Measuring Technical Efficiency of Central Hospitals in Zimbabwe: Application of Data Envelopment and Stochastic Frontier Analysis using Panel Data (2009-2014)

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Abstract

Zimbabwe is lacking resources to advance the country's health sector needs. The country is off-track the achievement of Millennium Development Goals that are health related in their totality. Central hospitals, the core of the hospital referral system, had been marred with congestion, and overburdened with patients. There had been therefore frequent calls, from the public, for the need to improve the delivery of service at public hospitals. Amidst fiscal constraints, efficient use of resources had been cited as the key, relevant and important aspect of improving the healthcare delivery system. This study was undertaken to determine the extent to which the country can improve health outcomes through efficiency improvement. Two efficiency measurement approaches were used to evaluate the efficiency levels of central hospitals in Zimbabwe using data set for the years 2009 to 2013; the two efficiency measurement approaches are the Data Envelopment Analysis and the Stochastic Frontier Analysis. On average hospitals were found to exhibit inefficiency levels of about 37-39%. The DEA calculated Malmquist indices indicated that total factor productivity improved by 2% between 2009 and 2014 largely driven by improvements in scale efficiency. The study proposed that hospital output can be improved by about 38% without increasing inputs. This will be achieved through improved hospital operating system, improved management of resources or close monitoring of human resources and adequate loss control systems.

Dedication

To my beloved husband; Simbarashe Chiweshe, daughters; Naledi and Natasha, and family

You are all that I have.

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Chapter One: Introduction and Background

1.0 Introduction

This dissertation used Data Envelopment and Stochastic Frontier Analysis (DEA) to empirically measure technical efficiency among central hospitals in Zimbabwe. Technical inefficiency herein refers to the extent to which more output can be achieved without absorbing additional resources or the extent to which the same level of output can be achieved by the use of fewer resources (Farrell, 1957). Zimbabwe has a referral hospital system where patients should report first at rural health centre or clinic and systematically be referred to district, provincial and lastly, central hospitals. Thus, central hospitals are the highest referral level offering the most specialist health services in the Zimbabwean public referral health system. We statically measure the extent resources are being wasted at this level of health care which is reportedly overburdened and congested due to resource shortages at lower referral levels. We discuss relevant and important policy outcomes arising from this study in relation to improvement of healthcare in Zimbabwe.

Health related studies (World Health Report, 2010) indicate that among health delivery problems facing low and middle income countries, inefficiency in the use of resources ranks high. Hsu (2010) noted as unfortunate the scarcity of literature on efficiency levels of health firms in these low and medium countries citing single or no studies at all in specific countries such as Zimbabwe and Zambia. In the new economic bulletin, Zim Asset (2013), the government of Zimbabwe indicated the need for optimal (efficient) use of revenue resources as fiscal challenges persist into the near future. This coincides with Hsu (2010) that efficiency use of resources should be of concern (of prime importance and relevance) in economic settings constrained by scarce resources and economic downturns and escalating health costs. Given the paucity of literature on technical efficiency in Zimbabwe, this study will be a significant contribution to economic planning by validating or refuting arguments of inefficiency in central hospitals, and providing a precise estimate of the extent to which output can be gained through mitigation of resource wastage.

1.1 Background of the Study

Zimbabwe is a landlocked country in Southern Africa. The country shares borders with Botswana, Mozambique, Namibia and South Africa. It measures 390 757 square kilometres and has a population density of 30 people per square kilometre. The 2012 population census estimated the total population at 13.06 million distributed as 52 % females and 48% males (ZimStat, 2012). Children (aged 5 years and below) and females younger than 25 years constitute the highest proportion of the population, thereby putting Child and Maternal care at the core of the health system.

The macroeconomic developments in Zimbabwe have a huge bearing on health. Following independence in 1980, moderate economic growth between the period 1980 and 1989 of around 5% enabled the government to improve the health expenditure for the rural poor in aim of achieving equity in health access. There was a decade of deep economic crisis between 1998 and 2008 that was characterised by decline in GDP of about 50%, record hyperinflation of 231 million percent by June 2008, massive brain drain and the closure of industries. The decline in socio-economic status during the decade means that the gains of the early decade after independence were reversed. The period beginning February 2009 marked economic revival phase which is largely fragile. Growth had not been consistent, with the years 2009, 2011 and 2012 marked with an GDP growth rates above 9 % while since 2013 growth has declined to below 5%. The developments hugely affected the health services sector particularly reducing availability of and access to health services.

1.1.0 The Structure of Health Delivery System

Health is considered a basic and fundamental human right and a social and economic entitlement such that its lacking define human poverty in Zimbabwe. In such context, the Zimbabwean government subscribes to the general goal of universal access to health and health services. Through the Growth and Equity Policy (1981) that followed independence, increased budget allocations were provided to the health and education sectors in efforts to improve social well being. Thus, following independence, a health system was developed that would address the colonial inequalities by ensuring that resources were channelled towards those sectors with the greatest socio-economic needs. Recent policy documents, the National Health Strategy Plan (2009-2013) and the Zimbabwe Investment Case (2010-2012) sought to promote and foster the provision of health services underlining universal health coverage, reduced maternal and infant mortality, abolishment of user fees and reduced HIV/AIDS mortality and morbidity as major policy outcomes.

In an attempt to meet health goals, Zimbabwe developed four tier referral public health system post independence and has not largely changed over the past three decades. The four tier system has two facets of primary care and hospital services. Primary level health care units are the periphery of the public health care system. These consist of community health workers and approximately 1000 rural health centres (or clinics) and urban municipal clinics. Community workers, families and the community are equipped to take various actions towards improving and maintaining their own health and nutrition status before contacting a Rural Health Centre (RHC) or Clinic. The RHC or Clinic provides health commodities such as medicines and insecticide treated mosquito nets, technical services and supervision to Village Health Workers or Health Promoters. The structure and nature of Primary Health Care is to provide at low cost accessible promotive, preventive and educative health services, prevent locally endemic diseases such as cholera and diarrhoea, simple treatments of conditions and diseases and local disease surveillance, family planning and home based care services among other things.

Due to its pro-poor health policies, this level of health care, the Primary Health Care, has been given much priority and attention and had been called to be revitalised following the decade of economic collapse between 1998 and 2008. However, challenges continue to plunge the effective provision of health services at this level as more resources tend to be channelled towards higher levels in the public health system. Each health worker is ideally expected to serve 100 people or a village and each RHC or clinic is manned by two nurses. While nurses at the RHCs are permanent health workers, VHWs are not permanent workers salaried but variedly receive monetary stipends and some material benefits from local authorities, government ministries, parastatals and non-governmental organisations (NGOs) in support of the Ministry of Health and Child Welfare (MoHCW) (MoHCW, 2010). The number of nurses at RHCs and population at the service of community workers raises questions on the quality of health services provided. MoHCW (2010) underlined that 19 % of villages countrywide has access to Village Health Workers (VHW) while VHW are nolonger supplied with basic medicines and commodities as clinics do not have sufficient stocks themselves. Therefore, despite the emphasised importance of primary healthcare (PHC) in the Zimbabwean health delivery system, it lacks essential commodities and human resources reducing its physical accessibility and utilization, hence quality of services.

District hospitals are in the secondary level of health service and they provide referal and supervision services to all RHC in the district. There were 164 district hospitals in Zimbabwe manned by nurses and atleast a doctor by 2010 (MoHCW, 2010). In addition to the primary health package, district hospitals provide inpatient and surgical services that do not require specialist services while severe cases are refered to the provincial hospitals that are in the tertiary level of health care. District hospitals provide complete health packages for some services imcompletely provided at the clinic level. The MoHCW (2010) noted the worrying supply of essential commodities and human resources indicating that atleast 60 % of district hospitals incurred atleast one stock out of essential medicines that include antibiotics. Thus, similar to the primary healthcare, district hospitals face challenges in essential commodity supply and human resources mainly due to inadequate funding, poor supply management systems, poor conditions of service and inadequate training.

The tertiary level category is constituted with provincial hospitals. Each province of the 8 provinces in Zimbabwe (excluding Harare and Bulawayo) has a provincial hospital with the exception of Matebeleland North Province. The centres are manned with specialists who provide services that include caesarean, blood transfusion, comprehensive obstetric and new born care and management of complicated paediatric cases referred from district hospitals. Major challenge within these centres is the vacant of specialists and experienced personnel and lack of essential medicines reducing the provincial hospitals to district hospital levels (MoHCW, 2010b).

Central hospitals are the highest level in the referral public health system providing sophisticated and specialist services to the provincial and district hospitals. There are six central hospitals in Zimbabwe namely Chitungwiza Central Hospital, Harare Central Hospital, Mpilo Hospital, Parirenyatwa Group of Hospitals, United Bulawayo Hospital and Intsungeni Central Hospital. These central hospitals are better equipped as compared to lower level hospitals. As a result provincial and district hospitals report most complicated cases to central hospitals even those that could have been dealt with at their levels. This availability of essential medicine and human resources, and the presence of private for profit hospitals in urban areas means that the urban population has better access to health facilities and delivery, diagnosis of complications, life saving interventions and referral than the rural population (MoHCW, 2010). This inequity needs to be corrected.

Congestion at central hospitals has largely been reported mainly as patients prefer to firstly present themselves at central hospitals where there are resources than at lower level hospital that face challenges such as transportation of patients in case of complications resulting emergencies. The referral of minor cases by district and provincial hospitals has also been reported as among the cause of congestion. It was noted as a priority the need to decongest central hospitals in National Health Strategy through availing of more resources and building of more district hospitals in Harare and Bulawayo where there is pressure due to increasing population and burden of the disease. This congestion can be dealt with through channelling more resources to the central hospitals or improving their technical efficiency.

The above described healthy system, largely unchanged since 1980, had been designed to ensure that patients first present at the primary care level and are progressively referred with respect to the level of ailment sophistication. The system is however handicapped in that lower level hospitals lack essential medicines, commodities, transport and have a poor quality of service. Central hospitals are therefore currently the heart of the health system in Zimbabwe despite that they are largely congested. The National Health Strategy, the government has noted the need to balance resource provision between primary care and hospital services. MoHCW (2010) has futher stated that district, provincial and central hospitals services need to be efficient and responsive to the need of lower levels and reffered patients as the major goal for the MoHCW.

