ENERGY USE EFFICIENCY IN KENYA'S CEMENT INDUSTRY

UNIVERSITY OF NAIROBI

SCHOOL OF ECONOMICS

Energy use efficiency in Kenya's cement industry

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A RESEARCH PAPER SUBMITTED TO THE SCHOOL OF ECONOMICS IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF MASTERS OF ARTS IN ECONOMICS OF THE UNIVERSITY OF NAIROBI.

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DECLARATION

I hereby declare that this research paper is my original work and that it has not been presented for a degree award in any other university or institution

Ndegwa Veronicah Ngonyo

X50/77258/2015

Signature.. Date..

This research paper has been submitted for examination with my approval as the University supervisor.

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Signature... Date..............................

DEDICATION

To my late daughter, *Jacinta Wangui Kariuki*. We did this together.

ACKNOWLEDGEMENT

Eternal gratitude to the Almighty God for You have never left my side.

Special thanks to AERC for financing my studies, I am forever grateful. Much appreciation to my supervisor Dr. Thomas Ongoro, even in your busy schedule you found time to guide and correct me. Much thanks to the entire School of Economics, University of Nairobi you have been of great assistance

To my entire family you have kept me on toes and your love has been a solace. To my class 2014-2016 you were a great family, much thanks.

However, I am responsible for any errors and omissions in this research paper.

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LIST OF ACRONYMS

ARM- Athi River Mining

BML- Bamburi Cement Limited

CEEC- Centre for Energy Efficiency and Conservation

CET- Common External Tariff

CSR- Constant Returns to Scale

DEA- Data Envelopment Analysis

DMU- Decision Making Unit

EAPCC- East African Portland Cement Company

EU ETS- European Union Emission Trading System

GDP- Gross Domestic Product

GLS- Generalised Least Squares

IDA- Index Decomposition Analysis

KAM- Kenya Association of Manufacturers

kWh- Kilo Watt Hour

SFA- Stochastic Frontier Analysis

VRS- Variable Returns to Scale

ABSTRACT

The current study sought to quantify energy efficiency in Kenya's cement subsector and identify different factors that explain energy efficiency variations across firms. The study adopted a production-theoretic approach to efficiency measurement. Data Envelopment Analysis and Tobit regression analysis were the analytical tools employed in the study. Firm-level data from three firms Bamburi Cement Limited, Athi River Mining, and East African Portland Cement Company for the period 2004-2014 was used to measure energy use efficiency and to estimate the effect of various factors on energy efficiency scores. Empirical results from the DEA model established that these firms could improve their level of energy use efficiency, though the scope for improving energy use efficiency varied across different firms. The Tobit regression revealed that only quality of the labour force had a positive and significant effect on energy efficiency score. The findings of this study are significant to policy makers in charge of promoting energy efficiency on the demand side. Energy audits, for instance, could be conducted for the inefficient firms to identify possible areas where they can improve efficiency in energy use.

CHAPTER 1: INTRODUCTION

1.0 Background

The government of Kenya in Vision 2030 aims to become a middle-income economy by the year 2030. Higher demand for energy, food and transportation is expected from higher level of economic growth and a growing population. Such a higher demand of energy will inevitably lead to increased emission of greenhouse gases and increased pressure on an already overstretched power supply (Nyangena, 2007). Thus, power generation will be very crucial if any development is to be achieved as we move into the future. Presently, electricity generation is one of the many barriers to economic growth (Ellis *et al*., 2013), a situation made worse by high cost of energy in Kenya in comparison to other countries such as South Africa and Egypt. Further, companies in Kenya have lost close to 10% of their production due to power outages and fluctuations in the supply of energy according to Kenya Association of Manufacturers (KAM) (2012).

According to the U.S. Environmental Protection Agency (2007), increased global competitiveness and increasing cost of energy are the two main challenges that the modern industry has to grapple with. Developing countries continue to face energy prices shocks thus; the effect on the cost of production among the manufacturers is very significant in these countries. Kimuyu (2005) conducts a productivity analysis of the Kenyan economy through which he establishes that power problems is the major obstacle to productivity and efficiency. Unreliable power supply has forced manufacturers in Kenya to resort to other measures such as thermal power and purchase of power generators. Such measures have inflated their cost of production (KAM, 2012).

Kenya through the Centre for Energy Efficiency and Conservation (CEEC) aims to help companies in identifying energy wastages, energy saving potential and make recommendations on companies energy policy. The centre also gives technical support in design and implementation of energy efficiency projects. The purpose of this program is to cut production cost to enhance competitiveness and promote environmental sustainability (Ellis *et al*., 2013).

According to Worell *et al*. (2013), energy cost accounts for 20%-40% of the total cost of production in cement industry. Such a high cost of energy warrants attention to energy efficiency. Energy efficiency is a multifaceted strategy that incorporates economic, social and environmental aspects of every business. It is low-cost investment, which allows firms to cut their cost of production and contribute to environmental sustainability (Worell *et al*., 2013). The cement industry is a unique sector of the economy. The set up cost for a plant for cement production capable of producing 1million tonnes annually is estimated at US$ 200 million while 130kg oil and 105kWh of electricity are needed to produce one tonne of cement (Faisal *et al*., 2009). Thus, energy efficiency would greatly influence cement production cost.

