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SCHOOL OF ECONOMICS

Technical Efficiency of Kenyatta National Hospital

By

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DECLARATION

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

DATE 26.10.2012

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This research paper has been submitted with our approval as university supervisors.

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DEDICATION

I dedicate this research paper to my parents: Mr. Enosh Odhiambo Magak and Mrs. Joyce Awuor Odhiambo for their support.

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I thank the Almighty God for his guidance, help and for keeping my health stable while pursuing this programme.

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I solely bear any errors and omissions in this research Paper.

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LIST OF ACRONYMS

ALS	Average Length of Stay
CRS	Constant Returns to Scale
DEA	Data Envelopment Analysis
DMU	Decision Making Unit
DRS	Decreasing Returns to Scale
ENT	Ear, Nose and Throat
FBO	Faith Based Organization
IRS	Increasing Returns to Scale
KNH	Kenyatta National Hospital
LP	Linear programming
MCH	Mother and Child Health
MOH	Ministry of Health
MOMS	Ministry of Medical Services
MOPHS	Ministry of Public Health and Sanitation
MPI	Malmquist Productivity Index
OBS&GYN	Obstetrics & Gynecology
PHU	Peripheral Health Units
RTS	Returns to Scale
SSA	Sub-Saharan Africa
STDEV	Standard deviation
TE	Technical Efficiency
TFP	Total Factor Productivity
VRS	Variable Returns to Scale

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ABSTRACT

This study uses Data Envelopment Analysis (DEA) and Malmquist Productivity Index (MPI) to estimate the degree of technical efficiency and levels of productivity change at Kenyatta national hospital. The study has also used Tobit regression to identify the factors responsible for efficiencies in the use of resource inputs among the units that constitute the clinical section of KNH. Panel data for eleven years (2000-2010) was used. The resource inputs used were: number of doctors, number of registrars, number of nurses (enrolled/registered and community nurses), number of administrative officers and number of beds, while outputs used were number of outpatients and number of inpatient admissions. The explanatory variables for the Tobit model were: bed occupancy rate (%); average length of stay (days); ratio of the sum of doctors and nurses to number of inpatient admissions number of beds and outpatient visits as a proportion of inpatient admissions. Tested at 95% confidence interval, bed occupancy rate and outpatient visits as a proportion of inpatient admissions were found to be insignificant, while the rest of the explanatory variables were significant. 40% of the decision making units were found to be were technically efficient while 60% were technically inefficient. The mean technical efficiency was 77%. There is need to undertake this kind of study to other hospitals in the country-where it has not been done, whether public or private- as doing so would aid the ongoing health sector reforms.

CHAPTER ONE

1.0 Background

Kenya is an East African country with a population of 38.8 million people. 78.4% of Kenya's population lives in rural areas as compared with the SSA average of 61.3%. Population in Kenya grows at a rate of 2.64% while the average for SSA is 2.35% (G.O.K, 2010; KNBS, 2010). Life expectancy at birth is 54.24 years; Infant mortality rate and under- five mortality rates are 52 deaths per 1,000 live births and 74 deaths per 1000 live births respectively (G.O.K, 2009); Kenya's human development index (HDI) is 0.509 and maternal mortality per 100,000 live births is 530 (World Bank, 2011). Public health sector financing as percent of total government expenditure was 1.5% of GDP. In the year 2010/2011, the public per capita health spending was 12.6 US dollars which was low compared to WHO recommendation of an average of 44 US dollars per capita on health care. Barnum and Kutzin (1993) stated that hospitals in developing countries consume an average of 50-80 % of public sector health resources.

The largest source of health funds in Kenya is 'households' which contribute 35.9% of total health care funding. Donors contribute 31% while the government contributes 29.3%. All public health facilities charge user fees for service, a move that has led to significant reduction in inpatient and outpatient services utilization of public health facilities (Mwabu et al. 1995). Health sector budget allocation increased from Kenya shillings 39.9 billion in 2009/2010 to Kenya shillings 41.5 billion in 2010/2011. Of the allocations, referral and teaching hospitals (KNH & Moi) received 11.6% in 2009/2010 (Cieza, N. and Holm, F., 2010) and 12% in 2010/2011 (Sealy, S. and Rosbach, K., 2011), equivalent to Kenya shillings 4.6 billion and 5 billion respectively. It is important to use the resources efficiently.

Efficiency is the extent to which a health decision making unit (DMU) uses the available health resources known as inputs to produce the maximum possible outputs of a given quality. There are three components of efficiency namely: technical efficiency (TE), allocative efficiency (AE) and cost efficiency. A health unit is said to be technically efficient if it is operating on the "best-practice" production frontier (Farrell, 1957). Technical efficiency can be defined as the capacity and willingness of a health unit to produce maximum possible output from a given bundle of inputs and technology, the concept that relates to maximizing the output for a given set of factor inputs (Kalirajan et al., 2002).

Measuring efficiency allows ranking and evaluating hospitals because it facilitates comparisons across similar hospitals or decision making units (Mizala et al., 2002). Measuring efficiency also allows future analyses to identify factors that cause variations in efficiency between various units. There is a high probability that if technical inefficiency exists, it will exert a negative influence on allocative efficiency hence there will be a cumulative negative effect on economic efficiency. Allocative efficiency is the ability and willingness of an economic unit to equate its specific marginal value product with its marginal cost (Kalirajan et al., 2002), while cost efficiency results when technical and allocative efficiencies prevail, and the health unit is producing output which maximizes consumer satisfaction (Bruning et al., 2002).

World Bank's policy study on financing health Services in developing countries indicates that inefficiency of government health programmes is one of the major problems of African health care systems, followed by inequitable allocation of resources (Akin et al., 1987). Inefficiency has been compared to a torn rice sack which cannot be filled if the holes are not identified and sealed. If not identified and eliminated, inefficiencies could lead to continuous leaking out of resources from the health care system (Kirigia et al., 2004).

Kirigia et al. (2004) outlined reforms initiated in Kenya to eliminate inefficiencies in healthcare namely: harmonization and decentralization of health care interventions, expansion of preventive health services and family planning services, use of health insurance schemes and integration of traditional medicine with western medicine. Efficiency determination is crucial especially because of increased budgetary allocations and recent reforms by the NHIF of financing health facilities.

1.1 Health System in Kenya

Kenya's health system comprises of public and private sectors whose primary aim is to promote, restore or maintain people's well being. The activities of a health system include: health promotion; treatment; rehabilitation and nursing (Murray et al., 2000). The formation of the Grand Coalition Government in 2008 led to the Ministry of Health (public sector) being divided into two ministries: Ministry of medical services (MOMS) and Ministry of public health and sanitation (MOPHS).The private sector has two main components: private for profit and private not for profit (NGOs & FBOs).

The public health sector is hierarchical - can be compared to a pyramid structure with six levels where patients are referred upward and downward depending on necessity. At the apex (Level 6) are tertiary hospitals (Moi teaching & referral hospital and Kenyatta national hospital), which are highly specialized. The level 6 hospitals provide sophisticated diagnostic, therapeutic and rehabilitative services. Level 5 hospitals are secondary hospitals, also known as provincial hospitals, which act as referral hospitals to the district hospitals in the various provinces. Level 5 hospitals also provide very specialized care. Level 4 are primary hospitals, which include district and sub-district hospitals (Mwabu, 1989).

Level 4 hospitals concentrate on the delivery of health care services and generate their own expenditure plans and budget requirements based on guidelines from headquarters through provinces. Level 3 are health centres, maternities, nursing homes, which offer preventive and curative services mostly adapted to local needs. Level 3 hospitals provide many of the ambulatory health services. Level 2 include dispensaries and clinics, which provide a link between community based health care and health facilities. The lowest level (Level 1) is the community (villages/households/families/individuals), which offer promotive and preventive health services (KSPA, 2004).

Secondary and tertiary hospitals (Levels 4-6) are administered by the MOMS, while primary health care facilities (Levels 1-3) are supervised by the MOPHS. The government is the main provider of health services, owning 48% of all health facilities. The private for-profit owns 32% of total facilities, while the private not-for-profit owns 14% of the facilities.

