PRODUCTIVITY CHANGE IN SUB-DIVISIONAL HOSPITALS IN FIJI

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A Thesis Submitted in Partial Fulfillment of the Requirements
for the Degree of Master of Science Program in Health Economics and Health Care Management
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การเปลี่ยนแปลงผลิตภาพการผลิตในโรงพยาบาลชุมชน ประเทศฟิจิ

นายราทิช วิเนย์ พอล ซิงห์

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรมหาบัณฑิต
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ราทิช วิเนย์ พอล ซิงห์ : การเปลี่ยนแปลงผลิตภาพการผลิตในโรงพยาบาลชุมชน ประเทศฟิจิ (PRODUCTIVITY CHANGE IN SUB-DIVISIONAL HOSPITALS IN FIJI) อ.ที่ปรึกษาวิทยานิพนธ์หลัก: พงศา พรชัยวิเศษกุล, หน้า.

การศึกษานี้มีวัตถุประสงค์เพื่อศึกษาผลิตภาพการผลิตและประสิทธิภาพของโรงพยาบาลชุมชนในประเทศฟิจิ ตั้งแต่ปี พ.ศ. 2548 ถึง พ.ศ. 2557 การศึกษานี้เป็นการศึกษาครั้งแรกในประเทศฟิจิ เพื่อเปรียบเทียบผลการดำเนินงานของโรงพยาบาลชุมชน การศึกษานี้มี 2 ส่วนหลัก ประกอบด้วย ส่วนแรก คือ การวิเคราะห์โดยการใช้การวิเคราะห์การล้อมกรอบข้อมูล และตัวชี้วัดผลิตภาพการผลิต Malmquist เพื่อศึกษาผลการดำเนินงานของโรงพยาบาลชุมชนในประเทศฟิจิ ตัวชี้วัดผลิตภาพการผลิตยังสามารถนำมาใช้วัดการเปลี่ยนแปลงระดับผลิตภาพการผลิตซึ่งเป็นผลของการเปลี่ยนแปลงประสิทธิภาพทางเทคนิคและการพัฒนาทางเทคโนโลยี ส่วนที่สอง คือ การวิเคราะห์ข้อมูลของปี พ.ศ. 2557 โดยใช้โปรแกรมการวิเคราะห์การล้อมกรอบข้อมูลแบบหลายขั้นตอน เพื่อประเมินผลการดำเนินงานของโรงพยาบาลในรูปแบบของประสิทธิภาพทางเทคนิคและประสิทธิภาพด้านขนาด ผลลัพธ์ของคะแนนจากทั้งสองส่วนของการศึกษาจะถูกนำมาใช้เป็นตัวแปรตามโมเดลทางเศรษฐศาสตร์ของ Log-Linear function และ Tobit function ถูกนำมาใช้เพื่อหาปัจจัยหลักที่มีผลต่อการเปลี่ยนแปลงผลิตผลการผลิตและประสิทธิภาพของประเทศฟิจิ ผลลัพธ์จากตัวชี้วัดผลิตภาพการผลิต Malmquist จะช่วยแก้ปัญหาของผลิตผลการผลิตที่มีแนวโน้มลดลงในช่วงเวลาที่ศึกษา ซึ่งหมายถึงโรงพยาบาลชุมชนในประเทศฟิจิไม่ได้ใช้ปัจจัยการผลิตอย่างมีประสิทธิภาพเพียงพอ เป็นผลให้รัฐบาลไม่สามารถกำหนดเป้าหมายของผลลัพธ์ได้ แนวโน้มของปัจจัยโดยรวมของผลิตผลการผลิตในช่วงเวลาที่ศึกษามีตั้งแต่การเพิ่มขึ้นร้อยละ 36.3 จนถึงลดลงร้อยละ 14.3 ในช่วงปี พ.ศ. 2548 ถึง พ.ศ. 2549 ในขณะที่การเปลี่ยนแปลงประสิทธิภาพทางเทคนิคที่ต่ำที่สุดมีค่าเท่ากับติดลบร้อยละ 18.4 ในช่วงปี พ.ศ. 2556 ถึง พ.ศ. 2557 ซึ่งผลที่ได้นี้ได้บ่งชี้ถึงการเปลี่ยนแปลงของคะแนนประสิทธิภาพทางเทคนิคของทั้ง 17 โรงพยาบาลมีค่าน้อยกว่า 1 ส่วนที่สองของการศึกษาโดยใช้การวิเคราะห์การล้อมกรอบข้อมูลแบบหลายขั้นตอนภายใต้โมเดลที่พิจารณาความสามารถในการผลิตสินค้าในปริมาณมากที่สุดภายใต้ปัจจัยการผลิตที่กำหนดได้ถูกนำมาวิเคราะห์ในด้านความแตกต่างของคะแนนประสิทธิภาพเมื่อเทียบกับโรงพยาบาลที่ใช้อ้างอิงภายใต้สมมติฐานผลได้ต่อขนาดคงที่และผลได้ต่อขนาดเปลี่ยนแปลง การศึกษานี้พบว่ามีเพียง 2 จาก 17 โรงพยาบาลที่มีการดำเนินงานอยู่ในช่วงการผลิตที่เหมาะสม และจากโมเดลนี้พบว่าโรงพยาบาลส่วนมากมีการผลิตผลลัพธ์ที่ผลได้ต่อขนาดลดลง หรือหมายถึงโรงพยาบาลส่วนมากไม่ได้ใช้ปัจจัยการผลิตอย่างมีประสิทธิภาพเพียงพอและจำเป็นต้องมีการพัฒนาเพื่อให้ได้ผลลัพธ์ที่มากขึ้น โดยสรุป การศึกษานี้พบว่าโรงพยาบาลชุมชนในประเทศฟิจิขาดประสิทธิภาพทางเทคนิค ซึ่งจำเป็นต้องมีการจัดการให้มีการใช้ทรัพยากรได้อย่างคุ้มค่าที่สุดสำหรับการลงทุนด้านการบริการด้านสุขภาพเพื่อให้ได้รับผลลัพธ์สูงสุด

สาขาวิชา	เศรษฐศาสตร์สาธารณสุขและการจัดการบริการสุขภาพ	ลายมือชื่อนิสิต	....
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RATISH VINAY PAL SINGH: PRODUCTIVITY CHANGE IN SUB-DIVISIONAL HOSPITALS IN FIJI. ADVISOR: PONGSA PORNCHAIWISESKUL, pp.

The study aims to investigate the productivity and efficiency trends of Sub-Divisional Hospitals in Fiji since 2005 to 2014. The study is first of such nature in Fiji where an objective evaluation of the performance of Sub-Divisional Hospitals is investigated. The study is divided into two major parts .The first major part explores the use of the extended version of the Data Envelopment Analysis (DEA), the Malmquist Productivity Index to measure and evaluate the performances of the Sub-Divisional Hospitals in Fiji.

The second part of the study applied the Multi Stage DEA programme to the most recent year data, 2014 to evaluate hospital performance in terms of technical and scale efficiency for the particular year. The results or scores of both parts of the study were then used as dependent variables and econometric models of a Log-Linear function and Tobit function were used to determine the key factors that were believed to have influenced the productivity and efficiency changes in Fiji's context. The results from the Malmquist Productivity Indices disclosed some concern in terms of the downward sloping trend of productivity over the period of the study. This meant that SDH's in Fiji were not utilising inputs efficiently which led to the inability of the Ministry to meet its targeted outputs. The trend in total factor productivity in summary of the period of the study fell from a positive gain in productivity of 36.3% in 2005-2006 period to a productivity loss of 14.3%. This was significantly attributed to the lowest change in technical efficiency which fell to a record low of negative score of 18.4% in the period 2013-2014. This was also reflected in the Technical Efficiency change scores where all 17 hospitals had scores below 1.

The Multi Stage DEA under the output oriented model also had considerable variations of efficiency scores from the reference hospitals under the assumption of Constant and Variable Returns to scale.Only 2 out of the 17 hospitals under the study were operating on the optimal production frontier. Majority of the hospitals were producing outputs at a decreasing returns to scale implying that many hospitals were not using their inputs in the most efficient manner and needed to decrease investment in the production of outputs or they needed to produce more outputs within the inputs that was consumed.

Field of Study:	Health Economics and Health Care Management	Student's Signature	....
		Advisor's Signature	....
Academic Year:	2014		

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CRS	-	Constant Returns to Scale
DEA	-	Data Envelopment Analysis
DEAP	-	Data Envelopment Analysis Programme
DMU	-	Decision Making Unit
DSPH	-	Deputy Secretary, Public Health.
DRS	-	Diminishing Returns to Scale
DMO	-	Divisional Medical Officers
GDP	-	Gross Domestic Product
GGE	-	General Government Expenditure
GCHE	-	Government Current Health Expenditure
HiT	-	Health Systems in Transition
IRS	-	Increasing Returns to Scale
IPD	-	Inpatient Department
MDG's	-	Millennium Development Goals (MDG's)
MPI	-	Malmquist Productivity Index
MTFPI	-	Malmquist Total Factor Productivity Index
MOH	-	Ministry of Health
NHA	-	National Health Accounts
NCD	-	Non Communicable Diseases
OB	-	Operational Budget
OPD	-	Outpatient Department
PATIS	-	Patient Information System
PHIS	-	Public Health Information System
SDMO	-	Sub-Divisional Medical Officers
SDH	-	Sub-Divisional Hospitals
TGHE	-	Total Government Health Expenditure
TE	-	Technical Efficiency

TFP	-	Total Factor Productivity
UMIC	-	Upper Middle Income Country
VRS	-	Variable Return to Scale
WHO	-	World Health Organisation

CHAPTER I

INTRODUCTION

1.1 Overview

Globally, the health care industry is becoming one of the most competitive and leading sector in its contribution towards economic growth and development. Many developed countries are also realizing the benefits of opening up market for entry of reputable private hospitals and investors in health. The health sectors in many developing countries are also experiencing phenomenal growth. The effects of the growth of the health sector is multidimensional as it is not only in the health care services that create economic activity, but other related essentials that provide the necessary support in delivering health care services are also affected either positively or negatively.

Liberalization of the health sector, removal of trade barriers have opened many opportunities for the exchange of new knowledge, resources and technology between developed and developing countries bridging the gap in accessing world class health care.

Complex regulatory mechanisms have opened up more opportunities for the insurance industry to expand coverage of health insurances and enter new markets. The problem is further compounded as the economy grows; citizens improve their living standards and fall in the middle income class group. The demand further puts serious pressure on the health system to deliver citizenship expectations of better improved quality of health services.

The phenomenal growth of health sector has led to an increased demand of adequate and appropriate health care services. The pressure in a competitive market necessitates the need for larger share of resources to be channeled to the health sector to meet this predictable yet unmet demand. The constrained ability to meet this demand due to lack of resources, in particular finance, puts a lot of burden on health providers to compromise on the objectives of quality of health care services against efficiency and effectiveness. This objective of the organization determines its effect on efficiency and productivity of the services as well as of the health workers.

The introduction of different forms of financing mechanism has created opportunities for Insurance markets in the health sector. It has opened up opportunities for a large middle income earner to use similar services as the few elite high earners thus increasing demand and pressure on the health system.

A Beveridge health system such as Fiji, where the health care services are predominantly funded through the public service are facing a demanding task in collecting, allocating and utilizing the limited resources efficiently and productively without burdening the tax payers and compromising on services and goods to be delivered by other important sectors including the health sector itself. It is commonly known to that many Governments are always trying to minimize wastage of resources due to the side effects of a health system where incentives and efficiency are not present.

Technological advancement has traditionally generated a lot of interest in the private sector to stay ahead of competitors. The public sector is many countries to meet citizens expectation is also largely investing in state of the art technology, which is partially politically driven apart from its demand. With the pattern of diseases constantly changing, the technology world is ever expanding too the demanding needs for new painless methods to treat people. Such machines are substantially expansive to procure and maintain but are necessary.

In some cases, especially in developing countries its Governments political commitment to its people. Ironically, it is the same tax payer's money that is used to fund these major procurements. The rationale of the procurement is also questioned specially in developing countries where only clinical analysis is undertaken to provide justification without much expert analysis in terms of economic costs effectiveness.. How many lives can the procurement save? Is the additional life saved within the marginal costs or less than costs? The lack of such analysis creates future problem such as utilization, creating need and demand, maintenance, support services etc which drain resources quite drastically.

The retention of qualified and skilled health workers has been one of the most daunting challenges faced globally. There has also been a vast inflow and outflow of human capital (health workers) due to many factors. Developing countries face the full brunt of migration of health workers which constantly affects the efficiency and productivity with which services are delivered. Eventually, countries like Fiji, easily lose their investment in health workers through natural attrition. Findings from the study by**(Prasad, 2012**), highlights that Fiji on average loses around 41 Doctors on a yearly basis. That is considered a worrying number for a small developing country like Fiji. The burden of performance then falls on a few remaining skilled doctors that usually are overloaded with work or delegate work to the new fresh graduates with major risks. The lack of performance incentives in the public sector, the sharing of physicians to work in public and private sector, lack of educational and career path and low wage scale puts a lot of pressure on developing countries to motivate health workers.

In many developing countries that have some dependency on Donor Partner countries are easily influenced to agree to terms and conditions of Donors. Donor partners are usually involved in roundtable meetings to discuss many issues. Donor partners usually look at financing ongoing structural changes or policy developments. The changes as such are recommended by experts therefore a lot of demand is created in financing the project or other supplementary projects. Reforms that are not mutually agreed may or could create unnecessary problems such as agreeing to unclear terms and conditions which could be in conflict with Governmental projects.

Financial sustainability of maintaining current level of care, increase in citizens expectations of quality health care, impoverishment of citizens from high cost of health care, inability of countries retaining human capital, new technology, competitive environment, lack of performance based incentives for health workers are all posing strong questions to hospital managers and policy makers to respond in a timely manner.

The question of measuring and evaluating the performance of health care facilities, in particularly hospitals, where majority of the funds are traditionally consumed is fast becoming a major discussion point with hospital managers and policy makers. Hospitals are becoming too crowded, cost of operations in hospitals are high, incentives for health worker retention are low leading to high staff turnover, new innovative high impact technology is too expansive are some of the reasons that continuous performance measures of hospitals are necessary. It is even of greater essence for developing countries that are challenged due to its history, geographical location, size, natural resources, and small economies of scale, low economic growth, high migration of health professionals, the need to measure hospital performance is more needed than ever.

While other industries have moved ahead towards measuring performance objectively for critical decision making, the health industry has lagged behind for a considerable amount of time. New methodologies are now emerging in measuring hospital performance, such as using efficiency and effectiveness measures. This study would focus on efficiency measures of the hospital, in particular looking at technical and scale efficiency and the determinants that drive efficiency levels of hospital operations in Fiji.

Performance, as in other service industries, can be defined as an appropriate combination of efficiency and effectiveness. Efficiency is generally utilized to express the use of minimum input to produce a given level of output or greater output with the same level of input. An efficient health care therefore can be described as a system or facility that uses a minimum level of resources and produces a reasonable standard of health care without compromising on quality**(Ozcan, 2008).**

1.2 Researchable Problem

Fiji, with a population size of just under a million faces similar problems as other countries in similar stages of growth. Being small in population size naturally faces a daunting task of creating ***economies of scale or volume*** of health care activities to efficiently and effectively provide health services.

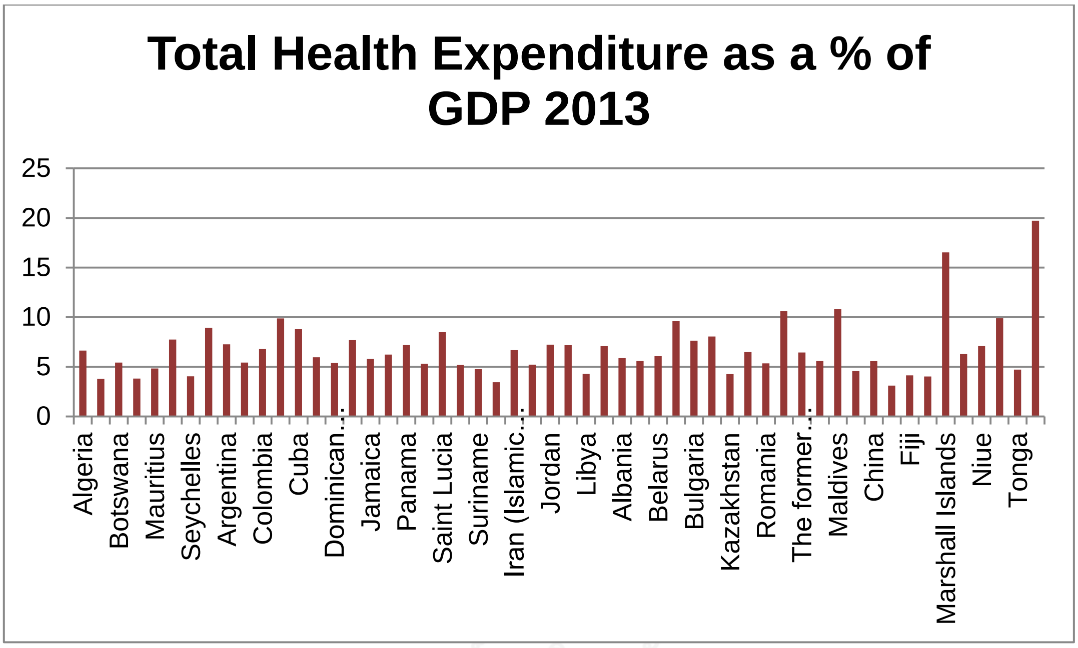
In a Beveridge model health system, in particular in Small Island Economies almost all the health services do not carry any fee to the patients. Governments under the Beveridge health system have historically prioritized equity over efficiency objectives. Usually, a prominent characteristic of such an economy is the lower per capita expenditure on health.

A Beveridge health system usually is also characterized by a lack of strong measurement system in place to measure and evaluate health system performances against standards and best practices. There is not strong enough motivation and incentive for such a system to identify and make comparative performance analysis as minimizing cost may not be a strong objective for such health systems. Pre-dominantly, the health care services in Fiji are funded by the

Government apart from external donor sources and out of pocket (OOP) by individuals.

Figure 1 compares the Total Health Expenditure as a percentage of GDP for the Upper Middle Income Countries (UMIC). Fiji is also part of the UMIC's.

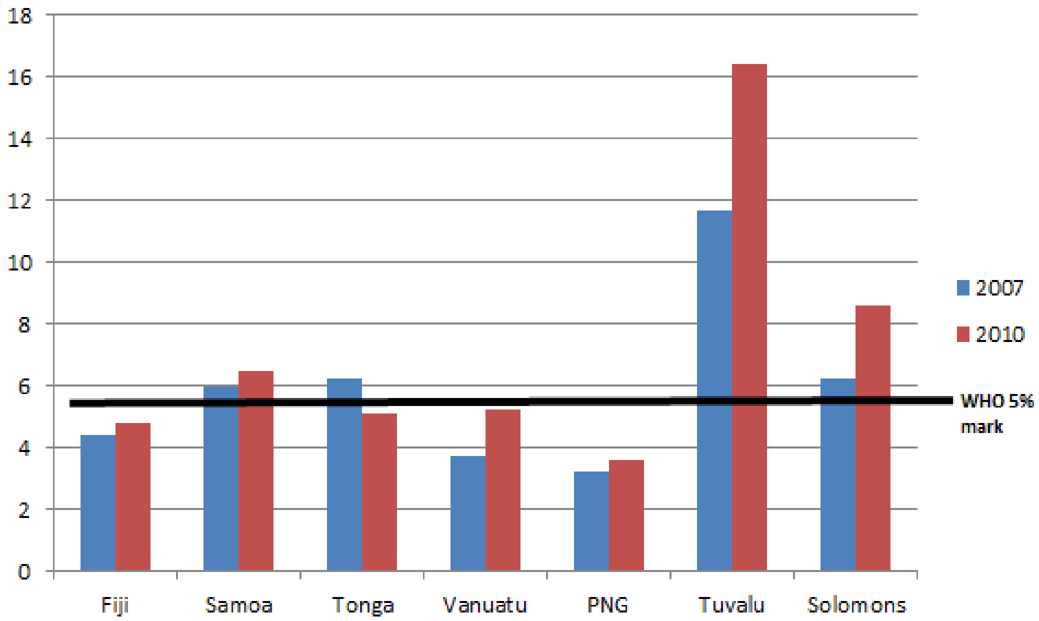
Figure 1: Total Health Expenditure as a % of GDP 2013 (UMIC)



Source: World Health Organization

Similar health systems, especially in Small Island Economies are confronted with the issue of the ability and capacity of sustaining feasible funding for its health system. Whilst there is very limited studies conducted in projecting on what is the "adequate level of health funding" the quantity of funding towards health in Small Island Economies have remained quiet low compared to WHO standards.

Figure 2: Total Health Expenditure as a % of GDP



Source: Ministry of Health, National Health Accounts Report, 2009-2010. Page 59.

A study in 2013 by **(Rannan-Eliya, Irava, & Saleem, 2013)** with the collaboration of the Ministry of Health of the Government of Fiji and World Health Organisation titled "**Assessment of Social Health Insurance Feasibility and Desirability in Fiji**" proposed that to increase health sector funding whilst maintaining or increasing equity, the only realistic option for Fiji was to increase financing from general revenue taxes. However simple, the scope of expanding revenue in a developing country may bring about more externalities and burden to a society that already have high tax thresholds.

Increasing efficiency in service delivery is the second major option that MOH has to mobilize resources. MOH has under-performed in productivity improvement since the mid-1980s, implying significant potential for efficiency gains. The timing of the productivity slowdown indicates that it is linked to the failures in governance since the mid-1980s **(Rannan-Eliya et al., 2013)**.

The Fiji Islands Health Systems Review report titled “Health Systems in Transition HiT”, conducted by the Asia Pacific Observatory on Health Systems and Policies found out technical inefficiencies in health facilities, in particular of hospitals in Fiji were primarily attributed to the inadequate funding towards new health infrastructure and also in maintaining and upgrading the existing infrastructure. Furthermore, supportive operational budget towards capital projects have been stagnant and therefore many a times has there been cases of “empty spaces” in capital projects left idle for many years.

Large quantity of purchases of bio-medical equipment are also undertaken yearly but the lack of expertise in maintaining and repairing these equipment’s with very limited funding towards spare parts, maintenance, consumables have led to many delays in the provision of health services. The lack of lab-technicians or repair men of bio-medical equipment further adds burden to the performance of the hospitals.

The lack of specialised human resources training in areas such as hospital administration and management have impacted on the technical efficiency of hospitals, as operational inefficiencies such as wastage, irrational use of drugs, medicines and consumables, and in some cases misuse of hospital products are still present. This is apparent in the audit reports that reflect a larger number of queries arising from hospital mismanagement.

Furthermore, heath workers lack the incentive to work efficiently in a salary paid system. Health workers in such a system may compromise on the quality of health care standards in order to increase numbers or turnaround time of consultation, diagnosis and treatment of patients. No studies have been conducted on assessing the efficiency of physicians or nurses in delivering services.

On the **demand side**, the geography of Fiji with over 300 plus islands, in it-self provides a mammoth challenge to small island countries in ensuring a balance in efficiency and equity is maintained. By funding an extensive delivery system including hospitals that is free or almost free for all patients, Fiji has chosen to prioritize equity, risk protection and access for the poorest over satisfaction of the better-off **(Rannan-Eliya et al., 2013).**

It implies that key policy and decision makers have prioritised equity objectives and issues ahead of efficiency most of the times when deciding on funding health projects. The fact is no efficiency or economics studies have been extensively done to show the use of cost effectiveness or cost benefit analysis in allocating resources that provides maximum output for health.

The improvement of health literacy of Fijians and the recent transition of Fiji to a democratically elected Government are leading to greater expectations and demand of improved health care from the public. Literature suggests that the accountability and transparency of how health services are provided are strongly related to the socio-economic and political stability of a country.

The demographic needs are also changing with generally a younger population in Fiji now, but with more complex health care needs than before due to lifestyle and behavioural related disease confronting the health sector. The rapid rise of Non-Communicable Disease (NCD) and the re-emergence of Communicable Diseases in tropical islands like Fiji, pose a double burden to the health sector. Needless to say, the problem of aged population is also surfacing. While there is no evaluation on the influence of a larger elderly population on health services, the study would try and provide an indication using the elderly population as an independent variable.

The purchase of attractive low cost health Insurance with added on benefits and coverage has provided incentives for middle income earners as well as some low income earners to purchase health insurance.

Generally with positive growth of the economy the rise in population of middle income earners is creating additional demand on health care utilization whilst no major study has been undertaken to prove this yet.

Geographically, the accessibility of health care services are improving thus more Fijians are able to access health care. This has necessitated the Government to invest more in health and other socio-economic sectors. Investment in socio-economic and infrastructure sectors such as roads and bridges, electricity, increased subsidies from Government to the elderly and school children in its poverty alleviation and social welfare programme, increased number of health facilities have either directly or indirectly created an effect on the demand for health care services.

Lastly, majority of the services provided in the public health sector are free thus by default creating a derived demand of the use of services, even though some cases of treatment are not necessary to be examined in hospitals. The decentralization policy for all outpatients to be seen at Sub-Divisional or Health Centre levels has been implemented, no assessment has been made whether the outpatient numbers in Tertiary hospitals have actually decreased. No utilization studies have been conducted in Fiji.

In the health care industry, the improvement in the **supply side** of health services could also create greater demand, a casualty effect. The investment in health care facilities, improved technology has a further increased demand for health care services. Whilst investment has been made in capital, the lack of operational resources has also caused government health workers to compromise quality of care especially in hospitals, which has led to frustration within the organization as well as from the public.

The payment mechanism in Fiji is through line item budgeting for all providers and health workers are paid through salary. The disadvantage of such as system lies in the inability to motivate hospital managers to produce a given level of output with the minimum resources available. Furthermore, Fiji while decentralizing services still maintains a centralized system in managing finance and human resources causing delays in the delivery of services at many levels of care.

Efficiency service benchmarks and best practices against which performances of hospitals could be measured is very limited in Fiji. While some benchmarks are adopted from Australia and New Zealand, these are process standards and have never been evaluated in terms productivity and efficiency. The lack of such benchmarks leaves a vacuum for strong knowledge of standards against which Fiji can make effective internal adjustment to minimize wastage and improve efficiency.

Decision making in the Ministry of Health in Fiji is not free of political influence and it should not be as it does provide a societal perspective of demand of health care. Some degree of political influence is important but literature also reveals globally that problem of inefficiency and ineffective investments and poor resource allocation arise if good balances of equity issues which are usually political are not balanced well with efficiency and effectiveness issues

Finally, like many other countries, Fiji also faces the problem of retaining human capital. Many of the “good” or “highly skilled” doctors and nurses from Fiji leave the service for better opportunities within and majority outside of Fiji. No such study has been done to understand the impact on hospital efficiency due to the above demand and supply factors.