The situation is additionally complex for cement manufacturers in Kenya who face cheap imports despite the high cost of production compared to countries such as China and Pakistan. High production costs, poor infrastructure, and failure of the East African Customs Union to increase their Common External Tariffs (CET) has created a market for cement imports from low-cost producers. Further, the East African Council of Ministers removed cement industry from the list of sensitive commodities and lowered duty on imports from 35% to 25% (Oxford Business Group, 2015). These factors taken together provide a case for increased energy efficiency in the Kenya's cement industry more so because energy accounts for 40% of the total cost of production in the cement industry (Oxford Business Group, 2015).

1.2 Kenya's Building and Construction Sector

The building and construction sector is among the fastest growing sectors in Kenya, the sector recorded growth rate of 14.2% on average for the period 2006-2011 compared to an average growth in real GDP of 4.3%. The sector recorded an improved growth rate of 13.1% in 2014 up from 5.8% in 2013 (Republic of Kenya, Economic Survey 2015). Growth in the building and construction sector was attributed to increased funding to road and railway construction and rehabilitation of existing roads.

Cement consumption recorded a much higher growth, an average of 14.1% between 2006 and 2011. Consumption reached 3.43 million tonnes in 2011 compared to 1.57million tonnes in 2006. Cement consumption was at 5.2 million tonnes in 2014 a growth of 21.8% from 2013 (Republic of Kenya, Economic Survey 2015). There was a matching rise in cement imports by 5.8% to reach 36.4 thousand tonnes in 2014. Rising housing demand, commercial construction boom, expansive donor and government-funded huge infrastructural projects fuelled the growth in cement consumption.

Table 1.1 Cement Consumption in Kenya

Year	Consumption (‘000 tonnes)	% Growth
2010	3085	16.2
2011	3823	10.6
2012	3991.2	4.3
2013	4266.5	6.8
2014	5196.7	21.8

Source: Republic of Kenya, Economic Survey 2015

Cement production, expanded at slower rate compared to consumption averaging 11.6% between 2006 and 2011. Production rose from 2.41mT in 2006 to 4.09mT in 2011 (Republic of Kenya, Economic Survey, 2015). Key drivers of the growth in cement production were new entrants and concerted capacity expansion by the existing producers in an effort to counter the increased competition. Cement production rose by 16.3% in 2014 from 2013 where 5.8825 million tonnes of cement were produced (Republic of Kenya, Economic Survey, 2015).

Table 1.2 Cement Producers in Kenya

Cement Company	**Mines**	**Cement Brand Name**
Bamburi Cement Limited (BMBC)	Mombasa	Nguvu
Athi River Mining Limited (ARML)	Athi River	Rhino
East African Portland Cement Company Limited	Athi River	Blue Triangle
National Cement Company Limited (NCC)	Lukenya	Simba
Mombasa Cement Limited (MCL)	Arhi River	Nyumba
Savannah Cement Company (SCC)	Athi River	Savannah

Source: Author’s compilation

As stated earlier, the realization of the Vision 2030 will be accompanied by massive infrastructural development cutting across various sectors such as ports, industrial zones, railways and housing whose demand is expected to rise to cater for a growing population. Inevitably, cement production will have to increase to meet the rising demand. A rise in cement production will increase energy demand by cement producers therefore, creating the need for energy use efficiency.

1.3 Statement of the Research Problem

Increase in input use has accompanied growth in Kenya's manufacturing sector. Energy is a key input whose cost continues to grow. A key aspect of energy cost is that it is not responsive to prices and substituting energy with other inputs is almost impossible (Onuonga*et al*., 2011). Therefore, achieving efficiency in energy use is a viable alternative in curtailing the cost of production. The government of Kenya has put in place various projects on both demand and supply side directed towards promoting efficiency in energy use. The current study aimed at assessing energy efficiency within the cement subsector. Several studies on efficiency exist in literature (Aggrey *et al*., 2010; Kamande, 2010; Haron& Arul-Chellakumar, 2012). These studies employ data from the entire manufacturing sector and focus on technical efficiency. This study employed Data Envelopment Analysis (DEA), which allows for benchmarking and Tobit regression. Apart from the methodology, the study is significant to literature as it employed unique data from the cement sub-sector. The sector is energy intensive, where energy use efficiency can contribute to significant reduction in energy costs.

1.4 Research Questions

Consistent with the research problem, the following research questions guided the study;

i. Are cement producers in Kenya efficient in their use of energy?

ii. What are some of the factors that influence energy efficiency scores in Kenya's cement industry?

1.5 Research Objectives

The general objective was to determine the level of energy efficiency in Kenya's cement industry.

