TECHNICAL EFFICIENCY OF TECHNICAL, VOCATIONAL AND ENTREPRENEURSHIP TRAINING INSTITUTIONS IN KENYA

PAUL WANJORA KARIUKI

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DECLARATION

This research is my original work and has not been presented for a degree award in any other university.

Signature...Date 21/10/14...

Paul Wanjora Kariuki

C50/CE/11261/2004

This project is submitted with our approval as supervisors:

Signature...Date 21/10/14...

Dr. Dianah Muchai

Department of Econometrics and Statistics

Kenyatta University

Signature...Date 21/10/2014...

Dr. Aflonia Mbuthia

Department of Econometrics and Statistics

Kenyatta University

DEDICATION

To My Wife Anne and My daughters Ivy and Alma

You are my inspiration!

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ACCRONYMS AND ABBREVIATIONS

TVET	Technical, Vocational and Entrepreneurship Training
DEA	Data Envelopment Analysis
SFA	Stochastic Frontier Analysis
DMU	Decision Making Unit
BCC	Banker, Charnes, and Cooper model
CCR	Charnes, Cooper and Rhodes model
TTI	Technical Training Institutes
IT	Institute of Technology
YP	Youth Polytechnics
CRS	Constant Returns to Scale
VRS	Variable Returns to Scale
IRS	Increasing Returns to Scale
UNESCO	United Nation Education scientific and Cultural Organization
KNEC	Kenya National Examination Council
ROK	Republic of Kenya
TE	Technical Efficiency
STI	Science technology and Innovation
JICA	Japan International Cooperation Agency
CHE	Commission for Higher Education
FPE	Free Primary Education
EFA	Education for All

PU	Production Unit
TFP	Total Factor Productivity
SE	Scale Efficiency
LP	Linear Programming
AU	African Union

OPERATIONAL DEFINITION OF TERMS

Efficiency	measure of how well the schools are using inputs to produce output
Performance	test scores obtained by students at the end of education cycle marked by national examination
School	institutions offering all forms of education at all levels ie primary, secondary and tertiary levels
Inputs	resources required in schools so as to provide educational services
Output	graduates completing diploma/certificate having passed final exams

ABSTRACT

The three educational systems of primary, secondary, and tertiary levels in Kenya are increasingly faced with resource scarcity and increasing unit costs. The government of Kenya and other international organization have over the years allocated more funds to basic education resulting to underfunding in tertiary particularly TVET institutions. But since 2005 the government has recognized the potential contribution these institutions can make especially towards the realization of The Kenya Vision 2030. The governments in collaboration with external donors have since then channeled significant amount of funds to improve TVET education. A TVET education system in Kenya was studied by comparing used resources with education outcomes. This study sought to establish the level of efficiency in TVET institutions and the determinants of the technical efficiency. Technical efficiency in TVET education systems across Kenya was assessed through Data Envelopment Analysis (DEA) which is a non-parametric method. The DEA results were further subjected to regression analysis using Tobit model to determine the determinants of technical efficiency of TVET institutions. Output was defined as students' educational achievement, measured by results obtained on standardized tests applied nationwide and graduation rate. Inputs considered were; student enrolment, teaching staff, non-teaching staff and physical facility index. The results of the study show that the overall efficiency of TVET institutions in Kenya is 79.4%. Using the Malmquist index it was clear that total factor productivity in TVET was increased in the period 2009-2011. Further, the study found out that the qualification of teaching staff measured by the number of teachers with advanced degree affected the performance of TVET institutions. The other factor that was found to determine efficiency was the proportion of engineering/science in comparison with art-based courses offered by these TVET institutions. Those TVET with high proportion scored less in terms of technical efficiency. This was could be attributed to the fact that engineering/science based course are more demanding in terms of input resources such as capital equipment. The TVET institutions in Kenya are not well equipped with adequate and modern equipments. Factors such as location of the TVET, boarding facilities and flexibility of modes of learning were found not to have significant influence of efficiency of TVET institutions. The study recommends that government and TVET institutions management should come up with a policy to promote acquisition of higher academic qualifications by the teachers. Equipping TVET institutions with proper, adequate and modern equipment will go a long way in enhancing performance in engineering courses. The TVET must produce the artisans, technicians, craftsmen and technologists required to fulfill the needs of Vision 2030.

CHAPTER ONE

INTRODUCTION

1.1 Background of the study

1.1.1 Education and Training

Globally it is recognized that political, social and economic growth of any country is largely a result of the transformation of knowledge, science and technology into goods and services (Tzeng, 2004). The role of education has also been emphasized in contributing to the human resource development in today's globalizing context. Empirical evidence, based on endogenous growth models, shows that human capital is a key determinant of economic growth (Glewwe, 2002). Furthermore rapid technological changes and globalization have made training of the workforce and especially post-primary training is critical prerequisite in any nation that wishes to survive (Mureithi, 2008).

The demand of education for economic purposes due to the pressure of technological progress and modernization has been constantly on the rise in most countries during the 21st century (UNESCO, 2008). The link between the rate of technical progress and the quality of human intervention has become increasingly evident as has the need for those active in the economy to be trained to use the new technologies to innovate. New skills are needed and educational institutions are required to meet the need by providing not only the minimum of schooling or vocational training, but also training for scientists, innovators and high level specialists (UNESCO,2002).

The role of Technical, Vocational education and Training (TVET) as an effective means of empowering society to engage in productive and sustainable livelihoods cannot be overemphasized. TVET plays an important role in supplying skills requisite for improved workers' productivity, economic competitiveness, occupational integration, raising income levels and expanding opportunities for employment (Budria and Telhado-Pereira, 2009). Statistics suggests that there is high correlation between country's GDP and the percentage vocational education and training enrolment. For example, countries such as Australia, Belgium and the UK , which have very high percentage s of technical and vocational secondary school enrolment also have very high GDP per capita; whereas countries in Africa like Eritrea, Malawi and Niger that have very low percentage of secondary school enrolment have correspondingly very low GDP per capita (UNESCO, 2008).

Generally, TVET in Africa has been left to the periphery and its significance has not really been embraced. Palmer, (2007), observed that Sub-Saharan Africa has little room for TVET at the post-primary school level. This fact partially explains why Africa lags behind the rest of the world in technology. In Kenya, Nyerere (2009) observed that TVET is accorded limited importance in government and donor financing schemes. The funding towards TVET considered ad hoc and arbitral, leading to year after year variations and uncertainty (Mureithi, 2008; Ziderman, 2002).This has resulted to poor quality of training due to lack of appropriate (qualitatively and quantitatively) tools and equipment (Mureithi, 2008).Under investment in TVET sector is made worse by the emphasis placed on the general academic sector by the government.

Table 1.1 Expenditure for Ministry of Education in TVET Sub-sector in Kenya Shillings (Millions)

	2004/05	2005/06	2006/07	2007/08	2008/09	2009/10	2010/11	2011/12
Development	4.19	185.00	72.00	1415.93	4795.00	2580.83	5097.80	5158.70
Recurrent	1637.41	1291.00	2625.00	3382.36	5087.90	4175.42	2414.40	4756.60
Total	1641.60	1436.00	2697.00	4798.29	9882.90	6756.25	7512.20	9915.30

Source: Economic Survey, 2008a, 2010

A careful analysis of budgetary allocation for the Ministry of Education (MoE) in Table 1.1 reflects an erratic expenditure on TVET. The matter is made worse by the fact that a huge share of the ministry's allocation goes to recurrent expenditure. Development expenditure which would see acquisition of best technology and modern equipment for teaching and learning is overlooked.

It is evident that some developed and developing countries, such as Italy, Brazil, China, Sweden and Japan, fund TVET programs sufficiently and, as a result, primary and secondary students are exposed to vocational training and to a culture of scientific investigation and application at an early age (UNESCO, 2008). In Europe at least 50 per cent of the students in upper secondary education pursue some form of technical or vocational education; in China, India and South East Asia the figure is 35–40 per cent; however in Africa it is less than 20 per cent (in Kenya, the figure is two per cent) (African Union, 2007).

According to World Bank (2013), Service Delivery Indicators (SDI) for Kenya show that urgent improvements are needed in the quality of education in the country for this generation to mature into highly productive citizens and be able to take advantage of economic opportunities and seek better jobs. The report shows a weak link between resources and service delivery outcomes in Kenya education.

Table 1.2 Service Delivery Indicators (SDI) for Education in Kenya

	ALL	PUBLIC	PRIVATE	RURAL PUBLIC	URBAN PUBLIC
Teachers absence from school	15.5%	16.4%	13.7%	17.2%	13.7%
Teachers absence from class	42.2%	47.3%	30.7%	48.8%	42.6%
Time spent teaching	2h 40min	2h 19min	3h 28min	2h 37min	2h 13min
Teachers minimum knowledge	39.4%	35.1%	49.1%	35.8%	32.9%
Test score on English, Maths, pedagogy	57.2%	56.2%	59.2%	54.4%	56.7%
Students per textbook	3.1	3.5	2.2	3.8	2.5
Teaching equipment availability	95.0%	93.6%	98.2%	93.5%	93.7%
Infrastructure availability	58.8%	58.5%	59.3%	58.7%	58.0%

Source: World Bank, 2013

Table 1.2 reveals suboptimal management of human resources as reflected by the rate of absence from school or classroom. Although in both private and public schools the absence from school is roughly equal, about 50% in public school are less likely to be in class teaching. Also a student in public school receives 1hour 9 minutes less than his counterpart in private school. In regard to mastery of curriculum, just a third (35%) of public teachers is competent. Kenya public schools do relatively well on the availability of inputs. Availability of text books exceeds the target of three books per student.

1.1.2 Vocational Education and Training in Kenya

Vocational education and training in Kenya is referred to as Technical, vocational, and entrepreneurship training (TVET). It is a comprehensive term referring to pragmatically important components of a national training system that entails those aspects of educational process involving, in addition to general education, the study of technologies and related sciences, and the acquisition of knowledge, practical skills, and attitudes relating to occupations in various sectors of economic and social life (UNESCO, 2008).

The vocational education in can be traced back to colonial era when vocational and technical courses were reserved for Africans in preparation for servitude. Post colonial Kenya introduced a relevant vocational educational program to its primary and secondary school students in order to equip them with vital skills and transform the vocational courses' image (Mwiria, 2001). The education system which followed British 7-4-2-3 was changed to 8-4-4 system. Under 8-4-4 system, the curriculum was expanded to include vocational and technical courses, with the aim of enhancing the transition of secondary graduates into the world of work, as well as giving them opportunities for further training in relevant post secondary institutions (Mwiria,2001). However between 2002 and 2005 vocational subjects were removed from regular primary and secondary schools following a review of the curricular, only to be re introduced in 2007. Currently, most secondary schools offer applied education subjects of agriculture, business, home science, industrial and computer course (UNDP, 2010).