The above challenges are very common in island developing countries but to date there is not enough literature to show performance evaluation of the health sector has been seriously considered. The study thus is a foundation, a starting point for policy makers and analysts to raise curiosity in measuring efficiency and productivity of the health sector to ensure resources are used efficiently and effectively without compromising on equity issues.

The study will use the Malmquist Productivity Index concept in measuring change of productivity over 10 years and also use the most recent data and the simple DEA Multi Stage method to measure the technical efficiency of the SDH's.

The scores of the Malmquist Productivity Indices and the DEA Technical Efficiency under the input oriented Variable Returns to Scale would be used as a dependent variable and regressed against a set of internal and external independent factors that may possibly have influence on the Productivity and Efficiency level of the hospitals.

Chapter 1 of the Paper highlights challenges faced nowadays in terms of managing health care system, **Chapter 2** covers the in-depth report on the background of Fiji's health system, its national referral system and overall its health status. **Chapter 3** draws literature on the area of study while **Chapter 4** maps out the conceptual framework that is adopted in this study. The method used in terms of calculating efficiency and productivity and what regression methods are used is captured in **Chapter 5**. **Chapter 6** looks at the results as an outcome of adopting the methodology and the discussions and recommendations is covered under **Chapter 7**.

1.3 Rationale of the study

The categorisation of hospitals in Fiji is based on many factors. Hospitals are categorised as SDH's firstly if they exist in one of the 17 medical boundaries. Furthermore, other factors include if the hospital manages a population catchment of around 15,000 to 30,000, patient travel time in terms of accessibility between the SDH and Divisional Hospital (main referral hospital) should be around an hour and services at the SDH hospitals are ranges from primary, secondary and basic tertiary care. Advanced tertiary care is supported by specialist services from the 3 main Divisional Hospitals.

The Services provided by SDH is a combination of public health and clinical services. Major clinical department in SDH's would include an Accident and Emergency department, Inpatient care of 25 beds or less, low risk deliveries, outpatient activities, Pharmacy, Laboratory , x-ray and more.

The SDH hospital in Fiji's referral system which, will be discussed in the background section, is the mid referral point between the Nursing Stations and Health Centres within each of the four divisions to the major Divisional Hospitals that provides advanced tertiary care services.

From the above description, it is apparent that SDH's is seen to be at the **core or the critical referral point** that manages patients referred from nursing stations and health centres at the primary level, their treatment and referral of the untreated to major referral tertiary care hospitals.

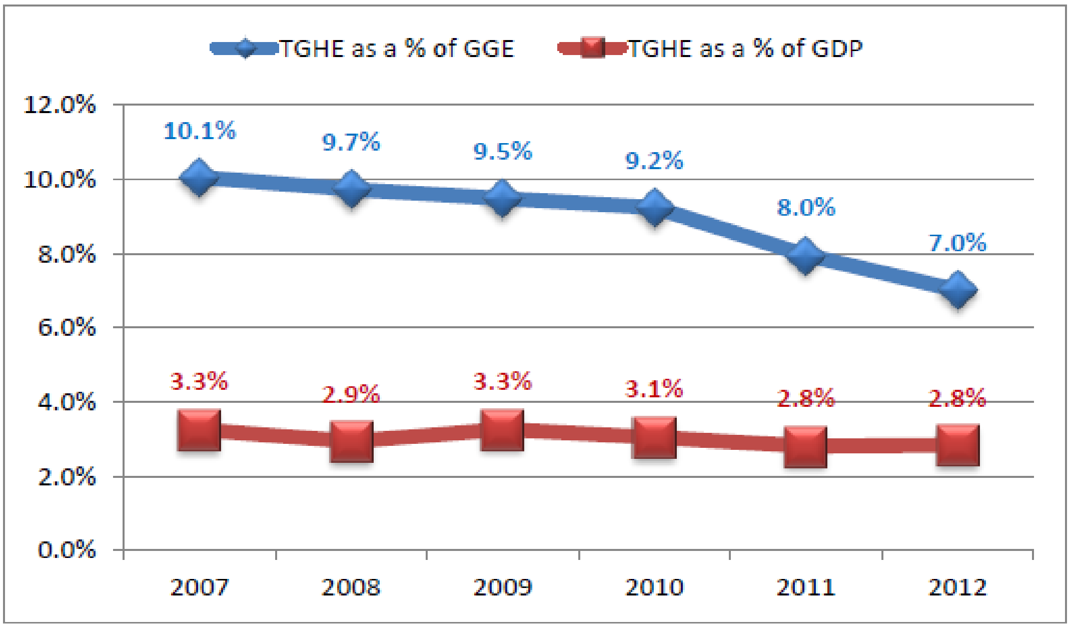
The management of patient from the primary level in terms of screening, diagnosing, treating and referral puts a lot of pressure on capacity of SDH's to efficiently skim out population that are healthy but could fall into the risk category, detect population that are at risk but could be educated earlier to avoid hospitalisation, population that could be treated at the Sub Divisional level and patients that need to be referred to Divisional Hospitals for tertiary care. The management of patients from and to is extremely important to ensure that facilities at all levels are able to deliver their outputs within the inputs provided1.

This study focuses on the measurement of productivity with which SDH hospitals have been performing based on the input resources provided. A lot of critical decisions are made at the SDH on management of patients and the processes involved and therefore the rationale would be to explore the factors that may influence whether the targeted outputs are met or not.

Financing of health system and hospitals is essentially been an important factor on how efficiently services are delivered by health facilities.

The National Health Accounts report trend from 2007-2012 clearly reflects a decline in Total Government Health Expenditure (TGHE) as a percentage of GDP as well as a percentage of the General Government Expenditure (GGE).

Figure 3: Total Government Health Expenditure as a % of Government General Expenditure & Gross Domestic Product.



Source: Fiji National Health Accounts Report, 2011-2012. Ministry of Health, Fiji.

From 2007 to 2012 the Government Budget as a percentage of Gross Domestic Product has been relatively stagnant while the National Roadmap (RDSSED) has targeted that a level of 7% would be achieved by 2015.

Furthermore, Government general budget as a percentage of the General Government Expenditure (Expenditure of the Whole Government) has been declining since 2007.

As a share of the Current Health expenditure on public health facilities, a total of 26.5% was spent in 2012 as a share of the Government Current Health Expenditure. In 2011 23.2% was spent by SDH's as a share of the GCHE. Major divisional tertiary hospitals continue to consume major share of the expenditure.

Table 1: Government Current Health Expenditure on public health facilities 2011 and 2012.

	2011		2012	
Providers by Geographic divisions	**(FJ$m)**	**Share (%)**	**(FJ$m)**	**Share (%)**
Central	**48.07**	**42.7%**	**47.2**	**40.8%**
Divisional hospitals	38.1		35.4	
Subdivisional Hospitals (SDHs)	7.6		8.0	
Public Health Centres (PHC)	2.4		3.9	
Eastern	**4.4**	**3.9%**	**5.3**	**4.6%**
Subdivisional Hospitals (SDHs)	3.5		4.2	
Public Health Centres (PHC)	0.9		1.1	
Western	**32.9**	**29.2%**	**36.5**	**31.5%**
Divisional hospitals	19.5		20.8	
Subdivisional Hospitals (SDHs)	11.0		12.4	
Public Health Centres (PHC)	2.4		3.2	
Northern	**20.8**	**18.5%**	**21.4**	**18.5%**
Divisional hospitals	13.6		14.3	
Subdivisional Hospitals (SDHs)	4.7		4.9	
Public Health Centres (PHC)	2.5		2.2	
Specialist Services (National Level)	**6.5**	**5.8%**	**5.3**	**4.6%**
Mental health hospitals	3.1		2.7	
Specialised- (Oversea visiting teams)	0.3		0.3	
Tamavua hospital (TB and Leprosy)	3.1		2.2	
Total	**112.6**	**100%**	**115.7**	**100%**

Source: Fiji National Health Accounts Report 2011-2012

The stagnant or decrease in overall funding on health and the increase in actual expenditure as reported in the NHA report illustrates that financial sustainability at levels experiencing expenditure growth would be an important issue to study. Of more importance in this study is to explore how much do finance influence service delivery efficiency at SD level.

Additionally, SDH's are seen as the central referral point pre-dominantly responsible for seeing patients referred from primary health facilities, screening and managing public health aspects of health service delivery including health promotion and primary care, attending to minor secondary and tertiary care as well as referring the patients to major tertiary care hospitals.

The management of patients at SDH has multiplying effects on the consumption of resources at other facility levels of care as well. Whilst, no qualitative output variables such as re-admission rates are investigated due to unavailability of data, it is highly likely that re-admissions has a significant impact on resource consumption, efficiency of delivery of services and effectiveness of using inputs to produce outputs.

Human resource for Health is notably the most important input factor in the production of health services. The lack of study on human resources for health in Fiji makes it interesting to explore its effect on efficiency levels of SDH over the 10 year period of the study.

Fiji, like many other developing countries face the challenge of training, recruiting and maintaining key cadres of health workers in particularly physicians and nurses. The quest for better opportunities, better working environment and external factors have constrained the health sector in producing the right quantity of health care services.

Overall growth of population in the 4 major divisions including the growth in elderly population in some divisions also influences the efficiency of the delivery of services as it takes much longer to screen and diagnose older patients than younger ones.

The point of the right number of health workers to meet the actual demand requires utilization studies to be undertaken to forecast the number of health workers actually required. Other means have been used to project human resources for health but do not reflect actual need or demand of services.

Finally, this study is believed to be the first study of such nature using econometric tools and new methodological procedures to undertake an objective assessment of productivity and efficiency in Fiji and if not in the South Pacific. Every detail is a new contribution to the health sector of the country which aims to minimize resource wastage and improve delivery of services to its people.

1.4 Research Question

1.4.1 What is the change in the level of Total Factor Productivity of all 17 SDH's in Fiji from 2005-2014?

1.4.2 What is the change in the level of technical efficiency and technical (technological) advancement of all the SDH's in Fiji from 2005-2014?

1.4.3 What internal and external factors are influencing changes to the level of Technical Efficiency and Total Factor Productivity of all 17 SDH's in Fiji?

1.4.4 Which factors influence technical and scale efficiency in SDH's in Fiji for the most recent period 2014?

1.4.5 What internal and external factors are influencing the level of technical and scale efficiency of all 17 SDH's in Fiji for the period 2014?

1.4.6 Which hospitals are "reference" hospitals for improving performance in inefficient hopsitals?

1.5 Research Objectives

1.5.1 Primary Objective

To measure a decade of change in Total Factor Productivity in Government sub-divisional hospitals in Fiji.

1.5.2 Specific Secondary Objectives

- To measure the change in total factor productivity from 2005-2014.

- To decompose total factor productivity into technical efficiency change or the "catching up effect" and technical change or the "true technological change".

- Identify the determinants or variables that have influenced total factor productivity and technical efficiency changes in Fiji over period of the study.

- To determine the technical and Scale efficiency of sub-divisional hospitals in Fiji in 2014.

- Identify the determinants or variables that influenced technical and scale efficiency in SDH's in Fiji in 2014.

- To identify “benchmark” hospitals and “best practices” for standardization of services.

1.6 Scope

1.6.1 Setting

The study primarily focuses on the measurement of productivity change of the 17 Government owned SDH’s in Fiji. The SDH’s are located in various parts of the 4 major divisions in Fiji. The assessment of productivity levels of sub-divisional hospitals in Fiji will use secondary data obtained from the Patient Information System (PATIS) and the Public Health Information System(PHIS) from 2005-2014. Data for various input and output variables that consume majority of the resources in the Sub-Divisional Hospitals would be collected for the period of the study.

The results are expected to highlight hospitals which are productive in using inputs to produce similar outputs or maximizing the targeted outputs within the given input resources. The productivity indices would be demarcated by technical efficiency change and technological change to ensure that structural reforms and policy measures are directed in appropriate areas for implementation, reference hospitals that fall on the production frontier will be identified to ensure that best practice planning processes and service delivery mechanism are incorporated in unproductive hospitals.

The secondary focus of the study would be to determine the technical and scale efficiency of the 17 sub-divisional hospitals in Fiji using the 2014 input and output data and setting of “benchmark hospitals” or “peer groups” and “best practices” would be key outcome.

Traditionally the indices will then be used as dependent variables and used in econometric regression analysis. For the Malmquist Productivity Indices a Log Linear regression is undertaken and for Technical Efficiency a Tobit regression will be used.

1.7 Possible Benefits

Firstly, the study would be a first for Fiji and possibly in the South Pacific which is an objective assessment of efficiency and productivity levels of the Sub Divisional Hospitals. The study would also be employing a globally recognized tool (DEA and Malmquist DEA) to obtain productivity indices.

The study provides an opportunity to key reform and policy analysts in the Government sector to measure efficiency and productivity levels of the SDH which is at the central of delivering quality clinical care and administrative support at secondary and tertiary level of care.

The critical role of SDHs in the organization of health service delivery will undoubtedly need the feedback of such studies to ensure that services are provided adequately and in a timely manner. It also provides as a benefit to hospital managers to utilize limited resources in the most appropriate manner and implement health reforms in key strategic areas that are based more on facts and evidences rather than some past experiences or .

Given its strategic position in the organization structure and as a key crucial link between primary secondary and tertiary care is important to ensure that policy makers are aware of the performance levels of sub-divisional hospitals, its capacity to produce outputs within the given input resources, the determinants of inefficiency in hospitals and the determinants that could influence performance improvements in unproductive hospitals.

The productive and efficient or reference hospitals would provide a locally based standard that other relatively underperforming hospitals could adopt the best practices to make improvements.

The identification of unproductive and inefficient hospitals allows hospital managers and policy makers to undertake structural changes in making improvements as well as allocating resources more efficiently and in more effective programmes.

Hospital managers are able to identify the major determinants of the causes of inefficiencies and further investigate means and ways to improving or influencing changes in the key determinants either internally or from the external environment.

Policy makers are able to identify major determinants of hospital productivity and efficiency and pursue the request of allocating resources based on those critical determinants. This also ensures that the Ministry of Health is able to convince the Ministry of Finance on the justification of allocating resources based on evidence.

Hospital managers and policy makers can identify deviations from plans and thus make timely adjustments in improving hospital performances.

As mentioned earlier, SDH's in Fiji are at the center of receiving and referring patients and a lot of health reforms are implemented through SDH's. To ensure success of health reforms, SDH's needs to be assessed in terms of its readiness to deliver. It is therefore uttermost necessary to measure or have audits of the current performance level to identify weaknesses and gaps that need to be addressed before reforms are implemented.

CHAPTER II

BACKGROUND

The strength of the Fiji health system is its foundation on a primary health care model. This foundation while facing many challenges and achieving milestones in meeting standards and expectations still needs strengthening due to the ever-changing internal and external environment of the health sector. Factors beyond the control of the system such as urban migration, coupled with some dissatisfaction and disconnectedness with urban primary health care services, and an apparent desire to receive an array of services in one place has put further burden on health services in particular on the hospitals. Because health services have been essentially free of charge, the health system has been exposed to the moral hazard of overuse. By international comparisons, the health system is relatively underfunded, placing a lot of pressure on health workers and the system to compromise on quality of health care services **(Dr Graham Roberts, 2011) .**

The policy of the Ministry of Health, Fiji for over two decades have relied largely on the concentration of action towards primary health care, health promotion and disease prevention to achieve health outcomes and to contain the potential for rising curative care costs. In the early 80's Fiji was quite successful in progressing towards international and domestic health objectives but has been stagnant since the 90's.

Existing evidence suggests, however, that health promotion and disease prevention services are not yet effective in reversing the trends regarding risk factors and chronic disease incidence. This is more visible in the case of an urbanizing population where the social cohesion and authority that allowed for the success of primary care in villages and settlements is no longer there to the same degree.

Few studies have been conducted to ascertain the performance of the Fiji health system as a whole. The WHO, using a defined set of criteria, ranked Fiji at 96 on the measure of overall health system performance in the year 2000. This placed Fiji on the bottom half of the international scale, but as the second highest country in comparison to other Pacific island countries.

2.1 Fiji's Strategic Goals and Objectives

The overarching goal of the government for the health sector is to provide: *quality, affordable and **efficient** health services for all.* There are three strategic objectives flowing from this goal:

I. **Strategic objective 1**: Provide communities with adequate primary and preventive health services, thereby protecting, promoting and supporting their well-being.

II. **Strategic objective 2:** Provide communities access to effective, efficient and quality clinical health care and rehabilitation services.

III. **Strategic objective 3:** Health Systems Strengthening across all sections and departments of the Ministry of Health.

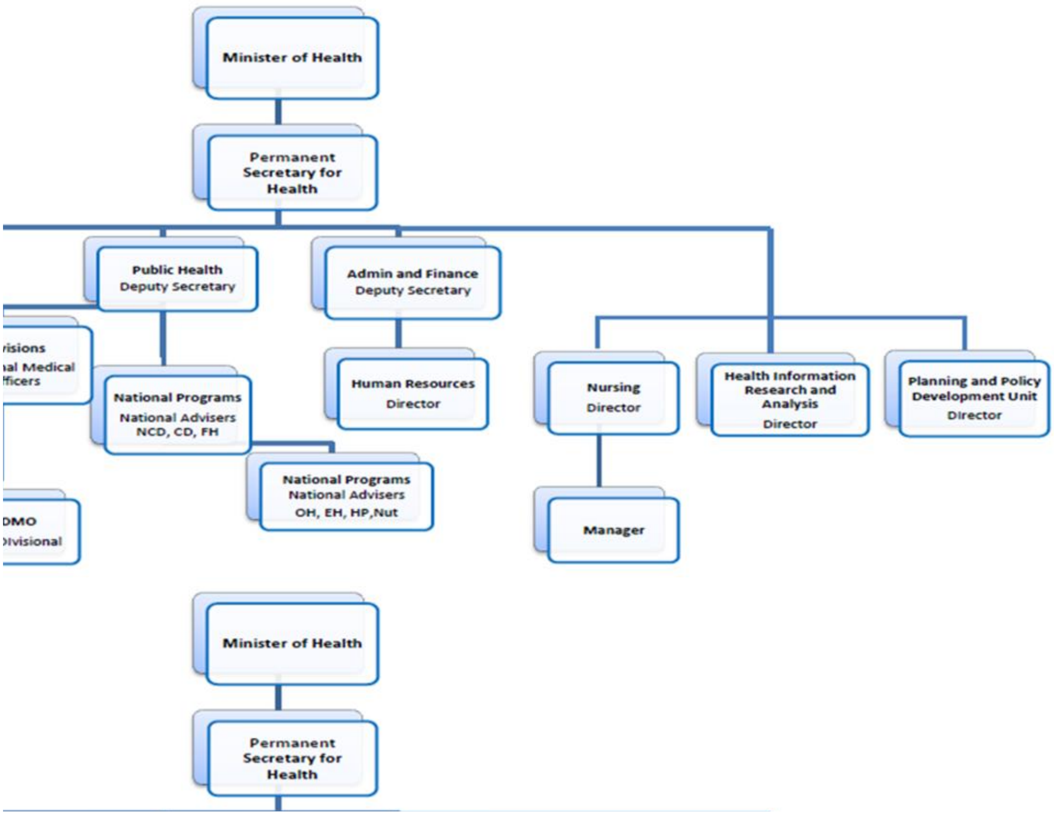
In addressing the goal and the strategic objectives of the health sector, the Ministry of Health emphasizes its strategic themes of: *provision of health services, protection of health, promotion of health, productivity in health, and people in health*.

While efficiency and productivity statement are clearly illustrated in our strategic objectives and thematic areas, no actual assessment or evaluation has been undertaken in these frontiers of our hospitals consuming most of the resources allocated through the budget.

2.2 Fiji's Current Health System

The Fiji Health system is structured as a three tier model health system that provides integrated primary, secondary and tertiary health care through health facilities located in all 4 major divisions. While service provision in terms of human resources, finance, procurement and supply of pharmaceuticals remain the priority of the central health headquarters, many of the primary and preventive and clinical services have been decentralized as per the demarcation in the Fiji Clinical Services Planning Framework 2010.

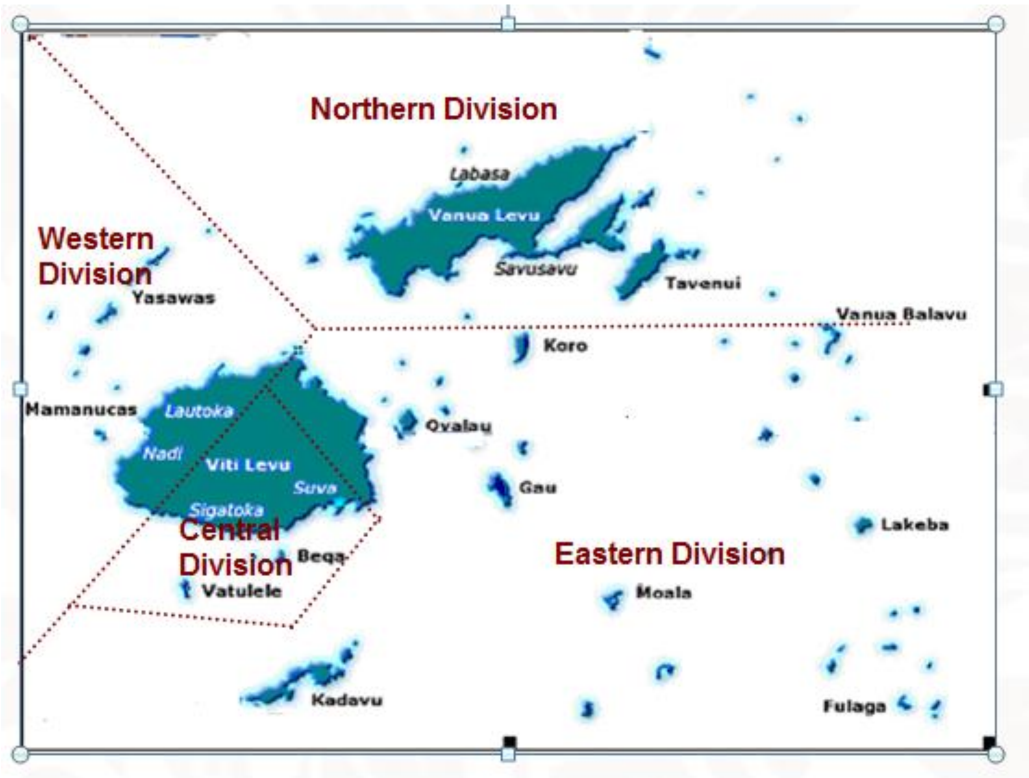
Figure 4: Organization Structure of the Ministry of Health, Fiji.



Source: Ministry of Health, Annual Report 2014.

As illustrated in the organization structure of the Ministry of Health above, which also depicts governance and service delivery structure apart from authority, the Public Health Services which are managed and administered to all the four major divisions under the responsibility of the Deputy Secretary for Public Health (DSPH) is delivered through the four Divisional Health Services in the Central, Western, Eastern and Northern parts of the island under the responsibility of the Divisional Medical Officers (DMO's).

Figure 5: Geographical Map of Major Divisions in Fiji.



Source: Ministry of Health, Annual Report 2014.

Under each division and under the responsibility of each DMO, the services are then filtered down to smaller Sub-Divisions overseen by the Sub-Divisional Medical Officers (SDMO's). Further below the responsibility of the SDMO under each Sub-Division exist several health centers and nursing stations that provide public health services and an initial point of contact with patients. These health centers and nursing stations are usually managed by a single physician or nurse practitioners.

For this study, the 17 Sub Divisional Hospitals outlined in Table 2 that is managed and administered by SDMO's, on average have 15-40 bed capacity and are equipped to provide inpatient services, outpatient services, pharmaceutical supplies, laboratory tests, x-rays, undertake minor surgeries including low risk deliveries and dental care to the population within each sub-division.

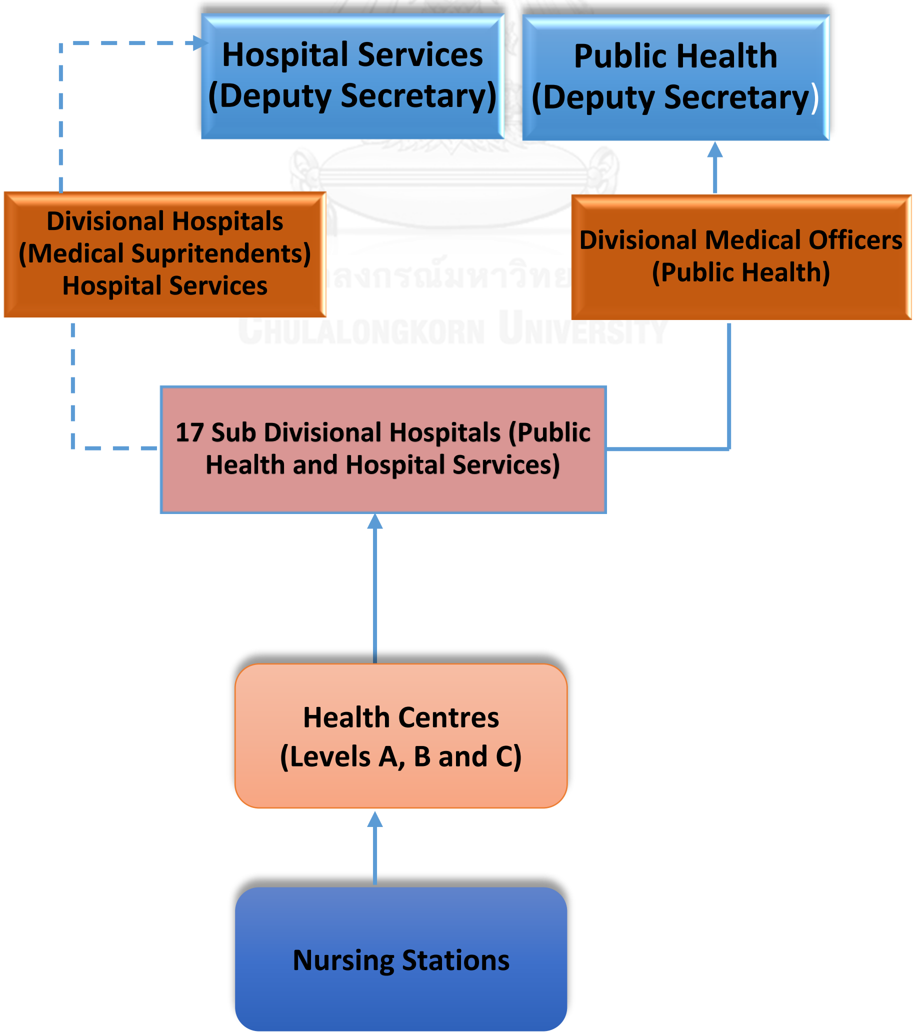
Table 2: 17 Sub-Divisional Hospital Study Group

Hospital 1	Rewa Sub Division
Hospital 2	Naitasiri Sub Division
Hospital 3	Serua/Namosi Sub Division
Hospital 4	Tailevu Sub Division
Hospital 5	Lomaiviti Sub Division
Hospital 6	Kadavu Sub-Division
Hospital 7	Lomaloma Sub Division
Hospital 8	Lakeba Sub Division
Hospital 9	Rotuma Sub Division
Hospital 10	Ra Sub Division
Hospital 11	Tavua Sub Division
Hospital 12	Ba Sub Division
Hospital 13	Nadi Sub Division
Hospital 14	Nadroga Sub Division
Hospital 15	Bua Sub Division
Hospital 16	Cakaudrove Sub Division
Hospital 17	Taveuni Sub Division

2.3 Patient Referrals Structure in Fiji

Under each of the 20 Sub-Divisional Hospitals, there are medical boundaries under which designated health centers of different levels A, B and C and Nursing stations exist. The Health Centers are usually managed by medical officer i.e a Physician in the case of level A or a Nurse Practitioner in the case of level B or C. Usually 2 nurses are allocated to either the Health Centre or Nursing Stations. In remote Nursing stations, one Nurse Practitioner is stationed to provide basic primary health care. It is also the first point of referral of patients that need further screening and treatment. Figure 2 illustrates the flow of the hospital referral system in Fiji.