The specific objectives were;

i. To determine whether firms in Kenya's cement industry are efficient in their energy use

ii. To establish factors that influence the energy efficiency scores for different firms

1.6 Significance of the Study

The current study contributes significantly to debate on the importance of energy efficiency in the production process. Kenya has paid great attention to energy efficiency through the Centre for Energy Efficiency and Conservation (CEEC). The study utilized data from the cement industry in Kenya, thus it results are particularly useful to the cement producers and investors interested in the cement industry. ARM and EAPCC were identified as inefficient thus should re-evaluate their production process to identify possible areas where they can improve their energy use efficiency. Firms that are more efficient are more profitable thus can attract more investors. Policy makers are also responsible for providing incentives to firms to promote energy efficiency. Such efforts would contribute to significant savings from reduced cost of energy, environmental sustainability, and improved energy security in Kenya (Ellis *et al*., 2013).

1.7 Organization of the Study

Following this introduction, chapter two is on literature review, which presents theoretical literature, empirical literature, and the overview of the reviewed literature. Chapter 3 is methodology that discusses the methodology for measuring energy efficiency, variables in the Tobit regression and their expected signs, and pre-estimation tests for the study. Chapter four discusses the empirical results while chapter five concludes and makes recommendations.

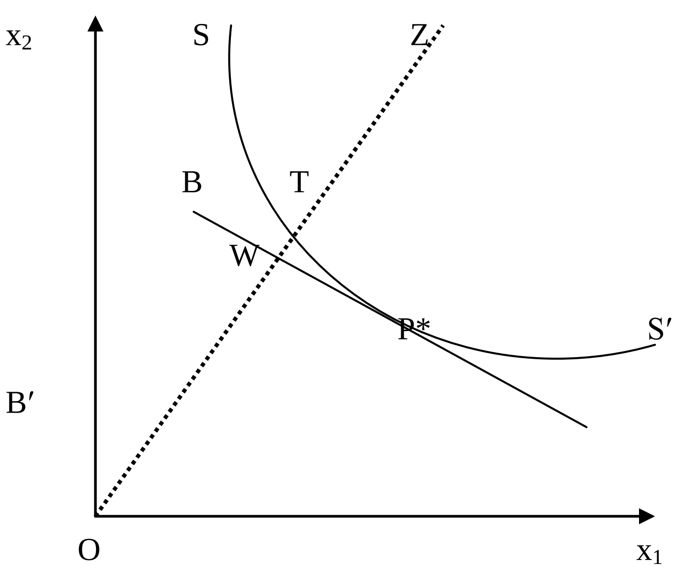
CHAPTER 2: LITERATURE REVIEW

2.1 Theoretical Literature

2.1.1 The Concept of Efficiency

Modern measures of efficiency began with the work of Farrell (1957) who drew a lot from earlier works by Koopmans (1951) and Debreu (1951) and sought to develop a simple measure of firm efficiency that could incorporate many inputs. He proposed two components of efficiency; technical efficiency and allocative efficiency. Technical efficiency represents the firm's capacity to maximize output from a given input set whereas allocative efficiency measures firm's capacity to employ inputs optimally given their corresponding prices (Farrell, 1957). Diagrammatic representation of input-oriented efficiency as proposed by Farrell (1957) is shown below;

Figure 2.1: Input- Oriented Efficiency



Source: Farrell (1957)

From figure 1, the curve SS′ is the isoquant of an efficient firm while the slope of the line BB′ is also the price ratio of inputs, x_1 and x_2. Points W, T, P*, and Z represent hypothetical production levels where a firm with production level P* is regarded as efficient. Taking a firm whose level of production is given by point Z then;

$$Technical efficiency = \frac{OT}{OZ}$$

$$Price Efficiency = \frac{OW}{OT}$$

$$Overall\ (Economic)\ Efficiency = \frac{OW}{OZ}$$

2.1.2 Efficiency and Data Envelopment Analysis

Frontier methodologies represent a very important development in measuring efficiency and productivity whose theoretical underpinnings originated in a seminal paper by Farrell (1957). Empirical measurement of efficiency involves comparing firms to the 'best practice' frontier that is constructed from the dominant firms in an industry. Firms that are located on the frontier are efficient against which other firm in the industry are compared. Parametric (econometric, for example Stochastic Frontier analysis (SFA)) and non-parametric (for example Data Envelopment Analysis (DEA) are the two main classes of methodologies for estimating frontiers (Eling & Luhnen, 2008).

DEA stems from Farrell's (1957) paper extended by Charnes *et al*. (1978) and Fare and Lovell (1978). Charnes *et al*. (1978) developed the model to make it possible to measure efficiency of DMUs employing multiple inputs to produce multiple outputs. DEA begins with defining an efficient frontier and then the efficiency of each DMU is calculated against the frontier. The frontier is convex and is estimated from the input output sets enclosing (enveloping) the data set with linear segments. Charnes, *et al.* (1978) were first to come with an input-oriented model that would measure the efficiency of each DMU under the assumption of CRS. Banker *et al*., (1984) relaxed the CRS assumption to allow for VRS.

