Technical Efficiency of Maternity Units of Regional Referral Hospitals in Uganda

Abaliwano Joyce[5], Lokina Razack[6], Turyareeba Dickson[7]

Abstract

The aim of the paper is to estimate technical and scale efficiency while investigating determinants of technical efficiency in Uganda's hospitals. A panel of 14 maternity units in the regional referral hospitals for over the period 2012-2016 is considered for empirical analysis. Nonparametric Data Envelopment Analysis approach is used in measurement of hospital technical efficiency. The results indicate existence of varying degrees of technical and scale efficiency in the maternity units in the hospitals at the individual and regional levels. Performance of the regional referral hospital's maternity units demonstrated existence of scale and management problems at different levels. Results further depicted existence of increasing returns to scale. Previous studies focused on the health sector in totality, however this paper only looks at efficiency in the maternity units in regional referral hospitals. Results point to the need for expansion in the size of the units through internal growth and improvement in management. Secondly increasing funding to regional referral hospitals is necessary for technical efficiency improvement to grantee reduction in maternal and infant death and improvement in the maternal health management in regional referral hospitals in Uganda.

Keywords: Data Envelopment Analysis, Technical Efficiency, Maternity Units.

Introduction

Increasing emphasis is being placed on measures of efficiency in hospitals to compare their performance given the need to ensure the best use of scarce resources (Rowena, 2000). The key component of health sector efforts in improving the operating efficiency has to do with making the best use of existing resources (Parker and Newbrander, 1994). Masiye, (2007) reports that hospitals are expected to be efficient though it is public knowledge that public hospitals are inefficient. The inefficiency partly stems from the inadequate staff, unmotivated staff, inadequate/unavailability of equipment, poor working environment and low funding. Considering that health is a human right, governments have tried to improve the standard of healthcare by training more staff, increasing the number of health units thereby building more public health centres and hospitals.

Uganda Bureau of Statistics, (2018) reports that women contribute 52 percent of the total population with 38.7 percent in the productive age of 15 to 49 years. The fertility rate is 5.4 children per woman with an annual population growth rate of 3 percent. Further, the youthful and young population stands at 21 percent for youth 18 to 30 years and 55 percent below 18 years of age. This means that given the 52 percent women population, it's expected that all pregnant women access health units and be attended to by skilled personnel. However, AHSPR

[5] 1Makerere University Business School, Kampala, Uganda
Email: jabaliwano@mubs.ac.ug OR abaliwano@yahoo.com
6University of Dar es Salaam, Tanzania
7 Makerere University Business School, Kampala, Uganda

2013/14 reports that for financial years 2010/2011, 2011/2012, 2012/2013 and 2013/2014 hospital deliveries were 39, 40, 41, and 44.4 percent respectively against the HSSIP target of 65 percent. AHSPR (2010) further reports a daily average of maternal death in the regional referral hospitals at 37 death per hospital. This average is higher than the national daily average of 16 maternal death making it crucial to review the causes given the 20.4 percent disease burden resulting from maternal health conditions (HSSIP, 2010). This is compounded by the visible gap between the availability of staff, quality of service and frequent drug stock outs in rural health units yet 76 percent of the population is rural based. These statistics depict the need to improve efficiency and evaluate the performance of maternity units at Regional Referral Hospital level. Reason is that on average 5 percent of the total budget goes to health with 26 percent of the total health expenditure spent on hospitals. For government to improve the health care status, there needs to be either increase in budget allocations to health or improve efficiency in public hospitals. This is crucial because efficiency in hospitals and maternity units in particular grantees reduction in the maternity mortality rate that enable achievement of global and national development goals like SDG, NDP II and Vision 2040. This is because maternal mortality has continued to register slow progress in Uganda despite, the significant progress made in the overall health targets set by the then Millennium Development Goals (MDGs) and now SDGs. Secondly, measurement of efficiency in health care systems has considerable importance in policy. In the East African regional block, Tanzania, Burundi, Southern Sudan and Kenya are also still below the required global maternal mortality standard with only Rwanda making visible progress. Scholars Kirigia et al (2013), Yawe (2006), Mujasi et al (2016) and Wang et al (2016) addressed technical efficiency in public hospitals of Eritrea, Denmark, Uganda and China respectively. These studies focus on technical and scale efficiency in all the departments in the hospitals but none specifically addresses maternal health efficiencies. However, Bergeson et al, (2010), Senfuka, (2013), Okal et al, (2013), Namazzi et al (2013), and Krut et al,(2016) try to address maternal health issues different from this study. The former identifies and addresses some of the maternal health problems but none addresses the literature gap on efficiency in the maternal health subsector in the Ugandan health sector. This paper addresses this gap on the efficiency in maternal health an area the literature reviewed has not covered. The paper measured technical and scale efficiencies while identifying the determinants of Technical efficiency in the maternal health units in the regional referral hospitals in Uganda for the period 2012 – 2016.

Theoretical background and Review of Literature

The microeconomic and the theoretical contribution of efficiency stems from the works of Debreu (1951), Koopmans and Farrell (1957) that introduced a measure of efficiency that utilises multiple inputs. Farrell looked at efficiency as a measure of relative best performance frontier determined by a representative peer group instead of as an absolute measure. In the 1957 Farrell further provided the meaning and calculation outline for technical efficiency and also provided the empirical estimation that differentiates technical from economic efficiency. This approach was explained using a process that produces a single output with multiple inputs and found that all points on the same pathway are technically efficient. The non-parametric data envelopment analysis suggested by Farrell (1957) and Charnes et al (1978) is a linear programming approach meant to study technical efficiency of decision-making units. The underlying concept of DEA was based on Pareto optimality (Charnes et. al., 1985). It attempted to measure efficiency by estimating the optimal level of output conditional upon the amount and mix of inputs. This technique allowed for multiple output production as is in health care services.

There are hospital production theories that guide treatment of firms with profit motivation and non-profit motivation. This paper discusses theories of non-profit motive firms like the public hospital. Public hospitals are non-profit entities therefore their existence is not pegged on profit margin but serving people. A number of theories explain the phenomena of effect of the market power, control of the input and the level of output for non-profit firms.