Figure 6: Fijis Patient Referral System



Patients usually are seen through the outreach programs that the nurse practitioners at nursing stations are responsible for in partnership with Village Health Workers. The patient could also visit the Health Centre or the SDH if they wish to. From the Sub-Divisional Hospital they may be referred to one of the three major Divisional hospitals if required so.

2.4 Efficiency of Health Service Delivery in Fiji.

A lot of emphasis is placed on the importance of delivering health services efficiently given the declining budget allocated as a percentage to the total Government budget to the Ministry of Health, Fiji illustrated in Figure 3. Almost 70% of the total budget allocated is consumed by hospitals in the provision of curative care and a very small proportion allocated towards primary and preventive care. Trends in hospital performance indicators captured in the National Health Accounts report indicate that curative services will continue to consume a larger proportion of the budget and leave very little room for public health programs.

With a declining budget allocation, increasing cost of health care and expenditure and an increasing trend of resource consumption by hospital services of larger portion of budget allocated, it is imperative that hospital managers need to make in-depth assessment of the use of limited resources through a thorough investigation in productivity trends of the SDH's, efficiency levels and major determinants of hospital efficiency in Fiji based on the enormous data that the Ministry has tirelessly collected.

Many structural and programmatic reforms have been put in place to improve efficiency of delivery of services such as the Clinical Services Planning Framework 2010, introduction of regular audits and health system performance assessments, a structured service planning system in place to determine appropriate or effectiveness of projects and programs on clinical basis. These intiatives have provided the Ministry of Health with models of care and delineation of services by different levels of hospital clearly illustrating the nature of services to be provided including the allocation of standard staffing and equipment needs.

The challenge though remains of how Fiji can implement the recommendations of the plan within its limited resources. A key recommendation of the Decentralisation policy which came into effect in 2009 stated that all outpatient activities were to be decentralised from the 3 main referrals tertiary hospitals to its respective SDH to ease the load at the tertiary care facilities. No assessment has been made to see gather feedback on the effectiveness of the policy and issues regarding the actual implementation.

Yearly, major capital investment is made into new infrastructure and equipment's. The increase in procurement of health technologies and construction of new health infrastructures compounded by the inadequate level of funding provided towards maintenance and upgrading of health facilities have affected the production of services at its optimal frontier level. The investment in capital infrastructure and equipment also places pressure on filling the facilities with manpower to use capital and provide services.

Furthermore, the lack of a comprehensive procurement plan of bio-medical technologies, knowledge of management of service contracts of new and old equipment's, maintenance and supply of biomed parts and consumables and untrained technicians has also been affecting technical efficiency of hospitals. Under purchasing or over purchasing of equipment's also create inefficiencies in the delivery of service and wastage of limited resources.

The lack of trained and specialised hospital administrators also have an impact on the technical efficiency of hospitals in Fiji and many issues such as the low utilisation of new technologies, underutilized beds, low occupancy rate, increase in average length of stay, unavailability of right equipment's when needed due to lack of spare parts and maintenance program have led to the lower output production and wastage of inputs.

Fiji also faces the threats of developed countries attracting qualified and skilled health workers in Fiji, in particularly, our physicians and nurses who are the backbone of the health sector. The lack of pay for performance measures, clear career paths and other incentives also contributes largely towards the loss of experienced and skilful doctors thus affecting productivity and efficiency through which health services are delivered.

Shortage of doctors and nurses has always put pressure on the efficiency with which services are delivered compounded by the lack of Allied health workers. Lack of appropriate incentives, career paths and now with contractual employment of all civil servants may put further pressure on the performances of health workers to their optimal capability.

In the absence of evidence to support improvements in efficiency, most efficiency gains are the result of improved resource use by individual managers, rather than systematic changes aimed at increasing technical efficiency and improved health outcomes.**(Dr. Graham Roberts, 2011)**

2.5 Health Status

On the international front despite the challenges faced of a Beveridge health system, Fiji has still performed better domestically and internationally. Fiji does well in meeting its key health related **Millennium Development Goals** (**MDGs**) indicators compared since 2009 on the inception of the MDG's globally.

Table 3: Milleinium Development Goals (MDG's 4,5 and 6) Health Indicator Progress.

Targets	2009	2010	2011	2012	2013
Goal 4 Reduce Child Mortality					

Under 5 Mortality Rate	23.2	17.7	20.95	20.96	17.5
Proportion of 1 year old immunized against Measles	71.7	71.8	82.5	85.9	79.9
2015 – Reduce by 2/3 between 1990 and 2015 the under 5 mortality	9.3	9.3	9.3	9.3	9.3
Goal 5 Improve Maternal Health					
Maternal Mortality Ratio per 100,000 live births	27.5	22.6	39.8	59.47	19.07
2015 – Reduce by ¾ MMR between 1990 and 2015	6.75	6.75	6.75	6.75	6.75
Goal 6 Combat HIV/AIDS and other Diseases					
HIV/AIDS prevalence among 15-24 year old pregnant women					0.037

Source: Ministry of Health, Annual Report 2013.

The table above provides a snap shot of Fiji's progress towards health related MDG's 4(Reducing Child Mortality), 5 (Improving Maternal Health) 6 (Combat HIV/AIDS and other diseases).

While progress has been made by Fiji in meetings its MDG's, it is worth mentioning that programs under the MDG's are usually well supported by international donor partners thus reducing a lot of pressure off the Government.

On the domestic front, Fiji has had a bag of mix results and there are many contributory factors to this outcome. The Health outcomes are derived from Fiji's National Strategic Plan for 2011-2015. The lead and proxy indicators in each outcome provide a glimpse of what Fiji has attained. While considerable progress has been made, no assessment has been made whether the achievements have been made effectively and efficiently and where there is room to further improve on the outcomes.

Table 4: Key Domestic Health Performance Indicators

Indicator	2012	2013
Reduced Burden of NCD (Strategic Plan Outcome 1)		
Prevalence rate of diabetes (per 1000 population)	25.8	25.6
Admission rate for diabetes and its complications, hypertension and cardiovascular diseases (per 1000 admissions)	98.5	118.5
Amputation rate for diabetes sepsis (per 100 admission for diabetes and complications)	41.5	47.3
Cancer prevalence rate (per 100,000 population)	127.3	169.8
Cancer mortality (per 100,000 population)	77.80	84.0
Cardiovascular disease (ICD code I00-I52.8) Mortality rate per 100,000 population	230.62	220.1
Admission rate for RHD (1000 admission)	2.16	1.6
Begin to reverse spread of HIV/AIDS and preventing, controlling or eliminating other communicable diseases (Strategic Plan Outcome 2)		
Prevalence rate of STIs among men and women aged 15-24 years per 100000	83	55
TB prevalence rate per 100,000	30 per 100,000	2013 will be estimated by WHO in the 2014 Report.
TB case notification rate of new and relapse cases (per 100,000 population)	25	29
TB case notification of new smear positive cases (per 100,000)	13	12

TB treatment success rate	93%	2013 will be reported in 2015 as some of the cases are still on treatment.
TB death rate	3.56	3.7
Incidence of dengue (per 100,000 pop)	51.16	105.92
Incidence of leptospirosis (per 100,000 pop)	44.04	23.62
Prevalence rate of leptospirosis (per 100,000 pop)	44.0	23.62
Incidence rate of measles (per 100,000 pop)	3.78	2.08
Incidence rate of Gonorrhea (per 100,000 pop)	108.0	84.7
Incidence rate of Syphillis (per 100,000 pop)	80.41	65.59
Improved family health and reduced maternal morbidity and mortality (Strategic Plan Outcome 3)		
Maternal mortality ratio	59.47	19.07
Prevalence of anaemia in pregnancy at booking	35.8	27.1
Contraceptive prevalence Rate	35.7	38.4
Proportion of births attended by skilled health personnel	99.3	99.7
Improved child health and reduced child morbidity and mortality (Strategic Plan Outcome 4)		
% of one year fully immunized	85.9	79.9
Under 5 mortality rate/ 1000 births	20.96	17.9
Infant mortality rate (1000 live births)	15.86	13.7
Improved adolescent, health and reduced adolescent morbidity and mortality (Strategic Plan Outcome 5)		
Rate of teenage pregnancy (per 1000 CBA pop)	3.98	7.75
Number of teenage suicides	13	14

Source: Ministry of Health, Annual Report 2013.

CHAPTER III LITERATURE REVIEW

3.1 Measuring Hospital Performance

Measuring Hospital performance on efficiency of delivery of services is fast becoming an important strategy for Hospitals managers in the private and public sector. The rising costs of health expenditure, greater budgetary demands on the Government, an increased competition in the private sector of gaining market share, greater expectations and demand of services from people and many other factors are pressuring hospital managers to focus on measuring hospital performances to ensure overall health outputs and outcomes are achieved without compromising much on quality of care.

Performance evaluation in other industries facing fierce competition have taken giant steps to ensure that they stay ahead of their competitors through use of various strategies and actions that use evidences to guide their plans and decision making process. Unfortunately, the importance of such assessments in the health sector has been adopted fairly recently. While the eagerness has been from the private sector mainly due to competition, costs minimization or profit generation, many public sectors of developing countries are just realizing how important it is to have an objective assessment of hospital performance to ensure scarce resources are efficiently utilized in producing targeted outputs.

"Management in all industries is moving towards more objective assessment performance evaluation and decision making. The health care industry has however lagged behind and as a consequence inefficiencies exist. Inefficiency in itself has been one of the causes of the high cost of medical care. When prospective payment system was first introduced in the USA in 1983, the health care industry had to scramble to meet the needs of their clients due to significant decreases in re-imbursements for Medicare patients. The reaction to this was first to cut costs and avoid cases that would likely lose money but later administrators realized that the only way to keep surviving was to improve performance thus words like “benchmarking” and “best practices” was given birth to. With a strong commitment to such new objectives, the need for strong performance evaluation techniques was created. **(Ozcan, 2008)** proposes that performance evaluation based on ***optimization*** techniques and their normative structure not only creates benchmarks, but also provides information for lacking organizations and illustrates how to improve performance. This is what is needed in health care industry today.

Hospital managers could use information on hospital performances for the purpose of setting service benchmarks and best practice guidelines. In a study by **N Maniadakis, Kotsopoulos, Prezerakos, and Yfantopoulos (2009)** the outcome of a hospital performance equips hospital managers with critical information in managing hospital operations and performances. Furthermore, performance assessment also identified success variables that hospital managers could use to improve or better performances in areas that lag behind. From the perspective of policy makers’ critical facts ensures that scarce resources in health are allocated to hospitals in areas that maximize the production of health outputs generally leading to better health outcomes. The identification of key determinants of hospital efficiency allows for policy makers to implement structural reforms in areas that hinder optimal performance of hospitals.

(Magnussen, 1996) reported that there could possibly be conflicting goals between the hospital as provider and the custodian of the hospital that is the hospital owner. The differences of goals and objectives and knowledge of information between the principal-agent relationships could lead to misalignment of goals and objectives of hospitals from the owners. The measurement of performances would bring out information on hospitals that are deviating from a single goal and monitored to ensure that hospitals with deviating performances are brought on track again. Additionally, he also highlighted that policy makers or managers are able to use performance measures to allocate resources to hospitals based on efficiency and productivity scores over time.

The justification in measuring hospital performance, in particular in developing countries, to measure hospital performance and importantly in the public sector has become increasingly important.

Developing countries and small island countries in years to come would face serious challenges in improving hospital performance for several reasons.**(Jacobs, Smith, & Street, 2006)** emphasizes on the supply side where health technologies are changing rapidly, new interventions to prolong quality of life have emerged and the pressure is on the providers, in particular on Government, to introduce such new technologies and interventions without much thought put to the cost and effectiveness of the technology.

The results of the efficiency measurements are the starting point in improving health care system; these measurements identify which care delivery units can be used as models, and illustrate the areas where inefficient units need to improve**(Ersoy, Kavuncubasi, Ozcan, & Harris II, 1997).**

Political pressures further complicate such decisions and health is very easily influenced by those in power. On the demand side, as mentioned earlier, citizens understanding or literacy on health services, expectations of services based on individual's needs, challenge of longevity of having an older population require a holistic response by the health system administrators and policy makers. Ironically, the same reasons exist in the developed countries but they have long adopted performance assessment and evaluation tools while many developing and small island countries either have just started or have never heard about it.

(Grosskopf & Valdmanis, 1987) study on measuring hospital performance using non-parametric highlights that measuring productive and efficiency performance in the health sector though is a bit different given its complicated nature of the "production" process. The production process is a chain of event where inputs are invested in a production plant to extract outputs. In the health sector the conceptual output would be improve health status which is a fact very hard to measure. The alternative used nowadays is to use the production of intermediate goods which is health services as key outputs that are to be achieved in order to achieve the ultimate output or nowadays referred to as Outcomes.

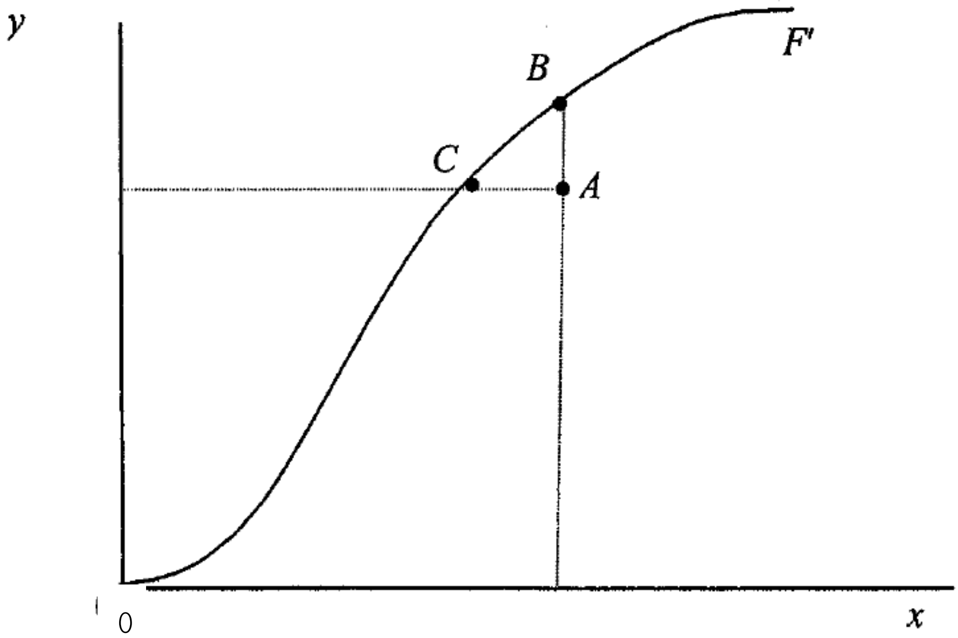
The same sentiments are reiterated by **(Chang, 1998)** in his study of determinants of hospital efficiency in the case of Central Government owned hospitals n Taiwan. As part of a good managerial control function, performance evaluations are necessary on a regular basis. The challenge is though in a non-profit sector where apart from reducing costs in order to manage resources, non-profit sectors including Government has conflicting objectives of improving efficiency without ignoring the goals of effectiveness and equity. What is more important in non-profit organization is to undertake a comparative efficiency measure of how well inputs are used to produce these services.

3.2 Theoretical concept of Productivity and efficiency

(T. J. Coelli, Rao, O'Donnell, & Battese, 2005) describes a natural measurement of performance is the ratio of outputs to inputs where larger values indicates relatively a better performing entity. The ratio is called the productivity ratio or total factor productivity if productivity measure involves all the factors of production.

Productivity = outputs/inputs

Figure 7: Production frontiers and Technical Efficiency



Source: (T. J. Coelli et al., 2005)

Over a number of years, productivity and efficiency has been used interchangeably by many academics, professionals etc. Both the concepts are very similar in its definition but the two are not the same concepts..

Line OF's represents a production frontier that maybe used to define the relationship between input and outputs. Figure 7 represents production frontier that defines the relationship between the input variables and the output variables. **T. J. Coelli et al. (2005)** provides a definition of production frontier that represents the maximum output attainable from each level of input.

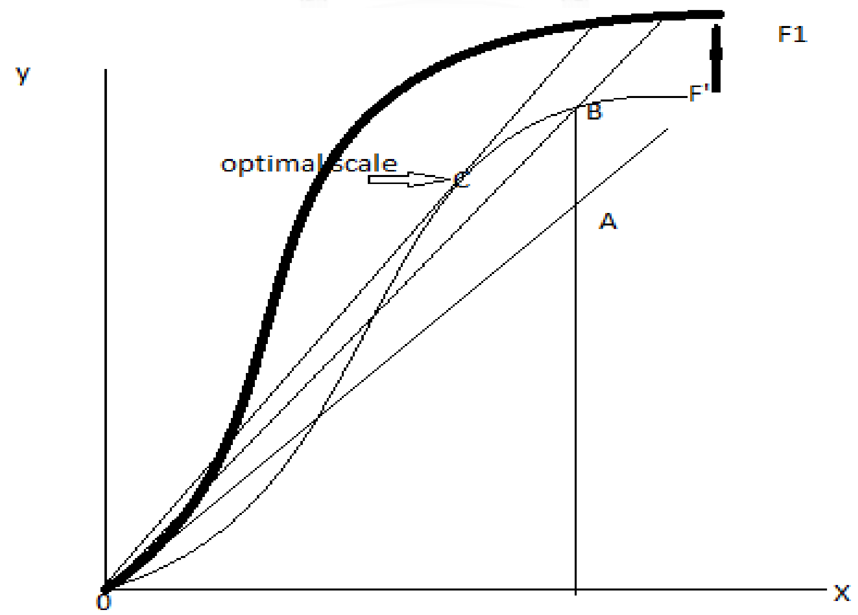
The firms that are technically inefficient are represented by **Point A** as they operate under the frontier and firms that are technically efficient are said to operate at points such as B and C that are on the frontier.

Since the study captures and measures efficiency and productivity as two different indices, it is important to graphically explain the distinction between technical efficiency and productivity.

In measuring the productivity at any point in Figure 8 below, the slope of the straight line from the origin to the production point A, B or C is represented by **Y/X.** The greater slope represents a higher productivity level point. Point C is the optimal scale at which firms needs to be producing as it is at this point where inputs are optimized to produce outputs or inputs are used to produce the maximum level of output. Any other point apart from point C would either indicate an inefficient production point as either as either a lot of input is used to produce less output or not enough input is used which intends to decrease output.

Therefore the above suggests that firms may be technically efficient but could possibly increase productivity by exploring scale economies.

Figure 8 : Productivity, Technical Efficiency and Scale Economics



Source: (T. J. Coelli et al., 2005)

If time component is brought in to measure efficiency and productivity over a certain period using panel data, an additional source of productivity change is possible which is termed as technical change. Such movement is also illustrated in Figure 8 where the whole production frontier shifts upwards from F' TO F1 could possibly be a result of advances in technology and major developments that increase the production of output to another whole new level relative to the base period.

In economics, efficiency is about a society making optimal use of scarce resources to satisfy needs & wants. There are several meanings of efficiency but they all link to how well a market allocates our scarce resources to satisfy consumers. Normally the market mechanism is good at allocating these inputs, but there are occasions when the market can fail. Developing countries where majority of the health care services are financed by government resources have more interest in assessing efficiency, or should ideally be interested but may not have the necessary data to undertake such a study.

In a study on efficiency measurement of health care: a review of non-parametric methods and applications **(Hollingsworth, Dawson, & Maniadakis, 1999)** defined efficiency or ***"technical efficiency"*** as the production of the highest level of output possible, given the technology adopted by the production firm, within the least amount of input.

(Worthington, 2004) described efficiency as having three difference categories that provided different forms of efficiency gains that could be useful for different users of such information. Firstly, hospital managers and policy makers are keen in understanding the ***technical efficiency*** of hospitals. Health care industry also consumes inputs to produce outputs. Therefore technical efficiency can be defined as the use of inputs in the most technologically efficient manner to produce outputs or outcomes in health. It is the physical relationship between resources consumed such as capital (infrastructure, labour and equipment's to produce health outputs and outcomes.

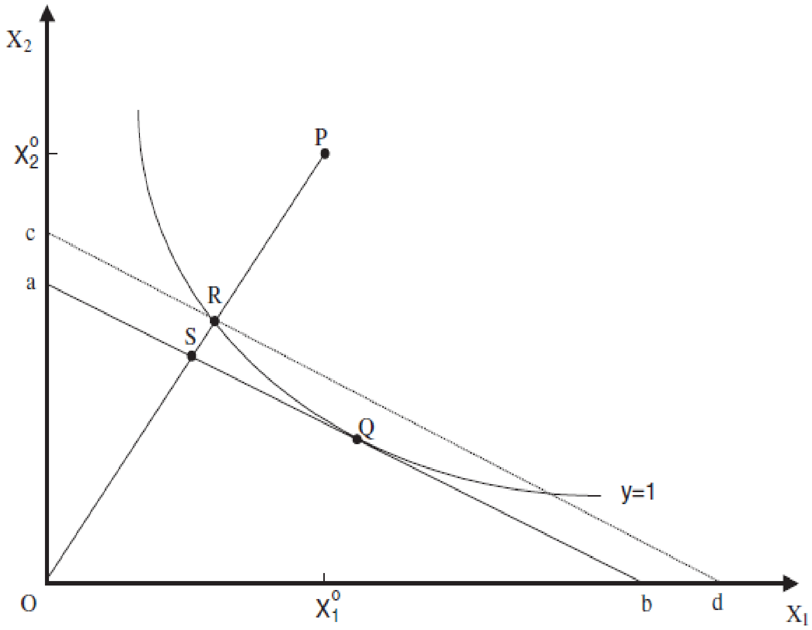
Allocative efficiency illustrates the relationship between the use of the inputs mentioned above to its optimal size given their respective prices and available production technology. The agency in achieving allocative efficiency is required to choose the best combination of inputs that are already technically efficient but would maximize the production of outputs to the maximum.

Finally achieving technical and allocative efficiency would ensure that agencies are **economically efficient**. In this situation, it is assumed that the firm is able to use the best mix of inputs to produce maximum outputs keeping inputs either constant or even if possible reducing the inputs used in producing the same level of output.

(Farrell, 1957) described efficiency as the point of production for a given level of output with the least quantity of input resources consumed or vice versa where the output production is maximized from a given set of inputs quantity. Usually the most efficient firm would be placed on the production frontier.

The diagram bellow illustrates the efficiency concepts. **(Hollingsworth, 2008)** assumes a simple case of using a single output (Y) being produced from two inputs, X1 and X2.

Figure 9 Technical and Allocative Efficiency with 2 input variables under Constant Returns to Scale



Source: (Hollingsworth, 2008)

The **production function** or frontier commonly used in economics is the convex curve represented by **Y=1**. All points sitting on the curve such as R and Q represents a different technically efficient combination of inputs used to produce the maximum level of outputs. Since **Y** is dependent on the combination of and magnitude of inputs used, it is said the output is a function of input. Mathematically, it is illustrated as an equation ***Y=f*(X1, X2).**

For simplicity, it is assumed that the production function is linearly homogenous meaning that the returns to scale are constant but in reality increasing or decreasing rate of returns is possible.

To explain the technical efficiency we take an example of a firm producing at point P where input mix consumed to produce output at **P** is (x_1^0, x_2^0). The output produced at **P** is technically inefficient as to produce maximum output on the isoquant line of **Y=1**, the firm could produce at point R using less of the same input quantities.

Therefore **technical efficiency** at P is:

$$TE = \frac{OR}{OP} \ (0<TE<1)$$

Since the efficient firms on the isoquant curve is equal to 1, the inefficient firms would be less than 1 but greater than 0. The more inefficient the firm, the more smaller or closer to zero would be the TE score.

Firms, and even in the health sector, apart from maximizing production of outputs, health administrators also focus on the objective of minimizing costs. The **cost function** mathematically describes that output Y is a function of the relative rice of X1 and X2 i.e ***Y*=*f*(Price X1,X2).**

The diagram above shows that given that relative price of the inputs are known then we could plot the isocost line. The cost minimization point under the isocost line of **ab** is at point **Q**. At point **Q**, the firm is able to minimize cost yet maximize production of output on the isoquant curve where Y=1 or efficiency is at its maximum.

Say if firm **P** is required to be technically efficient, it is required to move to point R where the production is at its maximum i.e Y=1 but on a higher isocost curve of **cd.** Therefore unit P needs to move to point S as R may not be a cost minimization point as it is on a higher isocost line of cd and therefore use input mix corresponding at point S.