Table 1.0 Health facilities by type and ownership (2010)

Controlling Agency	Hospitals	Health centres	Dispensaries	Maternity & Nursing homes	Clinics	Total
Ministry of health	273	579	2,716	1	1	**3,570**
Faith based organization & other NGOs	80	174	691	21	78	**1,044**
Other public institutions	11	47	336	0	35	**429**
Private	108	47	167	160	1,870	**2,352**
Total	**472**	**847**	**3,910**	**182**	**1984**	**7,395**

Source: (G.O.K, 2010)

1.2 Kenyatta National Hospital

Kenyatta national hospital (KNH) is the oldest hospital in Kenya. It was founded in 1901 as the native civil hospital and then King George VI in 1952. It had its centenary celebration in 2001. The hospital was built to fulfill the role of being a national referral and teaching hospital, as well as to provide medical research environment. KNH became a state corporation in 1987 with a board of management and is at the apex of the referral system in the health sector in Kenya.

Up to 1987, KNH operated as a department of the MOH on which it relied heavily for its day to day management. The hospital's operations were then controlled by the MOH, for instance, the hospital relied on the ministerial tender board for supplies and procurement, and ministry of works for maintenance. Due to this dependence, the hospital experienced numerous problems related to organizational complexity, centralized management and inefficiency. The bureaucracy resulted in delays in decision making and implementation of programmes and activities.

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KNH has fifty wards; twenty two out-patient clinics; twenty four theatres (sixteen specialized) and accident & emergency department. Out of the total bed capacity of two thousand, two hundred thirty six beds are for the private wing. The hospital is divided into various departments largely classified as administration, human resources, finance, supplies; and the clinical section. The clinical section is divided into various components namely medicine, pediatrics, surgery, obstetrics & gynecology and orthopedics. The hospital has a section that offers professional support services such as physiotherapy; medical social work; occupational therapy; medical records; nutrition; public health; diagnostic department: radiology; radiotherapy; laboratory medicine; bio-medical engineering department. The wards are distributed as follows: pediatrics- six, obstetrics & gynecology-six, orthopedic: four, surgery: nine, medicine: thirteen while the remainder are in the private wing. There is a doctor's plaza which consists of 60 suites for various consultant specialties (HMIS, 2011)

Kenyatta national hospital is mandated to receive patients on referral from other hospital or institutions within or outside Kenya for specialized care, provide facilities for medical education for the University of Nairobi and for research either directly or through other cooperating health institutions, provide facilities for education and training in nursing and other health and allied professionals and participate in national health planning, as a national referral hospital.

1. 3 Statement of the Research Problem

The health care systems of Sub-Saharan African countries including Kenya increasingly face critical resource constraints in their efforts to extend health services of acceptable quality to the vast majority of people. This severe shortage of health care resources is accounted for by many factors such as poor macroeconomic performance, cutbacks in public spending, rapid population growth, the AIDS pandemic and an upsurge in diseases such as malaria. Referral hospitals in Kenya consume a big portion of scarce health care resources, as shown in the background information, and it is important to use these scarce resources as effectively and efficiently as possible.

Previous research in Kenya reveals existence of inefficiency in public health sector, manifested by under-utilization or malfunctioning of facilities, inefficient utilization of staff and physical capacity, and lack of expenditure containment measures (Akin et al., 1987). Inefficiency may negatively affect the government's initiative of improving access to quality health care and scaling up of interventions that are necessary to achieve the health-related millennium development goals. Kirigia et al (2004) measured technical efficiency of public health centres in Kenya, and found 44 % of the centres sampled to be technically inefficient. In the presence of inefficiency, the efforts of a government to finance health care fairly and promptly respond to clients' rational expectations are undermined. If not eliminated, inefficiency in health care institutions could lead to leaking out of resources from the health care systems (WHO, 2000).

Other studies done in Kenya include: Kioko (2000) on the Impact of fiscal decentralization on hospital efficiency. He evaluated 39 public health facilities, and found their performance to have deteriorated in technical terms. Owino and Korir (1997) estimated efficiency of public hospitals in Kenya. The results revealed an average inefficiency level of 30%. Although teaching and referral hospitals in Kenya (KNH & Moi) are large consumers of scarce healthcare resources (about 12%), their levels of technical efficiency and productivity remain largely unknown. This study has attempted to fill this gap by measuring technical efficiency and productivity change of one of the teaching and referral health facilities in Kenya (KNH). This study has also attempted to present the importance of the factors that influence (in) efficiency at KNH, Nairobi.

1.4 Research Questions

The study seeks answers to the following questions:

- What were the levels of technical efficiency of individual units in the clinical section at KNH from 2000 to 2010?
- How did the levels of productivity at KNH change during the 2000-2010 periods?
- What factors are likely to influence technical (in) efficiency at KNH?
- Which policies may enhance efficiency improvements at KNH?

1.6 Objectives of the Study:

- To evaluate relative technical efficiency of individual units in the clinical section at KNH from 2000 to 2010.
- To measure changes in levels of productivity at KNH during the 2000-2010 period.
- To identify some of the factors that are likely to influence technical (in)efficiency at KNH
- To suggest policies for enhancing efficiency improvements at KNH.

1.5 Justification for the Study:

The public sector owns most of the health facilities in Kenya, standing at 54%, so it is important to use resources efficiently in the sector, as inefficiency would lead to huge losses. Understanding the (in) efficiencies of hospitals and identifying the sources of (in) efficiencies are important policy concerns for any country's health system. In Kenya, there is no study that has specifically evaluated technical efficiency and productivity change of a national teaching & referral health facility. This study has attempted to fill this gap.

The results of the analyses would be useful to the policy-makers and hospital managers when designing appropriate policy and managerial interventions for ensuring efficient use of health care resources. This study has identified the DMUs with 'best practice.' In the context of KNH, this study defines DMU as a large unit which comprises of sub-units, for example, medicine includes smaller units namely neurology, skin, special cardiac, general medicine, diabetes, chest and tuberculosis.

CHAPTER TWO

2.0. LITERATURE REVIEW

This section provides literature review, which begins with theoretical framework followed by empirical literature and finally an overview of the literature.

2.1 Theoretical Framework

2.1.1 The concept of Efficiency

Efficiency in health systems focuses on the relationship between health care resources such as labor, capital or equipment and either intermediate outputs such as number of patients treated and waiting time or final health outcomes such as lives saved and quality adjusted life years (Kirigia et al., 2004). There are two techniques of measuring efficiency namely frontier and non-frontier analyses. Frontier analysis includes data envelopment analysis (DEA) and stochastic frontier analysis (SFA), while Non-frontier techniques are ratio and regression analyses. DEA involves mathematical programming while SFA, econometric modeling.

Farrell (1957) introduced modern measurement of efficiency by drawing upon the works of Debreu and Koopmans (1951), and outlined a simple measure of efficiency that could account for multiple inputs (Coelli, 1996). Farrell assumed that a firm's efficiency is measured relative to the efficiency of other firms, and he outlined two components of efficiency namely technical, which reflects the ability of a firm to obtain maximal output from a given set of inputs, and allocative, which reflects the ability of a firm to use the inputs in optimal proportions given their respective prices. Technical efficiency and allocative efficiency provide a measure of total economic efficiency. Simply defined, efficiency is the ratio of weighted sum of outputs to weighted sum of inputs. There are input-oriented and output-oriented efficiency measures, as shown in figures 2.1 and 2.2.

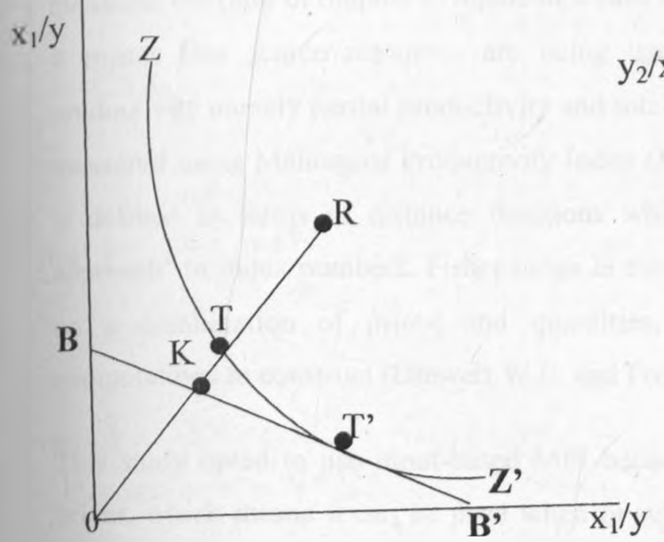
Seiford and Thrall (1990) observed that DEA is increasingly becoming a popular management tool commonly used to evaluate the efficiency of a number of producers since DEA compares each producer with only the best producers. A producer is referred to as a decision making unit (DMU) and the assumption is that there are a number of producers. The production process for each producer involves taking a set of inputs to produce a set of outputs, where each producer has a varying level of outputs. A major assumption behind DEA is that if a given producer, A, is capable of producing y (A) units of output using x (A) inputs, then other producers should also be capable of the same to operate efficiently. The same way, if producer, B, is capable of producing y (B) units of output using x (B) inputs, then other producers should also be capable of the same production schedule. Both producers A, B and others can then be combined to form a composite producer, with composite inputs and composite outputs.