Pauly and Redisch (1973) suggests that power centre of non-profit hospitals is divested in the medical staff where hospital staff policy on privileges is used in relation to the market power. The free entry and assess to the privileges encourages charging of low prices to ensure demand for the physician services. This makes pricing in non-profit firms low because the staff benefit from the privileges hence demand for the services remaining unchanged.

Baumol (1967) and Newhouse (1970) positions the centre of power in the hands of the hospital administrators in determining the hospital's non-profit objective with the aim of ensuring output maximisation. This affects output in terms of the number of deliveries handled for the case of maternity units. To reduce the effect on output, market power is eliminated from the factors that determine the level of output. Further control of quality and quantity as the hospital draws utility forces improvement of quality which may not be in line with the consumers' preferences. Market power and subsidisation of nonviable services is done where the level of output is kept high by the hospital using subsidisation of services, improving quality, quantity while ignoring the market power.

Sale maximisation (Rice, 1966), revenue sales maximisation (Baumol, 1967) and conspicuous production theory (Lee, 1971) are the other theories that have been discussed that control input, output and market power.

Hayajneh, (2007) explains systems theory in health care systems. The theory elucidates how hospitals as a system relate the different components from input, throughput, output and feedback to make a complete system. The aim is to apply system theory concepts and principles to understand and explain hospitals and their operations. He asserts that a system can be the entire hospital or any of it departments. The paper therefore looks at the sub system of the maternity unit in the regional referral hospital system. The hospital systems involve the extraction of inputs into output through a set of processes.

Systems theory was developed by biologist Ludwig Von Bertalanffy in the 1930s. The theory looked at the world as a system composed of smaller sub systems (Hayajneh, 2007). Hospitals are looked at as a system with inputs and processes that help turn inputs into outputs. In the theory inputs are raw materials that are processed to produce output in the hospital for example effort of the medical staff (doctors, Nurses), beds available in the hospital, other non-medical staff that work in the hospitals. Processes are used to convert inputs into outputs. Outputs are products resulting from the processes. These included deliveries, and death. Lastly there are expected feedback in terms of improvement in health status and decrease in maternal and infant death. Maternity units use treatment resources as inputs with a treatment services in the throughput intended to cure patients. For the women ages 15 to 49 years, it is the productive age therefore prevention and diagnostic services may not apply for those who are already pregnant. Treatment to ensure safe delivery is the most appropriate in this situation. Systems theory was adopted and used to explain the systemic nature of health care using the case of relationships and operations in the maternity department at regional referral hospital level. The required inputs in the maternity unit in a RRH are both physical in terms of buildings and equipment, health personnel (doctors, nurses/mid wives) and financial hence classification into capital and labour. The labour component included number of doctors qualified to handle obstetrics and gynaecological conditions in women and nurses trained to do obstetrics and gynaecology. The capital inputs were approximated by the number of beds in the maternity unit in the regional referral hospital. Further, bed capacity is one of the determinants of hospital size. In addition, Studies Kirigia et al (2004), Yawe (2009), Nedelea et al (2010), have used beds as a proxy for capital. Processes in maternity units in the RRH include capacity building for the unit staff in management of emerging health issues like HIV in pregnancy.

Secondly provision of funding by government is part of the process that enables conversion of inputs into outputs. RRH are fully funded by government and the services provided are free for the people in the area. . In health outcomes, it is sometimes difficult to have a direct measure between the input and output because the interaction may not be linear in nature. Secondly there situations in hospitals where it is not possible to have final outputs hence the use of intermediate outputs. Lastly hospitals provide a variety of services and it may be difficult to benefit from only the services of one unit. The desired output in maternity units include live births done by normal deliveries and C-sections in the unit while the undesired output is numbers of maternal and infant death. Death though undesired is an expected output in a hospital setting that is likely to have an impact on the efficiency levels. The likely interpretation is that high death would mean high efficiency. This study however interprets high death to imply low efficiency. Hence this study utilized deliveries in unit, C- section deliveries and the undesired output of Death (maternal and infant death) as outputs. There are a number of direct measures and proxy measures that estimate the outcomes in health status. This means that the outcome of improved management of maternal conditions is likely to bring about reduction in maternal and infant mortality by a given rate and improvement in health management.

Debreu (1951), Koopmans and Farrell (1957), Farrell (1957), Charnes et al (1978) and Charnes et. al. (1985) have been the foundation for a number of studies that have utilised the data envelopment analysis in hospital efficiency measurements. Secondly, Antonio (2007) confirms that Hospital efficiency analysis is an important concern within the field of health economics. Studies like Yawe (2006), Kristensen et al (2008), Kirigia et al (2013), Mujasi et al (2016) and Wang et al (2016) applied DEA non-parametric methods to study the measure of efficiency in health care systems. All the studies presented varying levels of inefficiency for the sample hospitals.

Rowena (2001) used both DEA and SFA to study the alternative methods to examine hospital efficiency. Cost indices were used to bench mark and compare the efficiency rankings from the SFA and DEA. The significant finding in this study is that both SFA and DEA approaches have strength and weaknesses and theoretically measure different aspects of efficiency. Worthington (2004) did a review of empirical techniques and selected applications to study the frontier efficiency measurement in health care since he believed that increase in health care costs in developed countries were partly due to inefficiency.

Mohammed et al (2011) applied DEA to estimate the hospital's unit efficiency where he confirmed the strength of DEA in estimating efficiency using similar multiple inputs and outputs in a DMU at the same ranking. Rutledge (1995) used DEA to assess hospital efficiency overtime. In this study he examines DEA and its ability to determine the relative efficiency of the hospital using inputs of nursing, ancillary, temporary, support services and patient supplies and outputs of major diagnostic.