Therefore **allocative or price efficiency** is:

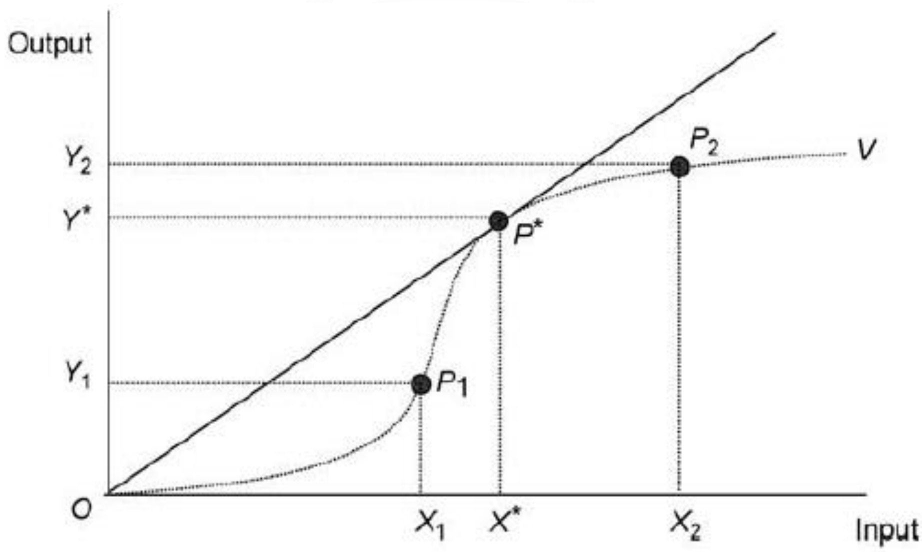
$$AE = \frac{OS}{OR} \ (0<AE<1).$$

Relaxing the assumption of constant returns to scale **by (Charnes, Cooper, & Rhodes, 1978)** in measuring efficiency, the production and cost functions could also explore the optimal point using a Variable Returns to Scale **(VRS).**

The assumption was extended to a variable returns to scale by **(Banker, Charnes, & Cooper, 1984)** . This assumption is practical; in particular in developing small island countries where market failures exist at a substantial scale and largely health care is funded in competition with other sectors leaving very little room for substantial increases in budget. Sub optimal funding or regulatory constraints, lack of competition limit the providers in delivering services at efficient scales.

The diagram below illustrates a simple example of a production frontier assuming a variable returns to scale (VRS) of a single input X in producing a single output Y.

Figure 10 : Scale Efficiency using single input and single output under Variable Returns to Scale



Source: (Hollingsworth, 2008)

OV represents the production frontier curve which represents increasing and decreasing returns to scale. At the start of a production line, due to the gains from larger economies of scale (as a result in increase in volume of production) and decreasing fixed costs, firms will experience an ***increasing returns to scale*** until the point where the marginal cost of producing an additional good is equal to the marginal benefit and any production beyond the optimal point where MB=MC would yield a ***diminishing returns to scale***.

In the figure above, as the firm increases production from 0 to P1 , they experience an ***increasing returns to scale*** as an additional output still provides additional benefit until the production reaches P*. The optimal scale of production is reached at P* as the ratio of output to input is maximized. Here the marginal benefit of an additional product is equal to the marginal cost with ***constant returns to scale***. Beyond P* to points such as P2, the firm experiences a ***decreasing returns to scale*** as more input is used to produce an additional output and is not economical.

The **Scale efficiency** ratios would be lower than 1 for points P1 and P2 as they are operating either below or above the optimal production point. The Scale efficiency therefore is the reduction in unit costs available to a firm when producing
at a higher output volume.

Therefore scale inefficiency is calculated by:

$$\textbf{Scale Efficiency P1} = \frac{OY1/OX1}{OY^*/OX^*} \quad \textbf{and} = \frac{OY2/OX2}{OY^*/OX^*}$$

The Output of P1 relative to input of P1 divided by the optimal point input output mix provides the scale efficiency of P1 and would provide similarly for P2.

3.3 Measuring Hospital Productivity and Efficiency

A number of methods exist in measuring hospital productivity and efficiency today. The methods allow a comparative analysis of performance amongst or within similar decision making units. Policy makers and hospital administrators could use such information for policy decision making, appropriate capital investment decisions, objective means of allocating resources and monitoring and evaluating any deviation of actions against targets as per the plan.

(Wang, Ozcan, Wan, & Harrison, 1999) proposes that there are three fundamental questions hospital managers must ask to measure hospital efficiency. What combination of hospital goods and services will be produced with the limited amount of resources allocated to hospitals, how they will be produced and in what quantity that will obtain the maximum value in terms of consumer well-being.

(Hollingsworth et al., 1999) undertook a review of non-parametric methods and applications commented that in order to measure efficiency or productivity, information of the production and cost function frontier is needed.

While the above study focused on non-parametric methods, as an extension to the study, **(Worthington, 2004)** explored the parametric programming function method. There was a general agreement as well that while measuring efficiency, knowledge is required of the frontier estimated by using a sample data of targeted firms under study. The frontier is formed by the most efficient units from the sample data and reflects those decision making units that are able to utilize either the least amount of input resources to produce a certain quantity of outputs or alternatively produce maximum output for a given amount of input.

Table 5 Analytical methods to efficiency and productivity measurement

	Parametric	**Non-Parametric**
Deterministic	Parametric mathematical programming Deterministic (econometric) frontier analysis	Data Envelopment Analysis (DEA) Malmquist Productivity Index.
Stochastic	Stochastic (econometric) frontier analysis	Stochastic Data envelopment analysis

There are two main approaches to efficiency and productivity measurement are discussed in detail by **(N Maniadakis et al., 2009)**.

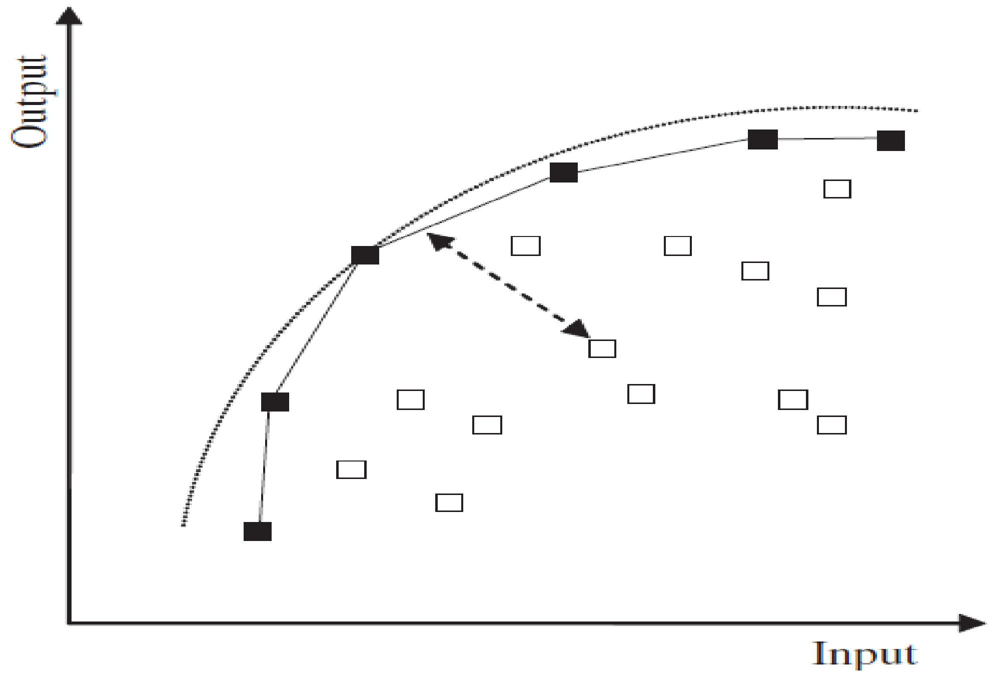
I. The econometric approach - are also called **stochastic** as the model also makes room or accommodates and accounts for random noise or error term in the sample data. The model also assumes a specific functional form for the frontier and therefore is termed Parametric.

II. Mathematical Programming – the mathematical programming approach in measuring efficiency and productivity could take either a Parametric or a Non-Parametric form. While the parametric form, similar to the econometric approach takes a functional form, the non-parametric form as the name defines does not need any assumption of take a functional form but takes assumptions of the shape of the frontier such as convexity and non-emptiness. Unlike the stochastic model, mathematical programming does not take into account for error terms or data errors. It assumes that the data collected are comprehensive complete and reliable.

A comparative analysis of 38 frontier efficiency and measurement techniques studies were reviewed by **(Worthington, 2004)**. The results revealed that **58** percent of the decision making units employed a **non-parametric techniques** with the remainder using **parametric techniques**. In his conclusion, there were no clear or outright statement made on which of the two approaches were better of as they both had its share of drawbacks.

While the study does not conclude on the popular approach, the non-parametric mathematical programming approach is the most popular in hospital efficiency and would be used in my thesis study thus more detailed information is provided next.

Figure 11 Mathematical Vs Econometric Formulae



Source: (Worthington, 2004)

The above diagram illustrates the difference between the mathematical and econometric approaches to production frontiers and efficiency measurement. The above diagram uses a simple single input (x) and single output(y) to represent the two methods.

In the mathematical programming approach, the frontier with a solid black line represents the use of observation of production of output y using input x. This means that the approach is data based and relies on observations of various input variables that are put into a production process to get some health output y. Using the data, the frontier is constructed. Some DMU's will fall on the frontier marked as the black filled boxes. Organizations that have unfilled boxes meaning those that are not producing at optimal scale would be compared and assessed against those DMUs on the frontier using some standard performance measures.

In the econometric approach, a parametric function is fitted to the data represented by the ***curved dotted line*** but it is not necessary that some firms will fall on this line although one does here.

The main difference between the two models revolved around the method of constructing the frontier and the different assumptions accommodated by the approaches.

3.3.1 Productivity Measurement

DEA has become one of the most preferred tools in measuring the performances of many large industries that consume multiple inputs in order to produce multiple outputs. The Health sector is no different as multiple inputs are used in treating patients at different levels of treatment to improve overall wellbeing of patients.

The name DEA itself defines the function of the tool because it envelopes or provides a frontier to all the observations from the data to assess which Decision Making Units are efficient and which ones are inefficient.

In DEA, the targeted populations that are observed or studied are referred to as "**Decision Making Units**" hereafter to be referred as DMU. **DMU's** is any firm or agencies that are usually characterized with having to use similar inputs in producing similar outputs. The evaluation of DMU's using DEA provides policy makers and hospital managers with scores of each DMU that represents the magnitude of efficiency.

Not only does the score represent the level of efficiency of each DMU, it also represents the sources and amount of inefficiency either in the consumption of input or the production of outputs. The score representing the efficient firms is located on the frontier. Those located on the frontier are considered the efficient hospitals relative to other hospitals in the study group. The efficient hospitals are then considered as "benchmark" hospitals to which inefficient hospitals need to make improvement on to move towards the frontier.

Coelli et.al 1998 defined ***DEA as a linear programming model*** used to measure technical efficiency. It comes up with a single scalar value as a measure of efficiency. Efficiency of any firm can be defined in terms of either output maximization for a set of inputs or input minimization for a given output. In DEA, relative efficiencies of a set of decision making units (DMU's) are calculated. Each DMU is assigned the highest possible efficiency score by optimally weighing the inputs and outputs. DEA constructs and efficient frontier composed of those firms that consume as little input as possible while producing as much output as possible. Those firms that comprise the frontier are efficient, while those firms below the efficient frontier are inefficient. For every inefficient DMU, DEA identifies a set of corresponding benchmark efficient units.

The DEA approach is a non-parametric linear programming model that uses data to build a frontier using multiple inputs and multiple outputs of Decision Making Units (DMU). The model was developed by **(Charnes et al., 1978)** using the Constant Returns to Scale model and was later expanded in a study by (**Banker et al., 1984)** using the Variable Returns to Scale Model.

"The DEA approach does not need to a prior assume weights on multiple inputs and outputs of a hospital. It also has the characteristic of unit invariance, so that we can calculate multiple inputs and multiple outputs of hospitals into both the numerator and denominator of the efficiency ratio without conversion to a common dollar basis" **(Hu & Huang, 2004).**

An extension of the DEA, the MPI index is also based on input and output data. The ability to compare results over different periods provides insights into the success or failure of health programs and activities. Popular Index measures such as Laspeyers, Paasche, Fisher and Tornqvist and Malmquist are index numbers that have been used by economists, policy makers and analysts to measure the change in productivity levels over a period of time and involves the measurement of the consumption of inputs in producing outputs(**Jacobs et al., 2006)**

Apart from Malmquist index measures, other index numbers require the information on quantity and price as well as supplementary assumptions on structure of technology and behaviour of producers. Malmquist index on the other hand only requires data on input and output quantities.

The Malmquist index was first introduced and suggested by Malmquist in 1953 and extended into a productivity index by Caves, Christensen and Diewert in 1982. The model was then further developed by Fare, Grosskopf and Lowell in 1994 as the Malmquist-DEA performance measure.

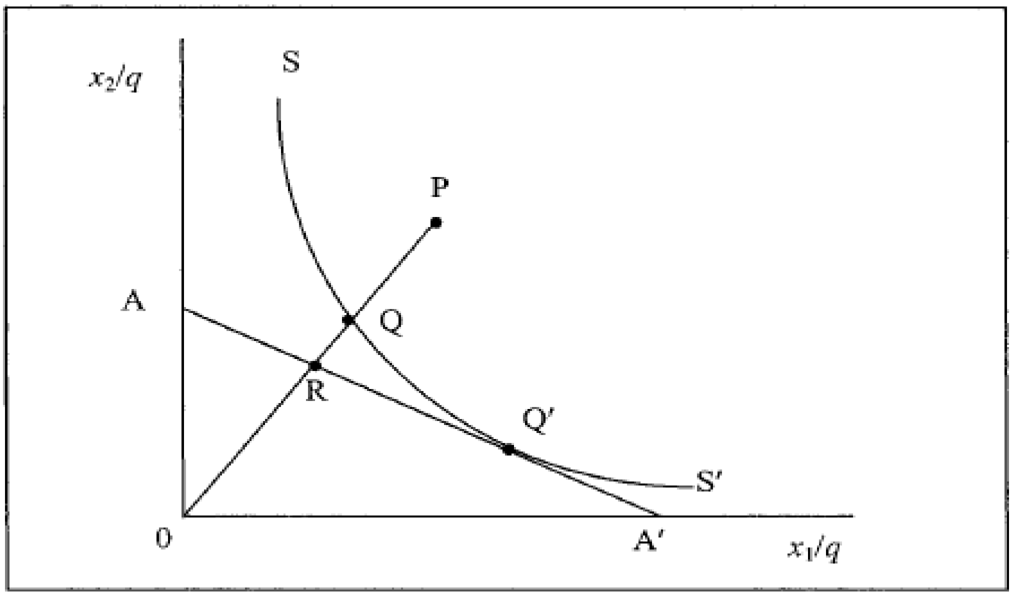
3.3.2 Efficiency measurement

(Farrell, 1957) developed a simple measure of efficiency that could account for multiple inputs. He proposed that the efficiency levels of an agency could be demarcated into two different efficiency measurements namely, technical and allocative efficiency. The two measures are then combined to provide a measure of total economic efficiency.

The following section outlines two commonly used methods of measuring efficiency.

1. **Input Oriented Measures** – The input oriented efficiency measurement method illustrated graphically below is an example of a firm that uses two inputs ($\times\, \mathbf{1}\ \boldsymbol{and}\ \times \mathbf{2}$) to produce a single output **(Chen & Ali).** A constant Returns to Scale assumption is assumed.

   Figure 12 Technical and Allocative Efficiencies from an input Orientation

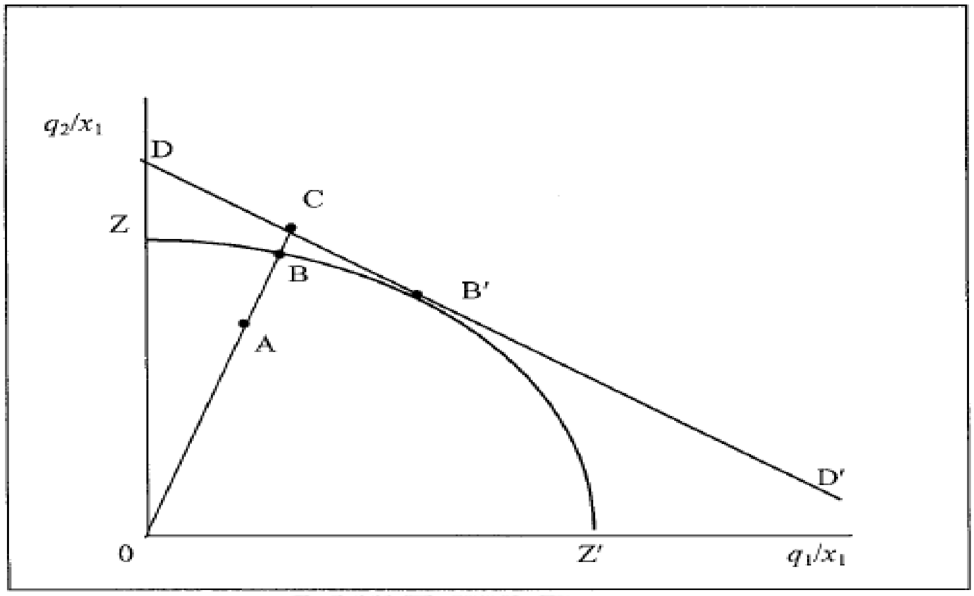


   Source: (T. Coelli, 2008)

   Fully efficient firms in the figure are illustrated by the isoquant line SS’. The technical inefficiency of the firm producing at P is represented by the distance of QP, which is the amount by which all inputs could be reduced without a reduction in output. The ratio method commonly used in measuring technical efficiency is TE = OQ/OP.

2. **Output Oriented Measures** – the output oriented model provides insights into the question of “By how much can output quantities be proportionally expanded without altering the input quantities used?

Figure 13 Technical and Allocative Efficiencies from an Output Orientation



Source : (T. J. Coelli et al., 2005)

Efficiency measurement from the output oriented approach discussed by Farrell investigates the magnitude of how much we need to increase health output without requiring extra input.

Assuming a Constant Returns to Scale, the above figure illustrates an output oriented measure by considering the case of two ouputs (q1 and q2) and a singly input. The production possibility curve is labelled as ZZ' and point A as the inefficient firm in this example. Since ZZ' represents the upper bound of the production possibilities, all inefficient firms would be operating below the curve, including point A.

1. **Technical efficiency** ratio measured in the output oriented model would be defined as follows: TE = OA/OB
2. **Allocative efficiency** given price information of inputs would be defined as AE = OB/OC

3.4 Previous Studies on Hospital Productivity and Efficiency Measurement

There has been extensive body of literature that has examined the performance of the health care sector. These studies have focussed on different methodologies of measuring efficiency and productivity using the frontier techniques. While a lot of studies have been carried out by developed countries, developing countries are now following suite given its strength in providing management with well informed decision making strategies in view of resource constraints.

The studies in different sectors have mainly been carried out in countries such as Vietnam, USA, UK, Austria, Canada, Brazil, Greece, Ireland, China, Taiwan and Botswana.

(Linh Pham, 2011) examined the relative efficiency and productivity of 101 hospitals in Vietnam during the health reform process. Data from the years 1986 to 2006 was collected for the study. The DEA method under an input oriented variable returns to scale approach was used to calculate efficiency scores. The Malmquist total factor productivity index approach was employed to calculate productivity of hospitals. The results indicated that there was an overall increase in technical efficiency by 11 percent between the periods of the study. The productivity of hospitals was also checked. The results reflected a 1.4% progress in productivity of hospitals due mainly to the improvement of the technical efficiency change in Fiji.

In identifying the total factor productivity growth of hospitals in Ireland, **(Gannon, 2008)** used a nonparametric approach. The objective of his study was to analyse the development of productivity growth and efficiency in the production of hospital care in Ireland from 1995 to 1998. The Malmquist Productivity Index was used to analyse technical efficiency over time. On average both the technical efficiency and productive efficiency change could be measured by the same case. Results showed that efficiency and technological change contributed to higher levels of productivity in larger hospitals and lower levels in smaller hospitals.

(Burgess Jr & Wilson, 1995) evaluated and examined the efficiency of hospitals in USA from four major ownership styles of local government, non-profit, profit and Veterans Affairs that are usually found in the USA. Data from 1985 to 1988 was used for such analysis. They also used the distance function to measure Malmquist indices of productivity change, which are further decomposed into efficiency change indices and technology change indices. Results indicated that changes in inefficiency due to changes in technology determined in most cases the changes in overall productivity.

Similar methodology was applied by **(Chen & Ali, 2004)** in the Computer Industry in USA using data from 1991 to 1997. The methodology of the project involved similar use of DEA measure of relative efficiency and measure of productivity change over time using the Malmquist Productivity Index.

In United Kingdom, **(Nikolaos Maniadakis & Thanassoulis, 2000)** used the Malmquist productivity Index to evaluate the performance of acute hospitals in the UK over the period after the National Health Service was introduced in 1991. DEA was used to measure technical efficiency and Malmquist Productivity Indices which gave insight into hospital performance. It was found that productivity regressed in the first year of the implementation of the reform and later progressed. Progress in productivity was attributed to the overall efficiency progress.

In 1997, the Austrian government implemented the hospital financing reform in order to improve the efficiency with which tasks are performed. The reform according to (Sommersguter-Reichmann, 2000) were expected to reduce the inefficiencies with which hospital care was delivered in Austria. The methodology used is the same where DEA using input based Constant Returns to Scale is calculated and decomposed into pure technical efficiency change, scale efficiency change and technology change. The results illustrated considerable positive shift in technology between the periods of financing reform.

A similar financing reform was implemented in the Brazilian teaching hospital. The study by **(de Castro Lobo, Ozcan, da Silva, Lins, & Fiszman, 2010)** evaluated the performance and productivity changes of these respective hospitals using the data for the year 2003 and 2006, that is before and after the financing reform was implemented in 2004. The results from using the Malmquist Productivity Indices indicated improvement in the technical efficiency. Technological change did not infer a shift of the production technology.

There is a dearth of literature when it comes to productivity measurement of public hospitals. One such study was undertaken of the Greek Public Hospitals. **(Dimas, Goula, & Soulis, 2012)** proposed to evaluate the productive performance of 22 Greek Public hospitals for the period 2003-2005 and decompose the changes as technical efficiency change and technological change. Malmquist indices and DEA wa employed to measure and decompose productivity and Tobit multivariate analysis to determine which factors influenced hospital productivity. As an outcome of the methodology employed, productivity changes were dominated by technical change while inefficiencies were attributed to the excessive increase of hospital expenditure.
Turkey introduced and initiated the “Health Transformation Programme” (HTP) in 2003 to align its health care to the European Union and OECD Countries. **(Sulku, 2012)** proposed to study the impact of these reforms on the efficiency and productivity of public hospitals. The DEA was employed and the Malmquist index

to examine and compare before and after reform years. As a result of the analysis, it was apparent that the HTP reform had generally boosted the productivity due to advancements in technology and technical efficiency but in provinces with a lower socio-economic activities, productivity gains were minimal or poor.

(Ng, 2011) investigated the inefficiency of Chinese hospitals using the DEA and Malmquist Productivity Index. Health Care reforms over the years had brought about some unnecessary provider behaviors that made the system inefficient. While the challenges were highlighted, no systematic analysis to identify determinants was ever done. This particular study aims to identify the determinants of inefficiency and productivity in the Chinese hospitals before and after the reforms. While the results found that technological progress was the underlying factor of productivity improvement, it also led to the inefficiencies over the period of the study.

Closer to home, literature on developing countries undertaking such studies is very limited. In 2010, the Government of Botswana undertook a study to measure productivity of non-teaching hospitals. **(Tlotlego, Nonvignon, Sambo, Asbu, & Kirigia, 2010)** undertook a study measuring the performance of 21 non-teaching hospitals over a period of 2006-2008. The DEA was used to analyze technical efficiency along with the DEA-based Malmquist productivity index. The analysis revealed that on average over 70% of the hospitals were run inefficiently over the period of the study. Furthermore, productivity had declined by 1.5%, a produce of an increase in technical efficiency change of 3.1 percent and a decrease in technical or technological change of 4.5 percent.

Whilst there is abundance of stand-alone literature on countries that have undertaken some form of measurement of hospital efficiency, there is generally a lack of a collective study investigating all countries that have used production and cost frontiers and econometric and mathematical modelling in measuring hospital efficiencies.

In identifying the total factor productivity growth of hospitals in Ireland, **(Gannon, 2008)** used a nonparametric approach. The objective of his study was to analyse the development of productivity growth and efficiency in the production of hospital care in Ireland from 1995 to 1998. The Malmquist Productivity Index was used to analyse technical efficiency over time. On average both the technical efficiency and productive efficiency change could be measured by the same case. Results showed that efficiency and technological change contributed to higher levels of productivity in larger hospitals and lower levels in smaller hospitals

A study in 2008, **(Hollingsworth, 2008)** reviewed collectively 317 published papers on countries that used frontier efficiency measurements. Pre-dominantly majority of the studies on hospital efficiency have been undertaken in USA since the 1980's. The number of studies has increased substantially over the years and so has methods developed with time.

While the preferred option has majorly been towards using a non-parametric approach, the use of parametric approach of using stochastic frontier analysis has gained much interest internationally.

Given the difference in the structure of the hospital systems in USA and other European and African developed or developing countries that have used one of the two methods of measuring hospital efficiency, there is a dearth of such studies in the Western Pacific part of the World, particularly amongst the Pacific Island Countries.

Regardless, many developing countries in the Sub-African region, Asia and small European countries with similar health services structure and similar health problems and issues as compared to Fiji, have started using the tools and techniques available to begin with the process somewhere.

Though the studies are not as in-depth as the studies from USA and other European states, the use of such tools and techniques would be beneficial for developing countries in their attempt to minimize health care expenditure through improvement of productivity of the inputs employed in increasing the output levels.

A total of 6010 hospitals were identified to be used in the analysis of American hospitals by **(Wang et al., 1999).** Using the DEA, a longitudinal study of hospital efficiency was conducted on all hospitals. As a result of the analysis, larger hospitals generally demonstrated higher inefficiency.

The Government in Kenya in 2002, driven by the motivation of envisioning inefficiency of its Public Hospitals as an **immoral** and **unethical practice** where there are leakages and its citizens are denied additional opportunities to improve health and health services at no costs, decided to undertake a study on measuring Technical Efficiency.

The study objective of **(Kirigia, Emrouznejad, & Sambo, 2002)** was to identify and eliminate inefficient hospitals through the measure of technical and scale efficiency of individual hospitals and the magnitude to which input reductions were needed to ensure inefficient firms moved to the efficient frontier hospitals. A better understanding of the determinants of the efficiency in their hospitals would ensure Policy makers are aware of areas that needed urgent attention in inefficient hospitals.

(Kirigia et al., 2002) used the **Data Envelopment Analysis (DEA)** tool in measuring the technical and scale efficiencies of multiple output and input variables. Inputs included human resources for health categorised by the doctors, pharmacists, dentists, nurses and other clinical and administrative staffs. Operational expenses were also used in particular related to drugs specifically and non-drug procurement such as maintenance expenses, food and as capital, the number of beds was used as a measure of hospital size. Output chosen depicted similar core activities undertaken at the public hospitals that consumed majority of resources such as OPD visits, special care visits, Maternal & Child Health activities, Inpatient admissions, and paediatric and maternity ward admissions.