DEA's aim is to find the best imaginary producer for each real producer. If the imaginary producer is better than the original producer by either making more outputs with the same inputs, or making the same output with fewer inputs, then the original producer is said to be inefficient. DEA has sometimes been criticized as inappropriate and not always the right tool for a problem because it does not decompose the error term into the white noise and inefficiency components, thus may overstate the level of inefficiency (Forsund, 1980).

The technical efficiency of a firm is characterized by the relationship between observed production and potential production. The measurement of firm specific technical efficiency is based on deviations of observed output from the best production of efficient production frontier. If a firm's actual production point lies on the frontier, it is perfectly efficient, but if it lies below the frontier, it is technically inefficient (Greene, 1993). A firm can be technically inefficient if it operates on the interior of its production set, in a congested region, or at too large or too small scale (Fare et al., 1983).

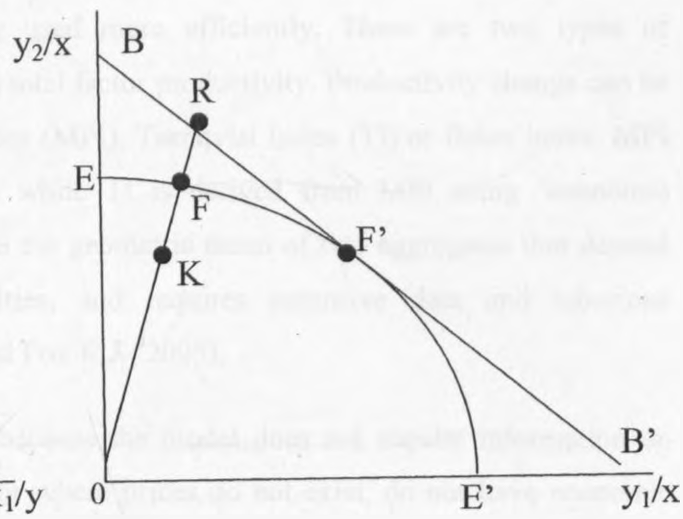
The figures below illustrate technical, allocative and total economic efficiencies.

Figure 2.1: Technical, allocative and total economic efficiencies (input orientation)



Sources: Farrell, 1957 and Coelli, 1996

Figure 2.2: Technical, allocative and total economic efficiencies (output orientation)



Sources: Farell, 1957 and Coelli, 1996.

From figure 2.1, technical efficiency is equal to $0T/0R$ and is similar to $1-TR/0R$. Farrell (1957) expressed his ideas using an example of a firm that uses two inputs to produce a single output. Line BB' represents input price ratio, which if known, can aid in calculating allocative efficiency, defined as: $0K/0T$. Total economic efficiency ($0K/0R$) is the product of technical and allocative efficiencies and all the three measures are bounded by zero and one. The input-based measures address the question of how input quantities may be decreased proportionally without decreasing output and by how much (Coelli, 1996).

Figure 2.2 represents output oriented efficiency measures. KF represents technical inefficiency, the amount by which outputs could be increased without increasing inputs. Technical efficiency is the ratio of 0K to 0F. BB' is the revenue line which, if its value is known, allocative efficiency can be calculated as the ratio of 0F to 0R. Total economic efficiency is the ratio of 0K to 0R. The measures are bounded by zero and one. The output-based measures address the question of how output may be increased without using more inputs and by how much (Coelli, 1996).

2.1.2 Productivity

Productivity of a firm is a measure of the relationship between the firm's production of goods and services, and the factors of production used such as capital, labour, and technology. It measures the ratio of outputs to inputs of a firm's productive efficiency. If productivity increases it means that scarce resources are being used more efficiently. There are two types of productivity namely partial productivity and total factor productivity. Productivity change can be measured using Malmquist Productivity Index (MPI), Tornqvist Index (TI) or fisher index. MPI is defined in terms of distance functions while TI is derived from MPI using 'economic approach' to index numbers. Fisher index is the geometric mean of two aggregates that depend on a combination of prices and quantities, and requires extensive data and laborious computations to construct (Diewert W.E. and Fox K.J., 2005).

This study opted to use input-based MPI because the model does not require information on prices, which means it can be used when or where prices do not exist, do not have economic meaning or are distorted; MPI does not require behavioral assumptions such as profit maximization or cost minimization, hence can be used whenever the producers' objectives are not achieved or are unknown, MPI is easy to compute, it can be calculated using non-parametric techniques which impose properties of monotonicity and complexity and it decomposes into constituent sources of productivity change – pure technical efficiency change, technical change and scale change (Fare et al, 1995; Kirigia et al., 2010).

MPI has become the standard approach in productivity measurement especially when non-parametric specifications are applied. When the index is defined on the basis of the quantity indices, it may not be bounded for all production units. Malmquist input and output indices provide important information that can explain certain aspects of productivity changes caused by underlying economic decisions and activities (Bjurek, 1996).

2.2 Empirical Literature

Kirigia et al. (2004) used DEA to measure the technical efficiency of 32 public health centres in Kenya. Their inputs were: clinical officers, nurses, physiotherapists, occupational therapists, laboratory technologists, laboratory technicians, administrative and general staff, dental technologists, public health officers, beds, and non-wage recurrent expenditures. The outputs included visits for diarrhea, malaria, sexually transmitted infection, intestinal worm, antenatal care, immunization, family planning, and other general outpatient visits. Out of the 32 health centres, 14 (44%) were technically efficient, 18 (56%) were technically inefficient. Among the inefficient health centres, 2 (13%) had a TE score of less than 50%, 9 centres (28%) between 51 and 74% and 6 centres (19%) between 75 and 99%. The inefficient health centres had an average TE score of 65% and a standard deviation of 22%, which implies that on average, they could reduce their utilization of all inputs by about 35% without reducing output. The study did not evaluate total factor productivity of the health centres.

Kirigia et al. (2002) used input-oriented DEA technique to measure relative efficiency of 54 public hospitals in Kenya. They found 26% of the hospitals to be technically inefficient and recommended that the inefficient hospitals could reduce their resource input utilization by 16 % without reducing output. 30% of the analyzed hospitals were scale inefficient. The mean scale efficiency score was 90%, meaning output could be increased by 10% without reducing or increasing resource inputs. The study did not analyze productivity change.

Kirigia et al. (2000) used DEA, linear probability and logistic regression to assess technical efficiency of 155 primary health clinics in Kwazulu-Natal province in South Africa. The input variables included number of nurses and number of general staff, while output variables were antenatal visits, child health care visits, number of births, family planning visits, dental care visits, psychiatry visits, tuberculosis visits and sexually transmitted diseases visits. 30% were found to be technically efficient. 70 % of the clinics were technically inefficient, 16% of which had efficiency levels of 50% and below. Number of nurses was found to be statistically significant at 95% confidence level. This study did not evaluate productivity change.

Kioko (2000) did a study on the impact of fiscal decentralization reforms on hospital efficiency. The study utilized secondary and primary data from thirty nine public health facilities, out of which twenty seven were district hospitals and twelve sub-district hospitals. Technical efficiency scores were computed and the regression done. The study found bed occupancy rate to be positive and statistically significant at 1% while medical staff was negative and statistically significant at 5% confidence level. The results revealed low productivity for the medical staff caused by low bed occupancy rate, lack of drugs and other essential inputs. The study did not include provincial or referral hospitals in Kenya.