Alongside the 8-4-4 system, technical and vocational courses are offered in TVET institutions including; Youth Polytechnics (YP), Technical Training Institutes (TTIs); Institutes of Technology (ITs), National Polytechnics and Technical Universities. There are also other institutions that offer TVET programs spread across government ministries as well as private institutions (R.o.K, 2008b). The country has 2 national polytechnics, 17 Institutes of Technology, 1 Technical Teachers' Training College and 21 Technical Training Institutes. In addition, there are over 600 youth polytechnics distributed throughout the country but only 350 of the youth polytechnics receive government assistance. The private sector operates close to 1,000 commercial colleges that offer courses in computers and non-technical areas of training (Kerre, 2010).

1.1.3 Performance of TVET in Kenya

The TVET sub-sector in Kenya has experienced moderate growth over the last 40 years. The sub-sector continues to produce the needed middle level human resource for the national economy. The Vision 2030 has however placed special demands on TVET as the leading engine that the economy must essentially rely upon to produce adequate levels of middle level manpower that will be needed to drive the economy towards the attainment of the vision (R.o.K, 2012). The existing public TVET system in Kenya, however, suffers from critical problems including the decline of quality; lack of relevance to occupational and social realities; under-enrolment; and under-funding (Johanson and Adams 2004). The lower quality can attributed to outdated equipment and low teachers' qualifications in TVET institutions. Lack of proper linkage of TVET with the industry is blamed for lack of relevance in the real world of work (Mureithi, 2008). In 2008, budget allocation to TVET accounted for 0.7 per cent of the total budget and 2.7 per cent of the education budget and although this was improvement from previous years, the funds are still inadequate (OECD, 2008).

A study by Word Bank, (1996) revealed that there was inefficient mix of inputs such instructional materials and staff in Kenya education system. R.o.K (2005a) noted that pursuit to internal efficiency in Kenya, education system required policy attention. As a consequence the performance in national examination especially in practical and engineering subjects was poor. The overall performance revealed that less than 1% obtained distinction score and more than 30% recorded failures and referrals. This translates to high levels of wastage in the system (Amuka, Olel and Gravenir, 2011).

In an effort to improve performance of TVET sub sector, the government came up with a national TVET strategy in the year 2005 to revitalized TVET with the objective of developing a national training strategy for TVET and ensure that the TVET institutions are appropriately funded and equipped (R.o.K, 2005b). In this respect, Kenyan government signed an agreement with Netherlands government to have eight technical institutions rehabilitated, upgraded and equipped with modern equipments. Instructors and trainers would undergo rigorous training in Netherlands to enhance their skills in the use of new equipments (R.o.K, 2005b).

The government has committed itself to provide resources for scientific research, enhance of technical capabilities of the workforce and raise of the quality of teaching science and technology in schools, polytechnics and universities. This in turn is expected to provide a well-harmonized, flexible and demand driven TVET system to ensure that the graduates contribute meaningfully to national development (R.o.K, 2007). In 2008 the government spent Kenya shillings 3.4 billion on issues of transition from primary, development of skills strategy and enhancement of ICT within the TVET sector among others (R.o.K, 2010). Financial assistance and bursaries to the needy and female students undertaking engineering courses was introduced to enhance enrolment in TVET programmes. Regulatory framework was enhanced by the passing of TVET bill into law which will ensure among other things establishment of TVET authority to oversee all operations of TVET institutions (R.o.K, 2012).

1.2 Statement of the Problem

Kenya's Vision 2030, makes particular reference to good education. This vision cannot be a reality without skilled artisans, craftsmen, technicians and technologists. These skilled personnel are drawn from the TVET sub-sector (R.o.K, 2007). A cursory look at the national budget shows a fair volume of money already flowing into TVET. Taxpayers in Kenya and donors have paid to build, renovate and equip public learning institutions (R.o.K, 2012). Kenya has done relatively well on making textbooks, equipments, and basic infrastructure available in learning facilities (World Bank, 2013). The report however noted that the country is still far from achieving optimal performance by these TVET institutions. As a result, there is a worrying gap between the money and materials that go into learning facilities on the one hand and the results that emerge on the other. The service delivery indicators show a weak link between resources and service delivery outcomes. These service delivery failures translate to poor student performance. In 2008, the government admitted that inadequate quality assurance mechanisms in TVET contributed a great deal to the poor curriculum delivery and the production of graduates who are insufficiently equipped for the labour market (R.o.K, 2008b). To correct this situation, the government published the National TVET Strategy (R.o.K, 2008b), which identified four impact indicators of relevance, efficiency, effectiveness and sustainability that would be measured during monitoring and evaluation.

An earlier study by Word Bank, (1996) had revealed that there was inefficient mix of inputs such instructional materials and staff in Kenya education system. Despite the several studies (for instance, Abagi and Odipo, 1997; Ngware, 2002; Nyerere, 2009) having looked into educational efficiency in Kenya, efficiency gaps are yet to be fully addressed. This study therefore is critical in the understanding of how best TVET inputs can be utilized to achieve the maximum output. The study seeks to answer the following questions:

i. What is the technical efficiency level of TVET institutions in Kenya?
ii. What are the determinants of technical efficiency in TVET institutions in Kenya?

1.3 Objectives of the study

The general objective of this study is to investigate the technical efficiency of TVET education in Kenya. The specific objectives are;

i. To estimate Technical efficiency level of TVET institutions in Kenya.
ii. To analyze the determinants of technical efficiency in TVET institutions in Kenya

1.4 Significance of the study

Kenya is among the countries that are geared towards Education for All (EFA), a process that will lead to vastly increased numbers of young people completing primary and secondary education in the coming years. Correspondingly, TVET institutions must determine ways of increasing enrolments in their programmes. Understanding efficiency and determinants of efficiency will allow TVET institutions to explore ways of making better use their resources. This will also enable them reaching out to many identify causes of inefficiencies that may hinder the realization of their mission. The study will yield findings that can be used as examples of good practice for improving the attractiveness of TVET institutions.

1.5 Scope and Limitation of the study

The study focused on technical efficiency of TVET institutions under the Ministry of education. These include Technical training institutes (TTIs) and institutes of technology (ITs). These category of TVET has so many similarities and therefore easy to compare. The Technical efficiency of these TVET was measured over the period 2009-2011. This was the period immediately after major interventions undertaken in this sector.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter reviews articles literature on efficiency. Specifically, this chapter presents a review of theoretical literature, empirical literature, determinants of efficiency and overview of literature.

2.2 Theoretical Literature

This section discusses the concept of production frontier, production possibility set, distance functions, efficiency and its measurement.

2.2.1 Production frontiers

To illustrate the concept of production frontier, one can use an important class of technologies having a single output y and an N-dimensional vector of input x. suppose the production possibility set satisfies $T(x, y) \geq 0$. A general representation of the frontier technology is given as;

$$y = f(x) \quad \text{..........} 2.1$$

The function $f(.)$ is the production frontier and equation 2.1 gives the upper boundary of T. Given input x, the maximum producible output $y = f(x)$ can be achieved. In the form of maximization, the production frontier is expressed by;

$$f(x) = \max\{y' : T(x, y')\} \geq 0 \quad \text{..........} 2.2$$

The production frontier serves as the standard against which to measure technical efficiency. It should contain only the efficient observations. Production frontier has a property of scale economies: constant returns to scale (CRS), decreasing returns to scale (DRS) and increasing returns to scale (IRS).

A frontier exhibits CRS if $f(tx) = tf(x) \forall t > 0$; DRS if $f(tx) < tf(x)\ \forall t > 1$; and IRS if $f(tx) > tf(x) \forall t > 1$ and an arbitrary input vector x (Coeli et al, 2005).

The assumption on scale is often required in production frontier estimation and efficiency analysis, especially in non parametric frontier methods.

2.2.2 Production Possibility set and distance functions

To illustrate production possibility set suppose a producer uses a vector of inputs, $x = (x_1, ..., x_n) \in \Re_+^n$ to produce non-negative vector of outputs, $y = (y_1, ..., y_m) \in \Re_+^m$

The production possibility set of a production unit is a subset T of the space $\Re_+^{m+n}$. A firm may select any input-output configuration $(x, y) \in T$ as its production plan. The production possibility set is the selection of all feasible input and output vectors. It is represented as;

$$T = \{(y, x) : x \text{ can produce } y\} \subset \Re_+^{m+n} \quad ....2.3$$

Furthermore, production possibility set can be represented by an input requirement set $L(y)$ or output producible set $P(x)$ (Fare, Grosskopf and Lovell, 1994). The input requirement set represents the collection of all input vectors $x = (x_1, ..., x_n) \in \Re_+^n$ that yields at least output vector $y = (y_1, ..., y_m) \in \Re_+^m$. It can be represented as;

$$L(y) = \{x : (x, y) \text{ is feasible }\} \quad ....2.4$$

The output producible set is the collection of all output vectors $y = (y_1, ..., y_m) \in \Re_+^m$ that are produced from the given input vector $x = (x_1, ..., x_n) \in \Re_+^n$. It can be represented as:

$$P(x)=\{y:(x,y) \text{ is feasible }\} \ldots\ldots 2.5$$

Equation 2.5 can also be defined as output distance function. The output distance function is defined on the is defined on the output set, $P(x)$ and is minimum scaling of the outputs, ȯ, such that expanded output, $y/$ ȯ remain a member of the output set $P(x)$ as well technology set S i.e.

$$d_0(x,y) = \min\{\delta : (y/\delta \in P(x)\} \ldots\ldots 2.6$$

Therefore if $y \in P(x)$, then $d_0(x,y) \leq 1$ and if y is on the upper boundary (frontier) of the output set, then $d_0(x,y)=1$.This is possible since $P(x)$ is closed (Coeli et al, 2005)

On the other hand input distance function is defined on the input set $L(y)$ and is maximum scaling of the inputs, ρ, such that contracted input, (x/ρ), remains a member of the input set $L(y)$ as well as technology set S i.e.

$$d_i = (x,y)\max\{\rho : (x/\rho) \in L(y) \ldots\ldots$$

Therefore, if $x \in L(y)$ then $d_i(x,y) \geq 1$; and if y is on the lower boundary (the frontier) of the input set, then $d_i = (x,y) = 1$. This is possible since the set $L(y)$ is closed (Coelli et al, 2005).

2.2.3 Efficiency

Productive efficiency has two components: technical (or physical) efficiency and allocative (or price) efficiency. The purely technical, or physical, component refers to the ability to avoid waste by producing as much output usage allows, or by using as little input as output production allows. Thus, the analysis of technical efficiency can have an output augmenting orientation or an input-conserving orientation. The allocative, or price component refers to the ability to combine inputs and outputs in optimal proportions in light of prevailing prices (Lovell, 1993). The absence of information on input prices makes the evaluation of allocative efficiency impossible. In this study therefore, only technical efficiency will be estimated.