The DMU was a sample of 54 public hospitals that represented 55% of all public hospitals in Kenya. Based on the objective of reducing inputs in order to improve efficiency of hospitals, an input-oriented DEA model was used under the assumption of a Constant Returns to Scale (CRS) and later the assumption was relaxed to calculate technical efficiency under the Variable Returns to Scale (VRS). Scale efficiency was derived by dividing the CRS TE Score over the VRS TE Score.

The Government of Ghana had a different motivation in measuring hospital efficiency. Structural and organisation health reforms in improving efficiency in health care were implemented by the Ghanaian Government, yet similar to Kenya no measure hospital efficiency has ever been undertaken to evaluate the impact of the programs on hospital and health centre efficiency.

The objective of the study by **(Osei et al., 2005)** similar to the previous study by Kenya; was to estimate the technical and scale efficiency of a sample of public hospitals and health centres and determine and recommend to policy makers areas where interventions may be required.

A DEA approach was also applied to input and output variables at hospital and health centre level. The approach chosen was also based on the ability of DEA to measure relative efficiency of decision making units that have multiple inputs and outputs. An input-oriented DEA model was used as the Government of Ghana believed that it had better management and control over the use of its inputs. However, an output oriented model was used for health centres as the management at health centres had a greater influence in increasing outputs with minimal control of inputs which was centrally controlled by the Ministry of Health, Headquarters.

Another south-western African nation, Angola, attempted to study the performance assessment method for hospitals. (Kirigia, Emrouznejad, Cassoma, Asbu, & Barry, 2008) points out that a high percentage of Angola's recurrent budget under the Ministry of Health is spent on operational expenses of the fixed health care facilities yet no studies have been undertaken in Angola health system. The factors driving the study are similar to many other African countries. Multifactorial reasons exist such as limited resources resulting in lower productivity, brain drain of medical health professionals etc. Similarly, the DEA method was used to measure the input and output variables impact on technical and scale efficiency. Productivity change was measured by the Malmquist productivity index (MPI). In comparison to other African states undertaking similar studies with similar methodologies, the efficiency scores in Angola was lower than those reported in other countries.

A study of the technical efficiency of 573 Turkish hospitals was undertaken during the period 1994 by **(Ersoy et al., 1997).** The study used the Data Environmental Analysis (DEA) to examine the technical efficiency of these acute general hospitals using resources from you. Results indicated that less than 10% of Turkish acute general hospitals operated efficiently.

(Al-Shammari, 1999) used a multi-criteria DEA methodology to measure and evaluate the productive efficiency of hospitals in Jordan. The major focus of the study was to develop a baseline of efficiency and inefficiency level and the efficiency reference set for the relatively inefficient hospitals. As a result, more than 50% of the total 15 hospitals were found to be inefficient.

CHAPTER IV CONCEPTUAL FRAMEWORK

The study has been demarcated into in 2 different stages in view of the general and specific objectives that is to be achieved.

Stage 1 of the study employs the DEA extended Malmquist Productivity Index method of measuring productivity changes of the DMU's at different points of time. The ability of the MPI to decompose these productivity changes by the source of the productivity change and further defining the total productivity change into technical efficiency change and technological change provides policy makers and analysts to target reforms for improvement at the source of the issue rather than just on the tip of the iceberg. The availability of complete and comprehensive panel data from 2005-2014 for the inputs and outputs chosen also influenced the use of the MPI.

Within stage 1, similar to the normal DEA method, the indices or coefficients of MPI will be used as a dependent variable and regressed against factors that are hypothesized to have a strong effect on hospital efficiency and productivity. While there is a dearth of literature on the use of an appropriate econometric regression model for MPI coefficients, the use of ***Log Linear functional*** model is employed in this study.

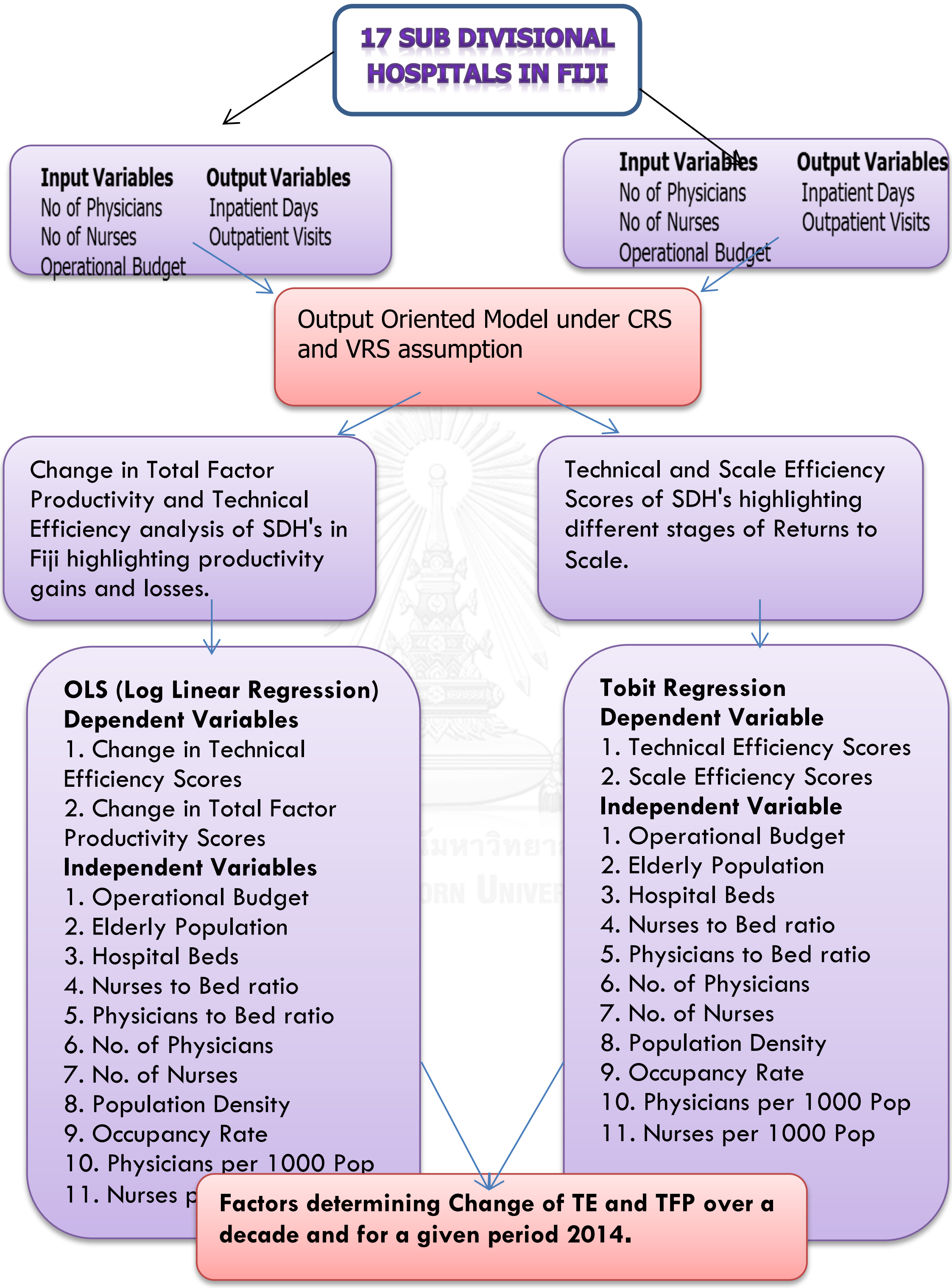
The **second stage** is to measure the technical and scale efficiency of all sub-divisional hospitals in Fiji with the Data Envelopment Analysis (DEA) using an input oriented approach of the most recent data available for variables chosen. The input oriented model is chosen as in Fiji and similar to many developing countries perhaps it is easier to control limited inputs and maximize outputs as much as possible.

The TE and SE scores would be evaluated using a Constant Returns to Scale and Variable Returns to scale in order to assess if inefficiency is a managerial issue or size factors such as number of beds or number of physicians that may actually be the cause. The outcome of the analysis would indicate scores of which sub-divisional hospitals are technically efficient under constant return to scale assumption, pure technical efficiency or technical efficiency under variable returns to scale and the scale efficiency scores.

Within the second stage the efficiency scores would then be employed similar to Stage 1 as dependent variable and regressed against the same factors or variables that may determine hospital efficiency. This stage identifies variables that affect hospital efficiency and will use a ***censored Tobit regression model***. In the regression analysis the technical efficiency scores under variable returns to scale and scale efficiency scores are treated as dependent variables and x number of independent or explanatory variables will be regressed to test our hypothesis and better understand which factors influence at what magnitude the technical and scale efficiency for policy implications.

The conceptual framework below illustrates the framework and stages of the study to be carried out.

Figure 14 Conceptual Framework



CHAPTER V

RESEARCH METHODOLOGY

5.1 Design of Study

The study is designed to provide a platform for policy makers and researchers wishing to use the information and methodology captured as a groundwork of measuring efficiency and productivity at any facility level depending on the availability of data.

While there is a lot of literature available on the measurement of efficiency and productivity in hospitals, the study provides a simple foundation of information that researchers would need to consider before other variables are incorporated in the analysis.

The study uses secondary **longitudinal data** that are recorded in the centralized Patient Health Information System (PATIS) and the Public Health Information System (PHIS) installed in all 17 Sub-Divisional Hospitals (SDH) that are part of the study. While literature acknowledges that qualitative measures are just as important to evaluate hospital efficiency and productivity, it is quite challenging to gather such data within time and resource constraints of the study.

The **first stage** of the descriptive quantitative study will be focusing on using the Non Parametric Malmquist Total Factor Productivity Indices. This methodology is an extension of the normal Data Envelopment Analysis (DEA) Computer Program Version 2.1.

(T. J. Coelli et al., 2005) defines Malmquist index as using distance functions. Distance function allows one to describe a multi – input, multi – output production technology without the need to specify a behavioral objective. An input based distance function approach categorizes the production technology by minimal input use for given output. An output distance function considers a maximum production of output within a given input level.

The MTFPI is an appropriate tool or software used when panel data is available. A comparison against a parametric method will be discussed in later section. For the MTFPI the input and output variables from 2005-2014 for all 17 DMU's would be used. Literature also indicates that the indices reflecting technical efficiency change and total factor productivity change are usually used in appropriate econometric regression functions. The indices would then be used as a dependent variable to be regressed against key independent variable using a Log-linear functional model under the Ordinary Least Square. This is intended to inform policy makers which variables are significant determinants of hospital efficiency and productivity and whether the influence is more of an internal or external issue.

The **second stage** of the study design measures technical and scale efficiency through the use of an input oriented DEA multi stage approach under a Constant Returns to Scale and a Variable Returns to Scale. The most recent data (2014) is used for the input and output variables. Similarly to stage 1, the Technical Efficiency Scores would be used as a dependent variable and regressed against explanatory variables to determine key variables that could affect hospital efficiency and productivity. The most recent and single year data is used for multi stage DEA as it measures performance in a singular time period and not over a span of more than 2 year. The Tobit econometric model is employed understand the factors that determine hospital efficiency entirely for 2014.

5.2 Target and Study Population

The targeted population as part of the study includes all Government owned sub-divisional hospitals in Fiji. All 17 hospitals have been in existence since the period of the study.

The National Health Accounts report for 2011-2012 findings on hospitals revealed that out of 68.2% of total expenditure, Sub-Divisional accounted for approximately 30% of Government current health expenditure and the balance consumed by the 3 major referral tertiary care hospital and two specialized hospital. As a proportion of the total expenditure on hospitals, SDH consume more given greater number of facilities (17). Furthermore, specific capital funding is allocated to all 17 SDH for the upgrading and maintenance of facilities and institutional quarters and also procurement of general and critical bio-medical equipment's.

The SDH hospitals service roles are clearly highlighted in the Clinical Service Plan 2010 and Staffing delineation plan 2010 of the Ministry of Health. After the budgetary allocation, resources are disbursed to SDH, the service role delineation guides Hospital Administrators to allocate resource efficiently to core activities on the assumption that all staffing requirements and different medical and non-medical cadres and all administrative support are provided along all necessary technologies and equipment to provide the expected services.

While no national assessment has been made on the actual provision of resources against the Clinical Service Plan, this study provides an objective assessment and critical evidence of whether the actual resources provided in terms of adequately funding input such as staffing, capital and technology provided are indeed adequate or not at the Sub Divisional level. This may explain to a large extent why some SDH may be efficient or inefficient. It could also tease out hospitals that have "good practice standards" and "benchmarks" against which inefficient hospitals could be compared for improvements.

The study also targets analysis of productivity change of the 17 SDH's over a 10 year period from 2005-2014. The Fijian Government in meeting its objective of improving population health and health service delivery have initiated many structural changes and reforms over the past 10 years and a substantial amount of resources has been consumed in doing so. Additional recruitment of physicians and nurses have been recruited to meet the shortages in manpower, procurement of new sophisticated bio-medical equipment's have been purchased, construction of new infrastructure, new supportive information technologies have been implemented and other regulatory mechanisms, policies and procedural changes have been made to improve efficiency in delivery of health services at SD level.

No study has ever been undertaken in Fiji to measure the efficiency level and change of productivity in SDH's in Fiji and hope this report provides the foundation for further in-depth analysis of our health sector.

5.3 Research instrument

Several lliterature reviews on the strengths and weaknesses of the different hospital efficiency and productivity measurement tools point towards the Data Envelopment Analysis mathematical non-parametric tool as one of the most commonly used tool to determine the Technical and Scale efficiencies of hospitals. The DEAP version 2.1 which is the software that has been commonly used by researchers and economist in assessing hospital efficiency performance was designed by Tim Coelli.

The ability of DEA over a stochastic frontier method to assess multiple inputs and outputs made it appropriate to be used to measure the technical and scale efficiency of all SDH in Fiji. Given its simplicity, such tools provide a foundation point for countries to undertake objective evaluation of hospital efficiency.

In view of the objective of the study, the basic or standard DEA model is sufficient to provide results that meet the objective. The DEA would duly inform hospital managers and policy makers which hospitals are most efficient and which are inefficient and which hospitals becomes a benchmark to ensure that methods and activities at the hospital is optimal. The basic DEA is able to identify by how much could inputs and resources be reduced to produce current level of outputs thus potentially saving resources.

For the measurement of ***change*** in total factor productivity over different time periods, the Malmquist index DEA model was selected. The DEA Malmquist approach is one of the most common and applicable approaches in the DEA literature in measuring productivity changes of Decision Making Units given the availability of longitudinal or panel data.

An increase in the efficiency level can be interpreted as a move by the hospital to “catch up” with the efficiency frontier and a shift in the frontier upwards is attributed to improvement in health technology.

5.4 Model Orientation

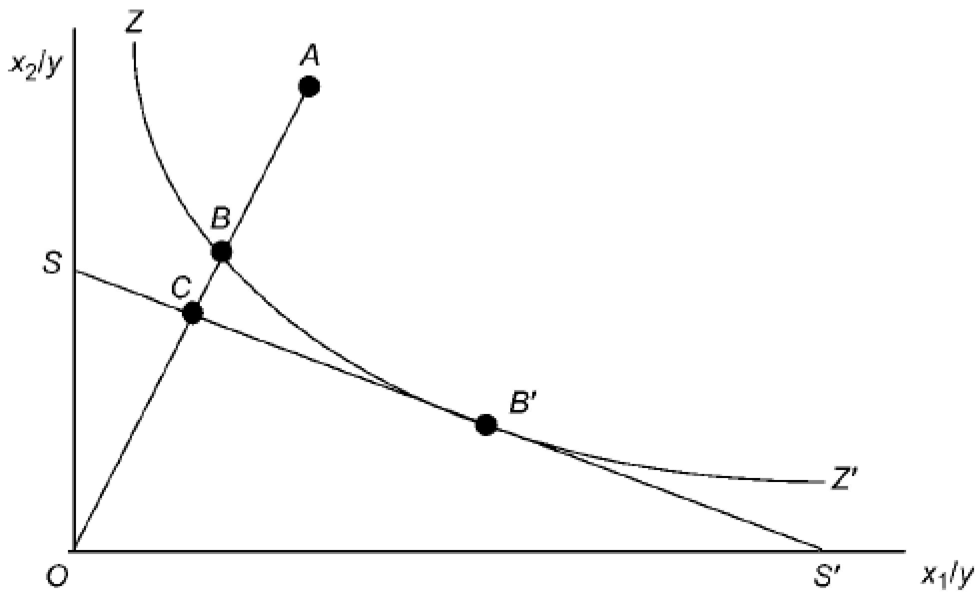
In DEA, the examination of efficiency and productivity of DMU’s can be measured either using an input or an output orientation with either the assumption of a Constant Returns to Scale or a Variable Returns to Scale.

Input oriented technical efficiency measures keep output fixed and explore the proportional reduction in input usage which is possible, while output-oriented technical efficiency measures keep input constant and explore the proportional expansion in output quantities that are possible**(Jacobs et al., 2006).**

5.4.1 Input oriented measure of efficiency

The diagram below illustrates the input oriented model under the assumption of a Constant Returns to Scale. Either a Constant Returns to Scale (CRS) or a Variable Returns to Scale could be used in measuring efficiency. This would be discussed next but in the interim a CRS is assumed to illustrate the model.

Figure 15 Input Oriented Model under Constant Returns to Scale (CRS)



Source: (Jacobs et al., 2006)

Figure 15 illustrates a simple example of two inputs **(X1, X2)** that are used in producing a single output assuming constant returns to scale. For the sake of simplicity, if we use inputs representing the health care sector, we could depict hospital inputs as labour of staff in hospitals such as physicians and nurses that are used in producing a single output for this matter the number of patients treated.

The isoquants are assumed to be constructed for the fully efficient firms, represented by **SS'** in the figure above. Along the frontier, which represent the optimal use of both the inputs of physicians and nurses in treating a single patient, the reduction of one input say physicians would necessitate that nurses are consumed more or in the case of increase in physicians, less nurses are consumed in order to remain on the frontier i.e able to maintain or provide the treatment service efficiently.

In the figure above **ZZ'** is assumed to be the production frontier on which all efficient DMU's lie on. Any firm lying above the production frontier is deemed to be using too much input in producing a given or standard level of output thus categorised as inefficient.

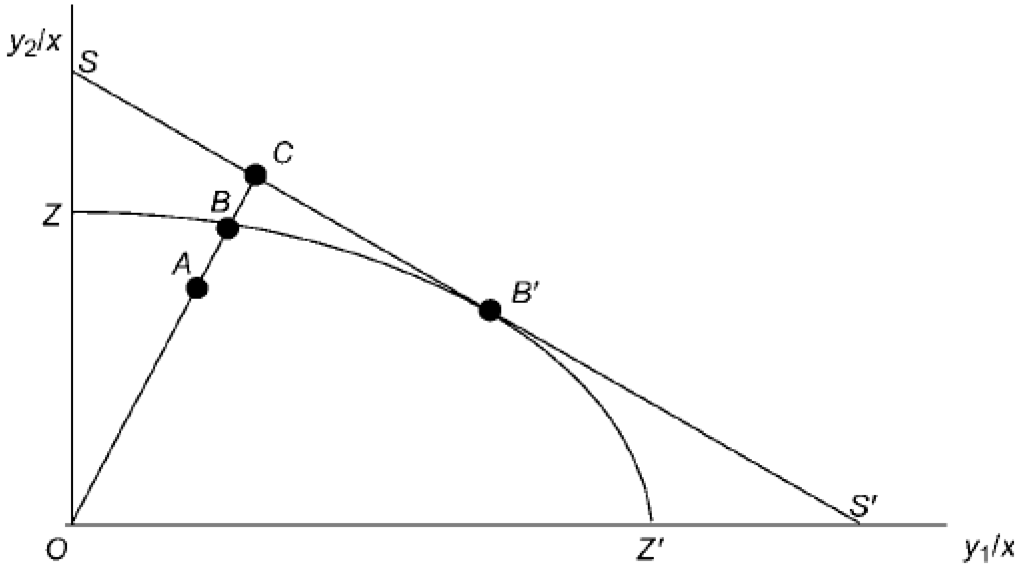
In an input-orientation approach of measuring efficiency, DMUs that lie outside or above the production frontier could proportionally reduce consumption of input X1 and X2 for a given output level Y. In the diagram hospital A is operating inefficiently as it does not lie on the optimal production frontier. Hospital A could proportionally reduce its use of doctors and nurses, given the amount of treatment it provides, and move to a feasible and technically efficient production point such as consumed by hospital B.

5.4.2 Output oriented measure of efficiency

Efficiency measurement of hospitals could also be undertaken using an output oriented approach. **Coelli 1989** proposes that while the above input oriented technical efficient measure addresses the question: By how much can input quantities be proportionally reduced without changing the output quantities produced? An alternative approach would be to ask the question "By how much can output quantities be proportionally expanded without altering the input quantities used?

The figure below is used in illustrating an output oriented approach under the CRS assumption. Supposedly, two hospital outputs are produced (Y1, Y2) namely inpatient treatment and outpatient visits, from a single input x, hospital staff.

Figure 16 Output oriented model under Constant Returns to Scale (CRS)



Source:(Jacobs et al., 2006)

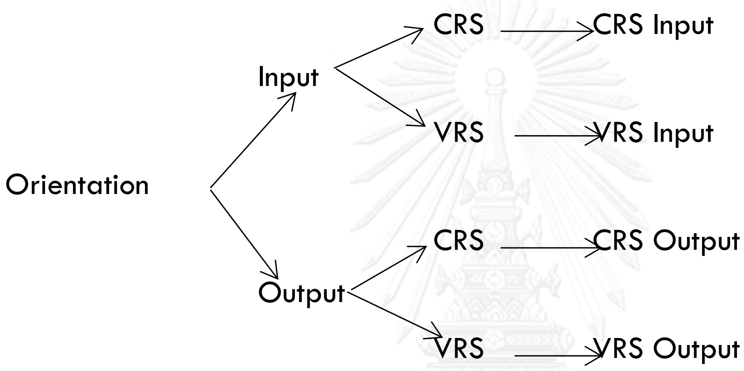
The production possibility frontier which represents the upper bound of all the technically feasible production possibilities is represented by ZZ'. All hospitals lie on the production frontier if they are efficient and inside or below the curve if they are inefficient in producing the optimal output using given input. Using the output orientation, hospitals which lie below the production frontier, such as hospital A, could proportionally expand their output quantities (Y1, Y2) of inpatient treatment and outpatient visits, holding their level of input use (X), hospital staff constant. Under the existing technology, they could do this up to a point such as B is located on the production frontier(Jacobs et al., 2006).

5.5 Basic Frontier Models

Types of DEA models concerning a situation can be identified based on scale and orientation of the model. If it is assumed that the scale of economies does not vary at all given an increase in the size of the service facility, then the **Constant Returns to Scale (CRS**) type DEA model is appropriate.

On the contrary if we do away with the assumption, then the appropriate DEA model to be used is called the **Variable Returns to Scale (VRS)** model. The figure below shows the possible DEA models that could be derived depending on the returns to scale.

Figure 17 Frontier Models

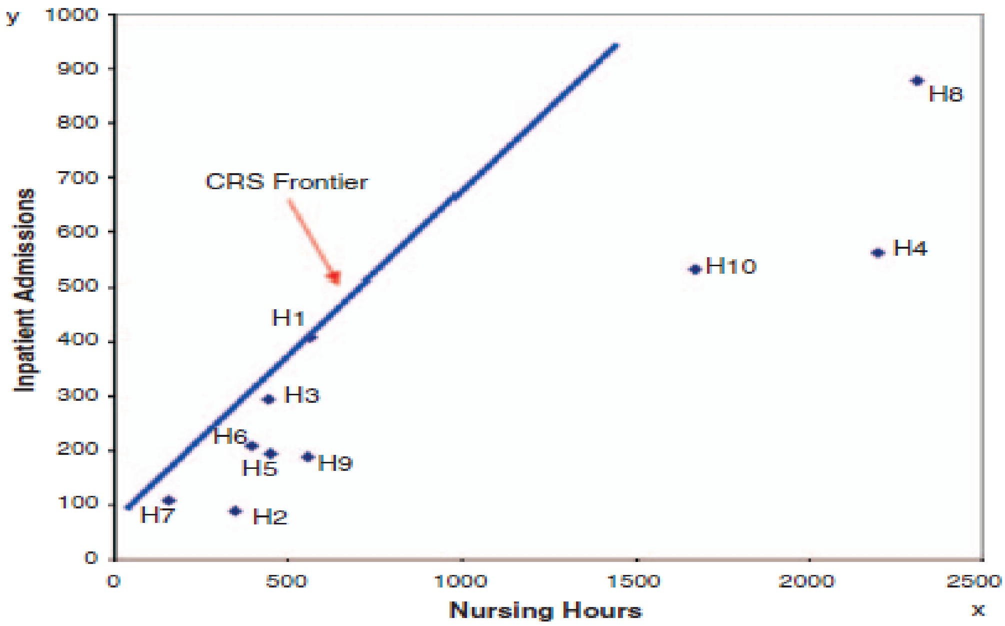


Source:(Jacobs et al., 2006)

5.5.1 Constant Returns to Scale

The **CSR** models assume a constant rate of substitution between inputs and outputs. The figure below depicts the CRS efficiency frontier for the sample hospital data of inputs and outputs in the above table. Assuming only one input and output, hospital H1 defines the CRS frontier. To reach this frontier all the hospitals must move their positions proportionately either to the left or towards the top wherever they can reach to the target line, which is constant(Ozcan, 2008).