Masiye et al (2002) used DEA to measure technical and allocative efficiencies of twenty hospitals in Zambia. The study estimated two models. The first model used one input and five outputs namely: total expenditure, outpatient visits for children aged less than five years, outpatient visits for children aged over five years, bed days for children aged less than five years, bed days for over five years and number of deliveries. The second model used three inputs consisting of non-labor expenditure, number of doctors and clinical officers, number of other personnel and three outputs namely total outpatient visits, total number of bed days and number of deliveries. Model two included price variables that helped to analyze allocative efficiency. Under the first model, 75% of the hospitals were technically inefficient with a mean score of 0.441. Under the second model, 50% of the hospitals were technically inefficient with a mean score of 0.543. 85% of the hospitals were allocatively and economically inefficient. The study did not estimate input reductions or output increases to make the inefficient hospitals efficient.

Zere (2000) estimated technical efficiency and productivity of a sample of 86 hospitals classified as level I, level II and level III in South Africa. Analytical techniques used were: DEA, malmquist productivity index and Tobit model. The output variables used were outpatient visits and inpatient days while the input variables were total recurrent expenditure and bed-size. The results showed overall technical efficiency of 0.74, 0.68 and 0.70 for the levels I, II and III, respectively. Results from the Tobit model revealed that the ratio of outpatient visits to inpatient days was statistically significant at 95 % significance level. The study did not include national referral hospitals in South Africa.

Tamiru (2002) examined the technical efficiency of 40 health centres in Ethiopia. He employed DEA model for a one year data set to obtain the efficiency scores and regressed the efficiency scores against health centre operating characteristics using both OLS and Logit models. He used five inputs: Doctors/health officers, nurses, health assistants, other technical staffs, administrative staff and three outputs: Outpatient visits, maternal & child care visits and delivery services. He used DEA computations as the dependent variable for OLS/Logit model, while his independent variables were health care operating characteristics, specifically population of the area, patients treated per health worker per day, availability of health care unit and location of health facility. He found out that 60% of the health centres were technically and scale inefficient. The regression results showed that location and availability of public hospitals in the area were significantly associated with efficiency levels. The study did not analyze productivity change.

Owino and Korir (1997) estimated efficiency in public hospitals in Kenya using both secondary and primary data. The secondary data were collected from the health information systems at the Ministry of health. The primary data was collected through a survey of twenty six hospitals. A non-linear short run variable cost function was estimated, with explanatory variables average wage, outpatient visits, admissions, and beds. The results revealed an average inefficiency level of 30%, increasing returns to variable factor inputs, existence of economies of scale that the public hospitals were operating at higher than minimum average costs, and low responsiveness of recurrent costs to changes in hospitals' capacity and output. The results attributed inefficiency to shortage of professional staff; poor combination of inputs; irregular or non-functioning theatres and laboratories; transport problems; lack of, or mal-distribution of drugs and medical supplies; and frequent breakdown and/or poor servicing of machines and equipment. This study considered panel data, allowed for time varying efficiency, and employed both econometric and DEA models to improve the reliability of the estimates of efficiency. All the explanatory variables were statistically significant at 5 percent level, except the output score. The study did not assess productivity change.

Osei et al. (2005) estimated technical efficiency of public district hospitals and health centres in Ghana. The output variables used were maternal and child health care visits, deliveries, and inpatient discharges, while inputs consisted of doctors, dentists, subordinate and beds. The study utilized data for the year 2000, with a sample of 17 hospitals and 17 health centres. The DEA (VRS) method was applied in the estimation, with results showing that 9 (53%) of the hospitals were technically efficient, with a relative technical efficiency (TE) score of 100%. The remaining 8 (47%) had a TE score of less than 100%, hence they were technically inefficient. On the other hand, 14 (82%) of the health centres had TE of 100%, while 3 (18%) were technically inefficient. The major limitation of the study is that it excluded drugs, which are an important input in provision health care services. The authors acknowledge this fact, attributing it to lack of data. The study did not assess productivity change.

Mutuku (2008) used DEA to assess technical efficiency of the Nairobi City Council health facilities. He collected data from fifteen out of forty eight facilities under the Nairobi health management board for the years 2006 and 2007. The study used two inputs and three outputs. The outputs included attendance in the children's clinic; number of antenatal visits and number of curative patients, while inputs used were number of nurses /clinical officers and number of support staff in the facilities. Productivity change was analyzed for two years. The results showed that the health facilities had a mean technical inefficiency of 24.1%.

Gakuru (2006) used DEA to estimate technical efficiency in the delivery of healthcare services in the public hospitals of Kenya, and obtained data from 63 hospitals. Inputs used included doctors/pharmacists, clinical officers, nurses, expenditure on buildings and maintenance, and expenditure on drugs. Outputs used were inpatient days and outpatient visits. Logit model was applied to identify factors affecting hospital efficiency. 30 % of the hospitals were found to be efficient. 21 % of the hospitals had a scale efficiency of 100 %.

Renner et al. (2005) measured technical and scale efficiency of 37 peripheral health units in Sierra Leone. They used a one time period sample data and employed Data Envelopment Analysis. Inputs included: technical staff and subordinate staff while outputs included: ante-natal and post-natal visits, child deliveries, nutritional/child growth monitoring visits, family planning visits, immunized children and pregnant women and total number of health education sessions. They found that 22(59%) were technically inefficient, and 24(65%) were scale inefficient. The main limitation of the study was the sample data. They used a single time period data, which might have led to bias due to extreme observations. The study did not assess productivity change.

2.3 Overview of the Literature

This section provides a brief review of the theoretical and empirical literature on studies about technical efficiency and productivity change, with special reference to DEA-based health sector studies. Technical efficiency studies on hospitals have been conducted in developed and developing countries, but very few have been done in SSA.

The empirical studies have varied evidence on the outcomes of health care reforms, with most countries experiencing certain levels of inefficiency and low levels of productivity. Different countries have different demographic, social, economic and political characteristics; therefore it is important to analyze each country differently, as has been done in the reviewed studies. The reviewed literature has outlined the use of DEA as a reliable and effective method of estimating relative efficiency levels in health institutions due to data specification and availability.

From the reviewed literature, it is a fact that very few studies have assessed productivity change or total factor productivity change, apart from Zere (2000), Gakuru (2000) and Mutuku (2008). The main tool used to analyze technical efficiency of the hospitals, DEA, has been used in this study. The reviewed literature has also revealed that these studies have largely ignored referral health facilities in the region, a gap that has been filled by this research paper.

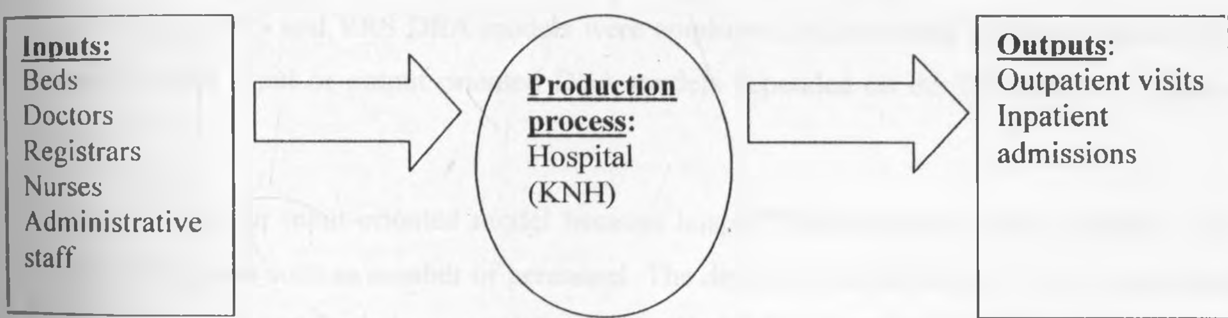
CHAPTER THREE

3.0 METHODOLOGY

3.1 Conceptual Framework

Efficiency analysts can choose to either employ econometric method such as stochastic frontier analysis (SFA) or linear programming method such as data envelopment analysis (DEA) to estimate technical efficiency. This study chose to employ DEA methodology to estimate technical efficiency of KNH and DEA-like malmquist productivity index (MPI) to assess changes in levels of productivity, because DEA is capable of estimating efficiency of hospitals which use multiple inputs to produce multiple outputs. Hospitals turn resource inputs into outputs through the production process as shown in figure 3.1below:

Figure 3.1: Relationship between inputs, production process and outputs:



DEA is preferred in efficiency analyses in non-profit sector such as health institutions where there are few errors of random noise, multi-product output production is relevant; price data are difficult to find and setting behaviour assumptions such as profit maximization or cost minimization as done with other methods such as cost/production function is difficult (Coelli et al., 1998).

