutions. A constraint $u^T q_i = 1$ is introduced. The maximization problem is transformed to equation two below:

Minimize (u v) $v^T x_i$

st $u^T q_i = 1,$

$$u^T q_j - v^T x_j \leq 0 \qquad (2)$$

$j = 1, \ldots\ldots, n \qquad u, v \geq 0$

The problem in equation (2) can be written as:

Maximize (θ_i , λ) θ_i

st θ_i , $q_i \leq \lambda^T Q$ (3)

$$X_i \geq \lambda^T X$$

$$\lambda \geq 0$$

Where λ is a (n $\times$ 1) column vector while θ_i is a scalar. The solution to equation three gives the technical efficiency in constant returns to scale approach (TE_{CRS}) if $\theta^*{}_i \geq 1$, otherwise the DMU is inefficient.

3.1.2 Pure Technical Efficiency

Equation 3 gives the TE when the firms are functioning at the most optimal scale. In reality, this is not always the case due to imperfect competition, different financial constraints, managerial decisions, and government regulations among others. The VRS model will then be calculated using the below equation by introducing a convexity problem to equation 3:

Maximize $(\theta_i, \lambda)\ \theta_i$

$$\text{st } \theta_i,\ q_i \leq \lambda^T Q + e^T \lambda \qquad (4)$$

$$X_i \geq \lambda^T X$$

$$\lambda \geq 0$$

Where e is a $(n \times 1)$ column vector of ones. The solution to equation 4 (θ_i^{**}), gives the pure technical efficiency (PTE), which can be denoted as TE_{VRS}.

3.1.3 Scale Efficiency

Scale efficiency is obtained by calculating the ratio of overall technical efficiency (OTE) and pure technical efficiency (PTE) as follows:

$$SE = \frac{TE_{CRS}}{TE_{VRS}} = \frac{OTE}{PTE} \qquad (5)$$

Scale inefficiency may be due to a firm's decision to operate in sub-optimal scale that is, increasing returns to scale (IRS) or a decreasing return to scale (DRS). However, the objective of the firm is to always operate in the most productive scale size which is the CRS. To determine the type of returns to scale, this study will apply methods suggested by Zhu (2003). If e is a $(n \times 1)$ column vector of ones and λ^* is a $(n \times 1)$ vector consisting of the optimum value of intensity variable λ of all the sugar firms in the industry, then Zhu (2003) proposed that:

$e^T \lambda^* = 1$ Constant returns-to-scale (CRS) is experienced.

$e^T \lambda^* < 1$ Increasing returns-to-scale (IRS) is experienced

$e^T \lambda^* > 1$ Decreasing returns-to-scale is experienced

3.2 Diagnostic Tests

To test for any significant statistical difference in the OTE, PTE, and SE levels between state-owned and private firms, the Student's t-test and the Analysis of Variance (ANOVA) will be used. The Wooldridge test will be used to test for serial autocorrelation, while the White's test will be used to test for heteroskedasticity. This study will apply Hausman's test to choose the most appropriate estimator between the fixed effects and random effects.

3.3 Model Specification

Variation of (in)efficiency among the sugar firms might be explained by various factors such an environmental, nature of ownership, level of technology, and other organizational factors. This study will apply panel regression to establish factors that influence technical inefficiency among sugar factories. A panel regression model explains the variation of the dependent variable due to either the fixed (unobserved effects) or the random (time varying effects). This study will apply either the fixed effects (FE) or random effects (RE) estimators. The fixed effects model assumes that time invariant features or characteristics that are unique to each entity may bias the predictor or dependent variables, hence should be controlled for (Wooldridge, 2016). This model assumes that there is correlation between error term of individual entities and the explanatory variables. The random effects model assumes that there is random variation across the entities, which are uncorrelated with the predictor variables applied in the model (Green, 2008). As a result, the random effects allow for the inclusion of time invariant variables that are controlled for in the fixed effects model.

The panel regression is specified as follows:

$$1 - OTE_{it} = \beta_0 + \beta_1 D1_i + \beta_2 D2_i + \beta_3 AGE_{it} + \beta_4 POL\%C_{it} + \beta_5 Labour_{it} + \beta_6 SKILL_{it} + \beta_6 \frac{K}{L}_{it} + \beta_7 ProdDV_{it} + a_i + \mu_{it} \quad (7)$$