Figure 18 Constant Returns to Scale

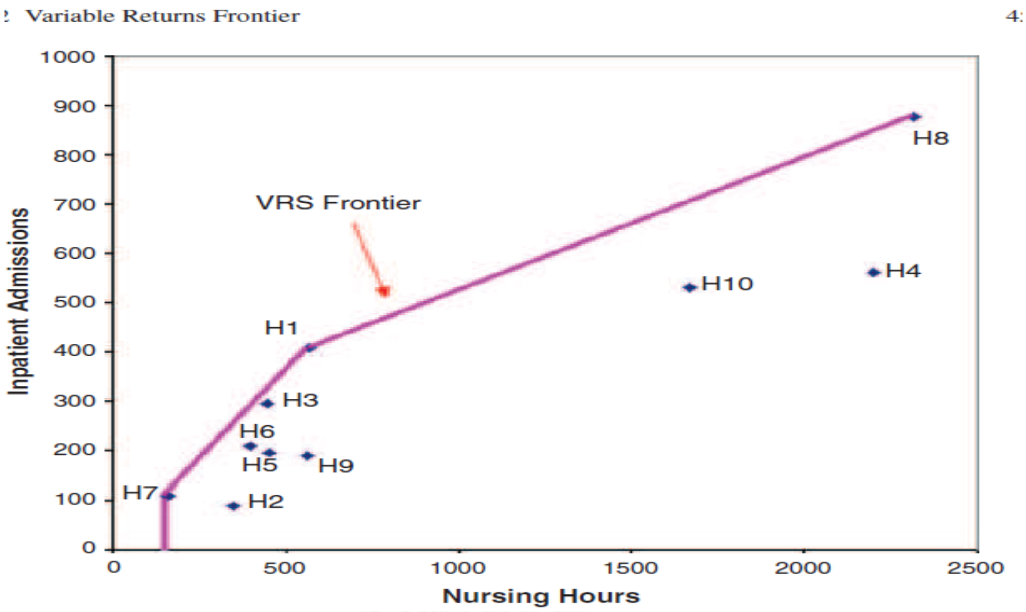


Source: (Ozcan, 2008)

5.5.2 Variable Returns to Scale

On the other side of the coin, when scale economies exist the frontier may be defined differently. For instance, if a proportional increase in one or more inputs can cause greater than proportion increase in outputs or vice versa, then constant returns are not present. In DEA literature this is identified as **Variable Returns to Scale** (VRS).

Figure 19 Variable Returns to Scale



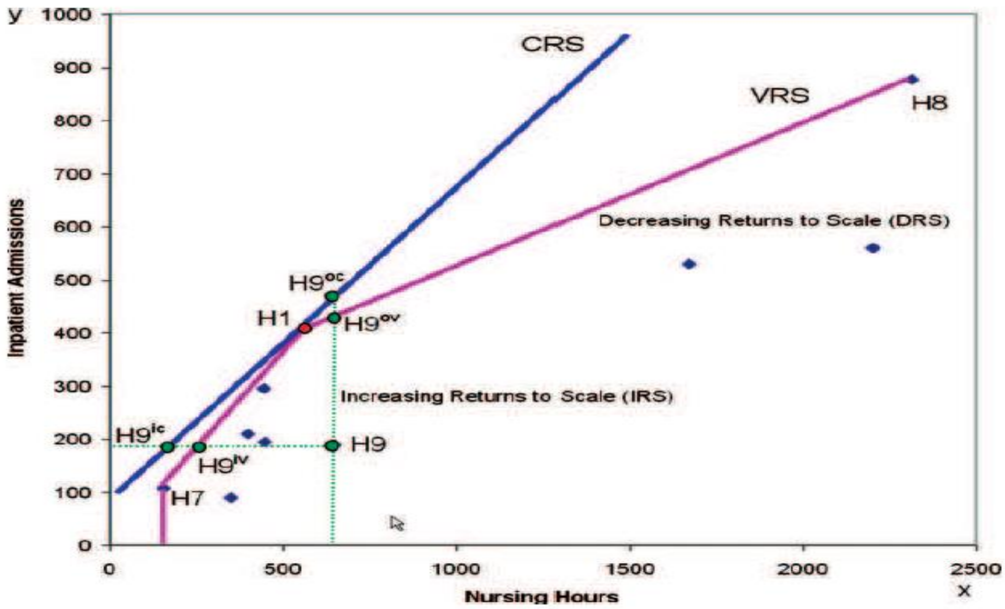
Source: (Ozcan, 2008)

In VRS, H7, H1, and H8 define the different parts of the frontier. The line between H7 to H1 depicts increasing returns to scale (IRS) as it shows a sharp increase reflected by the greater steepness of the slope. H1 and H8 also depict an increase, but at a decreasing returns to scale. Other hospitals such as H2, H5, H9, H6, and H3 would expect increasing returns, hospitals like H4, H10 and H8 would exhibit decreasing returns.

The choice of whether a CRS or a VRS assumption is made depending on various factors. Market failures usually cause externalities that may require Government intervention to either tax or subsidize these externalities or may be required if the production of public goods is heavily relied on the Government. Market failures such as limited resources in particular finance, regulations constraints on physicians in the public sector and the lack of prudent control of assets usually results in the DMU's operating at a sub-optimal scale. A CSR may not be applicable when some DMU's are not performing at a fully efficient level. The resulting effect of applying CRS when the firms are operating at a Sub-Optimal scale is called the Scale efficiency effect.

The orientation of the model (CRS, VRS) and the input and output, further plays a role in how inefficient hospitals would move towards the VRS frontier.

Figure 20 CRS Vs VRS Orientation Model



Source: (Ozcan, 2008)

H1 – is at a pin where CRS and VRS are tangent to each other, indicating H1 is both CRS and VRS efficient, and thus H1's returns are constant. Hence, H1 would be considered the "optimal" scale size.

Let's explore H9 and use either input based CRS or VRS model first. H9 is a non-frontier hospital.

Input Oriented VRS – to reach efficiency **H9** must reduce its nursing hours (input) by moving horizontally to H9iv where it becomes VRS efficient. Since H9iv is located at the increasing scale to returns, H9 can reduce its nursing hours further to the point H9ic, where it becomes CRS efficient.

Output Oriented VRS - H9 wishes to reach the efficiency frontier via output augmentation, the nearest point it can reach vertically is H9ov, which is at a decreasing returns to scale section of the VRS frontier. H9 can augment its output to H9oc where it can reach output oriented CRS efficiency.

5.6 Model Specification

5.6.1 DEA Framework

In this study, an **output orientation** model has been adopted using the Constant Returns to Scale (CRS) and Variable Returns to Scale (VRS) approach. . Since the DMUs are in control of the inputs which they use, the usage of an input-orientation was deemed appropriate here.

(Jacobs et al., 2006) describes that in many instances hospitals, in particular Government owned, more or less do not have much flexibility in deciding the level of resources received through the treasury budget and are usually fixed. Therefore, hospital managers are required to decide on how many patients they could treat within the given amount of inputs available. This implies that an output oriented measure of efficiency needs to be adopted.

The efficiency score depends on how well the DMU is performing vis-a-vis other firms. Under DEA, the Constant Returns to Scale (CRS) model states that the optimal mix of inputs and outputs is independent of the firm's scale of operation. Following the notations used by **Coelli (1996)**, the objective of CRS is:

$$\text{Max} \quad \boldsymbol{\mu}, \boldsymbol{\nu} \; (\, \boldsymbol{\mu}', \boldsymbol{yo}/\boldsymbol{v}'\boldsymbol{xo})$$

$$\text{Subject to:} \quad \boldsymbol{\mu}', \boldsymbol{yi}/\boldsymbol{v}'\boldsymbol{xi} \;\leq\; \mathbf{1} \;\; \boldsymbol{i} \;=\; 1,2......, \boldsymbol{I}$$

$$\boldsymbol{\mu}, \boldsymbol{v} \geq 0$$

The constant returns to scale (CRS) DEA model states that the optimal mix of inputs and outputs is independent of the firm's scale of operation, which implies that a proportionate increase in the inputs results in the same proportionate increase in the output.

The objective function specified above involves finding values for $\boldsymbol{\mu}$, and $\boldsymbol{v}$, so that the efficiency of the *i*th DMU is maximized, subject to the constraint that all efficiency measures must be less than or equal to **1**.

The above model is non-linear in nature and has infinite number of solutions. Since linear programming cannot handle fractions, the above formulation needs to be transformed in such a way that the denominator of the objective function is limited and maximization of the numerator is allowed. For this purpose, an additional constraint $\boldsymbol{v'xi}$ = **1** is imposed. Thus, the above non-linear model transforms into the following linear model.

$$\text{Max}_{\boldsymbol{\mu},\boldsymbol{v}} \quad (\boldsymbol{\mu}', \boldsymbol{yi})$$

$$\text{Subject to:} \quad \boldsymbol{v'xi} = 1$$

$$\boldsymbol{\mu' yi} - \boldsymbol{v'xi} \leq \mathbf{0} \quad \boldsymbol{i} = 1,2......,\boldsymbol{I}$$

$$\boldsymbol{\mu}, \boldsymbol{v} \geq 0$$

To solve the Linear Programming specified a dual of the primal can be formulated in the following form:

$$\text{Min}_{\boldsymbol{\theta},\boldsymbol{\lambda}} \quad \boldsymbol{\theta},$$

$$\text{Subject to:} \quad \boldsymbol{qi} + \boldsymbol{Q\lambda} \geq \mathbf{0},$$

$$\boldsymbol{\theta xi} - \boldsymbol{X\lambda} \geq \mathbf{0},$$

$$\boldsymbol{\lambda} \geq \mathbf{0}$$

Where $\boldsymbol{\theta}$ is a scalar and is the efficiency score of the ith DMU. $\boldsymbol{\lambda}$ is a N X 1 vector of constants.

If $\boldsymbol{\theta}$ = 1, it indicates a technically efficient DMU. The linear programming mentioned will be solved N number of times, once for each DMU, providing a value of $\boldsymbol{\theta}$ for each DMU.

The CRS assumption is appropriate in cases where all DMUs operate at an optimal scale. However, constraints may be placed on DMUs which do not allow them to operate at the optimal scale. Using CRS for such DMUs will yield Technical Efficiency (TE) scores, which are affected by Scale Efficiencies (SE). Therefore, one needs to use the Varying Returns to Scale (VRS) model of DEA. VRS implies that an increase in inputs may result in either more or less than proportionate increase in the output. The VRS model incorporates the dual of CRS model, with an extra convexity constraint on $\boldsymbol{\lambda}$.

$$\text{Min}_{\boldsymbol{\theta},\boldsymbol{\lambda}} \quad \boldsymbol{\theta},$$

$$\text{Subject to:} \quad -\boldsymbol{qi} + \boldsymbol{Q\lambda} \geq \mathbf{0},$$

$$\boldsymbol{\theta xi} - \boldsymbol{X\lambda} \geq \mathbf{0},$$

$$\mathbf{N1}'\boldsymbol{\lambda} = \mathbf{1}$$

$$\boldsymbol{\lambda} \geq \mathbf{0}$$

where N 1 is a N * 1 vector of ones. **(T. J. Coelli et al., 2005)** believed that this approach forms a convex hull of interesting planes that envelope the data points more tightly that the CRS conical hull and thus provides technical efficiency scores that are greater than or equal to those obtained using the CRS model.

The DEA programme also has the capability to obtain the hospitals returns to scale. A fixed return to scale hospital would indicate that all its inputs consumed are at its optimal and the respective efficiency score is one. A hospital that experiences a decreasing return to scale on the frontier would indicate that the hospital should decrease its inputs as it is utilising more inputs to produce similar or even less outputs as compared against the efficient hospitals. Hospitals that are producing at an Increasing returns to scale are said to be at the production frontier where its inputs are not optimally utilised to produce an output level that efficient firms are producing. In this case hospitals are encouraged to increase their consumption of inputs to improve efficiency**(Hu & Huang, 2004).**

5.6.2 Malmquist Index

(T. Coelli, 2008) proposed that the availability of panel data enables hospital managers and policy analysts to evaluate and track productivity performance and change of performance of health facilities over time. DEA linear based programs and Malmquist TFP index can be measure productivity change and easily decompose this productivity change into change as a result of technical efficiency and change due to technical efficiency.

The index was based on Malmquist proposal to construct quantity indices as ratios of distance functions for use in consumption analysis. (T. J. Coelli et al., 2005) defined distance functions as very important in describing the technology which ensures that DMU's are able to measure efficiency and productivity. The basic idea underlying distance functions involves radial contractions and expansions in defining these functions.

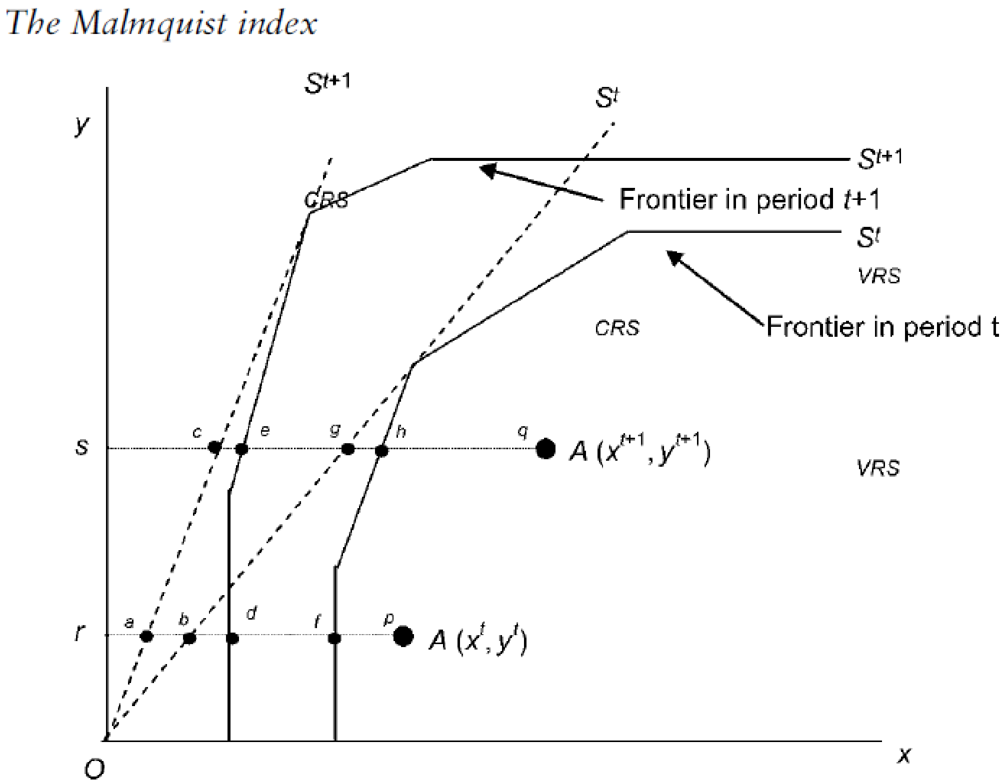
Distance functions allows one to describe a multi input and multi output production technology without the need to specify behavioral objectives such as cost minimization.

Depending on the orientation chosen, the input distance function characterizes the production technology by looking at a minimal proportional contraction of the input vector, given and output vector. An output distance function considers a maximal proportional expansion of the output vector, given an input vector.

(**Färe, Grosskopf, Norris, & Zhang, 1994)** defined distance functions as representations of multi-output multi-input technologies which required data on quantity of input and output.

5.6.2.1 Malmquist Methodology

Figure 21 Illustration of productivity change with one input and one output



Source: (Jacobs et al., 2006)

Figure above illustrates the Malmquist methodology by assuming that a Decision Making Unit, in this particular case Sub-Divisional Hospital in Fiji, consumes a singly input (x) say a physician to produce a single output (y) such as patients treated.

By examining the efficiency of the Hospital A, as illustrated in the figure above, in two time periods, *t* and *t*+1, and also the technology shift from *t* to *t*+1, we could measure the productivity change of Hospital A.

Similar to the frontier models in normal DEA methodology, the Malmquist index could also be calculated using the different returns to scale. The Variable Returns to Scale (VRS) technology in the above diagram is represented by the frontier labelled St(VRS) and the Constant Returns to Scale (CRS) technology is represented by the frontier labelled St(CRS).

In producing output $\boldsymbol{y^t}$ in time period $\boldsymbol{t}$ Hospital A consumes input labelled as $\boldsymbol{x^t}$**.** Similarly, as the hospital moves to a different higher point A, it consumes input of $\boldsymbol{x^{t+1}}$ to produce a new output labelled as $\boldsymbol{y^{t+1}}$ in the period of *t*+1. The VRS and CRS technology in the period of *t*+1 is represented by the respective label of $\boldsymbol{S_{VRS}^{t+1}}$ and the dotted line representing $\boldsymbol{S_{CRS}^{t+1}}$.

As mentioned earlier, the inefficiency measurement using the Malmquist index is measured by the distance function from the origin 0, known as the radial measure of inefficiency.

Using an input oriented approach, the distance *fp* represents the technical inefficiency of Hospital relative to the VRS technology in period *t*. The length fp also represents the amount by which input could be proportionally reduced without reducing output per say patients treated. The TE ratio is outlined as ***rf/rp.***

While DEA is used to estimate the hospital industry frontier and compare individual DMU's with the national frontier at a given period, it is also plausible that the overall frontier may shift over time. The major reasons for the overall shift of the production frontier takes into account the technological change and innovation. This is the total shift of the frontier from $\boldsymbol{S^t}$ to $\boldsymbol{S^{t+1}}$

(Jacobs et al., 2006) stated that the changes to productivity therefore measures how much closer are we to meet hospitals industry frontier i.e to measure *efficiency change* as well as how much the industry frontier shifts given the input use of each hospital i.e ***technical change****.*

The Malmquist index thus is calculated by measuring the change for hospital A from point (x^t, y^t) to point (x^{t+1}, y^{t+1}) using both the returns to scale technologies' using distance functions.

Upon thorough investigation, we could for now conclude that the Malmquist Index M, is a product of two main elements, namely the technical efficiency change E, and the T for technical change, M = E $\times$T. Technical efficiency, theoretically is further dis-aggregated into pure technical (P) and scale efficiency (S) thus M = (P$\times$S) $\times$ T

1. ***Pure Efficiency change P*** between periods $\boldsymbol{t}$ and $\boldsymbol{t+1}$ for Hospital A is computed by the ratio of : *P*= $\frac{se/sq}{rd/rp}$ which indicates the change in the hospitals distance function of the current technical efficient frontier from period $\boldsymbol{t}$ to $\boldsymbol{t+1}$ under the VRS oriented model.

2. ***Scale Efficiency change S*** - In the case of scale efficiency the efficiency of Hospital A is calculated relative to the CRS and VRS in each respective period of $\boldsymbol{t}$ and $\boldsymbol{t+1}$. The ratio is as follows: S = $\frac{sc/sq}{se/sq} \Big/ \frac{rb/rp}{rf/rp}$

3. ***Technical efficiency change E*** = P x S – The change in the scale efficient technology indicated by the CRS frontiers is estimated by:

$$T = \sqrt{\frac{sg/sq}{sc/sq} \times \frac{rb/rp}{ra/rp}}$$

5.6.2.2 General Mathematical form of Malmquist Index

The extensions to the standard DEA procedures such as the Malmquist Productive Index (MPI) provide management with a performance analysis over time series settings.

Malmquist productivity indices are defined as ratios of distancing functions. Distance functioning are a way of modelling the production frontier and any deviations from the respective frontier, indicating either a change in efficiency or a change in technology resulting in the shift of the whole frontier.

Suggested by Caves et al. (1982) the Malmquist Productivity Index provides a measure of productivity change. The method was further developed by Fare et al (1994) and proposed that a nonparametric Malmquist index is used to measure productivity with linear programming based DEA.

The Malmquist index either could be calculated using an input orientation or an output orientation.

The **input oriented approach**, the output is usually controlled or fixed and changes in the consumption of input are measured. The input-oriented Malmquist productivity index is composed of four input-oriented, distance functions. The change in productivity between base period of t and reference period of t+1 for a DMU is defined as follows:

$$M_i^{t+1}(y^{t+1}, x^{t+1}, y^t, x^t) = \left[\frac{H_i^t(y^{t+1}, x^{t+1})}{H_i^t(y^t, x^t)} \frac{H_i^{t+1}(y^{t+1}, x^{t+1})}{H_i^{t+1}(y^t, x^t)} \right]^{1/2}$$

In the input oriented MPI denoted by M_i, y represents the quantity of output that can be produced with the consumption of input x. In the equation above, H_i^{t+1} $(y^{t+1}$ $,x^{t+1})$ and $H_i^t(y^t, x^t)$ are two distance functions that measures the technical efficiency. The other two distance functions of H_i^t (y^{t+1}, x^{t+1}) and $H_i^{t+1}(y^t, x^t)$ are cross period functions where the latter represents the measurement of efficiency using the observation in the base period t relative to the frontier technology of the reference period $t+1$.

The DEA based Malmquist Productivity Index is also able to demarcate the overall productivity measure into two different categories of the effects of efficiency, technical efficiency which measures change of catching up to other firms or the efficient firms in the same given period and measuring change in technology, which is denoted by the shift of the whole frontier.
The above demarcation can be shown mathematically:

$$M_i^{t+1}(y^{t+1}, x^{t+1}, y^t, x^t) = \frac{H_i^{t+1}(y^{t+1}, x^{t+1})}{H_i^t(y^t, x^t)} \text{ EFFICIENCY CHANGE}$$

$$\left[\frac{H_i^t(y^{t+1}, x^{t+1})}{H_i^{t+1}(y^{t+1}, x^{t+1})} \frac{H_i^t(y^t, x^t)}{H_i^{t+1}(y^t, x^t)}\right]^{1/2} \text{ TECHNICAL CHANGE}$$

or **M = E x T**

In an input-oriented DEA based MPI model, if the values of the MPI are greater than 1, it indicates a regress meaning the productivity level of the DMU has deteriorated, equal to 1 would mean no change and smaller than 1 would mean an improvement of the productivity level of the DMU.

In the **output orientation model** requires that there is a control put onto the input use and producers measure the changes in output levels. Similarly to the input oriented model, the output model can me mathematically defined:

$$M_o^{t+1}\,(x^{t+1}, y^{t+1}, x^t\,, y^t) = \left[\frac{H_o^t\,(x^{t+1}, y^{t+1})}{H_o^t(x^t, y^t)}\;\frac{H_o^{t+1}\,(x^{t+1}\,, y^{t+1})}{H_o^{t+1}(x^t, y^t)}\right]^{\mathbf{1/2}}$$

In the equation above, the output distance function component for the periods $\boldsymbol{t\ and\ t+1}$ is represented by the notation H_o. The above equation is the geometric mean of two Caves et al's (1982) Malmquist productivity indexes given the assumption that at both the periods the DMU is at the efficient frontier, which is equal to one.

Relaxing the above assumption, the most common way of formulating the Malmquist index is:

$$M_i^{t+1}\,(x^{t+1}, y^{t+1}, x^t\,, y^t) = \frac{H_i^{t+1}\,(x^{t+1}\,, y^{t+1})}{H_i^t(x^t, y^t)}\ \text{EFFICIENCY CHANGE}$$

$$\left[\frac{H_i^t\,(x^{t+1}, y^{t+1})}{H_i^{t+1}(x^{t+1}, y^{t+1})}\;\frac{H_i^t\,(x^t\,, y^t)}{H_i^{t+1}(x^t, y^t)}\right]^{\mathbf{1/2}}\ \text{TECHNICAL CHANGE}$$

or **M = E x T**

In an output-oriented DEA based MPI model, if the values of the MPI are greater than 1, it indicates a positive growth in total factor productivity, , equal to 1 would mean no change and smaller than 1 would mean a decline in the TFP between two periods.

5.6.2.3 Regression Methodology

The results from the multi stage DEA analysis using the 2014 data will employ the Tobit regression econometric model. The use of a two stage procedure to analyse efficiency scores is one of the most common analytic tools used in DEA. In the first stage efficiency scores are calculated using DEA multi stage. An input and output oriented multi stage DEA would be run. As a result the efficiency scores are used as the dependent variable, which is regressed on the key internal and external environmental factors that is strongly believed to have an impact on the efficiency of hospital performance contextualised to local perspectives**.**

In a regression model, the basic idea is that the efficiency scores either obtained from the econometric or DEA, are treated as dependent variable in the regression model. For example, a number of health care studies have regressed the predicted inefficiencies on a set of organisation specific factors, such as the percentage of doctors, extent of local competition and dummy variables for teaching and non-profit and for profit hospitals**(Worthington, 2004).**

Once the relative efficiencies have been calculated, the determinants of the DEA efficiency scores can be investigated into. It is customary to regress the DEA efficiency scores on the relevant control.

Since the DEA efficiency score lies in the interval 0 and 1, the dependent variable is ***'a limited dependent variable'*** Tobit regression is an alternative to ordinary last squares regression (OLS) and is employed when the dependent variable is bounded from above, below or both with positive possibility pileup at the interval ends, either by being censored or by being corner solutions**(Wooldridge, 2010).**

Therefore, it is apt to use the Tobit model, which is a **censored regression model**, applicable in cases where the dependent variable is constrained in some way. The Tobit model may be defined as:

$$\gamma^* \; ; 0 \leq \gamma^* \leq 1$$

$$Y = 0; \gamma^* < 0;$$

$$1; 1 < \gamma^*$$

$$\gamma^* = \beta x i + \varepsilon t$$

Where Y is the DEA VRS TE score. εt ~ i e N(0, σ2)

γ^* is a latent (unobservable) variable.

β is the vector of unknown parameters which determines the relationship between the independent variables and the latent variable.

xi is the vector of explanatory variables,

To undertake this analysis, the efficiency score for each hospital as calculated using the DEA, will be used as dependent variable in the regression model against and a number of independent variables (regressand) representing the factors that is believed to have an impact on efficiency performance of the hospitals in Fiji.

γ * = α + β1*(Operational Budget)+ β2*(Elderly Population)+ β3*(Hospital Beds)+ β4*(Nur to Bed)+ β5*(NuR per 1000P Pop)+ β6*(Nurses)+ β7*(Occupancy Rate)+ β8*(Phy to Bed)+ β9*(Pop Density)+ β10*(Physicians)+ β11*(Phy per 1000 Pop)+ εt

Similarly, the scores of the MP index are treated as dependent variable would be regressed against the independent variable using a Log-Linear functional model. The Log Linear functional form is illustrated below. Such a model is generally used if the objective of the study is to measure the rate of growth of Y with respect to X.

Log-Linear Functional Form

Functional form: $\ln Y = \beta_1 + \beta_2 X$

Marginal effect: $m = \beta_2 Y$

Elasticity: $\varepsilon = \beta_2 X$

For this functional form, the slope parameter β_2 is interpreted as when X changes by one unit, Y will change by approximately β_2*100 percent. The smaller the absolute value of β_2 the closer the approximation. When calculating estimates of the marginal effect and elasticity, Y and X are evaluated at their sample mean values. To estimate this functional form using OLS, we would first transform the data for Y into logarithmic form. We would then run a regression of the log of Y on X.

$In\ (\widehat{Change\ \imath n}\ TE)$ = $\beta 0$ + $\beta 1$*(Operational Budget)+ $\beta 2$*(Elderly Population)+ $\beta 3$*(Hospital Beds)+ $\beta 4$*(Nur to Bed)+ $\beta 5$*(NuR per 1000P Pop)+ $\beta 6$*(Nurses)+ $\beta 7$*(Occupancy Rate)+ $\beta 8$*(Phy to Bed)+ $\beta 9$*(Pop Density)+ $\beta 10$*(Physicians)+ $\beta 11$*(Phy per 1000 Pop).+ Ɛŧ.