DEA utilizes linear programming technique to create an efficient frontier from the observed data on inputs and outputs. Any deviation from the estimated frontier reflects inefficiency. Optimization problem is solved for each DMU separately in DEA (Charnes, *et al*., 1994) as opposed to optimization over the whole sample as is the case in the parametric approach (Jarzebowski, 2013). SFA being a parametric approach adopts a specific functional form and an appropriate econometric method to estimate efficiency. The error term of the estimated function is decomposed into random and an inefficiency component which gives an estimate of efficiency for each firm (Eling&Luhnen, 2008).

DEA and SFA are two competing approaches in evaluating efficiency. However, there is no a priori rule on which method is suited for what situation. According to Cummis and Weiss (1998), the nature of a dataset should inform the choice between the econometric and non-parametric methods. Econometric approach is best suited for noisy datasets since the approach is able to separate the random component from inefficiency. They suggest linear programming approach for cases where the focus is on efficiency performance of individual firms, thus the choice of DEA since the study aims at estimating efficiency scores of individual firms.

2.2 Empirical Literature Review

Traditionally, researchers have employed the inverse of energy intensity as a measure of energy productivity or energy efficiency. Over time, a broad body of literature has come up to evaluate energy intensity among a range of end-users. This literature has focused on explaining various factors that have contributed to changes in energy intensity. However, according to Patterson (1996) other factors in addition to energy efficiency contribute to changes in energy intensity thus the inverse of energy intensity is an inaccurate measure of energy efficiency.

Index Decomposition Analysis (IDA) has also been employed in assessing changes in energy intensity in countries such as Canada, USA, New Zealand (Mandal and Madheswaran, 2011). The approach employs the inverse of energy intensity as a measure of energy efficiency. This is an inaccurate proxy for energy efficiency given that some factors, for instance improvements in the production technology, affect energy intensity (Patterson, 1996). Analysis based on IDA-approach comes with the disadvantage that it cannot compare entities to the best practice, say, in an industry. DEA addresses this problem thus its popularity in analyzing energy use efficiency.

The work by Farrell (1957) forms the basis on which DEA methodology was developed to assess relative efficiencies of similar entities referred to as Decision Making Units in DEA terminology. The DMUs employ multiple inputs to produce multiple outputs. DEA's main advantage is it does not impose any functional form to the observed data (Seiford and Thrall, 1990). The approach through linear programming estimates a frontier that envelopes the observed data by linear facets (Cooper et al., 2004). DEA has become an approach widely applied in estimating efficiencies since the pioneering work by Charnes *et al*., (1978). Zhou *et al*., (2007) conduct literature review on use of DEA in Energy and Environmental studies in which they establish that application of DEA in modelling energy efficiency and environmental performance comes second after electricity utilities benchmarking. Some of the empirical studies that have employed DEA to evaluate energy efficiency are presented below.

Mukherjee (2008a) conducts an interstate energy efficiency analysis among the manufacturing firms in India. The study adopts a production theoretic approach and uses data for the period 1998-99 to 2003-04. The study reports different energy efficiency scores across states and that energy pricing does not have an effect on efficiency. Through a second stage regression, Mukherjee (2008b) establishes that energy-intensive industry have low efficiency, high quality of labour is associated with high efficiency scores and that reforms in India's power sector have insignificant effect on energy use efficiency. Mukherjee (2008b) also adopts a production theory framework to estimate energy efficiency among US manufactures and top six energy consuming 2-digit sectors for the years 1970 to 2001 using DEA. From his estimation, he proposes a new framework for measuring efficiency.

Shi, Bi, and Wang (2010) employ DEA model where non-energy inputs are fixed to estimated energy efficiency at the industry level and maximum potential in saving energy among 28 regions in China. The study establishes that eastern industries are most efficient with those located in the central area coming second for the period 2000-2006. Low efficiency scores across regions of study are as a result of reliance on energy intensive industrial structure.

Mandal and Madheswaran (2009) adopt DEA and directional distance function to assess energy efficiency in India's cement industry. The study results indicate that cement manufacturers in India can reduce their energy consumption with the potential for reduction varying across firms.

Results from a second stage regression suggest that quality of labour force and production volume have a positive impact on efficiency scores whereas age has an insignificant impact on efficiency scores. Further, regulation through The Energy Conservation Act, 2001 had not yet led to efficient energy use.

Mandal (2010) estimates energy efficiency in India's cement industry and includes an undesirable output. He argues that estimating efficiency without considering an undesirable output may lead into biased results. The study applies DEA to estimate energy efficiency in India using data for the period 2000-01 to 2004-05. Study results indicate that efficiency estimates in the absence of undesirable output are biased and that environmental regulation has a positive effect on efficiency.