Where D1 and D2 represent two dummies for ownership structure D1 (1 for private firm and 0 otherwise) and D2 (1 for publicly owned firm and 0 otherwise). The variable (AGE) refers to the age of the firm as at beginning of the study period (2009). POL%C is a variable for cane quality measured by pol percentage of cane. Labour refers to all workers employed in each firm in a year. The skill variable represents the ratio of skilled employees to the total number of workers in a firm (Ghosh &Neogi, 1993; Kumar, 2003, Kumar &Arora, 2007). It represents the availability of trained human manpower at the factories including supervisors, administrative, and managerial staff. (K/L) is a measure of capital intensity given by the ratio of capital to labour. It shows the degree of mechanization of the production process. The variable (ProdDV) is a measure of whether a firm has diversified into the production of other products rather than sugar such as ethanol and electricity. The capital intensity will be calculated by dividing the company's actual capacity by the total number of employees, a_i is unobserved firm effect or the firm fixed effects, μ_{it} is the idiosyncratic error term, *i* represents different time factories, while t is the time period of study 2009-2018 (t=10).

The study hypothesizes that the effect of the dummy for ownership both for private and state-owned firms can either be positive or negative. Age variable can also have either a positive or negative impact on OTIE. The variables skill, pol percentage of cane, labour, product diversification, and capital intensity are hypothesized to have a negative impact on inefficiency level.

3.4 Study Sample and Period

The study sample consists of twelve sugar firms that include;

1. Kibos Sugar Company
2. South Nyanza Sugar Company (SONY)
3. Mumias Sugar Company
4. West Sugar Company
5. Sukari Industries Limited
6. Transmara Sugar Company
7. Butali Sugar Company
8. Muhoroni Sugar Company
9. Chemelil Sugar Company
10. Nzoia Sugar Company
11. Soin Sugar
12. Kwale International

The study period is ten years from 2009 to 2018.

3.5 Definition of Variables

Table 1: Definition of Variables

Variable	Type	Description and Expected Sign
Sugar Produced	Output	Total metric tonnes (MT) of sugar produced annually.
Cane crushed	Input	Metric tonnes of cane crushed annually.
Actual capacity	Input	Used as a proxy to machinery and equipment. Measured in tonnes of cane crushed per hour
Labour	Input	Total number of employees in a given year
D1	Independent variable	Dummy for private owned mills. (+/-)
D2	Independent variable	Dummy for public sugar firms. (+/-)
Age	Independent variable	The firm age of the mills as at 2009. (+/-)
Pol%C (cane quality)	Independent variable	Sugar quality variable represented by pol% of cane. (-)
Product Diversification (ProdDV)	Independent variable	Dummy variable for organizations engaging in the production of other products other than sugar such as ethanol and electricity. (+/-)
SKILL	Independent variable	Skill level of employees in a factory measured by the ratio of skilled employees to the total number of workers in each firm. (-)
K/L	Independent variable	Capital intensity variable of the firms measured by the ratio of capital to the total number of workers. (-)

3.6 Data sources

All the data used were collected from the Sugar Directorate Year Books of Sugar Statistics published from 2009 to 2018. The data obtained included inputs used in sugar production as well as sugar produced for twelve sugar firms used in the study sample. The panel used was unbalanced because some sugar firms began operations after 2009, which was the beginning of the study period. The Sugar Directorate publishes all data on production of sugar as well as the performance of all firms in the sector. Additional information was obtained from the Economic Surveys published from 2009 to 2018, while information on the different products manufactured by the various companies was collected from the companies' websites.

CHAPTER FOUR: RESULTS

4.0: DEA Efficiency Results

Table two below shows the ten-year average of OTE, PTE, and SE levels of all sugar firms estimated using DEA output method and VRS assumption.

Table 2: Ten Year Average of OTE, PTE and SE in Sugar Firms in Kenya

Factory	**Ownership Structure**	**Overall Technical Efficiency (OTE)**	**Pure Technical Efficiency (PTE)**	**Scale Efficiency (SE)**	**RETURN TO SCALE**
Muhoroni	State-owned	69.58%	69.95%	99.47%	Increasing Return to Scale (IRS)
Sony	State-owned	86.90%	92.95%	93.50%	Decreasing Return to Scale (DRS)
Mumias	State-owned	97.80%	100.00%	97.80%	Decreasing Return to Scale (DRS)
Nzoia	State-owned	82.14%	89.29%	91.99%	Decreasing Return to Scale (DRS)
Chemelil	State-owned	63.95%	64.59%	99.01%	Increasing Return to Scale (IRS)
Kibos	Private	100.00%	100.00%	100.00%	-
West Kenya	Private	99.76%	100.00%	99.76%	Decreasing Return to Scale (DRS)
Butali	Private	100.00%	100.00%	100.00%	-
Transmara	Private	100.00%	100.00%	100.00%	-
Sukari	Private	84.11%	84.71%	99.30%	Increasing Return to Scale (IRS)
Kwale Sugar	Private	76.28%	77.96%	97.85%	Increasing Return to Scale (IRS)
Soin	Private	58.22%	100.00%	58.22%	Increasing Return to Scale (IRS)

Source: Author's calculations. For Butali, Sukari, and Transmara firms seven-year average was calculated since these firms began operations in 2011. Soin Sugar seized operations in 2015, hence six-year average was obtained. Kwale operations began operations in 2016, therefore, a three-year average was calculated.