5.6.3 Hypothesis

Hospital productivity and efficiency measures are usually determined by both internal and external factors. Based on the availability of data the following are chosen independent variables that have a strong influence on productivity and will be used as independent variable in the case of Log Linear function regression and Tobit.

- **Health Operational Budget (HB)** – higher operational budget per hospital may have positive association with the technical efficiency of hospital.

- **Elderly population (EP)** – a higher number of elderly in catchment population of each division may have negative influence on the hospitals efficiency. Usually it takes more time to screen an older patient and therefore unit cost for each extra minute has diminishing returns.

- **Size - No. of Hospital Beds (HB)** – the proxy measure of hospital size is usually indicated by the numbers of beds that are catered for by the hospital. It is therefore hypothesized that if the size of hospital is either too big or too small it may have a negative influence on technical efficiency.

- **Number of Physicians (Phy)** – the number of physicians is expected to have a positive impact on the productivity and technical efficiency results

- **Number of Nurses (Sulku)** – the number of nurses is expected to have a positive impact on the productivity and technical efficiency results.

- **Physicians to Bed Ratio (PB)** – A large number of Physicians to Bed ratio is expected to have negative impact on productivity and efficiency.

- **Nurses to Bed Ratio (NB)** – A large number of nurses to bed ratio is expected to have a negative impact on productivity and efficiency.

- **Number of physicians per 1000 population (PPOP) –** Fiji still falls under the category of developing countries that face shortage of doctors, though it is not in a critical situation. Physicians are also one of the most important input factors into the health workforce. The use of the ratio as an independent variable would allow policy makers to see the magnitude of influence the shortages have on hospital efficiency.
- **Number of Nurses per 1000 population (NPOP) -** Nurses form the major component of any health workforce. Nurses are no longer only responsible

for supportive roles in hospitals and health facilities but also are very actively involved in more complex situations in hospitals. The specialisations of physicians demand nurses to be specialised in similar areas as well. But the nursing cadre especially in developing countries face shortage due to attraction of better opportunities outside from developed countries. The shortage is believed to have a negative impact on efficiency.

- **Population Density (PD)** – population density of the divisions in which hospitals are situated in can have an effect on technical efficiency. Density would be calculated using the total area of the population where a divisional hospital exists divided by the population of the catchment area.

- **Occupancy Rate (OR) –** proxy measure of utilisation of hospital resources. The occupancy rate is a calculation used to show the actual utilization of an inpatient health facility for a given time period. It is expressed as a percent or a ratio.

Table 6: Definition of Independent variables

Variables	Definition	Hypothesize
1. **Health Operational Budget**	Operational Budget per SDH	**Positive** influence on efficiency if adequately funded.
2. **Elderly population (EP)**	In Fiji's context those above 60 are considered to be senior citizens or the elderly.	**Negative** influence on efficiency in areas with high numbers of elderly population.
3. **Size - No. of Hospital Beds (HB)**	Proxy measure of hospital size (capital input).	**Negative** influence on hospital either too big or too small

4.	**Number of Physicians**	Actual count of physicians	**Positive** influence on Eff. If adequate number is provided to SDH. In access or shortage could lead to differences in sign.
5.	**Number of Nurses**	Actual count of nurses	**Positive** influence on Eff. If adequate number is provided to SDH. In access or shortage could lead to differences in sign.
6.	**Physicians to Bed Ratio**	Actual number of physicians assigned to each bed on average.	Access or shortage of physicians based on beds could lead to loss of productivity and inefficiency.
7.	**Nurses to Bed Ratio**	Actual number of nurses assigned to each bed on average.	Access or shortage of nurses based on beds could lead to loss of productivity and inefficiency.
8.	**Number of physicians per 1000 population (PHY)**	Number of physicians per 1000 patients secreened	**Positive** influence on Eff. If adequate number is provided to SDH.

9.	**Number of Nurses per 1000 population**	Number of nurses per 1000 patients screened	**Positive** influence on Eff. If adequate number is provided to SDH.
10.	**Population Density (PD)**	Population size PER SQ km per SD where the hospital is located.	Higher population density is expected to have a **positive** relationship on efficiency.
11.	**Occupancy Rate - OR**	Proportion of inpatient stay days in a year	**Positive** influence on Eff.

5.6.4 Data sampling for DEA

The study focuses on the entire population of Sub-Divisional Hospitals in Fiji where N = 17 public health facilities. The hospitals are located at different locations of the 4 Demographic medical areas.

5.6.4.1 Selection of Inputs and Outputs

One of the problems of efficiency analysis of health care institutions is that the production function or that the conceptual output of improved health status, or even more generally, the improvement in the quality of individual life is difficult or in some cases impossible to measure. **(Worthington, 2004).**

In modeling hospital production or technology, it is difficult to conceptualize (and measure) hospital output. One might argue that change in health status is appropriate output conceptually. Since we cannot accurately measure health status, we choose instead to measure hospital production as an array of outputs which are assumed to be related to improved health status**(Grosskopf & Valdmanis, 1987).**

The ultimate output or more commonly used by economists as ultimate outcome of any health care industry, either private hospital or public, is to ensure that the patient after been diagnosed is provided with the appropriate level of treatment and care in order to achieve additional quality of life.

(Worthington, 2004) also figured out that a second problem of the inability of countries to measure inputs or more specifically relevant inputs to undertake efficiency analysis may be very limited.

Changes in in health outcome cannot be entirely attributed to health care. Health is a multidimensional and affected significantly by a host of other socio-economic factors

While many countries work towards collecting more data sets on the final output measures such as those mentioned above, according to **(Hollingsworth, 2008)** most research published so far has used some variant of intermediate outputs, in terms of numbers of patients treated.

5.6.4.2 Factors justifying choice of variables

From the above literature, it is apparent that the choice of inputs and output variables in DEA is complex in nature and caution should be taken on the assumptions that are made for its inclusion or exclusion. **(Dyson et al., 2001)** proposed that the choice of inputs and outputs should be based on the following four assumptions:

1. **Covers the full range of resources used** - the mutual inputs in an economic production process is categorised by the amount of labour utilised, the capital investment into the machinery mechanism of the system and the provision of appropriate infrastructure to undertake production. Ideally, inputs should be chosen from the three input categories.
2. **Captures all activity levels and performance measures** – the choice of a homogenous DMU is based on the assumption that key activity levels are chosen based on the services provided at all 20 SDH and appropriate

performance measures are filtered out to all SDH. This also ensures that all key hospital procedures and operations that consume a lot of resources are included.

3. **The set of factors are common to all units** – the homogeneity of choosing SDH's that has standard levels of input factors that are used as standards or benchmarks in terms of allocating resources.
4. **Environmental variation has been assessed and captured if necessary** – there are factors outside of the health sector that have direct influence on health of people. Socio-economic and demographic environment also influence how health services are accessed and delivered.

5. Additionally, the following factors have also been taken into account as an inclusion strategy:

- **Literature** – literature on the use of various inputs and output variables by countries that have used DEA also provides a guide in choosing appropriate inputs and outputs.
- **Data Availability** – the availability of complete, relevant data is also taken into consideration in choosing inputs and output.

A key pitfall in the selection of inputs and output choices for use in DEA is the defining the appropriate number of variables that should be chosen. As DEA allows flexibility in the choice of weights on the inputs and outputs, the greater the number of factors included the lower the level of discrimination. A suggested 'rule of thumb' is that, to achieve a reasonable level of discrimination, the practitioner needs the number of units to be at least 2m x s where m x s is the product of the number of inputs and number of outputs**(Dyson et al., 2001).**

5.6.4.3 Input Categories

Taking into account the criteria discussed above and the core service and role delineation of Sub-Divisional Hospitals in Fiji, the DEA model will factor in the following inputs.

1. **Number of Physicians –** The total number of physicians in SDH who are full time employees. Physicians are the most important input variables in the health sector and in particular in secondary and tertiary care health facilities. They also account for more than half of the consumption in expenditure in the SDH in Fiji apart from operational and capital expenditure. Whilst there is a strong belief that the efficiency of hospitals could also be influenced by age and experience of physicians, the lack of data limited the analysis to purely physicians. Also the study uses general physicians input category to determine its influence on hospital efficiency.

2. **Number of Nurses –** The total number of nurses employed in the SDH. The nursing cadre employs and accounts for the most number of human resources for health in the Ministry of Health in Fiji as well as the majority if compared by level of health facility. Majority of nurses are stationed in SDH in Fiji as the SDH has greater need due to the service miss. The SDH concentrate on both primary and secondary care where nurses are critically required but face shortages to undertake their service roles adequately. The regression analysis should provide an indication of the magnitude of the influence of nurses on hospital performance.

3. **Expenditure of Operational Budget –** the total amount of budget, excluding salaries and wages and capital expenditure that are consumed in supporting the provision of services at SDH level. One of the most common areas that consumes substantial amount of resources due to its supportive function in

implementing core activities of any hospital is the amount of operational budget provided. It is strongly believed in SDH's of Fiji that technical inefficiency is attributed towards the inadequate funding provided towards operational expenditure despite the increase in service demand, use of high end technology, repair and maintenance of health facilities and increase in number of outreach programmes.

Table 7: Input Variables

Inputs	Abbr.	Operational Definitions	Units
Number of Physicians	Phy.	Proxy of Labour input and the most important labour input in the running of hospitals..	No. of Physicians/persons
Number of Nurses	Nur.	registered nurses in each year for each SDH	No. of nurses /persons
Expenditure of Operational Budget	HB	Dollar value of all actual expenditure on operational segments of the budget for each particular year	Fiji Dollar

5.6.4.4 Output categories

The following output variables from the 17 SDH's are considered in measuring hospital efficiency.

1. **Inpatient Days -** The total admission days of inpatient care in inpatient unit of SDH within a year.

2. Outpatient Visits – The total number of patient's visits recorded to emergency rooms and OPD in a year.

Table 8 Output Variables

Outputs	Abb.	Operational Definitions	Units
Inpatient days	Inp.	Total number of patient stay days in inpatient care unit of SDH in 2008	days
Outpatient visits	Outpat.	Total visits recorded in OPD of each SDH in 10 years	number of visits

CHAPTER VI

RESULTS AND DISCUSSIONS

The results section is divided into four parts. **Section 6.1** discusses the summary of the Malmquist Productivity Indices and how it has changed over the decade. The Malmquist Productivity Index also decomposes the measurement and evaluation of hospital performance by the change in technical efficiency, technological change and further breaks down technical efficiency change into pure technical and scale efficiency. The total factor productivity change as a product of technical efficiency and technological change is computed to understand the overall movement of productivity of the DMU's over the period of the study. **Section 6.2** explores the results of undertaking a multistage DEA to measure the technical and scale efficiency of the DMU in 2014 using output oriented model under the Constant and Variable Returns to Scale. **Section 6.3** outlines the results of a Log-Linear regression of the Malmquist Productivity indices using the scores of change in Technical Efficiency and Total Factor Productivity as dependent variables for the period of the study. **Section 6.4** outlines the results of a Tobit Regression using the coefficient of Technical and Scale Efficiency under the assumption of an output oriented model and a Constant and Variable Returns to Scale.

6.1 Summary of Malmquist Productivity Indices

The results of the Malmquist Productivity indices and decomposition of key components are presented in Table **9** below.

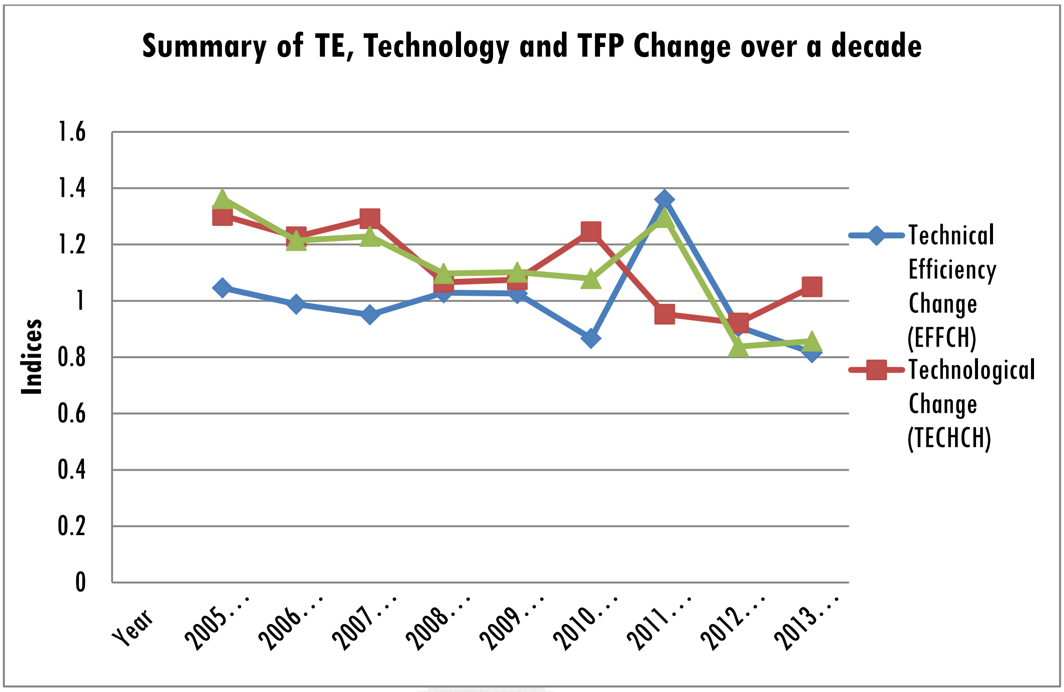
Table 9: Change in Technical Efficiency, Technological Change and Total Factor Productivity.

Year	Technical Efficiency Change (EFFCH)	Technological Change (TECHCH)	Total factor productivity change (TFPCH)
2005-2006	1.046	1.303	1.363
2006-2007	0.988	1.228	1.214
2007-2008	0.951	1.292	1.229
2008-2009	1.029	1.066	1.097
2009-2010	1.026	1.075	1.102
2010-2011	0.867	1.246	1.079
2011-2012	1.36	0.953	1.296
2012-2013	**0.908**	**0.922**	**0.838**
2013-2014	0.816	1.05	0.857
%change final yr	**-18.4**	**+5**	**-14.3**

All of these indices are measured by geometric means, which are used to preserve the multiplicative decompositions of the Malmquist productivity indices**(Färe et al., 1994)**.

Table 1 includes the geometric means of the key indices that are usually calculated by the Malmquist DEA methodology. It consists of indices for the entire period 2005-2014. The values of the Malmquist index or its components **greater than 1** denote progress or improvement in performance, whilst indices **less than 1** represent the regress or the deterioration of performance. The indices **equal to 1** reflect no change in performance. Using this rule of thumb, the results of all the indices are discussed below.

Figure 22 Summary of TE, Technology and TFP Change (2005-2014)



The results in the table for technical efficiency change **(EFFCH)** reflect that the performance of hospitals due to change in technical efficiency regressed from 2005 up till 2008 and picked up performance from 2009 to 2010. It regressed drastically in 2011 and again improved significantly in 2012 before regressing to the lowest technical efficiency level in the past decade to the value of 0.816, a decrease of technical efficiency by 18.4%. Due to the mix trend and the lowest performance level for the year 2014, the hospitals overall performance has been below the level of constant level of performance with a value of 0.989, on average regressing by **1.1%.**

Meanwhile, the results of technological change index **(TECHCH)** also show similar trends as the technical efficiency change but on the average reflect an improvement in performance due to technological improvement since 2005 to 2011. The result regressed temporarily in 2012 and 2013 but picked up during the last period of the study. This may be attributed to the increase in capital funding for new capital construction of health facilities and purchases of new major equipment's and technology.

The production frontier regressed in the initial years of the period of study (2005-2009) before progressing in the year 2010 and then regressing again in 2012 and 2013. In the final year of the period, the hospitals have again experienced progress in technological change, with an improvement of 9 per cent.

It also appears with that there is a downward trend in the total factor productivity index (TFPCH), a product of technical efficiency change and technological change, from 2005 to 2014; apart from 2012 where an improvement was made before performances dipped again. After an initial regression in the first two periods (2005-2006 and 2006-2007), productivity progressed in the year 2007 and then regressed again for another 3 periods. In 2012, it progressed and then regressed the very next year.

The year 2005-2006 saw productivity of hospitals to be at the highest at the value of 1.363 and the lowest productivity was experienced in 2012-2013 period. In 2005-2006 the high productivity level is attributed to the better performance of the hospitals in both the technical efficiency and technological change which indicates the better use of input resources and higher production level of outputs within the given resources.

The poor result in 2012-2013 was also attributed fall in the technological change and technical efficiency which actually regressed below 1.

6.1.1 Efficiency Change Index

The efficiency change index which is mathematically illustrated below represents the change in the technical efficiency levels between the beginning reference periods of $\mathbf{t\ and\ t+1}$

$$\frac{H_i^{t+1}(y^{t+1}, x^{t+1})}{H_i^t(y^t, x^t)} \quad \textbf{EFFICIENCY CHANGE}$$

This efficiency change is the same concept of technical efficiency Farrell had developed to illustrate efficiency in on period to the Farrell technical efficiency in period s.

In interpreting the results, a value of 1 would mean that the hospital has the same distance from the frontier in both periods. Values that are **less than 1** would mean that the hospital has moved further away from the frontier and those with **greater than 1** results would mean that the hospitals have improved its efficiency in period $t + 1$ compared to period t and it has moved closer to the frontier.

Table 10 Technical Efficiency Change (2005-2014)

DMU	*05/06*	*06/07*	*07/08*	*08/09*	*09/10*	*10/11*	*11/12*	*12/13*	*13/14*
1	1.103	0.943	0.997	1.026	0.985	0.854	1.315	0.834	0.756
2	1.137	1.045	0.876	2.13	0.466	0.872	1.384	0.881	0.587
3	1.024	0.964	0.998	0.949	2.548	**0.36**	1.353	0.882	0.968
4	0.997	0.986	0.99	0.963	1.021	0.83	1.381	1.022	0.97
5	0.97	0.943	0.991	1.001	1.008	0.849	1.71	0.96	0.892
6	1.108	0.933	0.964	1.046	0.958	0.979	1.412	0.928	0.496
7	1	1	0.871	1.148	1	1	1	1	0.937
8	1.123	1.67	0.726	0.835	1.093	0.74	1.724	0.793	0.62
9	1	1	1	1	1	1	1	1	1
10	0.981	0.946	0.994	0.982	1.015	0.897	1.538	0.927	0.997
11	0.986	0.944	0.99	0.962	1.025	0.922	1.415	1.045	0.965
12	0.988	0.884	0.992	1.026	0.986	1.039	2.054	0.595	0.952
13	1.155	0.944	0.9	0.972	1.02	0.977	1.076	0.947	0.937
14	1.037	0.955	0.992	0.949	1.07	0.901	1.491	0.895	0.66
15	1.033	0.937	0.983	0.985	1.019	0.901	1.432	0.866	0.948
16	1.016	0.988	0.968	0.94	1.054	0.946	1.31	0.893	0.907
17	1.164	0.906	0.989	0.986	1.015	0.995	0.978	1.102	0.607
Mean	1.046	0.988	0.951	1.029	1.026	0.867	1.360	0.908	0.816
%	4.6	-0.12	-0.49	2.9	2.6	-0.133	36.0	-0.92	-0.18

The table above illustrates the movement of technical efficiency of the hospital over the period of the study. From the table mixed overall results indicate that **hospital 5 (Lomaiviti)** has had increased intentions of moving towards the efficiency frontier in years 2008-2010 and 2011-2013.

While we do not consider **hospital 9 (Rotuma)** as inefficient as the technical efficiency has remained equal to 1, compared to other hospitals which has had mixed results, **hospital 9** seems to remain stagnant with no intention of moving towards the efficiency frontier in all years as compared to the **hospital 5** over 10 years. **Hospital 9** is located on an island quiet far away from the mainland and has had very limited or no change at all over more than two decades to its funding towards its operational and capital works.

On the contrary, if we consider the beginning period efficiency as compared to the end period efficiency, **hospital 9** can be considered as the most efficient as compared to **hospital 2 (Naitasiri)** which had a greater intention of moving towards the efficiency frontier in 2002 at a value of **2.13** but towards the end efficiency regressed drastically to **0.587**.

The Highest and lowest technical efficiency change were experienced by **Hospital 3** (Serua/Namosi Sub Division). The results were the highest in 2009-2010 period but fell drastically in 2010-2011 period. This particular hospital is located in the most flood prone area and is always affected during heavy rainfall.

6.1.2 Technical (Technological) Change Index

The second factor in determining overall factor productivity is the geometric mean of the shift in production frontier observed at $\boldsymbol{y^t}$ and the shift in the whole production frontier observed at $\boldsymbol{y^t + 1}$. While technical efficiency measures a shift of DMUs towards the efficiency frontier, Technological change indicates whether the production frontier as a whole has shifted between the two reference periods of $t\ and\ t+1$ under consideration **(Linh Pham, 2011).**

$$\left[\frac{H_i^t\,(x^{t+1}, y^{t+1})}{H_i^{t+1}(x^{t+1}, y^{t+1})}\,\frac{H_i^t\,(x^t\,, y^t)}{H_i^{t+1}(x^t, y^t)}\right]^{1/2} \quad \textbf{TECHNICAL CHANGE}$$

In interpreting the results, **(Jacobs et al., 2006)** defines that a value greater than 1 for technological change means the hospital has produced more output in period $t+1$ compared to period t. The result illustrates that the respective hospital has experienced productivity gain over time. On the contrary results less than 1 would mean a loss in the productivity level of the respective hospital and index which is equal to 1 means constant level of productivity over the year of comparison.

Table 11 Results of Technical (Technological) Change (2005-2014)

DMU	*05/06*	*06/07*	*07/08*	*08/09*	*09/10*	*10/11*	*11/12*	*12/13*	*13/14*
1	1.863	1.53	1.493	1.159	1.259	1.411	0.988	0.957	1.132
2	1.846	1.543	1.638	1.3	1.278	1.411	0.988	0.957	1.132
3	1.85	1.533	1.448	1.159	1.789	0.819	0.988	0.957	1.132
4	1.863	1.53	1.493	1.159	1.229	1.411	0.988	0.957	1.132
5	1.767	1.552	1.504	1.159	1.259	1.411	0.988	0.957	1.132
6	1.572	1.55	1.558	1.12	1.285	1.411	1.027	0.957	1.132
7	1.038	1.128	1.462	1.239	1.002	1.194	1.749	0.767	1.042
8	1.121	1.018	1.718	1.208	0.714	1.39	0.923	0.979	1.057
9	1.235	1.324	0.883	1.283	**0.639**	1.132	1.315	1.021	0.850
10	1.25	1.185	1.227	0.983	1.09	1.264	0.821	0.921	1.019
11	1.191	1.13	1.17	0.938	1.01	1.21	0.818	0.909	1.019
12	1.141	1.082	1.12	0.927	1.049	1.21	0.824	0.902	1.019
13	1.096	1.04	1.12	0.927	1.049	1.21	0.829	0.896	1.019
14	1.056	1.02	1.12	0.927	0.93	1.226	0.831	0.891	1.019
15	1.02	1.02	1.12	0.927	1.049	1.21	0.828	0.89	1.019

16	0.988	1.02	1.12	0.927	1.049	1.21	0.826	0.891	1.019
17	0.958	1.02	1.12	0.927	1.049	1.21	0.822	0.897	1.019
Mean %∆	**30.3**	**22.8**	**29.2**	**6.6**	**7.5**	**24.6**	**-0.47**	**-0.78**	**5**

From the table above, overall majority of the hospitals have experienced technological change since 2005 to 2011. From 2011 to 2012, there have been mixed results as some hospitals experienced lower productivity levels but interestingly all results improved in the 2013-2014 period. In this period all hospitals have had a gain in productivity level. This may partially be attributed to the large increase in capital funding for construction of new health facilities and procurement of new technologies since 2013.

Compared over the period of the study **hospital 6 and 7** have experienced productivity gains due to technological change and **hospitals 16 and 17** have experienced less productivity gains in the same period.

The highest productivity gain due to technological advancement was experienced by hospital 1 and 4 in the period 2005 to 2006. From the results it seems that this period was one of the most successful period in terms of productivity levels as all hospitals had results greater than 1. Since after this period 2005-2006 productivity has not been achieved consistently over any other period until recently in the 2013-2014 period where all hospitals have had results greater than 1 except for hospital 9. On average total factor productivity due to technical change had progressed since 2005 till it fell in 2011-2013 before picking up again in 2013-2014.

In summary, the total factor productivity of all DMU's has been improving due to technological change over the last 10 years, except for the period 2011-2013.

6.1.2 Total Factor Productivity Index

The Malmquist Index measures the change in total factor productivity over the two period of comparison. The index is mathematically illustrated as follows:

$$M_i^{t+1}(x^{t+1}, y^{t+1}, x^t, y^t) = \frac{H_i^{t+1}(x^{t+1}, y^{t+1})}{H_i^t(x^t, y^t)} \quad \textbf{EFFICIENCY CHANGE}$$

$$\times$$

$$\left[\frac{H_i^t(x^{t+1}, y^{t+1})}{H_i^{t+1}(x^{t+1}, y^{t+1})} \frac{H_i^t(x^t, y^t)}{H_i^{t+1}(x^t, y^t)} \right]^{1/2} \quad \textbf{TECHNICAL CHANGE}$$

A value of **greater than 1** indicates that there is positive change in the total factor productivity either as a result of positive technical efficiency change or technical (technological) change. A value **lower than 1** indicates a decline in total factor productivity either as the result of change in technical efficiency or progress in technical (technological) change.

Table 12 Results of Total Factor Productivity Change (2004-2015)

DMU	*05/06*	*06/07*	*07/08*	*08/09*	*09/10*	*10/11*	*11/12*	*12/13*	*13/14*
1	2.054	1.442	1.488	1.189	1.24	1.205	1.299	0.798	0.855
2	2.099	1.613	1.436	2.769	0.596	1.23	1.367	0.844	0.664
3	1.894	1.477	1.445	1.1	**4.559**	**0.295**	1.337	0.845	1.095
4	1.857	1.509	1.479	1.116	1.255	1.171	1.364	0.978	1.098
5	1.715	1.463	1.491	1.16	1.269	1.198	1.689	0.918	1.01
6	1.742	1.445	1.502	1.171	1.231	1.382	1.45	0.888	0.561
7	1.038	1.128	1.274	1.422	1.002	1.194	1.749	0.767	0.976
8	1.259	1.699	1.248	1.009	0.78	1.028	1.591	0.777	0.655
9	1.235	1.324	0.883	1.283	0.639	1.132	1.315	1.021	0.850
10	1.226	1.122	1.219	0.966	1.107	1.134	1.263	0.854	1.016
11	1.174	1.067	1.158	0.902	1.035	1.115	1.157	0.95	0.983
12	1.126	0.957	1.111	0.951	1.034	1.257	1.692	0.537	0.97
13	1.265	0.981	1.007	0.901	1.07	1.182	0.892	0.849	0.955
14	1.095	0.974	1.11	0.88	0.994	1.105	1.239	0.797	0.672

15	1.053	0.956	1.1	0.913	1.069	1.09	1.186	0.771	0.966
16	1.004	1.008	1.084	0.871	1.106	1.144	1.082	0.796	0.924
17	1.115	0.925	1.108	0.914	1.065	1.203	0.804	0.989	0.618
Mean %∆	**+36.3**	**+21.4**	**+22.9**	**+9.7**	**+10.2**	**+10.8**	**+29.6**	**-16.2**	**-14.3**

From the table above it is noted that on average, the sub divisional hospitals Malmquist index reports that from 2005-2006, 2006-2007, 2007-2008, 2008-2009, 2009-2010, 2010-2011, the hospitals experienced on average 36.3%, 21.4%, 22.9%, 9.7%, 10.2%, 29.6% productivity gain respectively.