DEA's objective is to measure performance of each producer relative to the best practice in the sample. The initial task is to determine which of the set of producers as represented by observed data form an empirical production function or envelopment surface. The producers that lie on the empirical production frontier are deemed efficient (Ali and Seiford, 1993).

There are two types of envelopment surfaces in DEA namely constant returns to scale (CRS) and variable returns to scale (VRS). The appropriateness of either CRS or VRS is determined by economic and other assumptions about the data to be analyzed (Ali and Seiford, 1993). In the CRS, increase in all factors of production by a certain proportion would result in the increase in output by the same proportion. However, in the VRS, output changes more or less proportionately than the changes in all inputs.

DEA drawbacks may not be very serious because there is no a priori specification of the functional form of the technology, so specification error that might show up as a noise is ruled out, and since inputs and outputs are measured in their natural physical units, measurement error is unlikely (Ferrier and Valdmanis, 1996).

3.2 Model specification

Input-oriented CRS and VRS DEA models were employed in computing efficiency scores. The choice between input or output oriented DEA models depended on the flexibility of inputs or outputs.

This study used an input-oriented model because hospital managers have more control of the supply side factors such as number of personnel. The demand side factors are mainly determined by the health care seeking behaviour of the public. Under the assumption of CRS, the efficiency of decision making unit j_0 can be obtained by solving the following model:

$$\text{Max } D_{0j} = \sum_{r=1}^{s} u_r y_{rj0}$$

subject to

$$\sum_{i=1}^{m} v_i, x_{ij0} = 1; u_r, v_i \geq 0$$

$$\sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} v_i, x_{ij} \leq 0; j = 1, \ldots, n \text{..........} (i)$$

Where:-

D_{0j} = Efficiency score for the decision making unit j

y_{rj} = Actual amount of r[th] output produced by decision making unit j

x_{ij} = Actual amount of i[th] input from decision making unit j

u_r = Weight given to output r computed in the solution by DEA model

v_i = Weight given input i computed in the solution by DEA model

n = Number of decision making units

s = Number of outputs

m = Number of inputs

The first constraint $\sum v_i, x_{ij} = 1$ indicates that the weighted sum of inputs for the particular DMU equals one because efficiency ranges between zero and one. The second constraint implies that all the DMUs are on or below the frontier, which means the inefficiencies of all DMUs have an upper bound of one. The weights u_r and v_i are treated as unknowns and their weights are obtained in the linear programming solution. Linear programming is a mathematical programming technique that establishes production possibilities frontier based on relatively efficient DMUs and measures how far the inefficient DMUs are from the best practice frontier. The efficient DMUs lie on the frontier and are assigned a score of 1 or 100%. Inefficient DMUs are allocated a score that is less than 1 (or less than 100%).

Under the assumption of variable returns to scale (VRS), which this study concentrated on, DEA measures the technical efficiency of decision making unit j_0 compared with n decision making units in a peer group as follows:

$$MaxD_{0j} = \sum_{r=1}^{s} u_r y_{rj0} + u_0$$

subject to

$$\sum_{i=1}^{m} v_i x_{ij0} = 1$$

$$\sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} + u_{j0} \leq 0; j = 1,...,n \text{...} (ii)$$

$$u_r \geq 0; r = 1,...,s$$

$$v_i \geq 0, i = 1,...,m,$$

The notations are the same as in equation (i) above, but the additional variable u_0 corresponds to an intercept, thus constrained. It is possible to analyze whether a DMU's output indicates increasing returns to scale, constant returns to scale, or decreasing returns to scale from the variable returns to scale model, by the sign of the variable u_0. $u_0 \prec 0$ indicates increasing returns to scale, u_0=0 implies constant returns to scale, and $u_0 \succ 0$ implies decreasing returns to scale (Bjurek et al., 1990).

Variable returns to scale model is capable of isolating pure technical efficiency component and scale efficiency which relates to the size or structure of the decision making unit. The constant return to scale assumption is only appropriate if all DMUs are operating at an optimal scale. Where the assumption does not hold, the technical efficiency measure is mixed with scale efficiency (Zere, 2000).

3.2.2 Malmquist Productivity Index (MPI)

This study employed input-oriented malmquist productivity index to assess changes in levels of productivity at KNH during the 2000-2010 period. MPI was introduced by Caves et al. (1982) to measure productivity differences over time. The malmquist index approach is suitable for measuring productivity in the public sector because it does not require a priori behavioral assumption about the production technology nor price data on inputs and outputs. This study used DEA-like linear programmes because these are mathematical programmes that are capable of handling multiple inputs and multiple outputs. Two mixed period distance functions, $D_0^{t+1}(y^t, x^t)$ and $D_0^t(y^{t+1}, x^{t+1})$, are required when defining input-oriented malmquist productivity index. Fare and Grosskopf (1992) employed the period distance functions to define input oriented MPI $M_0^t(y^t, x^t, y^{t+1}, x^{t+1})$ as

$$M_0^t(y^t, x^t, y^{t+1}, x^{t+1}) = \left[\frac{D_0^t(y^{t+1}, x^{t+1})}{D_0^t(y^t, x^t)} \times \frac{D_0^t(y^{t+1}, x^{t+1})}{D_0^{t+1}(y^t, x^t)}\right]^{1/2} \quad \text{...}(iiia)$$

Ray and Desli (1997) further decomposed the MPI into two parts, one measuring changes in efficiency and another one measuring technological changes in order to isolate various sources of productivity change (Lovell, 2003).

Thus:

$$M_0^t(y^t, x^t, y^{t+1}, x^{t+1}) = \left[\frac{D_0^{t+1}(y^{t+1}, x^{t+1})}{D_0^t(y^t, x^t)}\right] \times \left[\frac{D_0^t(y^{t+1}, x^{t+1})}{D_0^{t+1}(y^{t+1}, x^{t+1})}\right] \times \left[\frac{D_0^t(y^t, x^t)}{D_0^{t+1}(y^t, x^t)}\right]^{1/2} \quad \text{..........................}(iiib)$$

Where

$\left[\frac{D_0^{t+1}(y^{t+1}, x^{t+1})}{D_0^t(y^t, x^t)}\right]$ = Efficiency change, and

$$\left[\frac{D_0^t(y^{t+1},x^{t+1})}{D_0^{t+1}(y^{t+1},x^{t+1})}\right]\times\left[\frac{D_0^t(y^t,x^t)}{D_0^{t+1}(y^t,x^t)}\right]^{\frac{1}{2}} = \text{Technological change}$$

't and $t+1$' time periods being evaluated

'0' represents the technology being used, which in this paper is input-oriented variable returns to scale.

$D_0^{t+1}(y^t,x^t)$ and $D_0^t(y^{t+1},x^{t+1})$ are distance functions.

$M_0^t(y^t,x^t,y^{t+1},x^{t+1})$attains a value greater than, equal to or less than one depending on whether the decision making unit being assessed experienced growth, stagnation or decline in productivity between periods t and t+1. The same criterion is used to interpret results for technological change, productivity change, scale efficiency change and total factor productivity change (Griefell-Tatje and Lovell, 1997).

3.2.3 Econometric analysis of the determinants of inefficiency.

The (in) efficiency scores obtained from the DEAP software stated whether a particular decision making unit is technically efficient or not. But there are institutional and environmental factors that cause technical inefficiency and are beyond the control of managerial discretions. To examine how these factors affect the (in) efficiency of decision making units at KNH, the DEA efficiency scores were analyzed by regressing them against some characteristics of the DMUs. Since the dependent variable (efficiency scores) is continuous between one and zero, it was not advisable to apply logistic regression, and also since the efficiency scores are bounded from above at one, using OLS model would lead to biased results. Therefore, this study opted for a censored Tobit model, as this would overcome problems that may arise from using Logit or OLS. For computational convenience, it was preferred to assume a censoring point at zero in the Tobit model (Greene, 1993). Up to this level, DEA efficiency scores were to be transformed into inefficiency scores and left censored at zero using the formula:

$$\text{Inefficiency score} = \left(\frac{1}{DEAScore}\right) - 1 \quad \text{.................................... (iv)}$$

The model is specified as follows:

$$y_i^* = \beta_i x_i + \mu_i$$

$$y_i = y_i^* \text{ if } y_i^* > 0$$

$$y_i = 0 \text{ if } y_i^* \leq 0$$

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

y_i = observed inefficiency scores

β_i = $k \times 1$ vector of unknown parameters

x_i = $k \times 1$ vector of explanatory variables

Therefore the empirical regression model was specified as:

$$INEFF_{it} = \mu + \beta_1 OCC_{it} + \beta_2 ALS_{it} + \beta_3 DNADM_{it} + \beta_4 BEDS_{it} + \beta_5 OUTPRO_{it} + v_{it} \quad \text{...... (5)}$$

Where,

INEFF = Derived inefficiency scores from equation (4)

OCC = Bed occupancy rate (%)

ALS = Average length of stay (days)

DNADM = Ratio of the sum of doctors and nurses to number of inpatient admissions.