Sheikhzadeh et al (2012) applied DEA to measure technical, scale, allocative and cost efficiencies of public and private hospital services reforms. The main objective of the study was to suggest a suitable context to develop efficient hospital systems while maintaining the quality of care at minimum expenditures and to find the best practice standards for efficiency. The significant finding was that public hospitals were more efficient than private hospitals. This result is contrary to Masiye (2007) who finds that private hospitals are more efficient than public hospitals. In Asia, Ersoy et al (1997), Majumdar (1994) and Chang (1998) applied DEA to analyse the technical efficiencies of Turkish hospitals, measure relative efficiency points within the Indian pharmaceutical sector and determine technical efficiency of six class one public hospitals in Taiwan for five years respectively.

In Southern Africa, the DEA approach has been applied by Kirigia (2008), Kirigia (2001), Kirigia (2000) assessed the technical and scale efficiency and productivity change over a four year period among 17 public health centres in Seychelles, to find out what portion of 55 public hospitals of Kwazulu Natal province of south Africa were operating efficiently and for those inefficient hospitals what inputs and outputs contribute to their inefficiency and to estimate the technical efficiencies among 155 primary health care clinics in Kwazulu Natal province of South Africa in that order.

In Zambia, Masiye et al (2007) estimated technical, allocative and economic cost efficiencies for 40 private and public health centres. This study figures out that private centres had been run more efficient than public ones. In another study on 18 public hospitals 8 charity hospitals (affiliated with the church), and 4 private (overall 30 hospitals) estimated technical efficiency. Kirigia et al. (2004), Osei et al. (2005), Akazili (2008) applied DEA to assess technical efficiencies of public health centres and district level public hospitals in Kenya and Ghana found inefficiency in the public hospitals.

Kirigia (2013) also did an exploratory study on the technical and scale efficiency of public hospitals in Eritrea and Kirigia et al (2008) did a performance assessment method for municipal hospitals in Angola. Kinyanjui et al (2015) employed the Data Envelopment Analysis to unravel the technical efficiency of hospitals owned by faith based Organisations in Kenya using the Input orientation model. Results indicated that 36.67 percent of faith based organized hospitals were inefficient. Irungu (2012) examined technical efficiency in Kenyan pubic hospitals and discovers that inefficiencies remain a major challenge in the hospitals. Molem et al (2017) explains that location of health facilities and corruption are the significant determinants of inefficiencies in hospitals in Cameroon. And suggests the opening up to completion and increasing bed capacity to improve efficiency. Whilst Ali et al (2017) also confirms the presence of variable returns to scale technical inefficiency and scale inefficiency in the hospitals studied and suggests need for interventions that utilise excess capacity of hospitals like increasing the doctor staff ratio to improve efficiency.

In Uganda, Nabukeera et al. (2015) evaluated health centres and hospital efficiency in KCCA using the Pabon Lasso technique for the period 2012 to 2013. The results indicate unacceptably low levels of technical efficiency in the health centres. Results showed that the average variable returns to scale (Pure) technical efficiency score was 91.4 % and the average scale efficiency score was 87.1 % while the average constant returns to scale technical efficiency score was 79.4 %. Tobit regression indicated that significant factors in explaining hospital efficiency are: hospital size; bed occupancy rate and outpatient visits as a proportion of inpatient days. Mujasi (2016), explored the technical efficiency of referral hospitals in Uganda for the period 2009/10 to 2012/2013 in a longitudinal study using five-year panel secondary data. They used Data Envelopment Analysis to estimate efficiency of the hospitals in each financial year. The inefficient hospitals would need to increase the outpatient department visits by 10%, deliveries by 6% and inpatient days by 10% without increasing any of the inputs. Mulumba et al (2017)'s review of the referral hospitals using DEA confirmed technical inefficiency in hospitals and brings to light the congestion input in hospitals. The studies so far reviewed show the increasing importance of application of DEA in estimating efficiency in the health sector. While as the decision-making units studied have been district hospitals, regional referral hospitals and health centres, these studies have not addressed the efficiency of maternal health care aspect as a stand-alone DMU.

The studies done on maternal health include; Saronga et al (2014), Namazzi et al (2015), Kruk et al. (2016), Okal et al (2013), Abbasi et al (2015) and Rutaremwa et al (2015). They have assessed the efficiency of antenatal care and childbirth services in selected primary health care facilities in rural Tanzania with the aim of evaluating the actual dimension and distribution of the costs of providing antenatal care and childbirth services, describes the experience of building capacity for maternal and new born at district hospital level in eastern Uganda, evaluates maternal health programs in Uganda and Zambia and assesses the opportunities and challenges for public sector involvement in the maternal health voucher program respectively. The results of these studies indicate; that unit costs showed variations in relative efficiency in providing the services between the health facilities with efficiency in ANC depending on the number of staff, structural quality of care, process quality of care and perceived quality of care, the need for local solutions in ensuring sustainability of medical commodities to strengthen facilities for maternal and new born care, national investment in health system, provider training and identification of intervention components most associated with performance improvement to scale up and sustain maternal health programs in Uganda and the voucher program has the potential to address other sector challenges like under staffing and supply shortages respectively. Abbasi et al. (2015) investigates determinants of maternal mortality in Pakistan and discovers that they range from biological, socio-economic, cultural and poor quality of reproductive health services. He further stresses that poverty ranks highest in determining maternal mortality. Rutaremwa et al. (2015) investigates the utilisation of maternal health services in Uganda. The results indicated that utilisation of the maternal health services varied greatly by demographic and socio-economic characteristics. He finds that women with second education and those with higher income are likely to utilise the maternal health services than their counterparts in the lower social class therefore a need to have polices that target the socially marginalised group. All the above studies emphasize the importance of investment in capital stock in maternal health so as to improve the health outcomes from the sub sector. They report a need to increase medical supplies that are maternity specific like oxytocin, misoprostol, magnesium sulfate and MVA equipment, increase number of trained staff, improve the weak infrastructure so as to increase the health outcomes. In view of the above, maternal health issues continued to puzzle health practitioners given the poor progress in the set MDG and now SDG targets, therefore a need to evaluate its technical efficiency and scale efficiency so as to advise policy accordingly. Regional referral hospitals serve a big part of the population so ensuring that they are efficient is crucial in the health service delivery. This study therefore goes in to fill the knowledge gap on levels of technical and scale efficiency in maternal health in the regional referral hospitals.