1.1.1 Health risks and Demand for Health

There is no doubt that the demand for health is increasing as health risks are also increasing. HIV/AIDS, Malaria, Tuberculosis, under-weight in children and Diarrhoea are among the leading cause of morbidity and mortality in Zimbabwe together with emerging chronic diseases such as cancer and diabetes. Prevalence of HIV/AIDS though consistently falling remains high at 25% in adults and accounting for 20 % of death in children under five years of age (MICS, 2014). Tuberculosis had a prevalence rate of 431 per 100 000 people in 2012 (WHO, 2012). It was also noted in the Health Investment Case (2010-2012) that people are dying from easily preventable diseases and treatable conditions such as HIV/AIDS, malaria, pregnancy complications, diarrhoea and tuberculosis. These health risk factors increase the demand for health services especially as the population continue to grow at the rate of 1.1 percent while unmatched services provision has kept the country off-track its Millennium Development Goals as shown in Table 1 below.

Table 1: Progress towards Health Related MDGs

Indicator	1999	2005	2009	2014	MDG target
Infant mortality rate (per 1000 live births)	65	60	60	55	22
Under-Five Mortality Rate (per 1000 live births)	102	82	86	75	34
Stunting in Children Under-5 (%)	27	29	35	27.6	7
Exclusive breast feeding for 6-months (%)	27	22	26	41	70
Children 12-23 months fully immunised (%)	67	53	49	69.2	90
Maternal mortality ratio (per 100 000 population)	578	555	725	614	145
Skilled attendance at delivery (%)	72.5	68	60	80	100
Life expectancy at birth(years)	45	43	43	58	---

Source: MoHCW; The Health Sector Investment Case, 2010

Rising morbidity and mortality due to non-communicable disease is another cause of concern and has also burdened the health delivery system. Cancer and other non-communicable diseases constituted 18 % of government's preventive services budget in 2014 and were allocated 17.1 % in 2015 (GoZ, 2014). However, the country still faces a huge challenge in fighting these non-communicable diseases. In the 2015 National Budget Framework, the Ministry of Health and Child Welfare has identified as policy priorities reduction of the burden of disease with special emphasis on non-communicable diseases among others (including epidemics). This could be achieved through strengthening the health delivery system, thus improving quality, effectiveness and efficiency in service delivery.

High demand of health services is also accounted by the removal of user fees and a highly literate rate. MICS (2014) indicated that with a literate rate of 99 % and the fight to remove user fees in hospitals, the government and supporting agencies have to be prepared to meet the increase in health service demand. Additionally, the outbreak of Ebola in Western Africa in 2014 significantly poses a threat to the health delivery systems across the African continent, demanding huge resources to be channelled to the health sector. This is a daunting task to the Zimbabwean government which is already resource constrained.

1.1.2 Health Financing

The government as the largest provider of health and health services in Zimbabwe is responsible for majority of health financing. In its attempt to promote the health for all strategy early after independence in 1980, the Government of Zimbabwe increased health expenditure. Real per capita health expenditure was US$55.7 in 1980. The government however experienced budget deficits that exerted pressure to the government revenues such that in the second decade, government was cutting down its expenditure in the social sectors. Through the implementation of Structural Adjustment Programme, health expenditure was cut such that real health expenditure which was US$23.6 in 1990 declined to US$4.1 in 1995 (MoHCW, 2010). These trends were not good for the provision of health and health services and are partly accountable for the weakening health system painted above.

Health financing was a major challenge during the decade of economic meltdown that begun in 1998. As economic progress was in regression, resources were severely limited such that the country faced severe challenges in financing its operations. User fees were introduced during the period and have since become an important source of finance for the constrained government. Out-of- pocket health expenditure as a proportion of total health expenditure increased from 45.5 % in the year 2000 to 50.4 % in the year 2007. In addition, external sources of health financing increased from 13% in 2000 to 20% in 2007. The dwindled government health finances weakened the health system as massive shortage of drugs and brain drain led to worsening of health outcomes.

The government remained constrained in financing health in the post-crisis era. In 2010, (MoHCW, 2010) stated that lack of resources; financial, human and material resources are the major challenge facing the Zimbabwean health sector under the prevailing economic conditions. In the 2015 National Budget, health expenditure was 10.6% of total expenditure and implied per capita allocation of $29.23 against the ideal of US$60. The expenditure falls short of the Aduja Declaration prescribed target of 15% health expenditure from national budgets. The budget allocation is only 18% of the nation’s health requirements and its a decline from the 2014 health expenditure by 41% (MoHCW, 2015). These statistics undoutedly shows how the government is constrained in achieving its health related development goals.

Under these constraints hospitals continue to charge user-fees in attempt to supplement government expenditure and provide modest health services. In the 2015 National budget, the health ministry is expected to collect about US$35million (11.6% of health expenditure) through use-fees and other service charges in order to cover the gap between bid and allocated resources. User-fees however create health access gap and government is making an attempt to mobilise resources so as to successfully implement the non-user fee policy.

In the midst of resource challenges, external financing of major operations in the health sector has dominated. Donor support is expected to be US$132.7million for the year 2015, thus equivalent to 44% of the health expenditure budget for the same year. The challenge of reliance on donor support is that it is unpredictable, fragile and poorly aligned to national objectives. Thus, self-sufficiency is of primary concern for long term achievement of health objectives and developmental goals.

The Chapter has outlined the Zimbabwean health system. The major goal of the system is to fight morbidity and mortality through a community based health system supported by robust hospital referral system. However, financing the health system to adequately serve the nation is a daunting task due to the narrow fiscal space the country is operating on and increasing health risks and diseases. Mobilization of more resources is therefore of critical importance to provide essential health services and improve health outcomes. However, efficient use of resources is equally important as it can help the country to achieve health objectives without increasing the use of resources.

1.2 Statement of the Problem

The picture painted in the background of this study indicates that, lack of resources is the major challenge facing the health sector in Zimbabwe. As a result, the country is off-track in achieving its health related Millennium Development Goals. Amidst fiscal constraints, efficient use of resources had been cited as the key, relevant and important aspect of improving the healthcare delivery system. The World Bank (2010) noted that financing health, education and social protection expenditures in Zimbabwe are a challenge given the level of civil service wage bill. Consequently, the country's economic blueprint, Zim Asset (2013), upholds efficient resource use in public enterprises as a key parameter for improving economic growth and social well-being. Given that central hospitals play a key referral role in the health delivery system and consume a huge share of the health expenditure, there is need to provide evidence on the current levels of efficiency and potential output gains.

Literature on efficient use of resources in the Zimbabwean health sector is grossly limited compared to the international community where studies are abundant and more are still being carried out. A single study by Maredza (2012) covered a range of hospitals from district level to referral level and showed that output can be improved by an average of 26 % without adding more resources. Is this study adequate to guide economic planning and policy? We found the study too broad and unfocused, covering hospitals at all levels and we attempt to narrow down, precisely focusing on central hospitals which plays a key role of referral and also consume the huge proportion (34 %) of health expenditures (GoZ, 2014).

1.3 Objectives of the study

In broad terms, the study situates and analyzes efficiency levels of central hospitals in Zimbabwe.

Specifically, the study seeks to:

- To empirically measure the technical efficiency levels of central hospitals in Zimbabwe
- To evaluate the importance of the results above in improving goals of a healthcare system which are improvement, responsiveness and fairness.

1.4 Research Questions

1. What is the technical efficiency level for central hospitals in Zimbabwe?
2. What policy recommendations are implied by the results above?

1.5 Hypothesis

The study seeks to test the hypothesis that central hospitals in Zimbabwe are technically inefficient

1.6 Methodology

The study used the output-oriented approach of Data Envelopment Analysis (DEA) and the production oriented approach of Stochastic Frontier Analysis (SFA) to establish the technical efficiency scores for central hospitals in Zimbabwe. We evaluated the efficiency scores at variable returns to scale assumption. DEA is a non-parametric and non-stochastic mathematical programming approach to estimation of efficiency developed by Charnes et al (1978) and extended by Banker (1984). SFA is a parametric approach to production frontier estimation that was developed by Aigner et al (1977). DEA is capable of incorporating multiple inputs and outputs in the computation of efficiency and this presents a challenge under the SFA. The analysis used hospital number of beds, doctors and nurses as inputs and direct admissions, discharges and total attendances as outputs. These inputs and outputs were chosen among the multiple inputs and outputs of hospitals based on the availability of data.

1.7 Justification of the Study

There is wide literature gap on the levels of efficiency within the health sector in Zimbabwe. Evidence is really lacking regarding the extent to which resources are being wasted in the public health system. This knowledge is important given fiscal constraints confronting the country. It should be known, the extent to which output can be improved through better utilization of the available resources. The study therefore sought to narrow this gap by providing evidence on this neglected but important aspect in all functions of the health delivery system. The study will be valuable to policy makers, researchers and the academia as it adds to the literature on efficiency which is lacking in Zimbabwe as well as other African countries.

1.8 Organisation of the Study

In Chapter two literature was reviewed. A critical evaluation of the literature helped to link issues in the background to the efficiency concept while proving a theoretical answer to the problem at hand. Chapter 3 presented the methodology employed at evaluating the study problem. The empirical model specified in the methodology borrows from the theoretical discussion of models of efficiency in Chapter 2. Chapter 4 proceeded by presenting and analysing the study results and we concluded the study in Chapter 5 by summarising the results, providing some recommendations and presenting research challenges as well as future opportunities of research.

Chapter Two: Literature Review

2.0 Introduction

This section reviewed the existing theoretical and empirical literature on efficiency. Attempt was made to detail what the existing literature depicts regarding levels of efficiency in the production of healthcare. In addition, care was given in providing literature guidance on the best possible approach of estimating efficiency. The section therefore provided a snapshot answer to the efficiency problem under investigation and guided Chapter three on the specification of the best suitable method of estimation.