BEDS = Number of beds

OUTPRO = Outpatient visits as a proportion of number of inpatient admissions

$\mu, \beta_1, \beta_2, \beta_3, \beta_4$ are regression coefficients

$V_{it} = \alpha_i + u_{it}$.

$$\text{The occupancy rate (OCC \%)} = \frac{\text{Occupied Bed Days}}{\text{Available Bed Days}} \times 100\%$$

In this study, multicollinearity was not a problem because the value of the occupancy rate was determined by the relative position of each of the components of the occupancy rate.

$$\text{The Average Length of Stay (ALS)} = \frac{\text{Occupied Bed Days}}{\text{Discharges + Deaths}}$$

This model is adopted from Zere (2000) but it is slightly different in the sense that Zere's model classified hospitals into different levels and categorized them into various provinces, but this study considered different DMUs in the same hospital. Zere's model also assumed occupancy rate to be a composite index that incorporates inpatient admissions, the average length of stay and the number of beds, and he used the ratio of outpatient visits to inpatient days as another explanatory variable, while this model calculated occupancy rate as occupied bed days divided by available bed days, multiplied by 100%. This model has applied the formula that KNH uses to calculate occupancy rate.

3.3 Data and variables

3.3.1 Data and sources of data

Secondary data on outputs was obtained from hospital records at KNH. The data on inputs was obtained from the human resources department records at KNH. The data collected was as shown in appendix 1.

All main decision making units at the clinical section of KNH were considered for the study. The clinical section was chosen because the core business of KNH is healthcare provision. It is also important to note that DEA calculates relative efficiencies of units that perform similar functions. Other units of the hospital perform different functions, hence could not be considered for this particular study.

As Magnussen (1996) puts it, the selection of inputs and outputs for a DEA study requires careful thought because the distribution of efficiency is likely to be affected by the definition of outputs and the number of inputs & outputs included in the study. Basically, improved health status is the ultimate output of all health care systems, but it is difficult to measure health status because health is multi-dimensional, hence assessing the quality of life of patients is rather subjective (Clewer and Perkins, 1998). Because of the eminent difficulties in measuring improvements in health status accurately, hospital output is measured as an array of intermediate health services that are assumed to improve health status (Grosskopf and Valdmanis, 1987). This study used the following outputs: outpatient visits and inpatient admissions for each DMU.

3.3.2 Sampling and samples

All the departments in the clinical section were considered for the study, largely grouped into five as follows: **Medicine** which includes neurology, skin, special cardiac, general medicine, diabetes, chest and tuberculosis; **Pediatrics:** This includes hematology, pediatric surgery, pediatric neurology, skin, pediatric medicine, cardiac, chest and neonatal clinic; **Surgery:** This is sub divided into thyroid, neurosurgery, general surgery, cardiothoracic, urology, plastic surgery, psychiatry, liver, renal, breast, ophthalmology and ENT; **Obstetrics and Gynecology** includes antenatal clinic, general gynecology, post natal, colposcopy, maternity, infertility and oncology; **Orthopedics** includes orthopedic surgery and fracture. Data collection took place between July 2011 and August 2011.

3.3.3 Data processing and analysis

Inputs and outputs were modeled as multi-input and multi-output in the production process. The data collected was first processed into a spreadsheet-like table indicating the various fields or variables relevant in determining DEAP. The analyses were carried in accordance with the objectives of this study. First, the table data was converted to a digital format, and pasted in notepad then used by DEAP version 2.1 econometric software (Coelli, 1996) to calculate TE scores and MPI scores. The DEA efficiency scores were then converted into technical inefficiency scores and used as the dependent variable in the censored Tobit regression model to determine the factors that influence inefficiency. The explanatory variables included: Occupancy rate; average length of stay (days); ratio of the sum of doctors and nurses to number of inpatient admissions; number of beds and the number of outpatient visits as a proportion to inpatient admissions.

3.3.4 Description of variables

The study looked at three types of variables: inputs; outputs and explanatory variables. The input and output variables were used for the DEA model while the explanatory variables constituted the independent variables in the Tobit model.

3.3.5 Inputs:

Inputs in hospital production are classified as labour, capital and technological input. The labour input can be divided into the various professional groups like physicians, nurses and administrative staff. Capital is mostly proxied by the number of hospital beds (Zere, 2000). This study used the following inputs: number of doctors, number of registrars, number of nurses (enrolled/registered and community nurses), number of administrative staff and number of beds & cots.

3.3.6 Outputs:

Outputs are classified into: inpatient treatment, outpatient treatment, teaching and research. For this study, the following outputs were used: number of inpatient admissions and number of outpatient visits (Butler, 1995).

CHAPTER FOUR

4.0 RESULTS AND DISCUSSIONS

The results of this study give empirical evidence on the performance of KNH. The findings indicate that 60% of the units at KNH operate inefficiently compared to their peers, which means that some resource inputs are used inefficiently. 40% are technically efficient, and the mean technical efficiency over the ten-year period of analysis is 77%.

4.1 Descriptive statistics of KNH inputs and outputs:

The descriptive statistics of KNH resource inputs and outputs are presented in table 4.1 below:

Table 4.1 a) Descriptive statistics (mean inputs and outputs for 2000-2010)

DMU	Beds &cots	Doctors	Registrars	Nurses	Administrative Officers	Outpatient visits	Inpatient admissions
Medicine	420	17	6	220	1	39,155	15,917
Pediatric	322	12	2	251	1	18,350	15,025
Surgery	241	33	5	242	1	63,805	10,452
Obs & Gyn	191	18	5	219	1	32,518	21,419
Orthopedic	180	6	0	120	2	20,418	3,517

Source: Computed from survey data

The table 4.1a) above shows the descriptive statistics of KNH inputs and output variables used in this research paper. The study used five input variables namely: beds & cots, doctors, registrars, nurses, administrative officers and two output variables: outpatient visits and inpatient admissions. The results show that medicine unit has the highest number of beds & cots while the orthopedic unit has the least number of beds & cots. Surgery receives the highest number of outpatient visitors, obstetrics & gynecology admits the highest number of inpatient visitors although it only has 191 beds & cots. Each DMU has one administrative officer except orthopedics which has an annual average of two. Pediatrics has the highest number of nurses (251) while surgery has the highest number of doctors (33).

Table 4.1b) Descriptive statistics (standard deviation of inputs and outputs: 2000-2010)

DMU	Beds&cots	Doctors	Registrars	Nurses	Administrative officers	Outpatient visits	Inpatient admission
Medicine	35	2	3	11	0	5,494	3,90
Pediatrics	32	2	2	14	1	3,747	3,18
Surgery	97	3	4	11	1	22,247	90
Obs & Gyn	4	2	4	14	0	4,601	3,17
Orthopedic	53	1	0	6	1	1,310	1,04

Source: Computed from survey data

The table above shows the standard deviation of KNH inputs and outputs. All the variables are widely spread around the mean values.