Methodology

The research design was exploratory involving only quantitative approaches to estimate the technical and scale efficiency and Tobit regression to investigate the determinants of technical efficiency in the maternity units of the regional referral hospitals in Uganda. A panel of 14 maternity units for which data was compiled for the years 2012 to 2016 was used. Secondary data was collected from four regions of Uganda, namely; the western, central, northern and eastern. Data on deliveries, infant and maternal death was collected from Ministry of health HMIS, human resource data was collected from the staff lists in health human resource department, Bed capacity data was collected from clinical services department and health funding data was collected from the Ministry of Finance and Economic Development.

Measurement of Input and Output Variables

A healthcare institution uses a number of resources in terms of capital/financial and labour to produce the required output. DEA specifically requires careful selection of inputs and output because the distribution of efficiency is likely to be affected by the definition of outputs and the number of inputs and outputs (Magnussen, 1996). Inputs used include number of beds and number of obstetrics/gynaecology doctors and nurses (midwives) while outputs are deliveries, death, births by C-section.

Data Envelopment Analysis (DEA)

DEA is a non-parametric method in operations research used in estimation of production frontiers. DEA's basic theory and model are based on theory of micro economics. Modifications have been done on the original DEA on Farrell (1957)'s work, was done by Charnes et al. (1978) who suggested a formal linear programming approach known as Data Envelopment Analysis (DEA) for studying technical efficiency of "Decision making Units"(DMUs), allowing for multiple output production which is a common attribute of most health care service providers. They proposed an iterative algorithm where within each iteration; the technical efficiency of a DMU is computed relative to all the other DMUs in the set. The efficiency measure is obtained as "the maximum of a ratio of weighted outputs to weighted inputs subject to the condition that similar ratios for every DMU be less than or equal to unity." Charnes et al. (1978) DEA model assumed constant returns to scale (CRS) and is considered a sensitive model for measuring technical efficiency.

In a further modification, Banker, Charnes, and Cooper (1984), developed a second DEA model, which assumes variable returns to scale (VRS), to separate pure technical efficiency from scale efficiency. The CRS assumption is only appropriate if all DMUs are operating at optimal scale however imperfect competition as well as, constraints on finance, may cause a DMU not to operate at the optimal scale. When DMUs are not operating at an optimal scale, the technical efficiency can be decomposed into pure technical efficiency and scale efficiency. Therefore, in situations where the CRS does not hold, the technical efficiency measure is mixed with scale efficiency. To disentangle the effect of scale efficiency it is necessary to use a DEA model with a Variable Returns to Scale (VRS) assumption as suggested by Banker et al. (1984).

The use of the CRS specification when not all DMUs are operating at the optimal scale, results in measures of technical efficiency (TE) which are confounded by Scale Efficiencies (SE). The use of variable returns to scale data envelopment analysis specification permits the calculation of Technical Efficiency free of Scale Efficiency effects. The strength of DEA lies in the fact; it employs linear programming techniques and can handle multiple inputs and outputs as is with hospitals and health care systems. It is easy to assess the comparative efficiency of Decision-Making Units (DMUs) with its peers without requiring assumptions of the functional form that relates inputs to outputs as is with regression methods. Lastly it does not require information on prices of inputs or outputs and does not require cost minimisation. These have made it a popular approach in estimation of firm and departmental performance in many fields (see Hollingsworth et al 1999, Yawe 2006, among others).

Despite these positive attributes, DEA has limitations that arise from its characteristics and they involve; the fact that it does not require information on prices of inputs or outputs makes it difficult to evaluate marginal products, partial elasticities, marginal costs or elasticities of substitution from fitted models hence difficulty in deriving technological conclusions. Secondly the linear programming solution of DEA is non-statistical in nature and as a result it produces no standard errors and makes testing hypothesis difficult. This means that any deviations from the frontier are treated as inefficiencies with no room for random shocks.

Model Specification

DEA has both the input oriented and output oriented models of measuring efficiency. They are used as constant returns to scale and variable returns to scale model as developed by Charnes at al. (1978) and Banker et al. (1984) respectively. The former assumed that production has constant returns to scale and input oriented in nature while the latter assumes production has variable returns to scale. The input oriented model minimizes the input so as to produce a given level of output while the output oriented model maximizes output with a given level of input. Efficiency measurement systems was used to estimate the technical efficiency of maternity units in the Regional Referral Hospitals input oriented DEA for CRS,VRS assumptions while non-increasing returns to scale model was used to determine the nature of returns to scale.

a) Input oriented DEA for CRS

$$Efficiency = Max \sum UrYrj0 \qquad (1)$$

Subject to:

$$\sum Ur\,Yrj - \sum ViXij\ ; \quad \forall j \qquad (2)$$

$$\sum_{i}^{r} Vi\,Xij = 1$$

$$Ur, Vi \geq 0; \quad \forall r, \forall i \qquad (3)$$

b) The input oriented DEA for the Variable Returns to Scale model

$$Eff = Max \sum_r Ur\, Yrj0 + V0 \quad ; Vr; Vi \text{ .... (4)}$$

subject to:

$$\sum UrYrj - \sum ViXij + U0 \leq 0 \quad ; \quad \forall j \text{ .... (5)}$$

$$\sum_i^r Vi\, Xij0 = 1$$

$$Ur, Vi \geq 0\, ; \forall r, \forall i \text{ .... (6)}$$

c) Non increasing returns to scale model for determining nature of returns to scale

$$Max\ Ur_{Ur,\lambda r} \text{ .... (7)}$$

$$UY_r \leq \sum_{i-1}^{i} \lambda_{ir} Y_i \text{ .... (8)}$$

$$X_{ij} \geq \sum_{i=1}^{i} \lambda_{ir} X_{ij} \text{ .... (9)}$$

$$\lambda_{ir} \geq 0 \text{ .... (10)}$$

$$\sum_{i=1}^{i} \lambda_{ir} \leq 1 \text{ .... (11)}$$

Where Y_{rj} = amount of output r produced by hospital j, X_{ij} = amount of input I used by hospital j, U_r = weight given to output r (r = 1…….. t) and t is number of outputs, V_i = weight given to input I (I = 1………m) and m is the number of inputs, n = number of hospital, λ_{ir} = coefficients of linear combination between i and r and j_0 = hospital under study.