2.1 Microeconomic Theory of Production

Efficiency is a microeconomic concept of the theory of production and is the core of welfare economics. In a parsimonious model of production where a firm is viewed as a "black-box", efficient production occurs when there is a production possibility such that no other feasible production vector can generate as much output using no additional inputs and that produces more of some outputs or uses less of some inputs (Mas-Colell et al., 1995). If production entities are efficient, then aggregate production is socially efficient and this is desirable as it correspond to supreme societal welfare.

Despite the existence of the concept of production possibility frontier pointing that firms should produce on the frontier rather than the interior, empirical literature until the late 1950s focused on average cost functions and simple indices as measures of productivity. Farell (1957) pioneered work on efficiency measurement. Farell (1957) argued that efficiency measurement was important for planners to know by how much outputs can be improved without necessarily increasing inputs or the same output can be achieved using less inputs. In the case of healthcare provision, hospitals are regarded as technically efficient if there is no wasteful production. Allocatively, hospitals are efficient if they use resources optimally given their respective prices and the available technology.

3.0 Rationale of Efficiency Evaluation

The fundamental principle of economics states that scarce resources need to be used and distributed efficiently in order to maximise social welfare. Accordingly, Bravo-Ureta and Pinheiro (1997) stated that, "the presence of efficiency shortfalls means that more output can be achieved without requiring additional conventional inputs and without the need for new technology." Consistently, empirical measures of efficiency will necessarily guides policy on the magnitude of gains that could be achieved by simply improving performance at the given level of technology. Belbase and Grabowski (1985) and Shapiro and Muller (1977) shared the sentiments that higher levels of inefficiency imply that it may be cost effective to achieve more output through removal of wasteful production than the adoption of new technology.

A huge proportion of health expenditure consumed by the health sector has been a major motivator for the evaluation of efficiency in the health sector. Mathiyazhgan (2006) examined cost efficiency of public and private hospitals in Karnataka State in India as primed by the central role of hospitals in a resource constrained country. Hsu (2010) argued that the merits of efficiency studies are the significant proportions of hospital expenditure in the Organisation of Economic Cooperation and Development (OECD) countries and approximately 45-60 % of government health expenditure in sub-Saharan Africa. Limited resources have therefore remained the cause of efficiency studies as it is the basic concern of economists. Sectors that consume a huge proportion of resources need to be more efficient in resource constrained economies so as to make resources available to other sectors.

Efficiency is also important as a funding mechanism. Gannon (2004) posited that funding of Irish hospitals was based on case mix where resources are redistributed annually to hospitals with greater efficiency; this called for greater need of hospital efficiency measurement. Among Irish hospitals, Gannon (2004) found that regional and general hospitals exhibited lower levels of inefficiency of about 7%. Results however varied between DEA and SFA by mean efficient score of 0.16. The study thereby stated the need for greater caution on the methodology, type of hospitals considered and the need for reiteration of studies for adequate establishment of efficient scores. Pauly (1970) and Sherman (1984) also argued in the favour of accurate measurement of hospital efficiency for adequate reimbursement of healthcare. Efficiency measurement can therefore act as the guiding tool for public budgeting and planning on hospital funding.

Interesting debate has been generated on the relationship between efficiency and quality of care. This area is not burdened with empirical examination suggestive of difficulties in measuring quality of care and correlating it to efficiency scores. Wyszewianski (1987) argued in favour of a positive relationship between efficiency and quality of healthcare. Elimination of unnecessary surgery accounts for lower tonsillectomy rates, reduce treatment costs and simultaneously reduce exposure of patients to needless discomforts and negligible risks of operations. However, elimination of useful diagnostic and therapeutic services improves efficiency but lower quality of care. Nevertheless, if hospital personnel are rational and consider healthcare as an utmost service, a positive relationship between efficiency and quality can be maintained, making efficient measurement more necessary.

Efficiency studies have also played a more important role in guiding on the best possible way of providing hospitals services, either by private or public or both. Mathiyazhgan (2006) indicated that while both public and private hospitals in India were cost inefficient, public hospitals were more efficient than their private counterparts. Maredza (2012) also carried a study to examine efficiency between the for-profit and not for-profit hospitals in Zimbabwe. This study found that for-profit, mission and public hospitals had mean efficiency scores of 61.4%, 35% and 50.3%. Results are generally mixed and inconclusive on whether private hospitals are more efficient than public hospitals. However, the debate on whether private or public provision of healthcare has since been outdone by the need to determine the best mixes of the two in order for maximum production of health and health services.

Hsu (2010) indicated that the issue of ownership and efficiency largely varies across countries and overtime. Therefore the base of evidence on which form of ownership is more efficient need expansion for purposes of continuous improvement not comparison. Routine measurement of efficiency becomes plausible together with identification of causes and constraints, and possible changes to improve performance. In the need to know the best private-public mix, efficiency of private hospitals is driven by the profit incentives (Hsu, 2010, Maredza, 2012); this is different for public hospitals. Thus, Hsu (2010) commented the need for more evaluation of efficiency levels of public hospitals than private hospitals.

Efficiency scores have ready use by policy makers and public planners. Chirikos and Sear (2000) argued that relative efficiency scores are needed to gauge whether hospital cost containment efforts are successful, to evaluate effects of management care arrangements in local health markets and for the assessment of hospital service delivery. Efficiency scores are also useful in establishing criteria for selective contracting purposes and for reimbursement of hospital costs (Hadley and Zuckerman, 1994). It can therefore be concluded that measurement of efficiency has an essential directing role on the levels and the scope of expansion of health and health services in meeting health goals of improvement, responsiveness and fairness in financing.

4.0 Measuring Efficiency

Efficiency can be decomposed into technical and allocative efficiency; their product implies productive efficiency (Farell, 1957). Technically efficient firms produce at the production fronier while inefficient firms produce below the frontier (Coelli, 1995). Allocative efficiency measures deviation from optimal production levels given prices of inputs and outputs.

Simple partial measures of productivity have been widely used to measure efficiency. These express output as a ratio of input. The major criticism of such measures is their failure to consider multi-input and multi – output production setting in a way that will satisfactorily and adequately guide policy. Farell (1957) noted that use of simple measures of productivity will result in policies that will push for intensive use of a single input with over application of other inputs.

In 1957, Farell enormously detailed measures of efficiency that account for multiple inputs of a production process while avoiding problems of index numbers. These measures however require the full knowledge of the boundary (cost or production). Technical efficiency will then be calculated as deviations from the production frontier while allocative efficiency is deviations from the cost boundary. It is the estimation of the cost or production frontier that is a major constrain to Farell's measures of efficiency, and has generated wider debate in literature (Coelli, 1995; Timmer, 1971).

Efficiency can be conceptualised from the cost and production frontiers. Based on the production front, an efficient hospital is the one that is able to transform its inputs and produce output at the frontier. Inefficiency exists when production takes place underneath the frontier while given the available inputs production above the frontier is not feasible. Given this production frontier, there exists a dual cost frontier. Costs of producing healthcare can be on the cost frontier or above as it is not feasible to produce below the cost frontier given the production possibility frontier. Measures of efficiency therefore concentrate on establishing the extent to which a hospital deviates from the production or cost frontier.

4.1 The Production Frontier Approach

Using the production frontier,

$$Y_i \leq f(X_i, \gamma) \qquad (1)$$

where Y represent the hospital i's observed level of output, the expression $f(X_i, \gamma)$ is the frontier level of output (maximum possible output given the level of inputs; represents efficient production) that is defined by vector of inputs (X) and a vector of parameters explaining the transformation process (γ). Inefficiency is represented by the residual (ε_i) of observed production from the efficient level of production. Bravo-Ureta and Pinheiro (1997) specified the residual as follows:

$$\varepsilon_i = \frac{Y_i}{f(X_i,\gamma)} \text{ or } \varepsilon_i = Y_i - f(X_i,\gamma);\ \varepsilon_i \leq 0 \quad (2)$$

The inefficiency term (residual component) is strictly negative to ensure that the observed level of output will not exceed the maximum possible output (frontier output). The residual component takes the value of zero to when the observed output is equal to frontier output; thus this hospital will be perfectly efficient.

4.2 The Cost Frontier Approach

The production boundary defined in (1) above have, according to the duality theory, a corresponding dual cost function (Ganley and Cubbin, 1992). The observed costs of health production for any given hospital can only be equal to or exceed the minimum possible costs (residual component is strictly positive). Thus:

$$C_i \geq g(V_i;\lambda) \quad (3)$$

Where C_i is the observed cost of output, $g(V_i;\lambda)$ has the frontier explanation of the minimum cost which is defined by the determinants of healthcare costs (V) and a vector of parameters (λ). The residual inefficiency component (μ) is explicitly defined as;

$$\mu_i = \frac{C_i}{g(V_i;\lambda)} \text{ or } \mu_i = C_i - g(V_i;\lambda);\ \mu_i \geq 0 \text{ (strictly positive)} \quad (4)$$

4.3 Input or Output Orientation

Efficiency measurements can either be input or output oriented. Input oriented measures focus on the extent inputs can be reduced for a hospital to fall on the efficient frontier. That is, when input inefficiencies exist, effort focuses on cutting back input use, to ensure that the hospital will fall back onto the efficient frontier. Output oriented efficient measures focus on output expansion within the context of available inputs for the hospital to be efficient. The rationale for following an input or output approach depends on whether the hospital unit has much control over inputs or outputs. Hospitals under our consideration are reported to be mostly congested. This means the demand for the hospital services is high; hence focus on output oriented efficiency measurement framework is the most suitable.

5.0 Frontier Estimation Approach

Contestation on the efficiency literature principally centres on the unsurpassed estimation framework for frontiers that would result in the most plausible efficiency scores. The frontiers (cost or production) need to be estimated based on sample data (Coelli, 1995). At disposal are fundamentally two approaches to frontier estimation and the subsequent calculation of efficient scores. These are the stochastic frontier analysis (SFA) and the data envelopment analysis (DEA). Choice on the approach to follow implies trading off the strength and weaknesses of the two approaches as discussed below.