A firm with input output configuration $(x, y) \in T$ is efficient if there is no $(x^{'}, y^{'}) \in T$ for $(x^{'}, y^{'}) \neq (x, y)$ with $x^{'} \leq x$ and $y^{'} \geq y$.

Farrel (1957 introduced a measure of technical efficiency defined by one minus the maximum equiproportionate reduction in all inputs that still allows continued production of outputs. A score of unity indicates technical efficiency because no equiproportionate input reduction is feasible, and a score less than unity indicate technical inefficiency.

2.2.4 Measurement of technical efficiency

The two main approaches used are; the econometric methods such as Stochastic Frontier Analysis (SFA) and the non-parametric Data Envelopment Analysis (DEA) methods.

2.2.5 Stochastic frontier function approach (SFA)

SFA acknowledges the random noise around the estimated production frontier. In a simple case of a single output and multiple inputs, the approach predicts the outputs from inputs by the functional relationship;

$$y_i = f(x_i, \beta) + \varepsilon_i$$

Where i denote the PU being evaluated and $\beta's$ are the parameters to be estimated. The residual ε_i is composed by a random error v_i and an efficiency component u_i. The random error v_i is added to the non negative random variable u_i to provide the following model (Coelli et al, 1998):

$$ln(y_i) = x_i\beta + v_i - u_i \quad i = 1,2, \ldots N \ldots\ldots 2.2$$

Where i= 1, 2,…, N refers to the individual unit.

The random error v_i accounts for measurement error and other random factors together with the combined effects of unspecified input variables in the production function.

The model is called the stochastic frontier production function because the output values are bounded above by the stochastic (random variable), expressed as ($x_i\beta$ $+v_i$). The random error, v_i can be positive or negative and so the stochastic frontier outputs vary about the deterministic part of the frontier model, expressed as ($x_i\beta$) (Coelli et al, 1998). The main disadvantage of this approach is the imposition of an explicit functional form and distribution assumption of the error term. Therefore, stochastic frontier method is sensitive the parametric form chosen (Lewin and Lovell 1990).

2.2.6 Data envelopment analysis (DEA)

Data Envelopment Analysis (DEA) is a linear programming technique for measuring relative efficiency of a set of homogeneous decision-making units (DMUs) where the presence of multiple inputs and outputs makes comparisons difficult (Charnes et al, 1978). DEA uses the data from all DMUs to construct a "best production frontier" and simultaneously calculates the distance to that frontier for the unit. DEA assesses the performance of the DMU relative to the production frontier. Unlike SFA, DEA does not have to assume a particular functional form making it less prone to misspecification problem.

DEA models can be input and output oriented and can be specified as constant returns to scale (CRS) or variable returns to scale (VRS) (Banker, Charnes and Cooper, 1984). Coeli et al (2005), states that the two orientations give similar results under CRS assumptions but different results under VRS assumptions and the choice of orientation is influenced by the characteristic of the DMU under study. An output-oriented DEA uses the distance to the frontier as a measure of efficiency

The DEA linear programming model used to measure the output- oriented technical efficiency for each DMU is expressed as follows(Coeli et al , 2005);

$$\max_{\theta\lambda} \theta$$

$$\text{s.t} \; -y_i + Y\lambda \geq 0$$

$$\theta.x_i = X\lambda \geq 0,$$

$$Z'\lambda = 1,$$

$$\lambda \geq 0, \qquad \text{...2.3}$$

where θ is a scalar that measures technical efficiency of the ith DMU: Y is $P \times n$ matrix of output produced by the n DMUs; y_i is a $P \times 1$ quantities of output produced by DMU i; X is $m \times n$ matrix of m inputs used by the n DMUs, and x_i is the vector of these inputs for DMU i. λ is $n \times 1$ vector of the weights attached to the n DMUs for the construction of the virtual comparison unit for DMU i. The unit sum of the weights ($Z'\lambda = 1$) ensures the variable returns to scale condition, by folding a convex frontier around the observations. Thus the output oriented DEA problem finds the maximum possible output of the DMU in question, while still keeping the DMU within the possible input and output combination. The possible set of input and output combinations i.e. the production possibility set, is given by all convex combinations of the observed input and output values.

The efficiency of n DMUs is assessed by solving n LP models, in which the vectors y_i and x_i are adopted each time for the DMU i considered. It is important to note that when one has a few observations and many inputs and outputs most of the DMUs will appear on the DEA frontier. That is to increase the technical efficiency scores an investigator needs to reduce the sample size and increase the number of inputs and outputs (Zhang, 1998). Therefore, it is conventional that the minimum number of DMUs is greater than three times the number of inputs plus outputs (Raab and Lichty, 2002).

To measure the change in efficiency score, the Malmquist index approach is used to decompose the determinants of efficiency changes (Johnes, 2004). Equation (2.4) shows the output-oriented Malmquist productivity index (Fare et al, 1994):

$$M_0(x^{t+1}, y^{t+1}, x^t, y^t) = \frac{D_0^{t+1}(x^{t+1}, y^{t+1})}{D_0^t(x^t, y^t)} * \left[\frac{D_0^t(x^{t+1}, y^{t+1}}{D_0^{t+1}(x^{t+1}, y^{t+1}} * \frac{D_0^t(x^t, y^t)}{D_0^{t+1}(x^t, y^t)} \right]^{\frac{1}{2}} \quad \ldots\ldots\ldots..2.4$$

Where M_0 is the Malmquist index, D_0 the distance function, x represent input, y represent output, t the period of benchmark technology, $t+1$ the next period technology. The ratio outside the brackets measures the change in relative efficiency between year t and $t+1$. The geometric mean of the ratios inside the brackets captures the shift in technology between two periods analyzed at x^t and x^{t+1}. M_0 represents the Malmquist productivity index that measures the change over time of input- output mixes (x^{t+1}, y^{t+1}), relative to the input-output mixes at starting production point (x^t, y^t).

Productivity growth is the geometric mean of the two output based Malmquist indices of distance functions from period t to period $t+1$ in a given output(y) and input (x).

According to Coeli,(1996) five Malmquist indices can be derived: technical efficiency(TE), technological change(TC), total factor productivity change(TFP), pure efficiency change(PE) and scale change(SE). TE and TC are components of TFP, while PE and SE are components of TE.

2.3 Empirical Literature

Bradley et al, (1999) estimated technical efficiency schools in England. In the first stage, DEA efficiencies were estimated, while in the second stage the efficiencies were explained in a regression analysis. In the specification of the model two outputs i.e examination grades and attendance rate were included. The inputs used were; the proportion of pupils ineligible for free school meals and the proportion of qualified teachers. In the tobit analysis, factors identified as having effects on school efficiency included; type of school, proximity of school, composition of the school, local environment of the school, resource variables, size of class. The study findings indicated that there were efficiency differences among various schools in England. Resource availability and the school environment had significant impact on school's performance. Proximity of school and gender of the student were not statistically significant. The major drawback was failure to specifically state the resource variables considered. The aggregation of all resources into one may have resulted to misclassification problems. The study also omitted number and quality of pupils which is considered to be very important input in school and hence the efficiency score estimated excluding such an important variable could be misleading.

Jeon and Shields (2003) measured efficiency of public education in Michigan. The inputs included in the production function were; teacher to student ratio, the average teacher salary, the foundation allowance per student, and the proportion of students not qualified for free or subsidized school lunches. The outputs were; the graduation rate and the results of a proficiency test for mathematics, science, reading and writing. Socio-economic variables expected to affect school's efficiency were; value of housing, household income and percentage of population living in urban areas. The results of the analysis showed that most schools were fairly efficient but with big variations among them. Socio-economic factors such as, household income and poverty levels were positively related to educational efficiency. Variables such percentage of urban population and housing value reduced the efficiency of school. Failure to include the students as input variable as a major drawback of this study.

In the estimation of departmental efficiency in Greek university, Kounetas *et al* (2011), used the total expenditures, the number of academic staff, the total number of undergraduate students and the total number of postgraduate students as inputs in the DEA model. On the other hand, three output dimensions used in the assessment of production efficiency were: the number of conference papers and presentations, the number of publications and the number of monographs and translations of a book/chapter. Environmental variables deemed to influence efficiency score included: departmental infrastructure, age of the department and behavior of school personnel. The results showed high efficiency for the departments sampled. The second stage analysis results showed that departmental infrastructure and age had a significant influence on departmental efficiency. The main limitation of this study was that it was carried in the same university which could possibly be sharing certain resources making it difficult to distinguish inputs and outputs of each department. It is also possible that is interdepartmental influence which is not factored in the analysis. The results of the analysis are not representative and hence may not be generalized for all universities.

In Kenya Abagi and Odipo, (1997) investigated efficiency in primary education. The number of textbooks, teachers, and money and physical resources were inputs considered in this study. Completion rates and dropout rates were taken as outputs. The study found out that education in Kenya faces the problem of inefficiency. The study also indicated that teaching-learning time was not utilized efficiently in primary schools. The factors behind such inefficiencies included: education policies and management processes, mis-allocation of resources to educational levels; school based factors – teachers attitudes, time utilization, school environment; and household based factors -poverty, socio-cultural factors, and gender issues. The study used descriptive statistics in the analysis of data. However, they did not use any econometric analysis to show the extent of relationship between output and input or even the degree of influence of factors that impact on efficiency of the school. Statistical tests to support the findings were also missing.

Ngware (2002) investigated internal efficiency of seven institutes of technology (IT) in Kenya. Variables of interest in this study were; students population, physical facilities, teaching and non-teaching staff. The attractiveness of each institute was determined and Kaiboi institute of technology was found to be the most efficient institute of technology.

The major limitation of the study is use of very small sample which may result to statistical bias and misleading findings.

Kiveu and Mayio (2008) investigated the impact of cost sharing on the internal efficiency of public secondary schools in Bungoma district, Kenya. The study used repetition rate and graduation rates as indicators of internal efficiency. The direct costs, facilities utilization and class attendance by teachers were factors considered to impact on school performance. The direct costs were found to have negative impacts on internal efficiency of schools. Underutilization of facilities and teachers absenteeism was found to have negative impact on performance. The direct costs were found to have negative impacts on internal efficiency of schools. The assumption that cost of education is the only major determinant of schools performance is not valid. From several other studies it is clear that there are quite a number of factors that interact to influence school's performance.