Nature of Returns to Scale

Banker, Charnes and Cooper (1984) model that assumes constant returns to scale versus the variable return to scale model was not enough to determine the nature of returns to scale of decision-making units that are estimated. ~~So~~ Fare, Grosskopf and Lovell (1985) decided to modify the BCC model to incorporate the convexity assumption. This assumption resulted in the development of non-increasing returns to scale assumption model.

Scale Efficiency Measurement

Scale efficiency refers to the optimal size of a hospital. A hospital that is small for its volume of activities presents with economies of scale called increasing returns to scale in production whilst a large one for its scale of operation presents diseconomies of scale called decreasing returns to scale in production. Scale efficiency is measured by estimating two technical efficiency measures under different assumptions of constant returns to scale and variable returns to scale. Technical efficiency with the constant returns to scale assumption also known as total efficiency is decomposed into the variable returns to scale efficiency known as pure efficiency and the scale efficiency. A unit is said to be scale efficient when the size of the operations is optimal so that any modifications on its size renders the unit less efficient. Further, scale inefficiency can be identified by classifying the nature of the returns to scale.

Tobit Regression Analysis

The tobit regression analysis was used to identify determinants of hospital (in) efficiency. It related the efficiency scores (dependent variable) to a number of explanatory variables.

Explanatory variables included the maternity specific labour input of the unit (number of gynecology/ obstetrics doctors and midwives), then capital component as a proxy for equipment captured by the number of beds, the funding component to the regional referral hospital and hospital bed capacity to capture the hospital size. The empirical model is in the forms;

$$ineff_{it} = \propto_0 + \propto_1 DR_{it} + \propto_2 lNurses_{it} + \propto_3 lrrhbudget_{it} + \propto_4 lHosp\,size_{it} + \varepsilon_{it}$$

Where: ineff is inefficiency, DR is the number of gynecology/ obstetrics doctors, Nurses are the number of midwives, lrrhbudget is log of annual hospital budget and lHospsize is log of hospital bed capacity as a proxy for hospital size. The advantage with tobit regression is that it provides consistent estimates and uses all information including information on censoring as opposed to logit and probit analysis. Stata 14 was used to do the tobit regression analysis to determine the statistical significance of the coefficients of the explanatory variables.

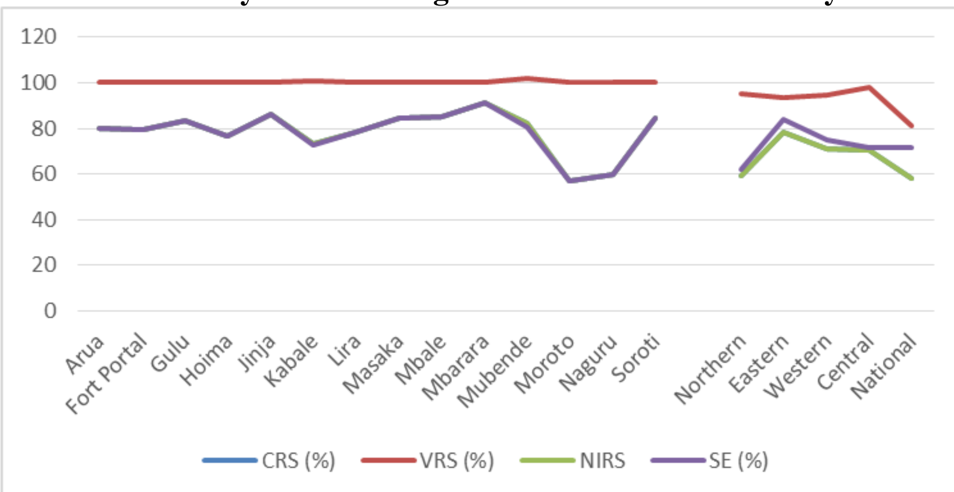
Analysis and interpretation of findings

The estimation was done using Efficiency Measurement System (EMS) by Holger Scheel (2000) with the convexity structure, constant returns to scale, variable returns to scale, non-increasing returns to scale, radial distance, input orientation and super efficiency assumptions. The radial distance indicates the necessary improvements when all relevant factors are improved by the same factor proportionally and is invariant with respect to units of measurement. Non-increasing returns to scale model was used to determine the nature of returns.

Inefficiency is unobservable if not benchmarked with DMU within the sample instead of absolute figures. Each efficiency score was calculated relative to an efficiency frontier. Maternity units located on the efficiency frontier have an efficiency score of 1 or 100 percent under super efficiency assumption while those operating under the frontier have efficiency score of less than 1 or 100 percent and have capacity to improve future performance. This implies that maternity units with efficiency score of 100 are efficient relative to others in the sample and those with 0 are totally inefficient. DEA measurement approaches allow for estimation of the same decision-making unit across time and also allows for efficiency estimation of many decision-making units to see which units are efficient and benchmark with others. The technical efficiency score was estimated using constant returns to scale under the input oriented model. We assumed that all maternity units were operating at optimal scale. However, CRS is a very ambitious assumption because maternity units don't normally operate at optimal scale due to the imperfectly competitive environment. Variable Returns to Scale was assumed for firms not operating at optimal scale resulting due to imperfect competition conditions.

The variable returns to scale helped in estimating the pure technical efficiency and Scale efficiency for each maternity unit. This was obtained by estimating both the constant returns to scale and variable returns to scale DEA technical efficiency scores and then divided CRS by VRS. Difference in CRS and VRS technical efficiency scores implied scale inefficiency. Comparison between the CRS and VRS efficiency scores reveals the source of the scale inefficiency but not the nature of returns to scale. Non-increasing returns to scale was assumed to decide the nature of returns to scale with the help of VRS technical efficiency scores. A result where VRS and NIRS scores are not equal signifies presence of increasing returns to scale, equal NIRS and VRS scores imply presence of decreasing returns to scale and equal CRS, VRS and NIRS scores imply constant returns to scale. Increasing returns to scale in production in this study was defined as a proportionate increase in all inputs under the control of a hospital resulting in a greater than proportionate increase in output. If the hospital size is too small for its scale of operation then we say there is presence of increasing returns to scale.