The stochastic frontier analysis is a parametric approach to estimation of frontiers and efficiency. The approach was developed by Aigner et al (1977) and Meeusen and Van den Broeck (1977). It is a more refined approach that addresses shortcomings of the deterministic approach developed earlier by Schimdt (1976) and Aigner and Chu (1968). The approach maps the frontier upon which observed output will be relatively compared to define efficient scores.

The SFA has the strength that is decomposes the deviations of observed output into two components; the efficiency component and the conventional statistical noise in data. Efficiency component is the deviation of output from the observed frontier due to mismanagement or wasteful production. The conventional statistical noise in data is the differences in data caused by measurement errors and other data measurement problems. Under this approach, standard error of efficiency scores can be calculated and tests of hypotheses carried out. However, the approach is criticised on its imposition of a functional form and the distributional assumptions imposed on the efficient component. The efficiency scores calculated are susceptible to the underlying functional form and the distributional assumptions of the error term. The approach is difficult to apply in multi-product settings.

Data envelopment analysis is a mathematical non-parametric linear programming approach to efficiency measurement that is a-theoretical in nature. Chirikos and Sear (2000) noted that DEA pieces together an efficiency frontier by maximising the weighted output/input (cost) ratio of each provider, subject to the condition that this ratio can be equal but never exceed, unit for each hospital in the data set. As a result, DEA yields measures of relative distance of any provider's efficiency ratio from the piecewise linear frontier; common measures are the proportional reduction of input/cost levels that could be achieved where the hospital delivering services in the most efficient manner.

This methodology has a weakness in that, by construction at-least one of the hospitals under investigation has to be defined as efficient. Other units are therefore defined as inefficient relative to the efficient unit; thus DEA provides relative measures of efficiency. The methodology attributes all the deviations in observed output to efficiency that is it fails to account for measurement errors and other statistical noise in data. However, its strength is in the flexibility of application under multi-product production settings and the need not to define any functional form underlying the frontier estimation. DEA is preferred where data measurement is not a possible threat while SFA is most suitable where data measurement is a common threat and specification of a functional form that closely matches the underlying technology is not a problem.

6.0 Summary of Empirical Literature

Scarce efficiency studies, both for developing and developed countries, posit that there exist inefficiencies in the production of health and healthcare and resources can be saved or output improved by simply improving the hospital production process. Studies in South Africa (Kirigia et al., 2001), Kenya (Kirigia et al., 2004), Siera Leon (Renner et al., 2005), Ghana (Akazili et al., 2008) indicate levels of technical inefficiency ranging between 13% and 74%. However, some of these studies indicate huge inefficiencies and the possibility of output to be increased by more than 50% through elimination of inefficiencies. Such results raise questions on the methodologies and precision of data sets used. Thus, more research is called for to validate or dispute the results for policy guidance. More studies will have to address issues of data caveats, observation of the unusual nature of health as a commodity and methodological flaws.

Given the methodologies for and components of efficiency, literature has given diverging views and different weight of attention. Empirical literature on hospital efficiency has focused more on technical than allocative efficiency. Studies (Kirigia *et al*., 2001; Renner *et al.*, 2005 and Osei *et al*., 2005) indicated that allocative efficiency is difficult to measure due to distortions in health products and services prices introduced by government and the unavailability of such data. However, some studies such as Akizili *et al* (2008) and Mathiyazhgan, 2006) estimated allocative efficiencies in public hospitals. The general conclusion from both components of efficiency suggests that inefficiencies do exist in provision of healthcare.

The bias of empirical studies towards technical efficiency seems to be founded in the arguments by Farell (1957) that allocative efficiency is both dubious and unstable measure of efficiency in the sense that hospitals can over invest in the short-run for long run goals, thus they may be found to be inefficient in static sense yet they are dynamically efficient. Similarly, Forsund *et al* (1980) had noted that allocative efficiency measures that do not take account structural rigidities introduced by government interventions and adjustment behaviour of firms tend to be overestimated. Therefore, this study will focus on technical efficiency of central hospitals to avoid problems of measuring allocative efficiency as discussed above.

Empirical use of the methodologies described above, DEA and SFA, has been different, with recent studies focusing on evaluating and comparing results of both methods. DEA has been widely applied in banking, health, telecommunications and electricity industries. Coelli (1995) stated major use of the DEA methodology in management sciences given its flexibility with multi-product settings. The use of different methodologies has produced different and mixed results. Chirikos and Sear (2000) compared results from the two approaches; results from both DEA and SFA yielded divergent results while Mathiyazhgan (2006) found both results robust with non-existent significant differences.

Empirical literature has also focused on detailing the factors that account for variation in efficiency. Results are mixed and tend to vary with countries concerned. Hsu (2010) posited that demand factors (income, population density and purchasing power) influence technical efficiency through levels of utilization, standards of care and duplications in the systems. Supply factors are said to influence input-mix through levels of economic development, management of human resources, institutional structures and the strength of public sector capacity. Lack of resources and decision making ability poorly motivate efficiency and constrain providers in choosing an efficient input-output mix. Uniform policies across hospitals also reduce the incentives to increase efficiency.

One of the major problems of studies that attempted to measure determinants of efficiency is the inclusion of all or most of the inputs of efficiency calculations as explanatory variables of efficiency scores. This trend has been followed by Mathiyazhgan (2006) and Maredza (2012). Inpatient days, medical personnel and bed capacity are used as inputs in the calculation of efficiency scores and determinants of the efficiency scores in the second stage modelling of determinants of efficiency scores. This has the possibility of introducing some econometric flaws particularly in the stochastic frontier efficiency analysis as the distributional assumptions of the error terms will be violated. Due consideration should be given to outside environmental factors or exogenous factors that affect the best use of these inputs.

Cognisant of weaknesses in the estimation of determinants of efficiency scores, Besstremyannaya (2011) used the SFA latent class approach and found that managerial performance and financial parameters influence the probability of the hospital to belong in a more efficient latent class. Results indicate that efficiency can be enhanced by quality management. Thus, efficient studies play a critical role in evaluating public management systems. This study further avoids the weaknesses of econometric methods on evaluating determinants of efficiency and uses a qualitative and statistical approach.

Dramatic differences in efficiency scores from various studies of German hospitals prompted Straat (2007) to reiterate efficiency evaluation of German hospitals. Straat noted that earlier studies were based on heterogeneous hospitals. Surprising savings of 50%, average efficient scores of 95% and about 75% of the hospitals were argued to be fully efficient from the earlier hospital efficiency evaluation studies in German. As a result, Straat (2000) examined a segment of hospitals with one internal unit of medicine and one surgery department located in the Old Federal states of German. The DEA-Bootstrapping procedure suggested an average bias corrected efficiency score of 80%. Reasoning here suggests that hospital efficiency studies need to be more focused and more precise, considerate of similar hospitals and avoid dealing with large data sets.

In Zimbabwe, literature on hospital efficiency is largely limited and a study available indicates huge inefficiencies. Maredza (2012) examined technical efficiency among for-profit, mission and public hospitals; this was the first attempt to evaluate hospital efficiency in Zimbabwe The study was based on the indications of widespread prevalence of inefficiencies in the health sectors of South Africa (Zere, 2000); Kenya (Kirigia *et al*., 2002); Ghana (Osei *et al*., 2005) and Namibia (Zere *et al*., 2006). In addition the study was motivated by cutbacks in public health spending, increased population pressure, dwindling donor support and increased HIV/AIDS disease prevalence which meant that more output had to be realised from less available resources.

Results from the DEA indicate mean efficiency scores of 61.4%, 35% and 50.3 % for the for-profit, mission and public hospitals respectively. These results mean that there is potential to increase output by close to 50% by simply doing away with wasteful production. Can this huge output increment be simply accounted by improvement in efficiency?

The study has some major flaws. Firstly we question the categorisation of hospitals into three distinct groups; for-profit, mission and public hospitals. This grouping undermines the heterogeneity within the three groups, as an example within public hospitals we can group hospitals into their levels of service as central, provincial and district hospitals. As the DEA computes efficiency scores relative to the best performing unit, results reported by Maredza are flawed as comparison was made across central, provincial and district hospitals. Certainly, this is impossible given the differences in complexity of health services provided by each category. At-least, a comparison of results from the two methods can be useful evaluation and validation of the possibility of inefficiency in the hospitals. Further evaluation of hospital efficiency is a valuable addition to literature given the scarcity of hospital efficiency literature and some flaws in the existing study.

7.0 Conclusion

The above analysis indicates that efficiency is an important concept for the health production units. Empirical results from increasing health efficiency literature are however mixed and depend on the context of each study. Results differ with methodologies, hence careful examination is necessary and studies need reiteration. We therefore found it necessary to undertake this study of central hospitals in Zimbabwe which is more precise and avoid the problems in literature that examined too many hospitals at a time hence compromising the relative efficiency scores.

The need to trade off the strength and weaknesses of DEA and SFA presents a major challenge for hospital efficiency measurement. It is neither convincing to rule out data measurement problems in Zimbabwe nor are we able to identify the functional form that closely matches the underlying production technology. As a result, the best approach to follow in this study is to employ both methods of efficiency estimation and compare the results.

Chapter Three: Methodology

3.0 Introduction

This chapter outlined the SFA and DEA for estimating technical efficiency of the central hospitals in Zimbabwe. The chapter further detailed the empirical model used, data issues and estimation techniques.

3.1 Stochastic Frontier Analysis

3.1.0 Stochastic Frontier Model

The study employed the following panel data time-varying model specified by Battese and Coelli (1992):

$$Y_{it} \quad = \quad f(X_{it}, \alpha)\exp(v_{it} - u_{it}) \ , \qquad 3.1$$

$$u_{it} = \eta_{it} u_{i\,i} \qquad 3.2,$$

Y_{it} is the output for the i^{th} firm at time t, $f(X_{it};\alpha)$ represents a suitable function of a vector, X_{it} of inputs (and hospital specific variables), that are associated with the production of the hospital, and a vector, α, of unknown parameters. $v_{it}'s$ are random errors assumed to be independent and identically distributed, $N(0,{\sigma_v}^2)$. u_{it} are non-negative of the $N(\mu,\sigma^2)$ distribution assumed to be independent of the $v_{it}'s$. In model 3.2, η is an unknown scalar parameter. In the model v represents the noise in data that is output differences outside the control of the decision making unit such as luck and measurement errors.