2.4 Determinants of Efficiency

According to Denaux, (2009), several factors may impact the efficiency of a school. These factors are neither inputs nor outputs in the education process, but rather circumstances faced by a particular school. Variables found to impact school efficiency scores, included; educational policy, community environment, and school characteristics. Public high schools were also distinguished by location (rural or urban). The study found out that rural schools were less efficient than urban schools. In the second stage of analysis parents' education, the race of residents and eligibility to scholarships had significant influence in academic achievements. Government spending per pupil and adequate year progress did not contribute to school efficiency.

Other studies about the determinants of educational outcomes are structured by distinguishing between student variables and school variables (Mancebonet *et al.*, 2010, Mizala, 2002, Kim *et al.*, 2006). At the student level, gender; household socio-cultural and socioeconomic characteristics are strong determinants of educational outcome. The other set of variables at the student level concerns household resources and how students use them (Kang, 2007; Woessman, 2003). At the school level, general school characteristics such as; ownership type (private or public), physical and human resources are strong determinants of school efficiency. Portela and Camanho (2007) used three groups of variables: characteristics of pupils (prior attainment, social-economic characteristics); characteristics of the school (number of teaching and non-teaching staff, expenditure per pupil, size of school, or class size); characteristics of teachers (their salary, experience, or level of education). Duncombe *et al.* (1997) concluded efficiency is negatively related to school district size, percent tenured teachers, district wealth, non-residential property values and labour intensity, and positively related to the percent of adults who are college educated.

2.5 Overview of literature

The review of literature indicates that educational efficiency can be evaluated using either parametric (SFA) or non parametric (DEA) approaches. However most a researcher uses DEA technique in the estimation of educational efficiency. DEA has several strengths over SFA techniques such as; no need to explicitly specify a mathematical form for the production function, handling multiple inputs and outputs, capable of being used with any input-output measurement and the sources of inefficiency can be analyzed and quantified for every evaluated unit. This study will adopt the DEA approach due to the aforementioned strengths.

Most of the studies reviewed estimated TE using a two-stage process. In the first stage level of efficiency/inefficiency is measured using a normal production function. In the second stage socio-economic characteristics that determine levels of technical efficiency are analyzed using a probit or tobit model. The choice of the output is pretty homogenous, and the vast majority of studies used tests scores (Chakraborty, 2009, Mancebonet *et al.* 2010, Rassouli, *et al.*, 2007). Other researchers (Bradley *et al*, 1999; Jeon and Shields, 2003; Kounetas *et al* 2011) considered graduation rate. Other output dimensions included are: number of conference papers and presentations, publications, monographs and translations of a book/chapter (Johnes and Johnes, 1993, 1995; Madden *et al.*, 1997). In this study student completion rates and examination pass rate will be taken as output.

Most studies reviewed (for instance, Athanassopoulos and Shale, 1997 ; Johnes, 2006; Jeon and Shields 2003; Portela and Camanho 2007) used total expenditures, the number of academic staff, number of students ,capital equipments, school size and number of non teaching staff as inputs in the DEA model. Other non discretionary factors identified to have an impact on educational efficiency includes; educational policy, community environment and school characteristics (Denaux *et al*, 2009). Students gender, social cultural and socio economic characteristics, family size, parental education were considered as determinants of school efficiency by (Kang, 2007; Woessman, 2003).

There are quite a number of studies on education efficiency especially in USA and Europe. However in Kenya there are only a few studies on this subject and mainly for primary and secondary schools. The said studies have mainly concentrated on internal efficiency of schools which are descriptive and without employing either parametric or non parametric measures. To the best of my knowledge there is no empirical study on the measurement of technical efficiency of educational institutions, specifically TVET using DEA technique.

CHAPTER THREE

RESEARCH METHODOLOGY

3.0 Introduction

This chapter presents theoretical framework, empirical model and describes the research design in the study. Hypotheses of the study meaning of variables used are described. The data, data sources and methods used for data analysis are explained.

3.1 Research design

The study adopted a survey research technique. Yin (2006) argues in favour of the use of surveys in educational fact-finding because they provide a great deal of accurate information. The intention of survey research was to gather data at a particular point in time and to use it to describe existing conditions. To obtain high accuracy, all the forty (40) public TVET institution under the Ministry of education were considered in the study. These TVET institutions have so many things in common and therefore can provide a more realistic comparison.

3.2 Theoretical Model

Suppose a firm uses a N dimensional vector of non negative real input x, to produce an M dimensional output vector y. The production possibilities can be represented by technology set:

$S = \{(x, y): x \, can \, produce \, y\}$ 3.1

The set consist of all input output vectors such that x can produce y. From 3.1 the output set is defined as:

$P(x) = \{y: x \; can \; produce \; y\} = \{y: (x, y) \in S\}$. 3.2

To know how the firm was efficient in the production process, the output distance function is used. It is defined as the maximum scaling $\frac{1}{\delta}(\theta)$ such that θ defines the amount by which output could have been expanded given the inputs, if technology for a certain period had been fully utilized i.e.

$$Do(x, y) = min \{\delta: (y/\delta) \in P(x)\} \text{ ....3.3a or}$$

$$[\, Do(x, y) \,] - 1 = max \{\theta: (\theta y) \in P(x)\} \text{ ....3.3b}$$

Suppose technical variation of a certain DMU is measured from period t to $t + 1$ with associate input output vectors (x^t, y^t) and (x^{t+1}, y^{t+1}). The output oriented period t Malmquist index (m_0^t) defined as a ratio of technical inefficiency in period t will be given by:

$$M_0^t(y_t, y_{t+1}, x_t, x_{t+1}) = \frac{D_0^t(y_{t+1}, x_{t+1})}{D_0^t(y_t, x_t)} \text{ ....3.4}$$

Where D_0^t is the output is oriented distance function based on period t technology, similarly the Malmquist index based on $t + 1$ technology is given by:

$$M_0^{t+1}(y_t, y_{t+1}, x_t, x_{t+1}) = \frac{D_0^{t+1}(y_{t+1}, x_{t+1})}{D_0^{t+1}(y_t, x_t)} \text{ ....3.5}$$

To avoid an arbitrary choice of technology, the Malmquist TFP change index from period t to $t + 1$ is defined as the geometric mean of 3.4 and 3.5

$$M_0(y_t, y_{t+1}, x_t, x_{t+1}) = \left[M_0^t(y_t, y_{t+1}, x_t, x_{t+1}).M_0^{t+1}(y_t, y_{t+1}, x_t, x_{t+1})\right]^{1/2} \text{ ....3.6}$$

To calculate 3.6 four distance functions namely $D_0^t(y_t, x_t), D_0^{t+1}(y_{t+1}, x_{t+1}), D_0^t(y_{t+1}, x_{t+1})$ and $D_0^{t+1}(y_t, x_t)$ are needed. To obtain TFP change the Malmquist index obtained in equation 3.6 is decomposed into efficiency change and technical change. Since most distance functions are less than one(there is technical inefficiency) equation 3.6 is equivalent to:

$$M_0(x^{t+1}, y^{t+1}, x^t, y^t) = \frac{D_0^{t+1}(x^{t+1}, y^{t+1})}{D_0^t(x^t, y^t)} * \left[\frac{D_0^t(x^{t+1}, y^{t+1}}{D_0^{t+1}(x^{t+1}, y^{t+1}} * \frac{D_0^t(x^t, y^t)}{D_0^{t+1}(x^t, y^t)} \right]^{\frac{1}{2}} \quad \ldots\ldots\ldots\ldots\ldots 3.7$$

The first ratio in equation 3.7 represents technical efficiency change from period t to t + 1 whereas the one in the parenthesis represents the technical change from period t to t + 1. Therefore, from the decomposition efficiency and technical change are given by:

$$\text{Efficiency change} = \frac{D_0^{t+1}(y_{t+1}, x_{t+1})}{D_0^t(y_t, x_t)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.8$$

$$\text{Technological change} = \left[\frac{D_0^t(y_{t+1}, x_{t+1})}{D_0^{t+1}(y_{t+1}, x_{t+1})} * \frac{D_0^t(y_t, x_t)}{D_0^{t+1}(y_t, x_t)} \right]^{1/2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.9$$

Under the assumptions of VRS technical efficiency change (3.8) can further be decomposed into scale efficiency change and technical efficiency change.

3.3 Empirical model

This section describes the empirical models that employed to achieve the objectives of the study.

3.3.1DEA model

In this study, it was hypothesized that each TVET institution maximizes outputs given the available inputs, and as such output oriented approach model was employed (Mancebon and Bandres, 1999). TE was measured using two outputs (y_1 and y_2) and three inputs (x_1, x_2, x_3 and x_4). The outputs considered here were; graduation rate and examination pass rate. The inputs considered were; students enrolled number of teaching staff, number of non teaching staff and physical facility index. Therefore, equation 3.6, 3.8 and 3.9 became:

$$M_0(y_{11+1}, y_{2t+1}, y_{1t}, y_{2t}, x_{1t+1}, x_{2t+1}, x_{3t+1}, x_{4t+1}, x_{1t}, x_{2t}, x_{3t}, x_{4t}) =$$

$$\left[\frac{D_0^{t+1}(y_{1t+1}, y_{2t+1}, x_{1t+1}, x_{2t+1}, x_{3t+1}, x_{4t+1})}{D_0^{t+1}(y_{1t}, y_{2t}, x_{1t}, x_{2t}, x_{3t}, x_{4t})} * \frac{D_0^{t}(y_{1t}, y_{2t}, x_{1t}, x_{2t}, x_{3t} x_{4t})}{D_0^{t}(y_{1t}, y_{2t}, x_{1t}, x_{2t}, x_{3t}, x_{4t}}\right] \quad \text{.................3.10}$$

Where

y_{1t+1}, y_{1t} -number of graduates in period $t + 1$ and t

y_{2t+1}, y_{2t} -average national examination pass rate in period t+1 and t

x_{1t+1}, x_{1t} -number of student enrolled in period $t + 1$ and t

x_{2t+1}, x_{2t} -number of teaching staff in period $t + 1$ and t

x_{3t+1}, x_{3t} -number of non teaching staff in period $t + 1$ and t

x_{4t+1}, x_{4t} -physical facilities index

The index obtained in 3.10 was decomposed into technical efficiency change(T.E) and technological change (T.C) to obtain sources of TFP change using the following equation:

$$TE = \frac{D_0^{t+1}(y_{1t+1}, y_{2t+1}, x_{1t+1}, x_{2t+1}, x_{3t+1}, x_{4t+1})}{D_0^{t+1}(y_{1t}, y_{2t}, x_{1t}, x_{2t}, x_{3t}, x_{4t})} \quad \text{...3.11}$$

$$TC = \left[\frac{D_0^{t}(y_{1t+1}, y_{2t+1}, x_{1t+1}, x_{2t+1}, x_{3t+1}, x_{4t+1})}{D_0^{t+1}(y_{1t+1}, y_{2t+1}, x_{1t+1}, x_{2t+1}, x_{3t+1}, x_{4t+1})} * \frac{D_0^{t}(y_{1t}, y_{2t}, x_{1t}, x_{2t}, x_{3t}, x_{4t})}{D_0^{t+1}(y_{1t}, y_{2t}, x_{1t}, x_{2t}, x_{3t}, x_{4t})}\right]^{1/2} \quad \text{.......3.12}$$

To estimate 3.10, 3.11 and 3.12 the following four output functions were required:

$D_0^{t+1}(y_{1t+1}, y_{2t+1}, x_{1t+1}, x_{2t+1}, x_{3t+1}, x_{4t+1}), D_0^{t}(y_{1t}, y_{2t}, x_{1t}, x_{2t}, x_{3t}, x_{4t}), D_0^{t+1}(y_{1t}, y_{2t}, x_{1t}, x_{2t}, x_{3t}, x_{4t}),$

$D_0^t(y_{1t+1}, y_{2t+1}, x_{1t+1}, x_{2t+1}, x_{3t+1}, x_{4t+1})$.