Maternity Unit DEA CRS, VRS, NIRS and Scale Efficiency Results
Table 1: Summary of the Average Statistics for the Maternity Units



Source: Authors' Compilation

The results indicate that at RRH level of the individual maternity units all presented CRS inefficiency but VRS efficiency scores. The result mean that the units operate on the VRS frontier but below CRS efficiency frontier. The interpretation is that all the 14 RRH maternity units presented a scale problem that requires modification in size to attain efficiency. Further, to a large extent the hospitals present increasing returns to scale due to the fact that there is a disparity between the variable returns to scale technical efficiency score and the non-increasing returns to scale score. The regional and national estimation show that efficiency scores for the maternity units indicate inefficiency for both the CRS and VRS scores. This means that the four regions all operate below the CRS and VRS efficiency frontiers hence existence of a scale and management problem. Secondly the results also showed existence of increasing returns to scale for all the regions.

Super Efficiency Result

The maternity unit performance for the individual regional referral hospitals indicate that super efficiency contributed most to the technical efficiency scores of the units. The result show that the maternity units presented super efficiency magnitudes of Arua (3.3%), Fort portal (10%), Gulu (10%), Hoima (8.3%), Jinja (3.3%), Kabale (3.3%), Lira (3.3%), Masaka (6.7%), Mbale (3.3%), Mbarara (8.3%), Mubende (3.3%), Moroto (6.7%), Naguru (6.7%) and Soroti (3.3%). Some of these magnitudes are the total efficiency scores of the maternity units. The regional and national performance of the maternity units indicate that of the months that presented technical efficiency during the study period, Northern (8.3% out of 11.67%), Eastern (5% out of 8.3%), Western (5% out of 16.7%), Central (6.67% out of 13.3%) and at national 13.33% were super-efficient.

Discussion of Results

Constant returns to scale assumption is appropriate when all maternity units in the regional referral hospitals are operating at optimal scale under a perfectly competitive economic situation. The reality is that constant returns to scale is seldom the case in the real world and as a result variable returns to scale is an alternate in a situation when maternity units are not operating in a imperfectly competitive economic environment. CRS technical efficiency is a global measure of performance composed of pure technical efficiency (VRS TE score) and scale efficiency. The difference between the two models therefore is the source of inefficiency.

The Data Envelopment Analysis is a measurement method that calculates relative and not absolute efficiency scores. The results at the individual RRHs maternity units presented varying magnitudes of technical and scale inefficiency scores. The CRS inefficiency requires increase in output to the magnitude of Arua 20.12%, Fort portal 20.26%, Gulu 16.54%, Hoima 23.44%, Jinja 13.55%, Kabale 27.25%, Lira 21.59%, Masaka 15.24%, Mbale 14.82%, Mbarara 8.78%, Mubende 19.46%, Moroto 42.82%, Naguru 40.14% and Soroti 15.46% so as to attain the same level of efficiency in the different maternity units. Increase in the outputs to the above magnitudes for the different RRH maternity units modifies the scale of the units.

The regional and national outlook showed CRS and VRS inefficiency so no maternity unit at regional level was on the efficiency frontier. The disparity between VRS and NIRS scores shows that all the regions are experiencing increasing returns to scale therefore operating below optimal scale. Secondly the disparity between the two inefficiencies also indicate that the maternity units at regional level are experiencing scale and management problems. For the units to attain CRS efficiency there has to be internal growth in the maternity units in the form of increasing the average output by 38.20%, 16.09%, 24.87%, 28.15% and 28.35% for the northern, eastern, western, central and at national level respectively so as to modify the size of the units. For the scale problem to be modified, the units need to increase output by percent to attain CRS efficiency and operate on the CRS frontier. Maternity units of Masaka, Mbale and Mbarara showed existence decreasing returns to scale so need to increase the inputs to match the level of output. Increase in output for units experiencing increasing returns to scale and increase in input for those experiencing decreasing returns modifies the scale problem. Yawe (2006), Kristensen et al (2008), Irungu (2012), Kirigia et al 2013, Mujasi et al (2016), Wang et al (2016), Ali et al (2017) and Mulumba (2017) all agree with the results in the study that referral hospitals have varying levels of technical and scale inefficiencies in public hospitals of Eritrea, Denmark, Kenya, Ethiopia, Uganda and China.

Determinants of Technical Efficiency

The predictor variables used in the estimation of the tobit regression were total budget, hospital size, maternity specific staff like midwives and obstetrics/gynaecology doctors while the outcome variable in the tobit regression is the inefficiency scores. All variables, except efficiency scores and obstetrics are log-transformed. Due to lack of maternity specific funding data, funding was excluded from the input variables. The total funding to the regional referral hospitals was used. A Tobit regression using the DEA technical (in) efficiency scores as the dependent variable to determine the statistical significance of the coefficients of the explanatory variables including funding to the regional referral hospitals to see the likely influence on inefficiency was run.

Table 3: Tobit Regression to Expound the Technical (In) efficiency

Efficiency Score	Coef	SE	P- value
lrrhbudget	26.44455	5.400941	0.000
obstetricsgynodrs	0.3842936	2.281866	0.866
lnurses	0.0349863	7.530506	0.996
lhospsize	6.61392	4.132165	0.109
cons	-548.9332	111.5171	0.000
Wald chi2(4) = 47.86 Prob > chi2 = 0.0000			

Source: Authors' Compilation

The results indicate a positive and statistically significant coefficient of 26.4 at 1 % level of significance (coeff=26.4, P=0.000) for hospital budget variable. This implies that variations in hospital funding have a positive and significant positive impact on the technical efficiency in the regional referral hospitals. This result partly explains the technical inefficiencies in the maternity units in the regional referral hospitals. A one percent increase in the annual total budget increases hospital efficiency score by approximately 26.4 percent, holding other factors constant. Results also indicate that the estimated coefficient on hospital bed capacity is positive and not far from being statistically significant at 10 percent level. This result could mean that hospital size may have a commendable impact on raising hospital efficient, that is to say bigger-sized hospitals may exhibit a higher efficiency level than their counterparts. The tobit model estimates therefore show that the key determinant of hospital technical efficiency is total funding to the regional referral hospitals because this will have a transformation effect on the motivation of staff, availability of medical supplies and a general improvement in the working conditions in the hospitals.