Mandal and Madheswaran (2011) use DEA to estimate efficiency in energy use among cement companies in India. In addition to measuring energy efficiency, this study also aimed at explaining variations in energy efficiency across firms. The study reveals that there is an energy efficiency gap among Indian cement manufacturers. The estimates indicate that firms with higher volume of production and higher quality of labour have superior efficiency scores. Firm age has mixed effect on efficiency scores (Mandal and Madheswaran, 2011).

Lundgren *et al*., (2015) employ DEA to measure energy efficiency in Swedish industry. They employ panel data for period 2001-2008 for firms in fourteen industrial sectors. The results reveal there is enough scope to enhance energy use efficiency in all sectors under study and highest inefficiencies were among the small energy-intensive industries. By employing the double bootstrap procedure, the study establishes that the EU ETS and CO_2 tax has no considerable effect on energy efficiency over the sample period under consideration.

2.3 Overview of the Literature

The theoretical literature reviewed indicates that DEA as methodology has continued to develop with researchers coming up with different extensions. The empirical studies report an energy efficiency gap in different industries with energy intensive industries recording energy inefficiencies. Various empirical studies (Murkherjee (2008a); Mandal & Madheswaran (2009, 2011); Mandal (2010)) have investigated various factors that affect the level of energy efficiency. The quality of the labour force has been found to have a positive impact on the energy efficiency. The studies produce mixed results on the effect of age on efficiency while the impact of policy regulations on energy on energy efficiency is insignificant. However, environmental regulation has a positive impact on energy efficiency. The studies reveal an insignificant relationship between energy efficiency and the capital-energy ratio.

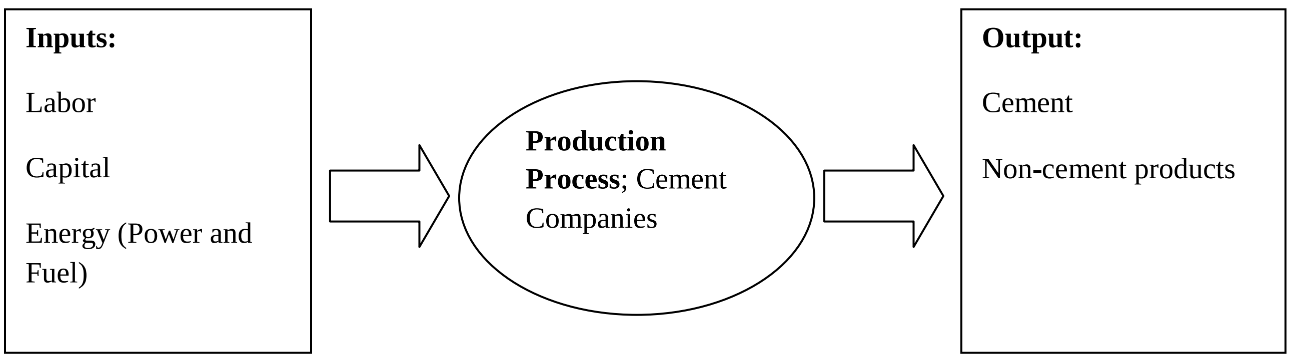
Studies on efficiency employing data from Kenya concentrate on technical and environmental efficiency (see Aggrey et al., (2010), Kamande (2010), &Mukwate et al., (2012)). Further, these studies employ data from the entire manufacturing sector. This study is different from the existing studies in that it employed unique firm level data from the cement industry in Kenya to estimate energy efficiency. It moved a further step to identify some factors that influence energy efficiency scores for cement firms in Kenya.

CHAPTER 3: METHODOLOGY

3.1 Conceptual Framework

To analyze efficiency one can employ either parametric methods such as SFA or non-parametric methods such as DEA. The current study employed DEA methodology to estimate energy efficiency scores and Tobit model to analyze factors affecting energy efficiency among cement companies in Kenya. These companies employ various inputs to produce various outputs.

Figure 3.1 Relationships between Inputs, Production Process and Output



DEA methodology is widely applied in measuring the relative efficiency of similar entities (for example firms) utilizing multiple inputs (labour capital, and energy) to produce multiple outputs (Makridou *et al*., 2014). DEA constructs efficiency frontier from the most efficient firms where the distance of a given DMU from the frontier gives its inefficiency. The efficiency scores obtained from solving the DEA minimization problem give in-depth information on the efficiency of a given DMU relative to the peer DMUs. Peer DMUs refer to firms comparable to the firm under evaluation (Hawdon, 2003).

Charnes *et al.* (1978) proposed an input-oriented model under the assumption of CRS. Later papers introduced other assumptions such as VRS as in Banker et al., (1984). Following Mukherjee (2008a, b), Mandal and Madheswaran (2011), the study adopts DEA to measure energy efficiency within a framework of production theory.

3.2 DEA Model Specification

Take N firms using M inputs x_i $(i = 1,2,3,\dots,m)$ to produce a single output Y. Let y_k and $\mu_k$represent the output and the input bundle of the k^{th} DMU respectively. Also, assume that there is observed data for N DMUs. Subsequently, the production possibility $S = \{(x,y): ycanbeproducedfromx\}$ defines the technology set assuming that all inputs are feasible, all inputs and outputs are disposable freely and a convex production set.