This study decomposed efficiency levels into OTE, PTE, and SE using DEA output orientation and variable return to scale (VRS) approach. Three firms that are privately owned, Kibos, Butali, and Transmara, were found to be operating in the efficiency frontier. On average, a technical efficiency level of 84.20% exists in the sugar industry, with private firms being more technically efficient than the state-owned firms by 8.26%. Therefore, an increase in technical efficiency by 8.26% can be credited to privatization although this is lower than 31.6% that Chirwa (2001), attributed to privatization among sugar factories in Malawi However, using both Student's t-test and ANOVA the difference in OTE among private and publicly-owned firms was found to be insignificant, consistent with other studies such as Balcilar & Cokgezen (2001). This study's average technical efficiency results is higher than the average level of 79.83% found by Irungu, Wambugu & Githuku (2009) but lower than 93.1% that Mulwa, Emrouznejad & Murithi (2009) found as the average technical efficiency score of five sugar firms after the liberalization of the industry

PTE can be used as a measure of managerial efficiency. There is an average PTE of 89.01% in the sugar industry. Publicly-owned firms had an average PTE of 83.35% compared to private firms that had an average of 94.67%. Private firms have 11.32% higher PTE than state-owned firms, although this difference was not significant. State-owned firms have a higher average SE level of 96.35% compared to private firms at 93.59%. This difference was also not statistically significant.

This study found that whereas some firms are experiencing DRS, some are still experiencing IRS. Five firms namely Muhoroni, Chemelil, Sukari Limited, Kwale Sugar, and Soin Sugar are experiencing IRS meaning they are yet to reach their maximum efficiency levels. SONY, Mumias, Nzoia, and West Sugar are experiencing DRS, hence have possibly attained their maximum efficiency levels.

4.1: Diagnostic Tests

Table 3: Hausman Test for Fixed and Random Effects Models

	Coefficients			
Independent Variables	**(b)**	**(B)**	**(b-B)**	**sqrt(diag(V_b-V_B))**
	Fixed Effects Model	**Random Effects Model**	**Difference**	**Standard Errors**
Dummy for State Ownership (Ds)	0.128947	0.126064	0.002883	0.013914
Age	0.001001	0.001063	-0.000062	0.000346
POL% of Cane (Cane quality)	-0.076480	-0.075223	-0.001256	0.006344
SKILL	0.021035	0.024314	-0.003279	0.034640
Labour	-0.000028	-0.000026	-0.000002	0.000004
Capital-Labour Ratio	-0.622708	-0.583934	-0.038774	0.186217
Product Diversification	-0.063318	-0.064150	0.000832	0.015974

Legend: Table above is used to measure consistency of the fixed effects and random effects estimators. The null hypothesis is that there is no systematic difference in the coefficients.

Prob>chi2 = 0.9998

The Hausman test was used to determine which between the fixed effects (FE) and random effects (RE) estimator is the most suitable. The null hypothesis (H0) is that RE is the most preferred while the alternative hypothesis (HA) is that the FE estimator is the most suitable (Greene, 2008). Since the probability of chi2 is not statistically significant, we conclude that the random effects estimators are the most appropriate.

Table 4: Wooldridge test for Autocorrelation for Panel Data

Wooldridge test for autocorrelation For Panel Data
H0: No first-order autocorrelation HA: First Order autocorrelation
F (1, 7) = 1.622
Prob > F = 0.2499

Table 3: The null hypothesis is that there is no first order autocorrelation while the alternative hypothesis is that there is presence of first order autocorrelation.

Since the probability of F-test is not significant, we conclude that there is no first-order autocorrelation.

Table 5: White's Test for Heteroskedasticity

chi2(33)	56.24
Prob > chi2	0.007

Legend: The null hypothesis is that there is no homoskedasticity while the alternative hypothesis is that there is presence of heteroskedasticity.

Since the probability of chi2 is statistically significant, we conclude that there is presence of heteroskedasticity in the dataset. To eliminate heteroskedasticity, robust standard errors were used.