General conclusions

The competing challenges and a growing population of women of reproductive age makes it difficult for health funding to grow commensurate to the health demands. This means that government should have a concerted effort in prioritising maternal health issues through (i) increase funding to regional referral hospitals modifying the size of maternity units which is crucial for improvement in technical efficiency and. (ii) Modification of size is possible through internal growth by increasing output to attain scale efficiency or merging units that are experiencing increasing returns to scale. In this particular study the former would be the most appropriate since location of the maternity units makes it difficult for merging to happen.

Policy Implications

Increasing funding to regional referral hospitals is necessary if technical efficiency is to be attained at individual hospital level with the aim of reducing death in the maternal units and improvement in the maternal health management in the regional referral hospitals in Uganda.

References

Abbasi S. & Muhammad Y (2015). Determinants of Maternal Mortality in Pakistan at a Glance. *Journal of Midwifery Reproductive Health*. 2015; 3(3):430-432.

Akazili J, Adjuik M, Jehu-Appiah C, Zere E (2008). Using Data Envelopment Analysis to Measure the Extent of Technical Efficiency of Public Health Centres in Ghana. *BMC Int Health Hum Rights*. 8:11.

Ali M., Megersa D. and Bamud T. (2017). Technical Efficiency of selected hospitals in Eastern Ethiopia. Health Economics Review.

Antonio, C. G. et al (2007). *Data Envelopment Analysis for Evaluating Public Hospitals in Brazilian state capitals*. Rev Saúde Pública 41(3).

Banker RD, Charnes A. and Cooper W.W. (1984). Models for Estimating Technical and Scale Efficiencies in Data Envelopment Analysis. *Management Science* Vol. 30, No. 9, pp.1078-1092.

Bertalanffy, V.L. (1962). *General System Theory. A Critical Review*. General Systems 1962; VII: 1-20.

Bruno, Y (2006). *Technical Efficiency and total Factor Productivity Growth in Uganda's District Referral Hospitals.* Unpublished, PhD Thesis.

Chang H. (1998), *Determinants of Hospital Efficiency. The Case of Central Government Owned hospitals in Taiwan.* Omega-Int J Manage S; 26:2-307.

Charnes, A. Cooper, W.W. Golany, B. Seiford, L. and Stutz, J (1985). Foundations of Data Envelopment Analysis for Pareto-Koopmans Efficient Empirical Production Functions. *Journal of Econometrics.* Vol. 30, pp. 91-107.

Charnes, A. Cooper, W.W. Rhodes, E (1978). Measuring the Efficiency of Decision Making units. *European Journal of Operational Research 2*: 429-444.

Debreu, G. (1951). The Coefficient of Resource Utilization, *Econometrica.* Vol. 19, pp. 273-292.

Ersoy K, Kavuncubasi S., Ozcan Y.A. and Harris J.M (1997). Technical Efficiencies of Turkish Hospitals. DEA Approach. *Journal of Medical Systems*, Vol. 21, No. 2, pp.67-74.

Farrell, M.J (1957). The Measurement of Productive Efficiency. *Journal of the Royal Statistical Society*. Series A, CXX, Part 3, pp. 253-290.

Government of Uganda (2010). Health Sector Strategic and Investment Plan Promoting People's Health to Enhance Socio-Economic Development 2010/11-2014/15. Ministry of Health. Kampala.

Government of Uganda (2013). Annual Health Sector Performance Report FY 2012/13. Ministry of Health. Kampala.

Hayajneh Y (2007). *Management for Health Care Professionals Series Systems & Systems Theory* Copyrighted Material – 2007 http://www.theinformatician.com/yaseen/

Holger Scheel (2000). EMS: Efficiency Measurement System User's Manual. Version 1.3 2000-08-15.

Hollingsworth B, Dawson P.J.& Maniadakis N (1999). Efficiency Measurement of Health Care. A Review of Nonparametric Methods and Applications. Health Care Management Science. Vol. 2, pp. 161-172.

Irungu K. N (2012). Analysis of Efficiency of Public Hospitals in Kenya 2008-2011. A research paper submitted in partial fulfilment of the requirements for the award of the degree of Master of Arts in Economics. University of Nairobi. November 2012 (unpublished).

Kariuki K.G., Mwangi G.P., Muniu M. J (2015). Technical Efficiency of Hospitals Owned by Faith Based Organisations in Kenya. *The Journal of Pan African Studies*, vol.8, No.6.

Kirigia J.M, Emrouznejad A. and Sambo L.G, Munguti N. and Liambila W (2004). Using Data Envelopment Analysis to Measure the Technical Efficiency of Public Health Centers in Kenya, *Journal of Medical Systems*, Vol. 28, No. 2, pp. 155-166.

Kirigia J.M, Lambo E. and Sambo L.G (2000). Are Public Hospitals in Kwazulu Natal Province of South Africa Technically Efficient? *African Journal of Health Sciences*, Vol. 7, No. 3-4, pp. 25-32.

Kirigia J.M, Emrouznejad A, Cassoma B, Asbu E.Z, Barry S (2008). *A Performance Assessment Method for Hospitals. The Case of Municipal Hospitals in Angola*. J.Med Syst 32: 509-519.

Kirigia J.M, Sambo L.G. and Scheel H (2001). Technical Efficiency of Public Clinics in Kwazulu-Natal Province of South Africa. *East African Medical Journal,* Vol. 78, No. 3, pp. S1-S13.

Kirigia, Asbu A (2013). *Technical and Scale Efficiency of Public Community Hospitals in Eritrea*. An Exploratory Study. Health Economics Review 3: 6.