4.2 Summary of efficiency results

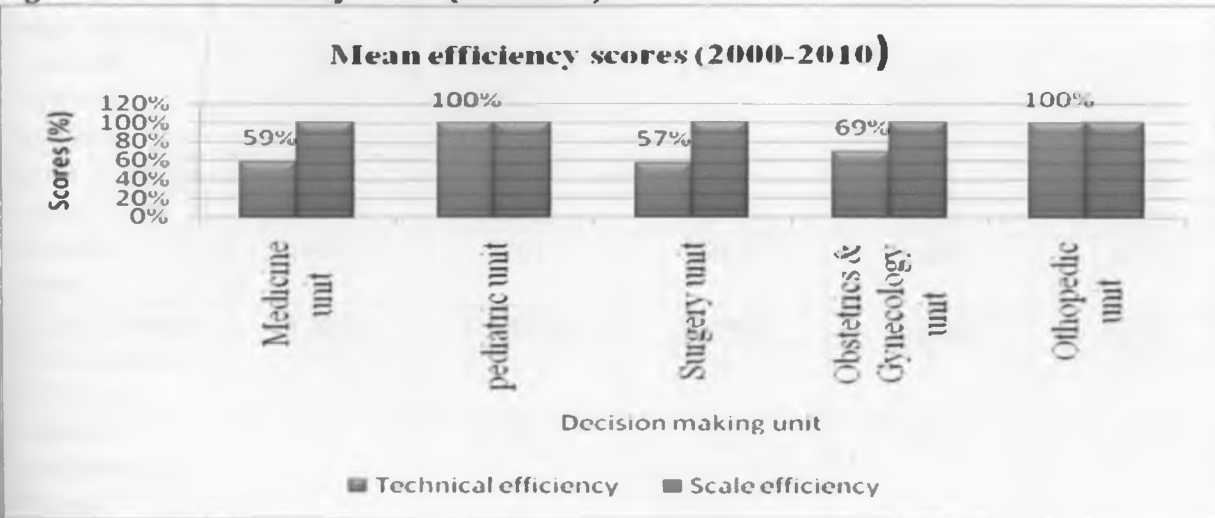
Table 4.2 Efficiency results

DMU	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	201
Medicine	0.585	0.602	0.469	0.531	0.529	0.526	0.522	0.525	0.523	0.521	0.5
Pediatrics	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.881	0.7
Surgery	0.574	0.537	0.556	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.0
Obs & Gyn	0.693	0.765	0.644	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.0
Orthopedics	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.0
Mean	0.771	0.781	0.731	0.906	0.906	0.905	0.904	0.905	0.905	0.880	0.8
Std dev	0.215	0.217	0.251	0.210	0.211	0.212	0.214	0.212	0.213	0.207	0.2
Median	0.693	0.765	0.644	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.0
Min	0.574	0.537	0.469	0.531	0.529	0.526	0.522	0.525	0.523	0.521	0.5
Max	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.523	1.000	1.0

Source: Computed from survey data

Table 4.2 above shows efficiency results for each decision making unit for the years 2000 t 2010, the mean, standard deviation, median, minimum and maximum efficiency score computed using DEA software. Efficiency scores range between 0 and 1 and indicate th presence of deviation from the respective best-practice frontiers. The mean annual scores rang between 0.771 and 0.906 from 2000 to 2010. The mean technical efficiency of KNH compute for a period of eleven years is 77% with standard deviation of 21%. The bar chart below show eleven-year mean efficiency scores for each DMU at KNH. The findings are that surgery unit is the most technically inefficient unit with a mean of 57%. The most efficient decision making units are pediatrics and orthopedics with mean scores of 100% over eleven years.

Figure 4.1 Mean efficiency scores (2000-2010)



Source: computed from survey data

4.3 Deviation of input targets from best practice frontier

An input change of zero symbolizes technical efficiency, while if the change is either negative or positive, it means the unit is technically inefficient, hence there is need to increase or decrease inputs. Table 4.3 below shows deviation of input targets from the best practice frontier. As reflected by the table, only medicine is efficient in terms of variable inputs, specifically number of doctors.

Table 4.3 Deviation of input targets from the best practice frontier

DMU	Medicine	Pediatrics	Surgery	Obstetrics & Gynecology	Orthopedics
Beds target	17,827	16,124	18,898	19,129	19,621
Available beds	4616	3543	2652	2101	1978
Input 1 change	**(13,211)**	**(12,581)**	**(16246)**	**(17028)**	**(17643)**
Doctors & Registrars target	246	388	157	137	97
Available doctors & registrars	246	161	433	260	67
Input 2 change	**0**	**-227**	**276**	**123**	**-30**
Nurses target	10,973	19,425	5,659	4,512	2,070
Available nurses	2422	2761	2663	2409	1317
Input 3 change	**(8,551)**	**(16,664)**	**(2,996)**	**(2103)**	**(753)**
Administrative staff target	12	21	6	5	3
Available administrative officers	13	16	12	14	19
Input 4 change	**1**	**-5**	**6**	**9**	**16**

Source: Computed from survey data

4.4 Summary of peer weights

Peers can be defined as DMUs that constitute a group of best practice with which a relatively technically inefficient DMU is compared. These lie within a boundaries defined by upper and lower bounds: 0 to 1. Table 4.5 below shows a summary of peer weights derived in this analysis.

Table 4.4: Summary of peer weights (2000-2010)

DMU	Peer weights		Peer count
Medicine	0.513	0.487	0
Pediatrics	1.000		3
Surgery	0.207	0.793	0
Obstetrics & Gynecology	0.141	0.859	0
Orthopedics	1.000		3

Source: Computed from survey data

From the table above, pediatrics and orthopedics are within the same peer count, lie above or on the frontier and are therefore deemed to be technically efficient compared to their peers. Medicine, surgery and obstetrics & gynecology lie below the frontier, implying that they are technically inefficient compared to their peers.

4.5 Productivity Change

In the application of malmquist productivity index to assess levels of productivity change over time, year 2001 was chosen for technological reference. MPI or its components attain a value greater than one, equal to one or less than one depending on whether the decision making unit being assessed experienced growth, remained stagnant or experienced decline in productivity between periods t and t+1. Tables 4.5a and 4.5b below show the results of the malmquist productivity index analysis. Table 4.5a presents malmquist indices by annual means, while table 4.5b presents malmquist indices by DMU means.

Table 4.5a: Malmquist Productivity Index summary of yearly mean

Year	Effch	tech	pech	Sech	tfpch
2001	1.012	0.950	1.012	1.000	0.961
2002	0.925	0.964	0.925	1.000	0.892
2003	1.259	0.727	1.259	1.000	0.915
2004	0.999	1.041	0.999	1.000	1.040
2005	0.999	1.015	0.999	1.000	1.013
2006	0.998	0.982	0.998	1.000	0.980
2007	1.001	0.968	1.001	1.000	0.969
2008	1.000	0.998	1.000	1.000	0.997
2009	0.974	1.028	0.974	1.000	1.001
2010	0.960	1.010	0.960	1.000	0.969
Mean	1.010	0.964	1.010	1.000	0.973

Source: Computed from survey data

Table 4.5a) above shows the average annual technical efficiency change (effch), technological change (tech), pure technical efficiency change (pech), scale efficiency change (sech) and total factor productivity change (tfpch) for the years 2001 to 2010. The total factor productivity growth was observed to be inconsistent through the years of analysis, but experienced growth in the years 2004, 2005 and 2009 by 4%, 1.3% and 1% respectively. Scale efficiency change remained stagnant throughout.

Table 4.5b) Summary of changes in productivity levels (2000-2010)

DMU	Effch	tech	pech	Sech	tfpch
Medicine	0.988	0.987	0.988	1.000	0.975
Paediatric	0.968	0.992	0.968	1.000	0.960
Surgery	1.057	0.957	1.057	1.000	1.012
Obs & Gyn	1.037	0.946	1.037	1.000	0.981
Orthopaedic	1.000	0.938	1.000	1.000	0.938
Mean	**1.010**	**0.964**	**1.010**	**1.000**	**0.973**

Source: Computed from survey data (Note: All Malmquist index averages are geometric means)

Table 4.5b) shows summary of changes in productivity levels between 2000 and 2010, in terms of technical efficiency change (effch), technological change (tech), pure technical efficiency change (pech) and scale efficiency change (sech) and total factor productivity index (tfpch) for the years 2000 to 2010 across decision making units. The mean value of total factor productivity change for all units was found to be 0.973. 20% of the decision making units experienced productivity growth since they had malmquist productivity value greater than one. Surgery unit experienced mean growth of 1.2 %.

4.6 Econometric analysis of the determinants of efficiency:

In order to explore the factors that influence the observed technical (in) efficiency, random effects Tobit analysis was done. Table 4.6 displays the empirical results of the analysis using technical inefficiency scores as the dependent variables.