Efficiency of a DMU, say$DMU_k (k = 1,2,3,\dots,N)$ is calculated as the ratio of its weighted combination of outputs to weighted combination of inputs.

Charnes et al. (1978) developed the CCR model to avoid the problem of assigning weights haphazardly. In the ratio form of the model, the optimal weights are calculated by maximizing the ratio of virtual output to virtual input holding the ratio for each DMU not greater than one. Banker *et al*. (1984) (BCC) developed the dual for this problem such that we would have an input-orientation. The BCC model is given as;

$$\varphi^* = \min \varphi \qquad (1)$$

Subject to the constraints

$$\sum_{j=1}^{n} x_{ij}\lambda_j \le \varphi x_{i0} \qquad (2)$$

$$\sum_{j=1}^{n} y_j \lambda_j \geq y_0 \qquad (3)$$

$$\sum_{j=1}^{n} \lambda_j = 1 \qquad (4)$$

$$\lambda_j \geq 0, j = 1,2,3, \dots, n \qquad (5)$$

x and y are input and output vectors respectively; i represents inputs (energy, capital, labour) while j represents firms. λ is a scalar by which the inputs of an inefficient firm is scaled down in order to get to efficient frontier. φ measures the radial technical efficiency which in this case gives equiproportionate decrease in all inputs without a change in the level of output (Zhou *et al*., 2008).

The BCC input-oriented model assumes that the firm's objective is to attain the highest equiproportionate decrease in all inputs such that to take into account any complementarity between energy and other inputs. It is crucial to have constraint (3) to ensure that the consequential output is at least equal to actual output produced. Removing constraint (4) collapses the model to a Constant Returns to Scale (CRS) model.

Any DMU with $\varphi^* = 1$ is fully efficient such that it is not possible to decrease all inputs in the same proportion, conversely an inefficient DMU has $\varphi^* < 1$. The above model gives a radial measure of technical efficiency, which gives the ability of a firm to contract all inputs equiproportionately without any reduction in the level of output (Simsek, 2014).

3.4 Inter-Firm Variations in Efficiency

Lovell (1993) highlights the importance of identifying different factors that have an impact on firm efficiency however; economic theory does have a model that explains differences in efficiency across firms. Various studies have made an attempt to explain different factors that determine firm efficiency classified as those internal to firm such as size and location, factors external to firm (that is competition) and dynamic changes (innovation) (Caves, 1992). Determination of variables to incorporate in modelling determinants of efficiency can only be made through rational judgment (Karamagi, 2002) due to the difficulty involved and lack of a well-developed methodology (Lundvall, 1999).

3.4.1 Model for Estimation

The study will employ a second-stage regression to explain various aspects that determine inter-firm disparities in efficiency. Given that the DEA model for the study will give radial technical efficiency which are censored at 1, the study will employ the Tobit model. The Tobit model is appropriate model for censored dependent variable. From the DEA model, the efficiency scores are censored to the right.

The standard Tobit model is of the form;

$$y_j^* = X_i\beta + \varepsilon_i$$

$$y = \begin{cases} \{y_j^* if y_j^* > 0 \\ 0 \; if y_j^* \leq 0 \end{cases}$$

Where $\varepsilon \sim N(0, \delta^2)$

y_i = observed inefficiency scores

β= k x 1 vector of unknown parameters

x_i= k x1 vector of explanatory variables

Therefore, the empirical regression model will be specified as:

$$EE_{it} = \beta_0 + \beta_1 Age_{it} + \beta_3 FS_{it} + \beta_2 FS^2{}_{it} + \beta_4 LF_{it} + \beta_5 CER_{it} + \varepsilon_{it}$$

Where

EE= Energy Efficiency score

Age=Age of the firm

FS= Firm size

FS^2= the square of the size of the firm

LF= Quality of the labour force

CER= Capital-energy ratio

3.4.2 Variables and Their Expected Signs

Dependent Variable

Energy efficiency (EE) scoreis dependent variable in the second-stage regression analysis

Explanatory Variables

Firm Size (FS)

Torri (1992) proposes that the size of a firm has an impact on efficiency if an improvement in efficiency comes with increased cost in terms of management such that a firm will maintain its performance. Firm size is an important determinant of energy efficiency variations across firms. Large firms utilize economies of scale and are able to diversify their business (Prescott &Vischer 1980). Among cement producers, firm size has an impact on energy demand. Higher capacity in terms of larger burning kilns translate into saving energy, a fact attributed to differences in wall heat losses per unit of clinker produced (Mandal & Madheswaran, 2010). Nonetheless, size may make the managerial task more difficult due to increased coordination needs (Downs, 1967) whereas according to Shepherd (1986) size has a positive correlation with market power creating the probability of generating inefficiencies. Clearly, there is no unanimity in theory on the impact of firm size on efficiency. Empirical results also produce mixed results (see Aggrey*et al.*, (2010)). Following Lundvall and Battese (2000) and Mandal and Madheswaran (2010), the study will investigate the relationship between firm size and energy efficiency with total assets as a proxy for firm size. A non-linear relationship will be captured by including both size and size squared.