Kirigia JM, Emrouznejad A, Sambo LG, Munguti N & Liambila W (2004). Using Data Envelopment Analysis to Measure the Technical Efficiency of Public Health Centers in Kenya. *Journal of Medical Systems*. Vol. 28, No. 2, pp. 155-166.

Kruk et al (2016). *Evaluation of a Maternal Health Program in Uganda and Zambia Finds Mixed Results on Quality of Care and Satisfaction.* Health Affairs 35, No. 3 (2016): 510–519, Project Hope-the People-to-People Health Foundation, Inc.

Lee ML (1971). A Conspicuous Production Theory of Hospital Behavior. *Southern Economic Journal*. Vol. 38, No. 1, pp. 48-58.

Magnussen J (1996). *Efficiency Measurement and the Operationalization of Hospital Production*. Health Services Research. Vol. 31, pp. 21-37.

Majumdar S.K (1994). *Assessing firm's capabilities theory and measurement as study of Indian pharmaceutical, industry.* Econ Polit Weekly; 29:M83–M89.

Masiye, F (2007). *Investigating health system performance. An application of data envelopment analysis to Zambian hospitals*. BMC health services research. 7, pp.58-58.

Mohammed A.A (2011). Measuring hospital's Units efficiency. A data Envelopment Analysis Approach. *International Journal of Engineering & Technology*, Vol: 11 No: 06.

Molem C.S, Parfait B.B and Ntangsi M.M (2017). Determinants of the Inefficiency of Public Hospitals in Cameroon. *International Journal of Academic Research in Business and Social Sciences 2017*. vol. 7, No. 6 ISSN: 2222-6990.

Mujasi P.N, Eyob Z. Asbu and Puig-Junoy J. (2016). *How efficient are referral hospitals in Uganda? A data envelopment analysis and Tobit regression approach.* BMC Health Services Research 16:230.

Nabukeera M, Boerhannoeddin A, Raja Noriza R.A (2015). *An Evaluation of Health Centers and Hospital Efficiency in Kampala Capital City Authority Uganda.* Using Pabon Lasso Technique. JUMMEC: 18(1).

Namazzi G., Waiswa P, Nakakeeto M, Nakibuuka V.K, Namutamba S, Najjemba M, Namusaabi R., Tagoola A, Nakate G, Ajeani J, Peterson S. and Byaruhanga R.N (2013). *Strengthening Health Facilities for Maternal and Newborn Care. Experiences from Rural Eastern Uganda*, Global Health Action 8: 24271.

Nedelea I.C, Fannin M, and Barnes JN (2010). *Analyzing Differences in Rural Hospital Efficiency: A Data Envelopment Analysis Approach.* The Agricultural & Applied Economics Association AAEA, CAES, & WAEA Joint Annual Meeting, Denver, Colorado.

Newhouse J (1970); *Toward a Theory of Nonprofit institutions. An Economic Model of a Hospital*. American Economic Review. Vol. 60, No. 1, pp. 64-74.

Okal J, Kanya L, Obare F, Njuki R., Abuya T, Bange T, Warren C, Askew I. & Bellows B. (2013). *An Assessment of Opportunities and Challenges for Public Sector Involvement in the Maternal Health Voucher Program in Uganda.* Health Research Policy and Systems, 11:38.

Osei D, Kirigia J.M, Almeida S.D, George M.O, Mensah AO and Kainyu LH (2005). Technical Efficiency of Public District Hospitals and Health Centers in Ghana. A Pilot Study, Cost Effectiveness and Resource Allocation (Online).

Parker, D. and Newbrander. W. (1994). *Tackling Wastage and Inefficiency in the Health Sector*. World Health Forum. Vol. 15, pp. 107-13.

Pauly MV and Redisch M (1973). *The Not-for-profit Hospital as a Physicians' Cooperative*. American Economic Review. Vol. 63, pp. 87-99.

Rice RG (1966); Analysis of the Hospital as an Economic Organism, Modern Hospital, Vol. 106, pp. 87-91.

Rowana, J. (2000). *Alternative Methods to Examine Hospital Efficiency. Data Envelopment Analysis and Stochastic Frontier Analysis*. Health Care Management Science, Vol. 4, pp. 103-115.

Rutaremwa G, Ojiambo S.W, Jhamba T, Akiror E and Kiconco A (2015). *Determinants of Maternal Health Services Utilization in Uganda*. BMC Health Services Research 15:271 Doi 10.1186/s12913-015-0943-8

Rutledge RW, Parsons S, Knaebel R (1995). Assessing hospital efficiency over time. An empirical Application of Data Envelopment Analysis. *Journal of Information Technology Management.* Vol. VI, No. 1.

Saronga et al (2014). *Efficiency of Antenatal Care and Childbirth Services in Selected Primary Health Care Facilities in Rural Tanzania*. A Cross Section Study. BMC Health Services Research 14: 96.

Senfuka S (2013). *Mapping Maternal Health Advocacy. A Case Study of Uganda*. Family Care International Kampala, Uganda.

Sheikhzadeh Y, Roudsari A, Vahidi RG, Emrouznejad A, Dastgiri S (2012). *Public and Private Hospital Services Reform Using Data Envelopment Analysis to Measure Technical, Scale. Allocative, and Cost Efficiencies.* Health Promotion Perspectives, Vol. 2, No. 1, P: 28-41.

Wan TTH, Hsu N, Feng R, Ma A, Pan S, Chou M (2002). *Technical efficiency of Nursing Units in a tertiary care hospital in Taiwan*. J Med Syst; 26:1-21.

Wang X, Hongye L, Qin X, Feng J, Gao H and Feng Q (2016). Evaluation of performance and impacts of maternal and child health hospital services using Data Envelopment Analysis in Guangxi Zhuang Autonomous Region China. A comparison study among poverty and non-poverty county level hospitals. *International Journal for Equity in Health* 15:131.

Worthington A (2004). *Frontier Efficiency Measurement in Health Care. A Review of Empirical Techniques and Selected Applications*. Medical Care Research and Review, Vol. 61, No. 2, pp. 135-170.

Yawe B (2010). Hospital performance evaluation in Uganda: a super efficiency data envelope analysis model. Zambia Soc Sci J. 1(No.1): Article 6.