To estimate them, the following DEA linear programming problems were solved.

$$D_0^t\left[(x_{1t+1}, x_{2t+1}, x_{3t+1}, x_{4t+1}, y_{1t+1}, y_{2t+1})\right]^{-1} = \max_{\theta\lambda} \theta \quad \text{.......... 3.13}$$

s.t.

$$-\theta y_{1(t+1)i} + (y_{1(t+1),1}\lambda_1 + y_{1(t+1),2}\lambda_2 + \dots\dots y_{1(t+1),40}\lambda_{40}) \geq 0$$

$$-\theta y_{2(t+1)i} + (y_{2(t+1),1}\lambda_1 + y_{2(t+1),2}\lambda_2 + \dots\dots y_{2(t+1),40}\lambda_{40}) \geq 0$$

$$x_{1(t+1)i} - (x_{1(t+1),1}\lambda_1 + x_{1(t+1),2}\lambda_2 + \dots\dots x_{1(t+1),40}\lambda_{40} \geq 0$$

$$x_{2(t+1)i} - (x_{2(t+1),1}\lambda_1 + x_{2(t+1),2}\lambda_2 + \dots\dots x_{2(t+1),40}\lambda_{40} \geq 0$$

$$x_{3(t+1)i} - (x_{3(t+1),1}\lambda_1 + x_{3(t+1),2}\lambda_2 + \dots\dots x_{3(t+1),40}\lambda_{40} \geq 0$$

$$x_{4(t+1)i} - (x_{4(t+1),1}\lambda_1 + x_{3(t+1),2}\lambda_2 + \dots\dots x_{4(t+1),40}\lambda_{40} \geq 0$$

$$n'\lambda = 1$$

$$\lambda \geq 0$$

Where $\lambda = \lambda_1, \lambda_2, \lambda_3, \dots\dots \lambda_{40}$

$n'\lambda$ is 40x1vector of ones

i=1, 2, 3.........40

$y_{1(t+1)i}$ – Number of graduates in TVET i in period $t+1$

$y_{2(t+1)i}$ – Standard examinations pass rate in TVET i in period $t+1$

$x_{1(t+1)i}$ – Number of students enrolled in TVET i in period $t+1$

$x_{2(t+1)i}$ – Number of teaching staff in TVET i in period $t+1$

$x_{3(t+1)i}$ – Number of non teaching staff in TVET i in period $t+1$

$x_{4(t+1)i}$ – Physical facility index of TVET i in period $t+1$

θ-is a scalar providing information on technical efficiency score of firm i

To know the number of LPs to calculate, it was assumed that there were T time periods and I firms, then applying the formula $I\ (3T - 2)$. In this case $40(3 * 3 - 2) = 280$ LP models were solved.

Each LP produced a θ and a λ vector. The θ parameter provided information on the technical efficiency score for the ith firm and the λ vector provided information on the peers of the (inefficient) ith firm. The peers of the ith firm were those efficient firms that defined the facet of the frontier against which the (inefficient) ith firm was projected.

3.3.2 The Tobit model/ efficiency Determinants model

In the second stage, efficiency scores were related to factors seen to influence efficiency using Tobit regression of the form;

$$y_i = x_i \beta + e_i \quad \text{.........3.14}$$

Where y_i is the DEA efficiency score, x_i determinants of efficiency, β is vector of parameters to be estimated, e_i is the error term.

Therefore to analyze the influence of factors influencing efficiency in TVET institutions, the efficiency score (EFF) were regressed on factors hypothesized to impact on technical efficiency. These include location of TVET institution (RURB), provision of boarding facility and services (BOFS), flexibility in training (FLEX), proportion of engineering/technology courses offered (CENTEX) and percentage of teachers with advanced degree (AD)

$$EFF_i = \alpha_0 + \alpha_1 RURB_i + \alpha_2 BOFS_i + \alpha_3 CENTEX_i + \alpha_5 FLEX_i + \alpha_6 AD_i + e_i \quad \text{.........3.15}$$

Where EFF_i is efficiency score TVET i, $RURB_i$ is location of TVET i , $CENTEX_i$ is proportion of engineering/ technology courses, $BOFS_i$ is boarding facility provided by

TVET i, $FLEX_i$ represents flexibility of the mode of training by TVET i, and e_i is the error term

3.6Definition and Measurement of the variables

The following variables were used in this study.

Outputs:

y_1- number of graduates per year

y_2– national examination pass rate for a particular TVET in each year

Inputs:

x_1-Number of students enrolled for all programmes each year

x_2- teaching staff in each TVET during the period of study

x_3-non teaching staff employed by each TVET

x_4-Physical facility index composed of three indicators i.e number of books per student, number of computers per student and number of other facilities per student. Each indicator was equated to 1 if the given facility was greater than corresponding average level. The physical facility index was then computed as the sum of the three indicators.

Determinants of efficiency

RURB- location of the TVET (rural or urban). A dummy 1 if TVET was in urban area, otherwise 0.It was assumed that a TVET in urban area was better in terms of teachers and facilities

BOFS-boarding facility provided by TVET institution i.e. bed and meals. A score of 1 was assigned to each service offered by the TVET. It was hypothesized that these services lowers students living expenses and reduces students' mobility.

CENTEX- whether TVET was a center of excellence in engineering and technology courses or Art-based courses. The main aim of TVET is to offer engineering/technology courses although other courses also are offered together. This was calculated by dividing the engineering and science based courses and the total number of courses offered by the institute.

FLEX-flexibility of courses was indicated by courses being offered in fulltime, fulltime and part time and fulltime, part time sandwich basis. A score of 1 was assigned for each mode; total was achieved by adding up the scores, with highest score equal to 3.

AD- percentage of teachers with a master's degree and above qualifications

3.7 Data Collection

Data was collected using questionnaires which were filled in by principals of 36 public TVET institutions under the Ministry of education for the period 2009-2011. This was the period after major reforms in the TVET sector were implemented.

3.8 Data Analysis

Data obtained was arranged to fit data envelopment analysis programme(DEAP) which estimated the efficiency score of each TVET institution. The scores obtained were further regressed against the determinants of efficiency to help explain what factors actually determines TE of TVET. The Tobit model was estimated by MLE assuming normality of the error term using STATA.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Introduction

This chapter presents the findings of the study. Technical efficiency of TVET institution was estimated using DEA. In the second stage determinants of technical efficiency were evaluated using Tobit model. The chapter starts by presenting and discussing descriptive statistics. All results from DEA and Tobit model are then discussed.

4.2 Descriptive Statistics

4.2.1 Inputs and Outputs

Table 4.1 present the summary statistics of the inputs and outputs. The number of TVET institutions analyzed was 36 over a period of three years which gives a total of 108 observations. Four (4) TVET institutions did not respond even after the first and the second follow up. The study respected the DEA convention that the minimum number of DMUs is greater than three times the number of inputs plus output (Barros et al., 2010).

Table 4.1: Descriptive Statistics

Variable	Description of variable	Mean	St. Dev.	Min	Max.
Student Enrolment	Numbers of students enrolled for all courses	1085.36	520.86	315	2602
Teaching staff	Number staff teaching	95.89	32.84	36	169
Non teaching staff	Number of staff carrying out other duties other than teaching	33.17	15.26	15	82
Physical facility index	Common physical facilities including classrooms, computers and textbooks(1 if number is more than the average)	0.88	0.33	0	1
Graduates	No. of Graduates per year	371.67	196.68	103	981
Pass Rate	Average pass rate for national examinations	44.65	11.17	25.68	79.54

Source: Author's compilation

From the data, there was wide variation with regard to student enrolment with a minimum of 315 students and a maximum of 2602 students. The average students enrolment was 1085.36 and standard deviation of 520.86. This shows that some TVET institutions are bigger in size than others. As a consequence, institutions with high enrolment have high rate of graduation. The difference between minimum and maximum graduation rate support the fact. This was also noted for teaching and non teaching staff. Average pass rate also varies among the institutions with a minimum of 25.68 and a maximum of 79.54 per cent, a mean of 44.64 and a standard deviation of 11.16. The average pass rate was below 50 per cent and could negatively affect the graduation rate.

4.2.2 Efficiency Determinants

The determinants of TE in TVET institutions identified were: location of the institution, boarding facilities provided by the institution, flexibility of the mode of study, proportion of engineering/science courses relative to art based courses, and the qualification of teaching staff.

Table 4.2 Location of TVET institutions

Location	No. of institutions	Percentage
Rural	22	61
Urban	14	39
Total	36	100

Source; Author's compilation

From table 4.2, it was found out that 61% of TVET institutions were located in the rural areas and 39% in urban areas. The high concentration of TVET institutions in the rural areas was an attempt to distribute these learning institutions throughout the country. Availability of land in the rural areas could also be a reason for high percentage of TVET being found in rural areas.

In terms of boarding facility and services provided by each TVET institution, table 4.3 shows the various services offered by TVET institutions.

Table 4.3: Boarding Facility and Services offered by TVET

Boarding Facility and Services offered	**No. of TVET institutions**	**Percentage**
Bed alone	12	33.3
Bed and meals	24	66.7
No Boarding	0	0
Total	36	100

Source; Author's compilation

The analysis of the boarding facilities and services offered by the TVET institutions revealed that all the institutions studied were offering these services but had limited capacity. The institutions reported that they were unable to accommodate all students studying in the institutions due to the limited capacity. 66.7% of TVET institutions studied were offering both bed and meals. The remaining 33.3% were only offering bed only without meals and the students were expected to buy or prepare meals on their own.

The proportion of engineering/science courses in relation to art based courses calculated by comparing the number of engineering/science courses with art based course was presented in table 4.4. The table shows the number of TVET institutions with greater number of either engineering/science or art based courses.