Age (A)

The age of a firm determine capital structure of a firm and therefore, it influences energy efficiency of a firm. New equipment come with new technology, thus new capital is more energy efficient. However, inertia make firms less flexible in adapting to new economic situations (Hannan& Freeman (1989) cited in Mandal & Madheswaran, 2010) thus they are likely to lose to younger firms. Literature also suggests that older firms may gain from learning and thus they are not susceptible to difficulties faced by younger firms. In addition, older firms have invested in research and development, thus may have overcome inefficiencies in energy use.

Quality of the Labour force (LF)

Labour productivity (output per unit of wages and salaries) can contribute to energy efficiency of a firm. A competitive market structure ensures that firms are paying the same wages, thus for a firm whose labour produces more output has its labour being more productive and skilled. Additionally, skilled labour is likely to have acquired knowledge on how to work with energy efficient technologies (Mandal & Madheswaran, 2010). Therefore, we hypothesize that labour productivity has a positive relationship with energy efficiency.

Capital- Energy Ratio(CER)

Improvement in energy efficiency is a capital-intensive process thus we would anticipate a positive relationship between capital-energy ratio and energy efficiency. Empirical literature does not establish a clear relationship between labour and capital. Some establish that capital and energy are substitutes whereas others indicate that they are complements. For instance, Onuonga, Etyang and Mwabu (2010), find that energy and capital and energy and labour are substitutes while labour and capital and energy and technology are complementary in Kenya's manufacturing sector. They also find a limited substitution possibility between factors. This was contrary to the findings by Chishti and Mahmud (1990) who found capital and energy to be complements.

3.5 Data

Specific company data was gathered on inputs (energy, labour and capital) and output (net sale) following Haron and Arul-Chellakumar (2012). The chosen firms fell within the cement industry, which is the major focus of the study. Data limitation will limited the study to three major players in the cement industry, which includeBamburi Cement Limited (BML), East African Portland Cement Company (EAPCC) and Athi River Mining(ARM) Limited. Panel data will allow for comparison among firms and across years and at the same time aid in explaining inter-firm differences in efficiency scores.

3.6 Pre-Estimation Test

Employing DEA requires that there be high correlation between the input variables and output variables. To this end, the study employed Pearson Correlation.

CHAPTER 4: RESULTS AND DISCUSION

4.0 Introduction

The study established that there is an energy efficiency gap in Kenya's cement industry. Bamburi Cement Limited was the most efficient among the firms under study. Athi River Mining and East Africa Portland Cement Company exhibited different levels of efficiency across the years.

4.2 Summary of Descriptive Statistics

Table 4.1 Summary of Descriptive Statistics for Output and Input variables

Variable	Mean	Standard Deviation	Min	Max
Output	13681.45	11040.05	1640	37491
Capital	11052.73	7536.985	1333	28257
Labour	2145.03	2298.166	175	8735
Energy	3042.767	2189.856	437.6	8164

All figures are in monetary values in million Kenya shillings (mKsh.)

Source: Author's Calculations

4.3 Efficiency Results

Before running the data in the DEA program, a correlation matrix was obtained to ascertain the correct output-input variables were included in the study. Table 4.2 is a representation of the correlation between the output and input variables.

Table 4.2 Correlation between the output and input variables

Variable	Capital	Labour	Energy
Correlation Coefficient (with Revenue)	0.7236	0.0166	0.9107

Source: Author's Calculations

Table 4.2 illustrates positive correlation between the output and input variables, thus the chosen variables were appropriate for DEA.

Table 4.3 Efficiency Results Summary

FIRM	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
BML	1	1	1	1	1	1	1	1	1	1	1
ARM	0.989	0.992	0.870	0.751	0.792	0.664	0.714	0.758	1	1	0.802
EAPCC	0.734	0.717	0.664	0.461	0.572	0.539	0.899	0.973	0.853	0.977	0.881

Source: Author's Calculations

Table 4.3 is a presentation of the energy efficiency scores obtained from running the data in DEA program. From the table, Bamburi Cement Limited is the most efficient compared to the other DMUs under study.