The scalar parameter, η represents whether the term u_{it} is constant, decreasing or increasing with time. Thus, $\eta > 0, \eta = 0, \eta < 0$ for decreasing, constant and increasing u_{it}. The term η is positive when hospitals are improving their level of technical efficiency with time implying decreasing inefficiency. The maximum likelihood estimation provides the efficient estimates of α, λ and σ^2: where $\lambda = \sigma_u / \sigma_v$ and $\sigma^2 = {\sigma_u}^2 + {\sigma_v}^2$. 3.3

3.1.1 Empirical Model Estimated

The Cobb-Douglas production function is imposed in this study to estimate equation (3.1) as:

$$\ln Y_{it} = \quad \alpha_0 + \alpha_1 \ln X_{it} + \alpha_2 \ln V_{it} + \alpha_3 \ln Z_{it} + v_{it} - u_{it} \qquad 3.4$$

In this empirical frontier model, Y_i is the hospital output measured in physical units. The study used direct admissions, total discharges and total attendances as the hospital outputs. We evaluated model 3.4 at each level of output; model 1, 2 and 3 had direct admissions, discharges and total attendances as outputs respectively. SFA is not able to capture multi-outputs production. On the right hand side, X is the number of hospital beds, V is the number of doctors, Z is the number of nurses for the hospitals units, α represents parameters to be estimated, i is the hospital subscript and t is the time subscript.

3.1.2 Empirical Estimation Procedure

The maximum likelihood method is used to estimate model 3.4 using the Stochastic Frontier estimation command in Stata 12. The estimates of σ_u, σ_v, λ and σ^2 are given among the estimated outputs. Model 3.3 is estimated by substituting the estimates of e, σ_* and λ to find the technical inefficiency of each hospital. The stochastic frontier model will be estimated at three levels in order to determine efficiency scores with respect to each of the three outputs considered in the study.

3.2 Data Envelopment Analysis (DEA)

Coelli (1995) noted that the constant returns to scale (CRS) proposed by Charnes, Cooper and Rhodes (1978) has been widely used in the literature. Thus we begin by defining the constant returns to scale input oriented DEA. The specification of data envelopment analysis for efficiency evaluation is detailed in the following discussion. The specification is based on data for K inputs and M outputs of N decision making units (DMU).These are represented by vectors, x_i and y_i respectively for each i^{th} hospital. We represent the data for all the DMU by $KX*N$ input matrix and $MX*N$ output matrix. According to Coelli (1995), DEA constructs a non-parametric envelopment frontier above the data points; that is, all the observed data points lie below the production frontier. For each hospital we would like to determine a ratio of all outputs over all inputs, such as $u^{'}y_{it} / v^{'}x_{it}$ where u is a $M*1$ vector of outputs weights and v is a $K*1$ vector of inputs weights.

We specify the mathematical programming problem of determining the optimal weights for each hospital as:

$$\begin{aligned} &\max_{u.v} \ (u^{'}y_{it} / v^{'}x_{it}), \\ &\quad s.t \quad u^{'}y_{it} / v^{'}x_{it} \le 1, \ i = 1,2..., N, \\ &\quad u, v \ge 0 \end{aligned} \qquad 3.5$$

The empirical question is that of finding the values of u and v such that the efficiency measure of each hospital is maximised subject to the constraint that all efficiency measures must be less than or equal to one. Coelli (1995) stated that the problem with this ratio formulation is that it leads to infinite number of solutions hence the need to impose a further constraint term, $vx_i = 1$. As a result, model above becomes[1]:

$$
\begin{aligned}
&\max_{\mu.v}\ (\mu' y_{it}),\\
&s.t \quad v' x_{it} = 1\\
&\qquad \mu' y_{it} / v' x_{ti} \le 1,\ i = 1,2...,N,\\
&\qquad \mu, v \ge 0
\end{aligned}
\qquad 3.6
$$

Model 3.6 is the multiplier form of the linear programming problem. An equivalent envelopment form to be solved is derived using the linear programming duality of 3.6. This is defined as:

$$
\begin{aligned}
&\min_{\theta,\lambda}\ \theta,\\
&s.t \quad -y_{it} + Y_t\lambda \ge 0\\
&\qquad \theta x_{it} - X_t\lambda \ge 0,\\
&\qquad \lambda \ge 0
\end{aligned}
\qquad 3.7
$$

In the model 3.7, θ is a scalar and λ is a $N*1$ vector of constants. This is the solved model because it involves lesser constraints compared to the multiplier form. The value of θ is the efficiency score for each hospital. It satisfy the condition that $\theta \le 1$ where a value of 1 indicate a hospital operating on the frontier and 0 indicates fully inefficient hospital, thus we satisfy Farell (1957) definitions of efficiency.

The specification above suffers in that it assumes that hospitals are operating at constant returns to scale. The assumption that the hospital industry is perfectly competitive is too restrictive. As suggested by Banker, Charnes and Cooper (1984), the CRS DEA model can be extended to incorporate variable returns to scale (VRS). The VRS DEA is represented as follows:

$$
\begin{aligned}
&\min_{\theta,\lambda}\ \theta\\
&s.t \qquad -y_{it} + Y_t\lambda \ge 0\\
&\qquad\quad \theta x_{it} - \lambda \ge 0,\\
&\qquad\quad N1'\lambda = 1\\
&\qquad\quad \lambda \ge 0
\end{aligned}
\qquad 3.8
$$

[1] Notation change from u to μ reflect the transformation.

Where $N1$ is a $N*1$ vector of ones. Through model 3.8, a convex hull of intersecting planes which envelope the data points more tightly than the CRS conical hull is defined. Thus, the framework provides technical efficiency scores which are less than or equal to those obtained using the CRS model.

In the panel data framework, DEA-like linear programs and a Malmquist total factor productivity (TFP) index are used to measure productivity change. The productivity change will be decomposed into technical change and technical efficiency change. Fare *et al* (1994) specified the following output based Malmquist productivity index that has been employed in this study.

$$m_0(Y_{t+1}.Y_t, X_t) = [[\frac{d_0{}^t(X_{t+1}, Y_{t+1})}{d_0{}^t(X_t, Y_t)}] * [\frac{d_0{}^{t+1}(X_{t+1}, Y_{t+1})}{d_0{}^{t+1}(X_t, Y_t)}]]^{1/2} \qquad 3.9$$

Equation 3.9 expreses the productivity of the production point $((X_t, Y_{t+1})$ relative to the production point (X_t, Y_t). The predicted values greater than 1 indicate positive growth in productivity between the period t and period $t+1$. The above index is a geometric mean of two output-based Malmquist TFP indices. One of the two indices uses the period t technology while the other uses the period $t+1$ technology.

3.3 Input and Output Variables

Hospitals are multi-product production units that use a mix of inputs to produce a mix of outputs. Patients are treated using a variety of inputs. Literature fails to identify the most suitable inputs to consider in hospital efficiency measurement as well as the outputs to utilize. Variables utilised in this study are those mostly used in the literature and available for our execution. Three variables are utilized as outputs: direct admissions, discharges and total attendances. The number of hospital beds, the number of doctors and the number of nurses are used as inputs in the models above. These inputs have been utilized in hospital efficiency by quite a number of studies (Maredza, 2011; Besstremyannaya, 2011). The number of hospital beds had been utilized as a measure of the level of capitalization of a hospital while the number of doctors and nurses measures the labour input in health production.

Table 2: Definition of Variables

Variable	Description
Output	
Direct admissions	These are the number of patients directly admitted at the hospital. Thus, it excludes patients referred from lower level hospitals and clinics.
Total attendances	This refers to the number of patients attended to by the central hospital. They are either non-admitted or admitted patients.
Discharges	These are the number of people who leaves the hospital returning home. The variable has a challenge that it does not differentiate between patients who leave hospital for home because of severely deteriorated conditions (beyond hospitalization) and those who leave after successful nursing. The study simply uses the gross discharge to indicate hospital output.
Inputs	
Beds	This refer to the number of beds in a hospital that are ready for use upon demand. It reflects the capitalization levels of hospitals.
Doctors	The study considers the number of specialist and general medical practitioner employed by the hospital.
Nurses	This is the total number of nursing practitioners employed by the hospital.

Chapter Four: Presentation of Study Results

4.0 Introduction

This chapter describes the data used and presents results of the study. We present results of the estimated frontier models first. Secondly, the mean efficient scores predicted by the stochastic frontier approach are discussed. Thirdly, we discuss efficient scores estimated using the data envelopment analysis. The Chapter is concluded by discussing the results in brief.

4.1 Descriptive Statistics of Data

The study collected data on six central hospitals, namely Harare Central Hospital, Parirenyatwa Group of Hospitals, United Bulawayo Hospital, Chitungwiza Central Hospital, Mpilo Central Hospital and Ingutsheni Central Hospital. The data was collected for six years on annual basis. There are 36 observations given that six central hospitals are studied over six years, the number of total observations. Table 3 indicates that there are huge variations in the data, for example the minimum direct admissions are 14 while the maximum direct admissions are 103 400. Similarly, outputs varied by large proportions. Thus, there exist large differences on the inputs and outputs of central hospitals.

Table 3: Descriptive Statistics of Data

Variable	Obs	Mean	Std. Dev.	Min	Max
Beds	36	4667.42	732.44	1589	9312
Doctors	36	2123.22	7471.751	1088	10786
Nurses	36	523.56	705.943	121	3428
Direct admissions	36	18775.61	23707.72	14	103400
Discharges	36	21946.42	19482.62	504	88682
Total attendances	36	13320.69	13763.91	331	41073

The Pearson's correlations coefficients are presented in the Table 4. The Pearson's correlation coefficients are below 0.8 indicating that there is no likelihood of linearly correlated variables in the frontier models.