Table 4.4 Proportion of Engineering/Science in relation to Art-based Courses

Proportion of courses offered	No. of institutions	Percentage
Engineering/Science>Arts	19	52.8
Arts> Engineering/Science	17	47.2
Total	36	100

Source; Author's compilation

From Table 4.4, it was reported that 52.8% were offering more courses in mechanical engineering, electrical engineering, automotive engineering, building & civil engineering, information & communication technology and health& applied sciences than in business studies, hospitality and liberal studies. The training in TVET was seen as vehicle to develop the needed artisans, technicians and technologists for the country. Therefore, the TVET institutions are expected to offer more of engineering, technology and science courses, if they are realize their mandate. The study revealed that 47.2% were concentrating on art based courses more than engineering/ science based courses. This could be due to the fact that they require little investment in capital and equipments.

Flexibility of the mode of study was measured by the different ways in which the TVET institution could offer their course. It was revealed that, TVET course were offered in three different modes; Full time (regular), Evening& Weekend (Part-time) and School based (Sandwich).

Table 4.5 Flexibility of the Mode of study

Mode of study	No. of institutions	Percentage
Full time only	18	50
Full time &Evening	16	44
Full time, Evening& school based	02	6
Total	**36**	**100**

Source; Author's compilation

Table 4.5, revealed that half of the TVET institutions offered their courses on regular of full time mode only. Another 44% of the institutions taught the TVET courses by using both full time and evening modes. Only 6% of the institutions were found offering the TVET courses by using the entire three modes i.e. full time, evening and school based modes of study.

The teaching staffs in TVET institutions were found to be holding different qualifications including; certificate, diploma, bachelors degree, masters degree and doctor of philosophy degree as shown in figure 4.1.

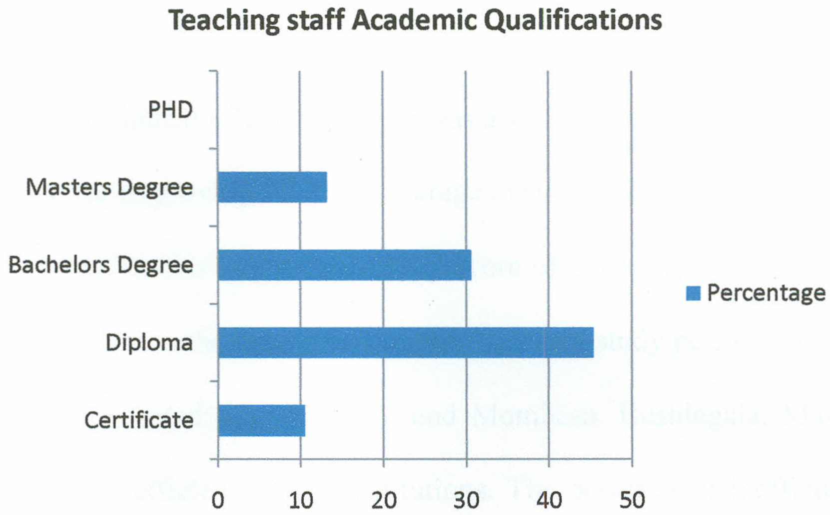

Figure 4.1: Teaching Staff Academic Qualifications

Source; Author

Figure 4.1, reveals that the qualification of teaching staff in TVET institutions were quite low. The study revealed that 10.6% of the teaching staffs were certificate holders, 45.4% were diploma holders and 30.7% had first degree qualifications. Only 13.3% of the teaching staff had master degree qualifications. The study further found out that only two teaching staff in TVET had doctorate qualifications. A high proportion of tutors with diploma qualifications teaching diploma courses are likely to affect a TVET's performance hence its efficiency.

4.3 Empirical Results

4.3.1 Efficiency Scores

The results show that on average the overall industry efficiency was high at 79.4 % in the years 2009, 2010 and 2011, denoting that most TVET institutions used inputs efficiently to produce output. This means that only 20.6% of TVET institutions in Kenya were inefficient during the study period. The TVET sub-sector thus had on average 20.4 % mean potential to improve its performance and efficiency without the need to use more resources. The findings were broadly in accordance with Abott and Doucouliagos (2003) who examined technical efficiency of polytechnics in New Zealand

In terms of technical efficiency, there was a wide dispersal of results, indicating that there was scope for improving TE. The average mean efficiency ranged from 0.51 to 1. 91.7% of TVET institutions had an efficiency score of over 0.5 with 8.3% of TVET scoring 1, hence identified as the best practice. For the entire study period, the three efficient TVET institutions included; Bumbe, NEP and Mombasa. Bushiagala, Mathenge and Michuki were the least efficient TVET institutions. The presence of inefficiencies indicated that the TVET institutions had excess inputs or insufficient inputs compared to those TVET on the efficient frontier. Nairobi was efficient in 2009 but this declined in 2010 only to emerge efficient again in 2011. Other institutions that recorded a score of 1 in some but not in all periods includes were; Kaiboi, Gusii, Moi, Nyandarua, Rift Valley, Kisumu, Kabete, Kisiwa and Friends College. Masaai and Mathenge recorded an efficiency score of less than 0.5 in 2009 and 2010 respectively. The findings were consistent with Abbot& Doucouliagos (2003), with individual polytechnics registering mixed efficiency scores in their study.

Table 4.6: Mean efficiency in years 2009, 2010 and 2011

Year	**2009**	**2010**	**2011**	**Average TE**
TE	0.753	0.787	0.840	0.794

Source: Author's compilation

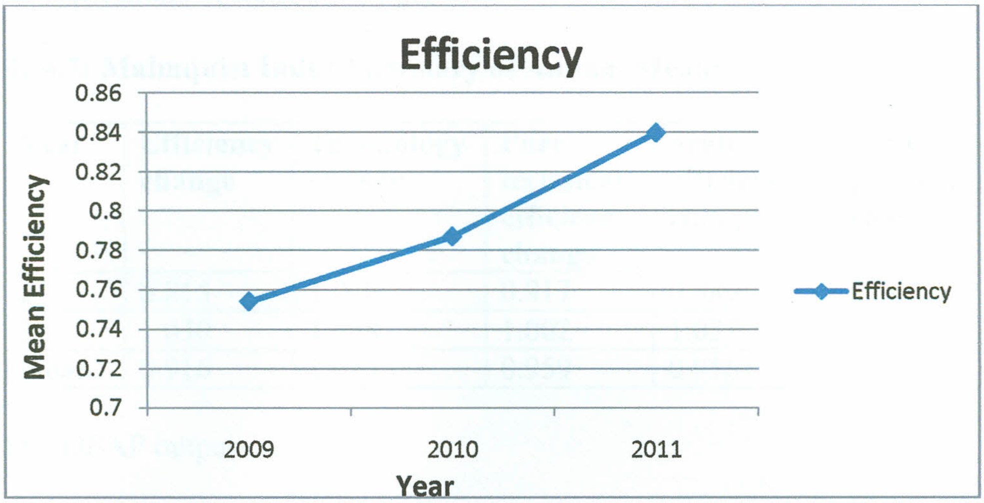

Figure 4.2: Technical Efficiency Means over time
Source: Author

Efficiency distribution over time summarized by table 4.3 and figure 4.1 indicated that the overall efficiency was 0.794. Mean efficiency TVET institutions was found to increase marginally for study period 2009, 2010 and 2010 with mean efficiencies of 0.753, 0.787, and 0.840 respectively. The findings are consistent with study by Chakraborty & Poggio (2008) in which Kansas schools mean efficiency increased marginally over a three years' study period.

4.3.2 Malmquist Analysis

The score for total productivity change (TFT) was less than one for most of TVET institutions, with the exception of twelve, showing that a large proportion of the TVET institutions experienced losses in total productivity in the period considered. The mean TFT of 0.965 implies that there was a fall in total factor productivity of about 3.5 per cent over the period 2009 to 2011. This was despite the fact that technical progress was recorded of about 5.3 percent whose benefits were all eroded by a decline in efficiency by about 8.4 percent over the period. This seems to concur with general performance of TVET institutions in Kenya, (Amuka, Olel and Gravenir, 2011).

Table 4.7: Malmquist Index Summary of Annual Means

Year	Efficiency change	Technology change	Pure technical efficiency change	Scale efficiency change	Total factor productivity change
2	0.815	1.058	0.917	0.889	0.863
3	1.030	1.058	1.002	1.027	1.079
mean	0.916	1.053	0.959	0.956	0.969

Source: DEAP output

The change in the technical efficiency score defined, as the diffusion of best-practice technology in the management of the TVET institutions is attributed to investment planning, technical experience, and management and organization in the TVET institutions. For the period under analysis, we can see that it is less than one for 67% of all the TVET institutions. The breakdown of the change in technical efficiency into pure technical efficiency change and scale efficiency change shows mixed results, with some TVET institutions obtaining simultaneous gains in both areas and others obtaining gains in one but losses in the other. The decline in pure technical efficiency, which means deterioration in managerial skills, shows that there was probably no investment in organizational factors associated with the management of the TVET institutions, such as best-practice initiatives, an improvement in quality and so on. The findings support the study by Muriithi,(2008) who noted that the quality of teaching, teaching equipments and graduates of TVET was declining. The scale efficiency decreases on average in the period as the mean change is 0.956 which is less than one.

Technological change is the consequence of innovation, that is, the adoption of new technologies by best-practice TVET institutions. This index was higher than one for most of TVET institutions with exception of nine which recorded an index lower than one, giving an average of 1.053. This was an indication that innovation improvement occurred in the period for most TVET institutions. This could be attributed to huge government investment in ICT within the TVET sector during that period (R.o.K, 2010)

4.3.3 Determinants of Technical Efficiency

Before the estimation, the variables used, they were tested for multicollinearity. Table 4.8 presents the correlation matrix.

Table 4.8: Correlation matrix

	RURB	BOFS	CENTEX	FLEX	AD
RURB	1				
BOFS	-0.5238	1			
CENTEX	-0.0269	0.1789	1		
FLEX	0.4377	-0.4581	-0.00538	1	
AD	0.0057	-0.1772	-0.0540	-0.0658	1

Source: Author's compilation

Correlation coefficients between variables were calculated and examined. Correlations tended to be low. This was an indication that the study was not plagued by problems of high co-linearity between the predictor variables.

The results of the censored tobit regression of the efficiency scores was given in table 4.9

Table 4.9: Tobit Regression Results

TE	Coef	Std Err.	P>|t|
RURB	.0471598	0.445564	0.292
BOFS	.0245079	.0485837	0.615
CENTEX	-.0030358	.0014554	0.039
FLEX	.0555558	.0345779	0.111
AD	.0319279	.0069017	0.000

Log likelihood = -19.1246
Jarcque Bera (chi square) = 1.7044 Prob = 0.4322
White test (Prob>chi-sq) = 1.327 Prob = 0.2428

The model was tested for normality and heteroskedasticity using Jarque Bera and White test respectively. The diagnostic tests for the tobit model revealed that the model was well specified. Normality tests established that the residuals in the model were normally distributed .The Chi square probability value was 0.4322 implying that the residuals were normally distributed. White tests indicated that the variance in the model was constant. The chi square probability (0.2428) is greater than 0.05 confirming the absence of heteroskedasticity in the Tobit model.