Table 4.6: Empirical results for Tobit model:

Explanatory Variables	Coefficients	Z	$P \succ \|Z\|$
Occupancy rate	0.003	0.68	0.497
Average Length of stay	-0.027	-2.15	0.031
The ratio of the summation of doctors and nurses to inpatient admissions	-0.003	-3.61	0.000
Beds & cots	0.004	5.37	0.000
Outpatient visits as a proportion of inpatient admissions	-0.090	-1.41	0.159
Constant	-0.026	-0.39	0.695
Wald Chi^2 (5)		65.30	
Prob > Chi^2		0.000	
Random effects		u_i ⊔ Gaussian	
Log Likelihood		0.071	
Number of observations		55	
Number of groups		5	
Number of observations per group		11	

Source: Computed from survey data

The Tobit coefficient measures the effect of the independent variables on the z scores of the dependent variables. The test statistic Z is the ratio of the coefficient to the standard error of the respective predictor. The Z value follows a standard normal distribution which is used to test a two-sided alternative hypothesis that the coefficient is not equal to zero.

$P \succ |Z|$ is the probability of the z test statistic (or a more extreme test statistic) that would be observed under the null hypothesis that a particular predictor's regression coefficient is zero, given that the rest of the predictors are in the model. For a given alpha level, $P \succ |Z|$ determines whether or not the null hypothesis can be rejected. If $P \succ |Z|$ is less than alpha, then the null hypothesis can be rejected and the parameter estimate is considered statistically significant at that alpha level.

The above table shows that at 95 % confidence interval, three out of five explanatory variables namely average length of stay, ratio of the summation of doctors and nurses to inpatient admissions and beds & cots are significant. The Z scores for the three variables were found to be more than 1.96; and their $P \succ |Z|$ values were less than 0.05, affirming that they are significant.

Beds & cots had a positive coefficient of 0.004, which implies a positive correlation with factors associated with technical inefficiency. The Z score for beds & cots was 5.57, while the critical Z is +1.96 or -1.96, therefore beds & cots is a significant variable in the Tobit model.

Average length of stay was found to be negatively correlated with technical inefficiency. The ratio of the summation of doctors and nurses to inpatient admissions was found to have a negative coefficient, meaning a unit increase in the ratio reduces technical inefficiency by 0.003 units.

CHAPTER FIVE

5.0 SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

This study was motivated by the fact that even though Kenyatta National Hospital is the largest teaching and referral hospital in Kenya, its levels of technical efficiency and productivity remains largely unknown. Employing data envelopment analysis (DEA), the study examined the levels of technical efficiency of various decision making units during the period (2000-2010). The study also employed DEA-malmquist productivity index to assess the total factor productivity change at the hospital, along with its mutually exclusive and exhaustive components efficiency change technological change. Mean technical efficiency was found to be 77% and 60% of the decision making units were technically inefficient.

5.1 Limitations of the study

The study encountered various limitations. First, there was a long bureaucratic procedure follow before being allowed to collect data. It was required that the researcher gets the ethical approval from the ethics and research centre of the hospital, which took very long. Some data was not available, particularly non-wage expenditure records for the period 2000-2004, and data for the years 2005 to 2010 was quite skewed. Thirdly, KNH had not computerized their health service delivery records up to the year 2004, and even then, the available information was scanty. This could lead to biased results hence biased conclusion. Lack of complete data led to a reduction in the number of inputs used for the study from six to five.

DEA does not suggest the cause or offer remedies for the identified declining productivity, but it is capable of estimating relative technical efficiency and levels of productivity change using multiple input and output variables. The same characteristics that make DEA a powerful tool can also create problems, for example, DEA is an extreme point technique, which means noise (such as measurement errors) can cause important problems. DEA estimates "relative" efficiency of a decision making unit, but it converges very slowly to "absolute" efficiency, that is, it only states how well a DMU is doing compared to other DMUs, but not compared to a "theoretical maximum." Follow-up review procedures could help define the types of operating changes that can facilitate productivity improvement in future.

5.2 Areas of further research

The Malmquist productivity index results showed that when there was a reduction in technological growth, positive efficiency change would not offset the effect of technological change and TFP growth would decline. In view of this, it would be necessary to investigate technology uptake at Kenyatta national hospital, among others, the challenges that come with the adoption of any new technology, and whether the technology fits the hospital's environment. Further research could be carried out to assess the levels of technical efficiency and productivity change at Moi referral and teaching hospital in Eldoret, Kenya, being the second largest referral hospital in Kenya. More detailed studies in future could examine and document operating practices of other hospitals to establish a guide to 'best practice' for inefficient decision making units to emulate. The methodology employed in this study could be replicated by future researchers in other sectors of the economy.

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APPENDICES

Appendix I: Variables used for medicine unit TE & MPI analyses

Year	Outpatient Visits	Admissions	Beds & Cots	Doctors	Registrars	Nurses	Administrative staff
2000	30479	18762	466	17	6	218	1
2001	30215	20018	477	17	6	211	1
2002	41064	19043	477	17	8	221	1
2003	46283	20820	389	14	5	242	2
2004	37315	16616	401	13	12	233	1
2005	35559	15669	401	15	8	214	1
2006	39866	16774	401	16	6	223	1
2007	41273	15556	401	20	2	224	2
2008	41153	12796	401	17	3	205	1
2009	40230	10016	401	18	3	205	1
2010	47265	9022	401	19	3	226	1

Source: Computed from survey data

Appendix II: Variables used for pediatrics unit TE & MPI analyses

Year	Outpatient Visits	Admissions	Beds & Cots	Doctors	Registrars	Nurses	Administrative staff
2000	16124	19425	388	14	7	254	1
2001	16116	19917	367	13	5	251	1
2002	16339	17182	314	10	2	257	1
2003	16788	18862	271	14	3	283	1
2004	14956	12961	337	14	3	264	1
2005	15406	12954	311	13	2	245	2
2006	16241	13380	311	13	1	249	2
2007	20266	14087	311	12	0	243	1
2008	19954	13275	311	11	1	238	2
2009	22701	12154	311	10	0	236	2
2010	26961	11081	311	13	0	241	2

Source: Computed from survey data

Appendix III: Variables used for surgery unit TE & MPI analyses

Year	Outpatient Visits	Admissions	Beds & Cots	Doctors	Registrars	Nurses	Administrative staff
2000	32899	9853	375	31	0	254	1
2001	37106	10301	372	29	0	261	0
2002	36206	11785	425	30	9	254	1
2003	56480	12133	188	33	4	248	1
2004	63272	10615	182	34	12	232	1
2005	62757	10331	182	32	10	230	2
2006	69674	10574	182	34	8	246	1
2007	103952	10769	182	37	1	233	2
2008	75048	10085	188	34	5	229	1
2009	79699	9166	188	33	4	239	1
2010	84766	9365	188	40	3	237	1

Source: Computed from survey data

Appendix IV: Variables used for obstetrics & gynecology unit TE & MPI analyses

Year	Outpatient Visits	Admissions	Beds & Cots	Doctors	Registrars	Nurses	Administrative staff
2000	27592	23597	199	18	8	245	1
2001	26080	19644	192	17	9	243	1
2002	32753	18448	192	16	6	222	1
2003	39929	19078	192	17	10	222	1
2004	31719	18472	186	18	10	212	1
2005	31412	18190	192	21	7	213	2
2006	35206	20413	192	21	1	218	2
2007	38995	21318	192	17	1	204	1
2008	27724	23286	192	20	2	216	2
2009	30297	25717	186	21	2	209	1
2010	35988	27450	186	17	1	205	1

Source: Computed from survey data

Appendix V: Variables used for orthopedic unit TE & MPI analyses

Year	Outpatient Visits	Admissions	Beds & Cots	Doctors	Registrars	Nurses	Administrative staff
2000	19621	2070	97	3	0	126	3
2001	20820	2190	98	4	0	120	3
2002	21729	2042	98	6	0	116	3
2003	23184	4955	208	7	0	133	3
2004	19806	4340	211	8	0	122	1
2005	18612	4123	211	7	0	109	1
2006	19259	4452	211	7	0	123	1
2007	21013	4230	211	6	0	117	1
2008	21127	3899	211	7	1	118	1
2009	20009	3267	211	6	0	118	1
2010	19417	3121	211	6	0	115	1

Source: Computed from survey data