Table 4: Pearson's Correlation Coefficients

	Direct admissions	discharges	Total attendances	beds	doctors	nurses
Direct admissions	1					
discharges	0.7320	1				
Total attendances	0.4967	0.7302	1			
beds	0.7304	0.1861	0.0403	1		
doctors	0.5162	0.5656	0.1979	0.7076	1	
nurses	0.3118	0.6883	0.4564	0.6910	0.3062	1

4.2 Results of the Stochastic Frontier Analysis

4.2.1 Stochastic Frontier Models

The study estimated three frontier models as output was measured by three different variables. In the first model, direct admissions were the dependent variable while in the second and third models the dependent variables were discharges and total attendances respectively. All outputs were set to be explained by three inputs, number of nurses, doctors and hospital beds. The results of the three frontier models are presented in Table 5.

The models presented are econometrically satisfactory. The Wald Chi2(3) test has a p-value of zero implying that at-least some coefficients of the model are non-zero. In model 1, the coefficients for number of hospital beds and nurses were found to be statistically significant at 1% level. Thus, direct admissions are a function of hospital beds and the number of nurses, the numbers of doctors were found to be unimportant in defining direct admissions. In both model 2 and 3, the coefficients for the number of doctors and nurses were found to be statistically significant at 1% level. That means the number of discharges for the hospital depends on its labour, which is doctors and nurses. In all the three models, the constant was statistically significant at 1% level, implying that there exist other important inputs that define the health production frontier than those included in the models.

Table 5: Estimated Time Variant Frontier Models

	Model 1	Model 2	Model 3
lbeds	0.2915* (0.1014)	0.1032 (0.1121)	0.0032 (0.1121)
ldoctors	0.0205 (0.1075)	0.9205* (0.1053)	0.8347* (0.1045)
lnurses	0.3501* (0.0702)	0.6430* (0.0702)	0.6354* (0.0790)
_cons	9.2827* (2.1004)	8.0827* (0.5814)	8.0824* (0.5434)
/mu	-37.3863* (17.7103)	-36.6134* (16.7053)	-38.6635* (15.0092)
/eta	-0.0458* (0.0090)	-0.0564* (0.0072)	-0.0669* (0.0107)
/lnsigma2	4.5921* (1.8590)	4.5921*** (1.8590)	4.5921*** (1.4659)
/ilgtgamma	5.1855** (2.1004)	5.1059*** (2.9081)	6.9801*** (3.8748)
sigma2	98.7025	98.9292	95.1411
gamma	0.9944	0.9947	0.9938
sigma_u2	98.1531	98.4098	94.5473
sigma_v2	0.5494	0.5194	0.5938
Number of Obs.	36	36	36
Number of groups	6	6	6
Obs. per group	6	6	6
Chi2(3)	174.46*	173.49*	174.45*

Note: *, **, *** are 1%, 5% and 10% significant levels
( ) are the standard errors

3.2.2 Predicted Efficient Scores

The predicted mean inefficiency term (mu) reported in table 5 above for model 1, 2 and 3 are 37.39%, 36.61% and 38.7% respectively. This inefficiency term is statistically significant at 1% level in all the three models. Additionally, the term eta (η) is negative and statistically significant at 1% level in all the three frontier models. This means that technical inefficiency had been increasing over time. The reported values of gamma are 0.9944, 0.9947 and 0.9938 implying that the inefficiency accounts for most of the variation in output compared to randomness in the data. This is also confirmed by the sigma_u2 values which are greater than 98 compared to sigma_v2 which has values less than 0.6. Thus, inefficiency is the largest contributor to observed variation in output.

Based on the estimated frontier models, we have predicted the efficiency scores for each central hospital. The mean values of efficient scores are presented in Table 6. Comprehensive results are shown in Appendix 1.

Table 6: Stochastic Frontier Mean Efficiency Scores

DMU	2009	2010	2011	2012	2013	2014	mean
1	0.77	0.77	0.72	0.73	0.73	0.72	0.74
2	0.53	0.53	0.52	0.56	0.57	0.52	0.54
3	0.66	0.54	0.57	0.56	0.54	0.51	0.56
4	0.49	0.43	0.51	0.56	0.63	0.48	0.52
5	0.44	0.67	0.68	0.66	0.66	0.65	0.63
6	0.54	0.67	0.75	0.71	0.66	0.63	0.66
mean	0.57	0.60	0.62	0.63	0.63	0.58	0.61

Table 6 indicate two important issues. Firstly, there exists inefficiency among central hospitals. On average, the annual efficiency score for hospitals is 0.61. Mean efficient scores for the central hospitals ranges between 0.52 and 0.74 while annual mean efficient scores for the time under consideration varied between 0.57 and 0.63. Thus, the most efficient central hospital, Chitungwiza, can increase its output by 26% at the same level of inputs. The least efficient central hospital can increase its output by 46% while holding the inputs constant. Appendix 1 provides a comprehensive outline of the efficiency scores predicted by the frontier models across individuals, overtime and relative to a specific hospital output. The scores varied from as low as 0.42 to as high as 0.79. Thus, inefficiency levels substantially vary across individuals.

Secondly, results in Table 6 indicate that mean efficient scores patterned an inverted U-shape. Between 2009 and 2012, the mean for individual efficient scores increased from 0.57 to 0.63.

The efficiency scores were constant at 0.63 for the years 2012 and 2013 and subsequently declined to 0.58 in 2014. Thus efficiency had improved from 2009 to 2012 before declining in 2014.

3.3 Efficiency Scores from DEA

Technical efficiency scores were estimated under the assumption of variable returns to scale. The results are presented in Table 7. The results are more of a mirror image of those presented earlier. Chitungwiza hospital was given the score of 1 implying that it lies on the frontier and other hospitals' performance was rated relative to its performance. Relative to the frontier hospital, other hospitals' mean efficiency scores ranged between 0.47 and 0.64. The mean efficient score was 0.63. This implies that on average hospitals can increase their output by 37% without increasing inputs.

Table 7: Efficiency Scores Predicted from DEA

Variable Returns to Scale Technical Efficiency Summary Results, DEAP 2.1							
Hospital	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**Hospital mean**
1	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2	0.560	0.472	0.472	0.562	0.562	0.497	0.521
3	0.631	0.666	0.530	0.530	0.530	0.370	0.543
4	0.452	0.370	0.480	0.530	0.530	0.450	0.469
5	0.432	0.670	0.700	0.639	0.639	0.639	0.620
6	0.530	0.690	0.721	0.645	0.645	0.612	0.641
annual mean	0.601	0.645	0.651	0.651	0.651	0.595	

Similar to the stochastic frontier predicted results, the annual efficiency mean scores declined over time. Technical efficient scores increased from 0.6 in 2009 to 0.65 in 2011. Since 2011 to 2013, the efficiency scores remained constant at 0.65. In 2014, the mean efficient score declined to 0.595. Thus, the pattern of efficiency scores predicted by DEA and SFA are similar and of an inverse U-shape overtime.

The efficiency scores from both DEA and SFA were similar and led to similar conclusions that hospitals are inefficient. Output can be increased by 37% to 39% without increasing inputs. Under DEA, Chitungwiza hospital was rated to be the frontier hospital while it is the best performing hospital with an average score of 0.74 under SFA. Similarity in DEA and SF results may be attributed to the fact that, the SFA has indicated that variation in data was not emanating from randomness, thus the data possibly constitutes minimal measurement errors.

4.4 Decomposition of Efficiency Scores

The use of panel data enabled the calculation of Malmquist Indices which decomposed productivity change into technical efficiency and technological change. Technical efficiency was further decomposed into pure technical efficiency and scale efficiency.

Table 8: Malmquist Index Summary of Hospital Means

Hospital	Efficiency change	Technological change	Pure efficiency change	Scale efficiency change	Total factor productivity change
1	1.02	0.98	0.98	1.05	1.02
2	1.015	0.984	0.976	1.050	1.018
3	1.02	0.98	0.98	1.05	1.02
4	1.015	0.984	0.976	1.050	1.018
5	1.015	0.984	0.976	1.050	1.018
6	1.02	0.98	0.98	1.05	1.02
Mean	1.015	0.984	0.976	1.050	1.018

Table 9: Malmquist Index Summary of Annual Means

Year	Efficiency change	Technological change	Pure efficiency change	Scale efficiency change	Total factor productivity change
2010	1.126	0.882	1.020	1.145	1.126
2011	1.097	0.952	1.002	1.099	1.046
2012	0.944	1.062	0.975	0.976	0.995
2013	0.964	1.001	0.942	1.024	0.964
2014	0.946	1.021	0.940	1.007	0.960
Mean	1.015	0.984	0.976	1.050	1.018

Table 8 indicates that there was minimal growth in total factor productivity for the hospitals averaging 2%. The mean growth in total productivity is 2%. This was mainly accumulated through improvement in efficiency as technological progress across firms was on regress of an average 1.6%. Decomposition of technical efficiency shows that pure efficiency was on regress across firms and scale efficiency was the driver of technical change.

The summary of annual means indicated that total factor productivity improved by 12.6% between 2009 and 2010 before marginally increasing by 4.6% between 2010 and 2011. Between 2012 and 2014, total factor productivity regressed by an average of 4%. Overall, total factor productivity change improved by a mean of 2% largely driven by changes in technical efficiency. However, scale efficiency was the driver of the minimal growth in total factor productivity over the years compared to pure efficiency which was on regression.

4.5 Conclusion

The study has indicated that inefficiency exists among central hospitals in Zimbabwe. Average mean efficiency scores are 0.61 and 0.63 from the SFA and DEA respectively. Thus, on average output can be increased by between 37% and 39% without increasing inputs. The results further pointed out that hospitals have not gained much through growth in total factor productivity. Minimal growth in total factor productivity of 2% in reported mainly driven by efficiency gains than technological gains. Efficiency gains were driven by scale efficiency as compared to pure technical efficiency growth. The following chapter will summarize the study and provide areas of further research.

Chapter Five: Conclusion and Policy Recommendation

5.0 Introduction

This Chapter serves to conclude this study. This is done by summarizing the motivation of study, methodology and study results. The Chapter also discusses weaknesses of the study and areas of future research.

5.1 Conclusion of the Study

The primary focus of the study was to estimate technical efficiency levels of central hospitals in Zimbabwe. The study also sought to evaluate total factor productivity growth of the public hospitals and to determine whether technical efficiency or technological gains are the drivers of such advancement in productivity.