Table 4.4 Summary of Descriptive Statistics for Energy Efficiency Scores

Variable	Mean	Standard Deviation	Min	Max
BML	1	0	1	1
ARM	0.8484	0.1272	0.664	1
EAPCC	0.7509	0.1780	0.461	0.977
Industry	0.8664	0.1606	0.461	1

Table 4.3 gives the summary statistics for the energy efficiency scores. BML is the most efficient DMU throughout the time period for the study. ARM follows closely with a mean of 84.84%, which implies that the company on average can reduce its energy input with at least 15.16% although its mean energy efficiency score is below the industry average. Therefore, ARM has enough scope of improving its energy use efficiency. EAPCC is the least efficient DMU with an average score of 75.09 % thus the company can improve its energy efficiency by 24.91% on average. EAPCC also records the highest standard deviation, which maybe a reflection of inconsistencies in the production process. 2013 is a year that stands out since BML and ARM record an efficiency score of 1 while EAPCC has its highest score in this year, 0.977. The year coincides with low consumption and lower volume of production of cement (Republic of Kenya, Economic Survey 2015)

4.4 Energy Efficiency Variations across Firms

The study employed a Tobit regression to identify different variables that explain energy efficiency variations across firms to meet the study's second objective. The Tobit model was most appropriate given the energy efficiency score are right censored at 1.

Table 4.5 Tobit Regression Results for Determinants of Energy Efficiency

Parameter	Coefficient Estimate	P>|Z|
Intercept	0.9744(0.4302)	0.031
Size	0.0000119(8.44e-6)	0.170
Size Squared	-0.643e-11(4.96 e-11)	0.205
Age	-0.00192(0.00404)	0.639
CER	-0.0786(0.0461)	0.099
LF	0.0219(0.0195)	0.0309

Source: Author's calculations

The coefficients from the Tobit regression give the impact of the explanatory variables on the dependent variable while the figures in brackets are their respective standard errors. The current study made use of the Z-statistic to determine the significance of the coefficient estimates. The statistic is calculated as the ratio of the coefficient to its standard error at 95% confidence level for this study and follows the standard normal distribution. Significance implies that the coefficient is statistically different from zero thus; the respective explanatory variable has an impact on the dependent variable.

The study employed total assets as a proxy for firm size and included the square of firm size to assess any non-linearity between firm size and energy efficiency. From table 4.5, the size coefficient is positive while the size square coefficient is negative. However, the two coefficients are insignificant at 95% confidence level thus; we cannot interpret the effect of size on energy efficiency. The results of this study are consistent with that of Aggrey *et al*. (2010) who found an insignificant relationship between firm size and technical efficiency of manufacturing firms in

Kenya. Mandal and Madheswaran (2011) report that age has a significant positive effect on energy efficiency from a cost minimization model while the effect is insignificant from the input-oriented measure. The current study established a positive but insignificant relationship between energy efficiency and age of the firm measured from the year of incorporation.

Mandal (2010) establish that energy efficiency is a capital-intensive process thus capital-energy ratio has a positive effect on energy efficiency. The current study included capital-energy ratio in the Tobit model and the results indicate a negative but insignificant relationship between capital-energy ratio and energy efficiency. Though insignificant, the result may indicate that capital and energy are complements not substitutes, which could be verified by employing a cost minimization model.

Labour productivity was found to a have a positive and significant impact on energy efficiency scores. Such a result is consistent with Mukherjee (2008b) and indicates that firms that are able to hire skilled labour are able to achieve higher efficiency in their energy use.

CHAPTER 5: SUMMARY, CONCLUSIONS, AND RECCOMMENDATION

5.0 Introduction

The current study drew its motivation from previous studies that establish that energy efficiency is a very important aspect of every company aiming at cutting its cost of production and at the same time promotes environmental sustainability. Further, DEA is a very powerful tool in benchmarking such that firms learn from the production processes of efficient firms in the same industry. It is also important to identify factors that influence energy efficiency. The study achieved this through a Tobit regression. The study established that BML is the most efficient firm among the DMUs whose data was analysed. The average performance of the cement industry in terms of energy efficiency was 86.64% implying there is enough scope for improved energy use efficiency. Among the explanatory variables, only quality of labour force was found to have a positive and significant effect on energy efficiency score for firms in Kenya's cement industry.

5.1 Limitations of the Study

The study objective was to measure energy efficiency and to identify factors that influence the level of energy efficiency in Kenya's cement industry. However, gathering the relevant data was quite difficult as there is no a database of data from manufacturing firms in Kenya. Thus, data limitation restricted the study to technical measure of energy efficiency though allocative measure of efficiency would have allowed for comparison of different models.

The study employed DEA to measure energy efficiency. DEA by design gives a relative measure of efficiency by comparing the DMUs with the most efficient DMUs in the sample. Thus, the efficiency measure obtained is not in reference to a theoretical best practice. Further, the efficiency scores from the DEA model do not have any statistical properties thus; one cannot make statistical inferences from DEA results. Further, data limitation may have reduced the reliability of results from DEA model which very sensitive to noisy datasets. Nonetheless, the study met its objectives and the results are very relevant for firms included in the study.

5.2 Areas for Further Research

The study employed DEA and Tobit regression as analysis tools. The study established there is enough scope to improve energy efficiency in Kenya's cement industry. The study further looked at various factors that influence energy efficiency. However, the scope of the study left room for possible areas for further research. Future studies, can employ the current methodology in other subsectors to obtain sector specific results. The current study can also be extended to look at the impact of policy regulation on energy use efficiency. With data availability, future studies could also include other cement firms that were not included in the current study.

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