The coefficient for *CENTEX* was negative and significant at 5% significance level. This means that the proportion of engineering/science based courses offered by a TVET institution negatively affects efficiency. The TVET institutions offering more engineering / science based courses are likely to be less efficient than the ones offered more art based courses. This finding supports Abbott and Doucouliagos, (2003), who found out that engineering and science based polytechnics centers were less efficient due to the fact they are more demanding in terms of inputs and requires sophisticated equipments. Since some TVET institutions in Kenya lack the necessary equipment to offer engineering/science courses effectively, equipping TVET institutions with necessary and modern equipments can lead to increased efficiency.

TVET with high quality of labour was expected to be more efficient. From the results, the coefficient for *AD* was positive and also significant at 5% level of significance. This means that the quality of labour (teaching staff) was a major determinant of efficiency in TVET institutions. A TVET institution with tutors who had master degree and higher professional qualifications, recorded better performance than the one with tutors of lower qualifications. This study supports Bradely *et al*, (1999) that quality of teachers matter in the school performance. The results were also consistent with the findings of Adkins and Moomaw (2005), that teacher's experience and advance degree enhances efficiency of schools. The TVET institutions should encourage the tutors to upgrade their qualification and improve their skills. This can in turn lead to higher efficiency of the TVET institution.

The coefficients of three factors-location of TVET (RURB), flexibility of study mode (FLEX) and boarding facility and services offered by TVET (BOFS) were not significant at 5% and 10% level of significance indicating that these factors did not matter in relation to technical efficiency of TVET institutions in Kenya. These results however, contradicted the findings of Denaux (2009) who found out that rural schools were less efficient compared to urban schools. From the study all TVET institutions reported to be offering boarding facilities, some with bed and meals while others bed only. The findings were also inconsistent with findings of Conroy & Arguea (2007) that students' mobility disrupts learning leading to low achievement. These findings suggest that the Kenya situation is unique in regard to these two factors.

CHAPTER FIVE

SUMMARY, CONCLUSION AND POLICY RECOMMENDATIONS

5.1 Introduction

This chapter summarizes the findings of the study and makes the necessary conclusions. The policy implications from the findings and areas of further research are also proposed.

5.2 Summary and Conclusion

The purpose of the study was to measure the technical efficiency of TVET institutions in the Kenya education sector. The study also aimed at establishing the determinants of this efficiency. This education subsector is expected to play a key role in the realization of Kenya Vision 2030 through provision of artisans, craftsmen, technicians and technologists to spur economic growth.

This study estimated the level of technical efficiency of the TVET institutions in Kenya using DEA for the year 2009 to 2011. The study further examined the factors that influenced the level of technical efficiency of the TVET institution. The study findings revealed that overall efficiency level of the TVET institutions in Kenya is 79.4%. This was an indication that, there was a potential of 20.6% to improve output without the use of more input resources by the TVET institutions. The variation of efficiency levels among the firms was wide with the least efficient firm at 0.51 efficiency level and the most efficient at 1. On average none of the 36 TVET institution analyzed in this study had an efficiency score less than 0.5. The efficiency over time was increasing for the period under study. The findings show that, average level of efficiency increased from 0.754 in 2009 to 0.840. Total factor productivity for TVET institutions except for twelve declined over the study period.

The regression analysis of the external factors on efficiency scores using censored Tobit regression sheds some light on the possible drivers of efficiency in TVET institutions in Kenya. The study findings concluded that, the proportion of engineering/science in relation to Art-based course affected the level of technical efficiency of TVET institutions. Better quality labour in terms of tutors possessing advanced degree was also found to positively and significantly influence TE of TVET institutions in Kenya. The study further concluded that location of TVET institutions does not influence efficiency of TVET institutions in Kenya. The flexibility of the mode of study and provision of boarding services by TVET institutions were also found not to determine the efficiency of these institutions.

In the light of research findings, Kenyan TVET subsector had an opportunity to improve technical efficiency within the system. It may be concluded that inefficiency in this sector was due to lack of highly qualified tutors and offering engineering/science courses without appropriate modern equipments. This may have affected the quality of teaching and hence low performance in the final examination and graduation rate.

5.3 Policy Recommendations

In the present day, vocational education and training have become an integral part of the economy and should therefore be monitored more critically. The research findings showed that on average 91.6% of the TVET institutions were not a hundred per cent efficient. This implies that existing resources could lead to improved performance without necessarily having to inject new resources. Inefficiency could be corrected through efficient utilization of the existing resources. The use of modern technology and up to date equipment in teaching and learning in TVET sector can greatly improve the performance.

The quality of labour in TVET institution positively affects efficiency. The reforms initiated by the government of Kenya in the year 2008, to upgrade all technical teachers' qualification to at least a bachelors degree, should be enhanced through more budgetary allocation to enable more staff to acquire higher qualifications. Having many tutors in TVET institutions with little low education qualifications can jeopardize the proper training of the highly needed experts to support Kenya vision 2030. With this low qualification, the tutors are unable to deliver effectively in class and to produce the good results. The policy to upgrade all technical teachers to at least bachelors' degree would ensure that the teachers with diploma qualification stop teaching diploma students. The government should encourage technical teachers to pursue masters degree by offering scholarships and streamlining the study policy for those can privately pay for their studies. Incentives such as higher pay for those with advanced degree and promotion based on academic qualification will go a long way in promoting teachers to acquire higher qualification. The exchange programme organized between Kenya and Netherlands in the years 2008 ought to be continuous and to ensure that at least all technical teachers undertake part of their study in Netherlands and other countries with developed TVET sector and learn from the best.

This study finds a negative but statistically significant impact of proportion of engineering/science programmes on TVET efficiency. These courses are more demanding in terms of resources such as capital equipments. Arrangements to equip the TVET institutions began in 2008 and have seen eight TVET institutions well equipped with modern and adequate facilities for engineering/science courses. This was meant ensure that these courses are taught practically and improve performance. Offering of bursary to female students pursuing engineering/science based courses is also aimed at encouraging more students to enroll for such programmes. The government should however extend this programme to the remaining TVET institutions and ensure that they acquire modern and adequate equipments.

To deal with issues of under enrolment in most of TVET institutions, the male students should start receiving the support such as provided to their female counterparts to increase enrolment in engineering and science based course. This will boast performance in these courses leading to production of the most needed artisans, craftsmen, technologists and technicians Kenya needs to meet long term development needs.

5.4 Suggestion for further study

This study only considered the TVET institutions managed and operated under the Ministry and covers the year 2009-2011 due data availability. A further study can be done for the TVET subsector both private and public to establish the efficiency differences in them. More factors that are likely influence efficiency of TVET can be considered for an extended time period.

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APPENDICES

APPENDIX I

LETTER OF TRANSMITAL

I am a student at Kenyatta University pursuing a Master of Art Degree in Economics. I am carrying out a research study entitled "Technical Efficiency of TVET institutions in Kenya"

Your help in filling in the questionnaire will be highly appreciated. All information will be treated with strict confidentiality, as the purpose of this study is for academic purposes only.

Yours faithfully,

PAUL WANJORA KARIUKI

APPENDIX II

QUESTIONNAIRE NO……………………………………………

INSTRUCTION

This questionnaire is aimed at gathering data in order to measure Technical Efficiency of TVET institutions in Kenya. Please give the information needed openly and sincerely. The exercise is purely for academic pursuit.

PLEASE FILL IN REQUIRED INFORMATION

1. Name of TVET institution…………………………………………………………

2. The county in which the institution is located..

3. Name the nearest town from the institute and estimate of the distance from main town in Kilometers……………………………………

4. What was the student population and new enrolment in each year

Year	Student population	New enrolment
2009		
2010		
2011		
2012		

5. Indicate the number of teaching staff and their Qualifications

Year	Teaching staff	Qualifications(Indicate the number with following qualifications				
		Post Graduate	Bachelors degree	Diploma	Certificate	Others
2009						
2010						
2011						
2012						

6. Indicate the number of non teaching staff and their qualifications in the following table.

Year	Non-Teaching Staff	Qualifications(Indicate the number with following qualifications					
		Post Graduate	Bachelors degree	Diploma	Certificate	Artisan	Non
2009							
2010							
2011							
2012							

7. A) Fill the number of physical facilities in the institute

Year/ Facility	Computers	Text books	Classrooms	Laboratories	Workshops
2009					
2010					
2011					
2012					

b) What is the number and capacity of your library? *Number*.............*Capacity*.........

8. Indicate the departments, in your institution in 2009, 2010, 2011, and 2012. Indicate levels of programmes offered (diploma or certificate or Artisan) and the mode in which it is offered.

Tick the departme In your institution	Level at which Course are off (Tick appropriately)			Mode(Full time, Part-time or Sand (Tick appropriately)		
	Diploma	Craft	Artisan	FT	PT	SW
1.Mechanical Engineering						
2.Electrical& Electronics						
3.Automotive Engineering						
4.Institutional Management/ Hospitality						

5.Health&Applied Sciences						
6.ICT						
7.Business studies						
8.Building&Civil Engineering						
9.Agriculture						
10.Liberal studies						
11. others(Specify)						

9. Fill the number of graduates per year and percentage pass for all courses

	Number of gradu		**KNEC Final Examination overall Percentage Pass**		
	Diplon	**Certificat**	**Diploma exam**	**Certificate Exa**	**Artisan Exams**
2009					
2010					
2011					
2012					

10. a) Does the institution offer boarding facility? YES/NO..............

b)If YES, How many students are accommodated in the halls of residence?.......

c) Are meals included in the boarding services? YES/NO...............

11. Give the number of students who received bursary in the years indicated

Year	Number that received bursary/ Financial Assistance
2009	
2010	
2011	
2012	

Thank you!