The reported congestion in central hospitals and public resource shortage in Zimbabwe was the major driver of the need to evaluate the gains in output that can be achieved from technical efficiency improvements. Zimbabwe is currently operating at tight fiscal space with a National budget of US$3.9 billion (G.O.Z, 2014). Among these resources more than 75% are recurrent expenditure mostly expenditure on salaries. Health expenditure is about 10.6% of national expenditure. Given this trend, the government has frozen increased activities that may increase recurrent expenditure in order to improve capital expenditure. This will likely affect the health delivery system as it requires more funding for improved health delivery (MoHCW, 2010). The central hospitals are largely reported chaotic by the public media. Thus patients are reported to take long hours to be attended and some may fail to be attended on the day of their arrival. The blame has been shifted to the shortage of enough hospitals at lower levels that will ensure that central hospitals purely undertake their referral function. In the midst of all these arguments, this study asked a simple question: By how much can central hospitals increase their outputs at the current level of inputs?

This study employed two methods to answer this question. These are the Data Envelopment Analysis and the Stochastic Frontier Analysis. The two approaches were used given that literature has identified that efficiency scores vary with the methodology employed. In this study we compared the efficiency scores reported by the two methods in order to answer our main research question. The study revealed that inefficiency does exist in the provision of health services by the central hospitals. The mean efficient score reported by the DEA and the SFA are 0.63 and 0.61 respectively. This implies inefficiency levels of 37% to 39%. This study therefore validates results by Maredza (2012) who indicated that mean efficient scores of central hospitals was 34%. The study also indicated that efficiency scores vary across hospitals and declined over time to give an inverted U-shape. Thus, since the year 2009, efficiency scores improved until 2011; between the years 2012 and 2013 efficiency scores stagnated and subsequently declined in the year 2014. The study also found that there had been minimal growth in total factor productivity of 2% among the central hospitals. The minimal growth that existed was driven by efficiency gains than gains in technological change. Scale efficiency gains contributed to efficiency gains while pure technical efficiency change was on regress.

5.2 Policy Recommendations

This study proposes that health policy can focus on improving the operational management of central hospitals in order to increase their inputs. Close monitoring of the hospital operations and motivated staff that is integrated in the health delivery decision making process can play a great role of increasing output. Effective implementation of schemes such as institutionally integrated Results Based Management can have a great effect of increasing output at the given level of inputs. Furthermore, careful monitoring, budgeting and planning in the central hospitals can help to improve output. Further to this, hospitals need to have intensive input control system. The input system control may encompass mechanisms that could ensure that inputs are used within the hospital, thus curbing leakages. Such a control system may also ensure that human resources at central hospitals work for the required hours. The results basically point out that operational management of the inputs can lead to substantial gains in output of about 37-39%.

This study did not evaluate factors that influence efficiency or inefficiency. Thus, we drew some of our recommendations on improving efficiency levels of the hospitals from the reviewed literature. Uniform policies across banks had been identified as a disincentive to efficiency improvement (Hsu, 2010). Thus, we recommend that given the low levels of efficiency among central hospitals, policy makers may need separate treatment of efficient and inefficient hospitals in financing, expenditure and human resource allocation. This differentiate treatment likely induces competitive behaviour among hospitals thereby promoting inefficiency.

Training and capacity building of management staff can be an important way of improving efficiency. Trained staff may be equipped with skills of decision making under constrained resources. Basically, training improves managerial performance and act as an incentive to efficiency improvement, reduces non-wasteful use of resources and duplication of systems.

The second area that may need focus is on technological gains. Results pointed out those central hospitals were not able to shift their frontier production functions over the period under study. Actually they experienced technological decay. There is need to devise mechanisms of driving technical gains among these hospitals at the climax of the health referral system to ensure increased health provision.

5.3 Weaknesses of the Study

The main weaknesses of this study emanate from the availability of data, failure to consider unobserved heterogeneity effects in panel data and failure to determine the environmental factors that accounts for the observed inefficiencies. Data availability remains an issue and prohibits effective and efficient analysis of the health delivery system in Zimbabwe. The present study compiled data from the ZimStats Database which is used to compile the National Health Profile Reports since 1997. In 2009, the database had a lot of gaps that had to be filled using other surveys by ZimStat. Data availability dictated the inputs and outputs used in the study. The study only estimated efficiency scores and failed to determine the factors that explain such efficiency scores. This presents a challenge in recommending what should be done to improve hospital efficiency scores. Thirdly, the use of panel data implies that there exists unobserved heterogeneity across individuals that should be accounted for in modelling the health frontier. However, this area has not been developed to ensure account for this unobserved heterogeneity in panel frontier models.

5.4 Areas of Future Research

Improved data sets may enable comprehensive analysis of efficiency levels of hospitals. More inputs and outputs are used and produced by a hospital and as a result these should be considered in health studies. Availability of input prices may also enable the analysis of economic efficiency evaluation as allocative efficiency scores may be evaluated. Efficiency studies may also need to adjust for quality of health services. The issue of quality in the provision of health services has been debated in the health literature. Empirical studies need to adjust for quality of outputs.

References

Aigner, D. J. and Chu, S. F. (1968). *On estimating the industry production function.* American Economic Review 58: 826-839.

Aigner, D. J., Lovell, C. A. K. , and Schmidt, P. (1977). *Formulation and estimation of stochastic frontier production function models.* Journal of Econometrics 6(1): 21-27.

Akazili, M., Adjuik, M., Chatio, S., Kanyomse, E., Hodgson, A., Aikins. M., and Gyapong J. *What are the technical and allocative efficiencies of public health centres in Ghana?* Ghana Medical Journal, 2008, 42(4):149-155.

Akazili, M., Adjuik, M., Jehu-Appiah, C and Zere, E. (2008). *Using data envelopment analysis to measure the extent of technical efficiency of public health centres in Ghana*. BMC International Health and Human Rights, Vol 8:11.

Battese, G. E. and Coelli, T. J. (1995). A Model for Technical Inefficiency Effects in a Stochastic Frontier Production Function for Panel Data. Empirical Economics, 20, 325-332.

Battese, G. E. and Coelli, T. J. (1992). Frontier Production Functions, Technical Efficiency and Panel Data: With Applications to Paddy Farmers in India. The Journal of Productivitry Analysis, 3(1992):153-169.

Belbasel, K. and Grabowshi, R. (1985). *Technical efficiency in Nepalese agriculture*. Journal of Development Areas 19 (4): 515-25

Besstremyannaya G. (2011). Managerial Performance and Cost Efficiency of Japanese Local Public Hospitals: A Latent Class Stochastic Frontier Model. Health Econ, 20 (Suppl. 1): 19–34 (2011)

Bravo-Ureta, B. E. and Evenson, R. E. (1994). *Efficiency in agricultural production: The case of peasant farmers in Eastern Paragua.* Journal of Agricultural Economics, Vol 10 (1): 27-37.

Charnes, A., Cooper, W. W. and Rhodes, E. (1978). *Measuring the Efficiency of a Decision Making Unit*. European Journal of Operational Research, Vol 2(6): 429-444

Chirikos, N. T. and Sear, M. (2000). *Measuring Hospital Efficiency: A Comparison of Two Approaches*. Health Services Research 34(6): 1389-1408

Coelli, T. J. (1995). *Recent developments in frontier modeling and efficiency measurement*. Australian Journal of Agricultural Economics 39(3): 219-245.

Farrel, M. (1957). *The measurement of productive efficiency*. Journal of the Royal Statistics Society; Series A, 120(3): 253-90.

Farrell M. J. (1957). The measurement of productive efficiency. Journal of the Royal Statistic Society, 120(3):253-281.

Ganley, J and Cubbin, J. (1992). *Public sector efficiency measurement: Applications of data envelopment analysis.* New York: Elsevier science publishers.

Gannon, B. (2004). *Technical Efficiency of Hospitals in Ireland*. The Economic and Social Review, Vol 36(3): 273-294

Government of Zimbabwe. (2013). Zimbabwe Agenda for Sustainable Socio-Economic Transformation (Zim Asset): Towards an Empowered Society and a Growing Economy; October 2013- December 2018.

Govindaraj, R. and Chawla, M. (1996). Recent Experiences with hospital autonomy in developing countries. What can we learn?

Grosskopf, S. and Valdmanis, V. Measuring hospital performance: a non-parametric approach. Journal of Health Economics, 1987, 6:89-107.

Hadley, J. And Zuckerman, S. (1994). *The Role of Efficiency Measurement in Hospital Rate Settings*. Journal of Health Economics, Vol 13 (3): 335-340

Hsu J. (2010). The relative efficiency of public and private service delivery. World Health Report, 2010.

Kirigia, J. M., Emrouznejad, A., Sambo, L. G., Munguti, N. and Liambila, W. (2004). *Using data envelopment analysis to measure the technical efficiency of public health centres in Kenya*. Journal of Medical Systems, 2004, 28(2):155-166.

Kirigia, J. M., Sambo L. G. and Scheel, H. *Technical efficiency of public clinics in Kwazulu-Natal province of South Africa*. East African Medical Journal, 2001, 78(3):S1-S13.

Maredza. A. (2012). Are for-profit hospitals more efficient than non-profit hospitals? A case study of Zimbabwe using data envelopment analysis and the Tobit model. African Journal of Business Management Vol. 6 (47), pp. 11670-11682, 28 November, 2012

Mas-Colell, A., Whinston, D.M and Green, J.R. (1995). Microeconomic Theory. Oxford University Press, New York.

Mathiyazhgan. K. M. (2006). Cost efficiency of public and private hospitals: evidence from Karnataka state in India. Institute of South Asian Studies (ISAS), Working Paper Series, 2006.

Meeusen, W. and Van den Broeck, J. (1977). *Efficiency estimation from Cobb-Douglas production functions with composed error.* International Economic Review 18(2): 435-44.

MoHCW. (2010). *The Health Sector Investment Case (2010-2012): Accelerating progress towards MDGs, Equity and Quality in Health, A Peoiple's Right.* Harare: Ministry of Health and Child Welfare.