4.2: Panel Regression Results

Table 6: Panel Regression Results

Dependent Variable: Overall technical inefficiency (OTIE)

Independent Variable	**Random Effects Estimators**
Dummy for State ownership	0.1261*** [0.028]
Age	0.0011 [0.001]
Cane quality (pol% of cane)	-0.0752*** [0.011]
Skill level	0.0243 [0.082]
Labour	-0.0000*** [0.000]
Capital-Labour ratio	-0.5839 [0.723]
Product diversification	-0.0641*** [0.016]
Number of observations	64
Adjusted R-Squared	0.7209

Legend: Robust standard errors in brackets *** $p<0.01$, ** $p<0.05$, * $p<0.1$

This study applied the random effects estimators. Four variables namely; state ownership, cane quality, labour, and product diversification were found to have significant effects on the dependent variable, overall technical inefficiency, at one percent significance level. Holding other factors constant, state-owned sugar firms had, on average, a higher technical inefficiency level by 12.61% than the privately owned sugar firms. Therefore, this study is consistent with (Chirwa, 2001); (Ali & Jan, 2017) and (Kumar & Arora, 2011) that found state-owner to adversely affect the technical efficiency of sugar firms. A unit increase in pol% of cane (primary juice in cane) caused, on average, 7.52% reduction in firms' overall technical inefficiency when other factors are held constant. Labour had a significant inverse effect on technical inefficiency; however, the effect was negligible. This can be due to missing data on labour for three year from 2014 to 2016 due to organizational at the Sugar Directorate.

Firms that engaged in the production of other products besides sugar such as ethanol and electricity experienced, on average, a reduction in technical inefficiency by 6.41% when other factors are held constant. This shows that firms in the sugar sector can leverage on economies of scope by engaging in the production of other related products. Variables like age, skill level, and capital-labour ratio were found to have insignificant effects on overall technical inefficiency. The explanatory variables explain 72.09% of the variations in technical inefficiency. Unlike the study by Irungu, Wambugu & Githuku (2009), this study found variables like age and capital-labour ratio to have insignificant effects on inefficiency levels.

CHAPTER FIVE: CONCLUSION, RECOMMENDATIONS, STUDY LIMITATIONS

5.2 Conclusions

This study applied data envelopment analysis (DEA) method and the variable return to scale (VRS) assumption to estimate the overall technical efficiency (OTE) levels in the sugar industry. The results found an average overall technical efficiency of 84.21%, meaning that firms were operating 15.79% off their efficiency frontier. Private firms have higher OTE and PTE scores than the state-owned firms, while the publicly owned firms had higher scale efficiency scores than the private firms. However, the difference in efficiency levels between private and state-owned firms is insignificant. Using panel regression, this study found state ownership, cane quality, labour, and product diversification to have significant effects on inefficiency scores.

5.3 Recommendations

This study recommends the adoption of policies of that improve the quality of cane delivered to the factories. For instance, more investment in extension services can help guide farmers on the appropriate farming methods to improve the quality of cane delivered. Extensive research and the introduction of new cane varieties that mature faster and have high sucrose content are equally necessary. This study also recommends a change in the payment system from the current weight-based payment system to a sucrose content method. This will provide an incentive to farmers to produce cane varieties with high sucrose content.

Firms should invest in the production of other products that use sugar by-products as their inputs. For instance, the current environmental concerns on fossil fuels present an opportunity for sugar firms to engage in ethanol production using molasses produced from sugar processing. Furthermore, firms can invest in the generation of electricity using bagasse, a by-product of sugar.

This study supports the privatization of the state-owned firms to improve technical efficiency. The 2019 Government Taskforce Report on Sugar Reforms that proposed the leasing of five state-owned sugar factories will help improve efficiency levels in these firms.

5.4 Limitations of the Study

Due to the missing data on firm machinery and equipment, the study used factory actual capacity as a proxy. Factory actual capacity may not reflect differences in the level of technology of the machinery and equipment used by the various sugar firms, which is critical in the production process. Moreover, there was missing data of labour in 2014, 2015, 2016 which was not collected because of the organizational change from Kenya Sugar Directorate (KSB) to the Sugar Directorate. However, to mitigate against the problem of missing data, this study applied the unbalanced panel approach using existing data to measure the estimators. Moreover, the DEA methodology applied in this study ignores statistical noise due to measurement errors and inappropriate stochastic processes.

5.3 Areas of Further Research

Although this study found private firms to have higher technical efficiency levels than state owned firms, the difference in efficiency scores was not significant. This implies that efficiency in state owned firms can be achieved without privatization. As a result, future studies should examine how state-owned firms can be more efficient without privatization. For instance, these studies can examine whether other types of ownership such as increased farmers' shareholding in the sugar firms has significant effect on the firms' technical efficiency. In addition, future studies should examine the effects of labour on technical inefficiency when all data is available since missing labour data in some years might have affected this study's result on the effect of labour on technical inefficiency.

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