APPENDIX III

TE OF TVET INSTITUTIONS

	TVET Inst.	2009	2010	2011	Mean TE
1	Nairobi TTI	1	0.913	1	0.971
2	Kinyanjui TTI	0.62	0.836	0.888	0.7813
3	Thika TTI	0.624	0.778	0.789	0.7303
4	O'Lesos IST	0.577	0.852	0.846	0.7583
5	Ramogi Institute	0.96	0.692	0.825	0.8256
6	Bumbe TTI	1	1	1	1
7	Gusii IST	0.876	0.794	1	0.89
8	Moi IST	0.98	1	0.753	0.911
9	Kiambu IST	0.636	0.956	1	0.864
10	Kaiboi TTI	1	0.821	0.943	0.921
11	North Eastern Province TTI	1	1	1	1
12	Nyandarua TTI	0.895	0.712	1	0.869
13	Nkabune TTI	0.802	0.749	0.846	0.799
14	Nyeri TTI	0.54	0.849	0.957	0.7786
15	Mombasa TTI	1	1	1	1
16	Coast Institute of Technology	0.725	0.895	0.846	0.822
17	Athi River Vocational Training	0.533	0.732	0.949	0.738
18	Rift Valley TTI	0.733	0.82	1	0.851
19	Kisumu Polytechnic	0.603	1	1	0.8676
20	Masaai TTI	0.498	0.739	0.676	0.6376

21	Sigalgala TTI	0.614	0.706	0.988	0.776
22	Siaya TTI	0.521	0.726	0.758	0.6683
23	Kitale TTI	0.642	0.782	0.754	0.726
24	Rift Valley IST	0.883	0.902	0.911	0.925
25	Kabete TTI	1	0.566	0.788	0.7846
26	Rwika TTI	0.95	0.909	0.882	0.9136
27	Kisiwa TTI	0.659	0.852	1	0.837
28	MathengeTTI	0.589	0.452	0.544	0.528
29	Friends College Kamusinga	1	0.568	1	0.856
30	Michuki TTI	0.67	0.511	0.506	0.5623
31	Bushiagala TTI	0.511	0.603	0.416	0.51
32	Mawego TTI	0.74	0.84	0.542	0.7073
33	Keroka TTI	0.805	0.65	0.977	0.8106
34	Matili TTI	0.605	0.709	0.493	0.6023
35	KiiruaTTI	0.633	0.729	0.593	0.6516
36	Sangalo IST	0.704	0.686	0.767	0.719

APPENDIX IV

DISTANCES SUMMARY

year = 1

firm no.	crs te rel to tech in yr t-1	t	t+1	vrs te
1	0.000	1.000	1.752	1.000
2	0.000	0.569	0.611	0.620
3	0.000	0.577	0.729	0.625
4	0.000	0.545	0.481	0.566
5	0.000	0.877	0.713	0.898
6	0.000	1.000	1.218	1.000
7	0.000	0.821	0.712	0.844
8	0.000	0.865	0.699	0.934
9	0.000	0.449	0.388	0.636
10	0.000	0.997	0.963	1.000
11	0.000	1.000	1.167	1.000
12	0.000	0.810	0.887	0.812
13	0.000	0.705	0.634	0.705
14	0.000	0.705	0.678	0.764
15	0.000	1.000	0.952	1.000
16	0.000	0.680	0.610	0.683
17	0.000	0.621	0.519	0.646
18	0.000	0.937	1.152	0.944
19	0.000	0.815	0.880	1.000
20	0.000	0.708	0.608	0.726
21	0.000	0.609	0.517	0.689
22	0.000	0.601	0.510	0.629
23	0.000	0.626	0.527	0.712
24	0.000	0.913	0.957	1.000
25	0.000	0.854	0.811	1.000
26	0.000	1.000	0.808	1.000
27	0.000	0.994	1.152	1.000
28	0.000	0.896	0.727	0.896
29	0.000	1.000	1.104	1.000
30	0.000	0.910	0.767	0.943
31	0.000	0.890	0.720	0.908
32	0.000	1.000	1.086	1.000
33	0.000	1.000	1.226	1.000
34	0.000	0.821	0.692	0.840
35	0.000	0.927	0.830	1.000
36	0.000	1.000	0.932	1.000
mean	0.000	0.826	0.826	0.862

year = 2

firm no.	crs te rel to tech in yr ************************ t-1	t	t+1	vrs te
1	1.011	0.971	0.866	1.000
2	0.594	0.644	0.591	0.692
3	0.697	0.625	0.594	0.787
4	0.718	0.646	0.597	0.654
5	0.706	0.645	0.640	0.682
6	1.566	1.000	2.045	1.000
7	1.163	1.000	0.922	1.000
8	1.397	1.000	1.115	1.000
9	0.586	0.520	0.496	0.726
10	0.731	0.710	0.578	0.856
11	0.941	1.000	1.029	1.000
12	0.720	0.680	0.660	0.713
13	0.768	0.708	0.677	0.849
14	0.752	0.676	0.619	0.872
15	1.150	1.000	1.201	1.000
16	0.450	0.399	0.403	0.481
17	0.439	0.413	0.466	0.600
18	0.635	0.574	0.497	0.742
19	0.628	0.678	0.561	0.834
20	0.754	0.716	0.659	0.738
21	0.474	0.435	0.400	0.535
22	0.539	0.476	0.544	0.726
23	0.620	0.543	0.574	0.813
24	0.806	0.863	0.705	0.986
25	0.677	0.668	0.518	0.768
26	0.890	0.743	0.787	1.000
27	0.703	0.540	0.932	0.756
28	0.505	0.454	0.428	0.531
29	0.784	0.810	0.609	0.815
30	0.684	0.575	0.572	0.591
31	0.518	0.511	0.522	0.614
32	0.671	0.693	0.769	0.844
33	0.466	0.421	0.486	1.000
34	0.723	0.692	0.650	0.748
35	0.673	0.714	0.623	0.729
36	0.821	0.797	0.676	0.837
mean	0.749	0.682	0.695	0.792

year = 3

firm crs te rel to tech in yr vrs

no.	************************			te
	t-1	t	t+1	
1	0.886	0.921	0.000	1.000
2	0.610	0.673	0.000	0.821
3	0.526	0.553	0.000	0.750
4	0.755	0.650	0.000	0.665
5	0.785	0.805	0.000	0.823
6	1.246	1.000	0.000	1.000
7	1.330	1.000	0.000	1.000
8	0.890	0.831	0.000	0.861
9	0.533	0.491	0.000	0.647
10	1.018	0.819	0.000	0.980
11	1.228	1.000	0.000	1.000
12	1.619	1.000	0.000	1.000
13	1.067	1.000	0.000	1.000
14	0.761	0.716	0.000	0.954
15	0.893	1.000	0.000	1.000
16	0.444	0.443	0.000	0.501
17	0.545	0.602	0.000	0.712
18	0.671	0.572	0.000	0.767
19	0.799	0.661	0.000	0.864
20	0.558	0.524	0.000	0.562
21	0.489	0.464	0.000	0.591
22	0.392	0.428	0.000	0.540
23	0.621	0.523	0.000	0.654
24	0.921	0.752	0.000	1.000
25	0.752	0.652	0.000	0.875
26	0.813	0.816	0.000	0.994
27	0.838	1.000	0.000	1.000
28	0.495	0.481	0.000	0.597
29	1.775	1.000	0.000	1.000
30	0.612	0.640	0.000	0.715
31	0.408	0.400	0.000	0.454
32	0.579	0.539	0.000	0.581
33	0.613	0.682	0.000	0.977
34	0.519	0.481	0.000	0.522
35	0.664	0.574	0.000	0.597
36	0.846	0.704	0.000	0.853
mean	0.792	0.706	0.000	0.802

[Note that t-1 in year 1 and t+1 in the final year are not defined]

APPEDIX V

MALMQUIST INDEX SUMMARY OF ANNUAL MEANS

year	effch	techch	pech	sech	tfpch
2	0.815	1.058	0.917	0.889	0.863
3	1.030	1.048	1.002	1.027	1.079
mean	0.916	1.053	0.959	0.956	0.965

APPENDIX VI

MALMQUIST INDEX SUMMARY OF FIRM MEANS

firm	effch	techch	pech	sech	tfpch
1	0.960	0.895	1.000	0.960	0.858
2	1.087	0.960	1.151	0.944	1.043
3	0.979	0.969	1.096	0.894	0.949
4	1.092	1.122	1.084	1.008	1.225
5	0.958	1.073	0.957	1.001	1.028
6	1.000	0.941	1.000	1.000	0.941
7	1.104	1.179	1.089	1.014	1.302
8	0.980	1.135	0.960	1.021	1.112
9	1.045	1.104	1.008	1.037	1.154
10	0.906	1.129	0.990	0.916	1.024
11	1.000	0.990	1.000	1.000	0.990
12	1.111	1.127	1.110	1.001	1.252
13	1.191	1.077	1.191	1.000	1.283
14	1.008	1.076	1.117	0.902	1.085
15	1.000	0.974	1.000	1.000	0.974
16	0.807	1.057	0.857	0.942	0.853
17	0.985	1.005	1.050	0.938	0.989
18	0.782	1.050	0.902	0.867	0.821
19	0.901	1.058	0.930	0.969	0.953
20	0.861	1.091	0.880	0.978	0.939
21	0.873	1.101	0.927	0.942	0.961
22	0.843	1.017	0.926	0.911	0.858
23	0.914	1.111	0.958	0.953	1.015
24	0.908	1.075	1.000	0.908	0.976
25	0.874	1.123	0.936	0.934	0.981
26	0.903	1.087	0.997	0.906	0.982
27	1.003	0.860	1.000	1.003	0.862
28	0.732	1.106	0.816	0.897	0.810
29	1.000	1.199	1.000	1.000	1.199
30	0.838	1.080	0.871	0.963	0.905
31	0.671	1.057	0.707	0.948	0.709
32	0.734	0.964	0.762	0.963	0.708
33	0.826	0.916	0.989	0.836	0.756
34	0.765	1.093	0.788	0.971	0.836
35	0.787	1.087	0.773	1.019	0.856
36	0.839	1.118	0.923	0.909	0.939
mean	0.916	1.053	0.959	0.956	0.965

[Note that all Malmquist index averages are geometric means]

APPENDIX VII
TOBIT REGRESSION

					Number of Obs = 108 LR $Chi^2(5)$ = 29.90 Pro>chi^2 = 0.0000 Pseudo R^2 = 0.5251	
TE	**Coef**	**Std Err.**	T	**P>|t|**	**[95% Conf. Interval]**	
RURB	.0471598	0.445564	1.06	0.292	-.0412072	.1355268
BOFS	.0245079	.0485837	0.50	0.615	-.0718464	.1208623
CENTEX	-.0030358	.0014554	-2.09	0.039	-.0059223	-.0001493
FLEX	.0555558	.0345779	1.61	0.111	-.0130214	.1241329
AD	.0319279	.0069017	4.63	0.000	.01824	.0456158
Cons	.6070933	.1523797	3.98	0.000	.3048841	.9093025
Sigma	.1800584	.0146181			.1510668	.20905

-Log likelihood = -19.1246

Jarcque Bera (chi square) = 1.7044 Prob = 0.4322

White test (Prob>chi-sq) = 1.327 Prob = 0.2428