MoHCW. (2010b). *National Child Survival Strategy 2010-2015.* Harare: MoHCW.

Osei, D., D'Almeida, S., George, M. O., Kirigia, J.M., Mensah, A.O. and Kainyu, L.H. (2005). Technical *efficiency of public district hospitals and health centres in Ghana: A pilot study.* Cost Effectiveness and Resource Allocation, Vol 3:9.

Pauly, M.V. (1970). *Efficiency Incentives and Reimbursement for Healthcare*. Inquiry 7:114-131

Prior, D. and Sola`, M. (2000). Technical efficiency and economics of diversification in healthcare. Healthcare Management Science, 3: 299-307.

Renner, A., Kirigia, J. M., Zere, E., Barry, S.P., Kirigia, D. G., Kamara, C. and Muthuri L. H. K. (2005). *Technical efficiency of peripheral health units in Pujehun district of Sierra Leone: a DEA application.* BMC Health Services Research, Vol 5:77

Schmidt, P. (1976). *On the Statistical Estimation of Parametric Frontier production functions.* The Review of Economics and Statistics 58: 238-239.

Shapiro, K. H., and Muller, J. K. (1977). *Sources of technical efficiency: the roles of modernization and information.* Economic Development and Cultural Change 25(2): 293-310.

Sherman, H.D. (1984). *Hospital Efficiency Measurement and Evaluation*. Medical Care 22: 922-928

Straat, M. (2006). *Efficiency of hospitals in Germany: a DEA-bootstrap approach*. Applied Economics, Vol 238: 2255-2263.

The World Bank. (2010). World Development Report 2010: Sustainable development in a dynamic world. Washington DC, The World Bank, 2010.

World Health Organization. (2010). The World Health Report 2010. Health systems financing: The path to universal coverage. Geneva. (http://www.who.int/whr/2010/en/index.html – accessed 8 February 2012).

World Health Organization. (2010). The World Health Report: Health systems financing: the path to universal coverage. Geneva.

Zere, E. (2000). *Hospital efficiency in Sub-Saharan: Evidence from South Africa*. World institute for development economics research; working papers p.187.

Zere, E., Mbeeli, T., Shangula, K., Mandlhate, C., Mutirua. K., Tjivambi, B. and Kapenambili, W. (2006). *Technical efficiency of district hospitals: evidence from Namibia using data envelopment analysis*. Cost effectiveness and resource allocation, Vol 4:5

Zere, E., McIntyre, D and Addison, T. (2001). *Technical efficiency and productivity of public sector hospitals in three South African provinces*. South African Journal of Economics, Vol 69 (2):336-358.

Guarda, P. and Rouabah, A. (2009*). Bank Productivity and efficiency in Luxembourg: Malmquist indices from a parametric output distance function*. Banque central du Luxembourg.

Appendix

Appendix 1: Efficiency Scores Predicted by the Frontier Models

DMU	Year	Eff/Discharges	Eff/Total Admissions	Eff/attendances	Mean
1	2009	0.76	0.77	0.77	0.77
2	2009	0.53	0.54	0.52	0.53
3	2009	0.65	0.66	0.66	0.66
4	2009	0.47	0.50	0.52	0.49
5	2009	0.44	0.45	0.45	0.44
6	2009	0.54	0.55	0.54	0.54
1	2010	0.79	0.76	0.76	0.77
2	2010	0.55	0.51	0.53	0.53
3	2010	0.54	0.53	0.54	0.54
4	2010	0.42	0.43	0.44	0.43
5	2010	0.66	0.67	0.69	0.67
6	2010	0.65	0.67	0.68	0.67
1	2011	0.72	0.71	0.72	0.72
2	2011	0.54	0.52	0.51	0.52
3	2011	0.56	0.58	0.58	0.57
4	2011	0.51	0.51	0.52	0.51
5	2011	0.68	0.67	0.68	0.68
6	2011	0.74	0.75	0.75	0.75
1	2012	0.73	0.72	0.73	0.73
2	2012	0.56	0.57	0.54	0.56
3	2012	0.56	0.57	0.56	0.56
4	2012	0.55	0.58	0.57	0.56
5	2012	0.65	0.67	0.66	0.66
6	2012	0.70	0.71	0.72	0.71
1	2013	0.74	0.70	0.74	0.73
2	2013	0.61	0.49	0.60	0.57
3	2013	0.53	0.54	0.55	0.54
4	2013	0.65	0.63	0.62	0.63
5	2013	0.66	0.67	0.66	0.66
6	2013	0.66	0.65	0.67	0.66
1	2014	0.73	0.69	0.73	0.72
2	2014	0.53	0.47	0.56	0.52
3	2014	0.50	0.51	0.51	0.51
4	2014	0.48	0.47	0.48	0.48
5	2014	0.64	0.65	0.66	0.65
6	2014	0.63	0.64	0.63	0.63

Appendix 2
Results from DEAP Version 2.1
Instruction file = middy2015-ins.txt
Data file = middy2015-dta.txt
Output orientated Malmquist DEA

DISTANCES SUMMARY

year = 2009

Hosp. no	crs te relative to technology in year						vrs te
	t-1[2]	t	t+1	t+2	t+3	t+4	
1	0.000	1.000	0.375	1.000	0.567	1.000	1.000
2	0.000	0.450	0.375	0.545	0.367	0.675	0.560
3	0.000	0.310	0.750	1.000	0.786	0.834	0.631
4	0.000	0.450	0.600	0.923	0.345	0.546	0.452
5	0.000	0.833	0.625	1.000	0.387	0.367	0.432
6	0.000	0.437	0.732	0.456	1.000	0.657	0.530
mean	0.000	0.580	0.576	0.821	0.575	0.680	0.601

year = 2010

Hosp. no	crs te relative to technology in year			vrs te
	t-1	t	t+1	
1	0.435	0.834	0.670	1.000
2	0.560	0.617	0.561	0.472
3	0.631	0.530	0.570	0.666
4	0.345	0.460	0.631	0.370
5	0.670	0.610	0.731	0.670
6	0.673	0.430	0.732	0.690
mean	0.552	0.580	0.649	0.645

year = 2011

hosp. no	crs te relative to technology in year			vrs te
	t-1	t	t+1	
1	0.335	1.000	0.710	1.000
2	0.470	0.607	1.000	0.472
3	0.657	0.560	0.771	0.530
4	0.450	0.410	0.519	0.480
5	0.670	0.630	0.400	0.700
6	0.560	0.450	0.450	0.721
mean	0.524	0.610	0.642	0.651

year = 2012

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

Hosp. no	Constant returns to scale technical efficiency relative to technology in year			Variable returns to scale technical efficiency
	t-1	t	t+1	
1	1.000	1.000	0.890	1.000
2	0.513	0.510	0.730	0.562
3	0.510	0.520	0.771	0.530
4	0.479	0.430	0.509	0.530
5	0.440	0.517	0.480	0.639
6	0.661	0.510	0.450	0.645
mean	0.601	0.581	0.638	0.651

year = 2013

Hosp. no	crs te relative to technology in year			vrs te
	t-1	t	t+1	
1	0.590	1.000	0.890	1.000
2	0.513	0.510	0.730	0.562
3	0.450	0.520	0.771	0.530
4	0.590	0.430	0.509	0.530
5	0.570	0.517	0.480	0.639
6	0.610	0.510	0.450	0.645
mean	0.554	0.581	0.638	0.651

year = 2014

Hosp. no	crs te relative to technology in year			vrs te
	t-1	t	t+1[3]	
1	0.520	1.000	0.000	1.000
2	1.000	0.473	0.000	0.497
3	0.430	0.499	0.000	0.370
4	0.510	0.487	0.000	0.450
5	0.513	0.430	0.000	0.639
6	0.538	0.547	0.000	0.612
mean	0.585	0.573	0.000	0.595

[3] See 1 above

MALMQUIST INDEX SUMMARY

year = 2010

firm	effch	techch	pech	sech	tfpch
1	0.934	0.466	1.000	0.934	0.934
2	1.371	0.908	1.213	1.130	1.371
3	1.710	1.191	1.000	1.710	1.710
4	1.022	0.750	0.650	1.573	1.022
5	0.732	1.098	1.137	0.644	0.732
6	0.984	1.565	1.117	0.881	0.984
mean	1.126	0.882	1.020	1.145	1.126

year = 2011

firm	effch	techch	pech	sech	tfpch
1	1.071	0.835	1.000	1.071	0.894
2	0.984	0.774	1.010	0.974	0.762
3	1.057	1.173	0.890	1.187	1.240
4	1.067	0.916	1.090	0.979	0.978
5	1.033	1.063	1.030	1.003	1.098
6	1.370	0.951	0.991	1.382	1.302
mean	1.097	0.952	1.002	1.099	1.046

year = 2012

firm	effch	techch	pech	sech	tfpch
1	1.000	1.050	1.000	1.000	1.050
2	0.840	1.163	1.050	0.800	0.977
3	0.929	1.019	0.897	1.035	0.946
4	1.059	0.921	0.879	1.205	0.976
5	0.821	1.191	1.031	0.796	0.978
6	1.014	1.027	0.992	1.022	1.041
mean	0.944	1.062	0.975	0.976	0.995

year = 2013

firm	effch	techch	pech	sech	tfpch
1	1.000	1.000	1.000	1.000	1.000
2	0.967	1.041	1.000	0.967	1.006
3	0.958	0.904	0.930	1.030	0.865
4	1.023	1.034	0.950	1.077	1.058
5	0.985	1.002	0.910	1.082	0.986
6	0.849	1.024	0.860	0.987	0.869
mean	0.964	1.001	0.942	1.024	0.964

year = 2014

firm	effch	techch	pech	sech	tfpch
1	1.000	1.000	1.000	1.000	1.000
2	0.959	1.026	1.000	0.959	0.984
3	1.002	0.862	0.945	1.060	0.863
4	0.915	1.047	0.970	0.944	0.959
5	0.845	1.193	0.859	0.983	1.008
6	0.953	0.996	0.868	1.098	0.949
mean	0.946	1.021	0.940	1.007	0.960