As noted in the mathematical equation, the Malmquist Index is a product of the hospital average technical efficiency change and technological change, it is useful that the results are analysed collectively to decompose which of the two factors influenced the Malmquist index more.

The highest productivity level on average was obtained in 2005-2006 and the lowest in 2012-2013 where productivity levels decreased by 16.2%. 2005-2006 also recorded the only year where productivity gains were made in all 10 years.

Hospitals 4, 5 and 7 over the period of study reflected that they have managed to keep productivity levels up for majority of the period except in year 2012 – 2013. This is predominantly attributed to the consistent growth in the technological changes in the respective hospitals while the technical efficiency did reflect a move away from the efficiency frontier.

Hospitals 13 and 17 recorded the lowest productivity levels over 10 years. The hospital was able to make productivity gains in 2005-2006, 2007-2008, 2009-2010 and 2010-2011 while other years reflected a decline in productivity levels. The results was an outcome of a mix of results, mainly a move away from the efficiency frontier by the hospitals over the 10 years.

Hospital 3 experienced the highest and lowest level of productivity gain and loss respectively. This was mainly attributed to a substantial increase and then a drastic drop in technical efficiency predominantly from the period of 2009-2010 to 2010 to

2011. This is similar to the results of a drastic decrease in technical efficiency of hospital 3 in the same period which is prone to natural disasters.

Overall, it appears that the total factor productivity of all 17 SDH's has deteriorated since 2005 and many interventions have failed to improve this. Despite short term productivity gains have been made due to improved technological change through increase funding of operational and capital works, it seems that technical inefficiency still is a major drawback of the SDH's in Fiji in achieving better overall productivity results.

Despite the increase in funding of operations and construction of new health facilities and purchase of new equipment's, only short term gains are made. It is of more importance that determinants of technical efficiency is explored to see which factors needs to be addressed in improving technical efficiency of these hospitals.

6.2 Multi-stage DEA Efficiency results

The results of the multistage DEA using an input and output oriented model are presented in the Tables below.

6.2.1 Input Oriented Multi-Stage DEA Efficiency Results

Table 13 Input Oriented DEA Results

Hospital	*CRSTE*	*VRSTE*	*SE*	*Returns to Scale*	*Peers*
1	0.459	0.468	0.98	drs	13.11
2	0.182	0.369	0.495	irs	11, 9.
3	0.404	0.618	0.653	irs	11, 9, 13.
4	0.558	0.848	0.658	irs	11, 9, 13.
5	0.484	0.733	0.66	irs	11, 9, 13.
6	0.17	0.41	0.414	irs	11, 9, 13.
7	0.174	0.968	0.179	irs	11, 13, 9.
8	0.134	0.379	0.352	irs	11,9.
9	0.159	1	0.159	irs	9
10	0.552	0.769	0.718	irs	11, 9, 13.

11	**1**	**1**	**1**	**-**	**11**
12	0.874	0.886	0.986	drs	13,11
13	**1**	**1**	**1**	**-**	**13**
14	0.536	0.604	0.888	irs	13,9
15	0.399	0.702	0.568	irs	11,13,9
16	0.654	0.714	0.915	irs	11,13, 9.
17	0.243	0.46	0.529	irs	13,9.
Mean	**0.469**	**0.702**	**0.656**		

Using an input oriented DEA model, only 2 hospitals, 11 and 13 reflect a Decision Making Unit that is working at full efficiency level. This implies that these two hospitals are sitting on the parameters of the production function and are seen as reference hospitals to which other hospitals are to design their systems and structures for further improvement.

It is noted with interest that there are two firms 1 and 12 that are producing outputs at a Decreasing Returns to Scale implying that they would need to reduce the investment of inputs further into the production cycle and produce at the frontier as additional input is not providing the same marginal rate of return.

Hospitals 2 to 10 and 14 to 17 are producing well below their capacity given the input resources provided and should be increasing their production of outputs within the given amount of input.

6.2.2 Output Oriented Multi-Stage DEA Efficiency Results

Table 14 Output Oriented DEA Results

Hospital	*CRSTE*	*VRSTE*	*SE*	*Returns to Scale*	*Peers*
1	0.459	0.704	0.652	drs	13
2	0.182	0.206	0.886	drs	11 , 13

3	0.404	0.413	0.978	drs	13,11
4	0.558	0.694	0.804	irs	11, 9, 13.
5	0.484	0.518	0.934	irs	11, 9, 13
6	0.17	0.178	0.956	drs	11, 13.
7	0.174	0.771	0.225	irs	11, 13, 9.
8	0.134	0.146	0.913	drs	13, 11.
9	0.159	1	0.159	irs	9
10	0.552	0.622	0.888	irs	11, 9, 13.
11	1	1	1	-	11
12	0.874	0.907	0.963	drs	13, 11.
13	1	1	1	-	13
14	0.536	0.62	0.865	drs	13
15	0.399	0.455	0.877	irs	11, 9, 13.
16	0.654	0.673	0.971	drs	11,13.
17	0.243	0.263	0.924	irs	13, 9.
Mean	0.469	0.598	0.823		

Using an output oriented DEA model, the same 2 hospitals, 11 and 13 reflect a Decision Making Unit that is working at full efficiency level. This implies that these two hospitals are sitting on the parameters of the production function and are seen as reference hospitals to which other hospitals are to design their systems and structures for further improvement.

It is noted with interest that there are nine (9) firms now compared to the CRS results that are producing outputs at a Decreasing Returns to Scale implying that they would need to reduce the investment of inputs further into the production cycle and produce at the frontier as additional input is not providing the same marginal rate of return. The VRS removes the assumption of constant returns to scale implying that outputs could also be influenced.

Hospitals 4, 5, 7, 9, 10 and 15 are producing well below their capacity given the input resources provided and should be increasing their production of outputs within the given amount of input.

6.3 Log-Linear Regression Outcomes

6.3.1 Technical Efficiency Change

The Log-Linear regression analysis using the functional model below used the log of the change in technical efficiency score as dependent variable and was regressed against 11 independent variables that were expected to influence technical efficiency in the SDH's in Fiji.

The Log-Linear function is illustrated below:

$In\ (\widehat{Change\ in}\ TE)$ = β0 + β1*(Operational Budget)+ β2*(Elderly Population)+ β3*(Hospital Beds)+ β4*(Nur to Bed)+ β5*(NuR per 1000P Pop)+ β6*(Nurses)+ β7*(Occupancy Rate)+ β8*(Phy to Bed)+ β9*(Pop Density)+ β10*(Physicians)+ β11*(Phy per 1000 Pop).

The table provides a comparison summary of what were the expected signs that were hypothesized of the independent variables to reflect against the resulting coefficient signs after regression.

Table 15 Change in Malmquist Technical Efficiency Coefficient Results

	Independent Variable	Expected Sign	Results
1	Operational Budget	+	-
2	Elderly Population	-	+
3	Hospital Bed	+	-
4	Nurses to Bed Ratio	-	-
5	Physicians to Bed Ratio	-	+
6	Physicians	+	-
7	Nurses	+	+
8	Physicians per 1000 Population	+	-

9	Nurses per 1000 Population	+	+
10	Occupancy Rate	+	-
11	Population Density	+	+

The resulting numerical expression of the coefficients from the regression analysis is illustrated below.

$\boldsymbol{In\ (\widehat{Change\ \imath n}\ TE)}$ **= 0.359604 - 0.000000279*(Operational Budget)+** $\mathbf{0.0000058}$***(Elderly Population) -** $\mathbf{0.000625}$***(Hospital Beds) – 0.050888*(Nur to Bed)+ 0.034933*(Nur/1000Pop)+ 0.03073*(Nurses) – 0.000223*(Occupancy Rate)+0.1628*(Phy to Bed)+ 0.000221*(Pop Density) – 0.009833*(Physicians) – 0.230543*(Phy/1000Pop)**

The coefficients in a log-linear model represent the estimated ***percent change*** in the dependent variable for **a *unit change*** in the independent variable. The coefficients as mentioned in the methodology are interpreted as follows with explanatory narration of the results.

- **Operational Budget** – an increase in the operational budget was expected to have a positive effect on the technical efficiency of SDH's and a negative effect if there was a reduction of operational budget. The results from the regression reflected a negative but significant coefficient, indicating that budget had a strong influence on the technical efficiency but in an opposite way. The interpretation of the coefficient is:

  "For a one unit change in the ***Operational Budget****, the change in technical efficiency is expected to decrease by 0.0000279 percent, holding other independent variable constant".*

  The Operational Budget of SDH's are determined mainly by the central head of departments rather than the Hospital managers. While every effort is made to resource the SDH's adequately, the decision made centrally may not reflect a good understanding of the real need and demand of services on the ground and therefore while numerically the SDH's may receive an increase in budget, the proportional increase based on actual utilization or demand of services may be below the growth of the demand of services thus still reflecting a reduction in technical efficiency over the period of the study.

A Beveridge health system usually reflects such results as a unit increase in operational budget may not guarantee improvements in technical efficiency. Minor increases in the operational budget may not be able to influence health workers to improve technical efficiency given the lack of motivation to increase output with the given level of input resources.

The use of economic and econometric tools to assess and evaluate program and project feasibility and viability is not a common practice in Fiji thus there are possibilities of funding of programs and projects that are not feasible. Money spent may not be necessarily in the most cost effective or beneficial program project.

- **Elderly population** - a large number of elderly populations was expected to slow down technical efficiency operations of hospitals. It is apparent that health workers are required to spend more time taking care of the elderly population. The coefficient for EP reflects the following:
  *"For a one unit change in the **elderly population**, the change in technical efficiency is expected to increase by 0.00058 percent, holding other independent variable constant".*

  There is a strong possibility that the elderly population in the period of the study has either remained stagnant or reduced. This effect coupled with the availability of more doctors and nurses possibly reflects that efficiency improved despite the elderly population in the sub divisions.

- **Hospital Bed** - the number of hospital beds is expected to have a positive influence on the technical efficiency. A large number of hospitals under the study were built close to 20-25 years thus catering for a smaller population than today. The number of beds has remained same more than a decade ago and does not reflect the optimum size to provide adequate service delivery based on demand.

  Hospital beds could cause a decrease in efficiency if underutilised. The SDH's under the study have been around for over 20 years and the size of number of beds have not changed a lot despite the increase in population therefore resulting in the coefficient interpreted as follows:

  *"For a one unit change in the **hospital bed**, the change in technical efficiency is expected to decrease by 0.625 percent, holding other independent variable constant". **May not be a good policy option.***

  The construction of hospitals two decades ago may not have taken into account the current demand and utilisation of beds. The inability of hospitals to adequately provide for the demand based on current demographics may have lead to a decrease in technical efficiency.

- **Nurse to Bed Ratio** – nurses to bed ratio reflects on average the number of nurses assigned to a single bed to treat patients. A higher ratio was expected to decrease technical efficiency change and vice versa. This would interpret as more nurses are assigned to look after a single bed unit therefore decreasing efficient as more time is spent on patient or patient is staying in the hospital for longer. The result is interpreted as follows:

  *"For a one unit change in the **number of nurse**, the change in technical efficiency is expected to decrease by 5 percent, holding other independent variable constant".*

The results do indicate a few possibilities. The number of nurses assigned to SDH's in Fiji is based on the Clinical Services Role Functional Plan. There is a possibility that excess nurses are available in the SDH's in Fiji. It must be noted that these hospitals have been been almost two decades ago and structures limit the increases in bed numbers. With the increase in number of nurses and no change in number of beds, technical efficiency could be affected negatively as more nurses are assigned to beds by default.

There is a concentration of nurses in some hospitals where there services could be deployed to other stations where their need is. This is a good reflection of how national posting of our Health Workers does not take into account actual demand and utilisation of services before deployment. But the issue may be temporary as Fiji looks at building new hospitals with new bed numbers meeting actual demand and utilisation, the ratios would adjust to its appropriate size naturally.

- **Physicians to Bed Ratio** – physicians to bed ratio reflect on average the number of physicians assigned to a single bed to treat patients. The higher ratio was expected to decrease technical efficiency change and vice versa. The result is interpreted as follows:

  "For a one unit change in the ***number of nurse****, the change in technical efficiency is expected to decrease by 16.3 percent, holding other independent variable constant".*

  The Bed physician ratio was expected to reflect similar to Nurses to BED Ratio sign of negative effect but the result points to a positive relationship. The above ration may mean there are shortages of physicians in SDH's based on number of beds and actual demand and utilisation therefore a unit of increase in physicians to bed could increase technical efficiency substantially.

- **Number of Physicians** – the number of physicians is expected to have a positive effect on the technical efficiency of the hospitals. The results illustrate that:
  *"For a one unit change in the **number of Physicians**, the change in technical efficiency is expected to decrease by 0.9833 percent, holding other independent variable constant".*

The results reflect again that there has been a significant imbalance of how physicians are distributed in the country. The Clinical Services Role Delineation report for Fiji illustrates the service mix of the hospital and the staffing requirements. While the services have expanded substantially, Fiji has not been able to train and retain physicians or met the supply towards meeting actual demand and utilisation.

- **Number of Nurses** - the number of nurses is expected to have a positive effect on the technical efficiency of the hospitals. The results illustrate that:
  *"For a one unit change in the **number of Nurses**, the change in technical efficiency is expected to increase by 3.1 percent, holding other independent variable constant".*

The Clinical Services Role Delineation report for Fiji outlines the service mix of the hospital and the staffing requirements. The Ministry has been receiving approval of increasing staff numbers, in particular nurses thus reflecting a positive result as a matter of the new nursing numbers.

- **Physicians per 1000 population** – The physicians per 1000 population provides the density of physicians compared to the catchment population of the medical area. A higher density or physicians per 1000 population was expected to have a positive effect on the technical efficiency of the hospital.
  *"For a one unit change in the **number of physicians per 1000 population**, the change in technical efficiency is expected to decrease by 23 percent, holding other independent variable constant".*

In the case of Fiji, the proportionate change in the number of physicians has lagged behind over two decades which has seen strong population growth in the sud-divisions. It is therefore, practical that within the period of the study, the increase in physicians have been small which does not really have a major impact on technical efficiency over time.

- **Nurses per 1000 population** - The Nurses per 1000 population provide the density of nurses compared to the catchment population of the medical area. A higher density or nurses per 1000 population was expected to have a positive effect on the technical efficiency of the hospital. The results were as expected.

"For a one unit change in the ***number of nurses per 1000 population****, the change in technical efficiency is expected to grow by 3.5 percent, holding other independent variable constant".*

The results reflect a positive relationship of the growth in population complemented by the growth or increase in number of nurses. There is still room for improvement in improving technical efficiency if nurses could be allocated rationally to SDH's based on proportionate increases in population.

- **Occupancy Rate** – The occupancy rate or bed occupancy rate in hospitals reflect the actual consumption of an inpatient health facility for a given period of time. A lower occupancy rate indicates a low utilization of health facility and lower technical efficiency and a higher occupancy rate would indicate that the facility is been used towards its maximum capacity. The results indicate that:

  "For a one unit change in the ***occupancy rate****, the change in technical efficiency is expected to fall by .0223 percent, holding other independent variable constant".*

As mentioned before, hospital sizes in Fiji were not predominantly built on economic merit such as demand and utilization of services. A decade ago data may not have been easily available to undertake such analysis and construct hospitals based on economic tools and methodologies.

- **Population Density** - is the number of people living per unit of an area (e.g. per square mile) or the number of people relative to the space occupied by them.

  *"For a one unit change in the **population density**, the change in technical efficiency is expected to fall by .0221 percent, holding other independent variable constant".*

Dependent Variable: LOG(Y)

Method: Least Squares

Date: 06/18/15 Time: 09:28

Sample: 1 153

Included observations: 153

Variable	Coefficient	Std. Error	t-Statistic	Prob.
BUD	-2.79E-07	8.11E-08	-3.444626	0.0008
EP	5.86E-05	5.09E-05	1.151993	0.2513
HB	-0.000625	0.003953	-0.158092	0.8746
NB	-0.050888	0.151391	-0.336139	0.7373
NPOP	0.034933	0.048231	0.724269	0.4701
NUR	0.003073	0.004147	0.741085	0.4599
OR01	-0.000223	0.001659	-0.134584	0.8931
PB	0.162835	0.723982	0.224916	0.8224
PD	0.000221	0.000271	0.815957	0.4159
PHY	-0.009833	0.020254	-0.485499	0.6281
PPOP	-0.230543	0.223161	-1.033079	0.3033

C	0.359604	0.146255	2.458738	0.0152
R-squared	0.234575	Mean dependent var		-0.010764
Adjusted R-squared	0.174861	S.D. dependent var		0.232741
S.E. of regression	0.211415	Akaike info criterion		-0.194803
Sum squared resid	6.302178	Schwarz criterion		0.042879
Log likelihood	26.90241	Hannan-Quinn criter.		-0.098253
F-statistic	3.928310	Durbin-Watson stat		1.790153
Prob(F-statistic)	0.000056			

6.3.2 Total Factor Productivity Change

The Log-Linear regression analysis using the functional model below used the log of the change in total factor productivity score as dependent variable and regressed it against the same 11 independent variables that were expected to influence productivity changes in the SDH's in Fiji.

$\boldsymbol{In\ (\widehat{Change\ in}\ TE)}$ = $\boldsymbol{\beta}$0 + $\boldsymbol{\beta}$1*(Operational Budget)+ $\boldsymbol{\beta}$2*(Elderly Population)+ $\boldsymbol{\beta}$3*(Hospital Beds)+ $\boldsymbol{\beta}$4*(Nur to Bed)+ $\boldsymbol{\beta}$5*(NuR per 1000P Pop)+ $\boldsymbol{\beta}$6*(Nurses)+ $\boldsymbol{\beta}$7*(Occupancy Rate)+ $\boldsymbol{\beta}$8*(Phy to Bed)+ $\boldsymbol{\beta}$9*(Pop Density)+ $\boldsymbol{\beta}$10*(Physicians)+ $\boldsymbol{\beta}$11*(Phy per 1000 Pop).

Table 16 Change in Malmquist TFP Coefficient Results

	Independent Variable	Expected Sign	Results
1	Operational Budget	+	-
2	Elderly Population	-	+
3	Hospital Bed	+	-
4	Nurses to Bed Ratio	-	+
5	Physicians to Bed Ratio	-	-
6	Physicians	+	+

7	Nurses	+	-
8	Physicians per 1000 Population	+	+
9	Nurses per 1000 Population	+	-
10	Occupancy Rate	+	-
11	Population Density	+	+

The resulting numerical expression of the coefficients from the regression analysis is illustrated below.

$In\ (\widehat{Change\ in}\ TE)$ = 0.681644 - 0.000000125*(Operational Budget)+ 0.000108*(Elderly Population) - 0.004683 *(Hospital Beds) + 0.140797*(Nur to Bed)-0.089962*(Nur/1000Pop)-0.003418*(Nurses) – 0.003052*(Occupancy Rate)-0.735852*(Phy to Bed)+ 0.000345*(Pop Density) + 0.010649*(Physicians) + 0.325317*(Phy/1000Pop)

The coefficients in a log-linear model represent the estimated *percent change* in the dependent variable for a *unit change* in the independent variable. The coefficients as mentioned in the methodology are interpreted as follows with explanatory narration of the results.

- **Operational Budget** – an increase in the operational budget was expected to have a positive effect on the productivity change of SDH's and a negative effect if there was a reduction of operational budget. The results from the regression reflected a negative coefficient. The interpretation of the coefficient is:
  "For a one unit change in the ***Operational Budget****, the change in technological change is expected to decrease by 0.000000125 percent, holding other independent variable constant".*

The Operational Budget of SDH's are determined mainly by the central head of departments rather than the Hospital managers. While every effort is made to resource the SDH's adequately, the decision made centrally may not reflect a good understanding of the real need and demand of services on the ground and therefore while numerically the SDH's may receive an increase in budget, the proportional increase based on actual utilization or demand of services may be below the growth of the demand of services thus still reflecting a reduction in technical efficiency over the period of the study.

A Beveridge health system usually reflects such results as a unit increase in operational budget may not guarantee improvements in productivity change. Minor increases in the operational budget may not be able to influence health workers to improve production of outputs given the lack of motivation within the given level of input resources.

The use of economic and econometric tools to assess and evaluate program and project feasibility and viability is not a common practice in Fiji thus there are possibilities of funding of programs and projects that are not feasible. Money spent may not be necessarily in the most cost effective or beneficial program project.

- **Elderly population** - a large number of elderly populations was expected to slow down productivity of operations of hospitals. It is apparent that health workers are required to spend more time taking care of the elderly population. The coefficient for EP reflects the following:

"For a one unit change in the ***elderly population****, the change in total factor productivity is expected to increase by 0.000108 percent, holding other independent variable constant".*

There is a strong possibility that the elderly population in the period of the study has either remained stagnant or reduced. This effect coupled with the availability of more doctors and nurses possibly reflects that efficiency improved despite the elderly population in the sub divisions.

- **Hospital Bed** - the number of hospital beds is expected to have a positive influence on total factor productivity. A large number of hospitals under the study were built close to 20-25 years thus catering for a smaller population than today. The number of beds has remained same more than a decade ago and does not reflect the optimum size to provide adequate service delivery based on demand.

Hospital beds could cause a decrease in productivity if underutilised. The SDH's under the study have been around for over 20 years and the size of number of beds have not changed a lot change in the population configuration therefore resulting in the coefficient interpreted as follows:

*"For a one unit change in the **hospital bed**, the change in productivity is expected to decrease by 0.004683 percent, holding other independent variable constant".* ***May not be a good policy option.***

The construction of hospitals two decades ago may not have taken into account the current demand and utilisation of beds. The inability of hospitals to adequately provide for the demand based on current demographics may have led to a decrease in productivity.

There is also a tendency of people by passing the SHD's hospitals to get treatment at the National Referral hospitals.

- **Nurse to Bed Ratio** – nurses to bed ratio reflects on average the number of nurses assigned to a single bed to treat patients. A higher ratio was expected to decrease technical efficiency change and vice versa. This would interpret as more nurses are assigned to look after a single bed unit therefore decreasing efficiency as more time is spent on patient or patient is staying in the hospital for longer. The result is interpreted as follows:

*"For a one unit change in the **number of nurse**, the change in technical efficiency is expected to increase by 0.140797 percent, holding other independent variable constant".*

The results do indicate a few possibilities. The number of nurses assigned to SDH's in Fiji is based on the Clinical Services Role Functional Plan. There is a possibility that excess nurses are available in the SDH's in Fiji. It must be noted that these hospitals have been existing almost two decades ago and structures limit the increases in bed numbers. With the increase in number of nurses and no change in number of beds, productivity of a nurse could be affected negatively as more nurses are assigned to beds.

There is a concentration of nurses in some hospitals where there services could be deployed to other stations where their need is. This is a good reflection of how national posting of our Health Workers does not take into account actual demand and utilisation of services before deployment. But the issue may be temporary as Fiji looks at building new hospitals with new bed numbers meeting actual demand and utilisation, the ratios would adjust to its appropriate size naturally.

- **Physicians to Bed Ratio** – physicians to bed ratio reflect on average the number of physicians assigned to a single bed to treat patients. The higher ratio was expected to decrease total factor productivity change and vice versa. The result is interpreted as follows:

*"For a one unit change in the **number of nurse**, the change in total factor productivity is expected to decrease by 0.735852 percent, holding other independent variable constant".*

The physician to bed ratio as expected reflected that a unit increase in physicians could decrease total factor productivity.

- **Number of Physicians** – the number of physicians is expected to have a positive effect on the productivity of the hospitals. The results illustrate that:

*"For a one unit change in the **number of Physicians**, the change in total factor productivity is expected to increase by 0.010649 percent, holding other independent variable constant".*

The increase in number of physicians would increase overall productivity of SHD's.

- **Number of Nurses** - the number of nurses is expected to have a positive effect on the technical efficiency of the hospitals. The results illustrate that:

*"For a one unit change in the **number of Nurses**, the change in total factor productivity is expected to decrease by 0.003418 percent, holding other independent variable constant".*

The result of the coefficient states that there is a possibility that SDH's have adequate nurses to achieve their targeted output and adding in more would certainly reduce productivity gains.

- **Physicians per 1000 population** – The physicians per 1000 population provides the density of physicians compared to the catchment population of the medical area. A higher density or physicians per 1000 population was expected to have a positive effect on the technical efficiency of the hospital.

*"For a one unit change in the **number of physicians per 1000 population**, the change in productivity is expected to increase by 0.325317 percent, holding other independent variable constant".*

In the case of Fiji, the proportionate change in the number of physicians has lagged behind over two decades which has seen strong population growth in the sud-divisions. It is therefore, practical that within the period of the study, the increase in physicians would have a positive impact on productivity.

- **Nurses per 1000 population** - The Nurses per 1000 population provide the density of nurses compared to the catchment population of the medical area. A higher density or nurses per 1000 population was expected to have a positive effect on the technical efficiency of the hospital. The results were as expected.

"For a one unit change in the ***number of nurses per 1000 population****, the change in technical efficiency is expected to decrease by* **0.089962***, holding other independent variable constant".*

The result reflects the possibility that there are sufficient number of nurses to population ratio and adding more would decrease the productivity of existing nurses.

- **Occupancy Rate** – The occupancy rate or bed occupancy rate in hospitals reflect the actual consumption of an inpatient health facility for a given period of time. A lower occupancy rate indicates a low utilization of health facility and lower technical efficiency and a higher occupancy rate would indicate that the facility is been used towards its maximum capacity. The results indicate that:

"For a one unit change in the ***occupancy rate****, the change in productivity is expected to fall by .***003052** *percent, holding other independent variable constant".*

As mentioned before, hospital sizes in Fiji were not predominantly built on economic merit such as demand and utilization of services. A decade ago data may not have been easily available to undertake such analysis and construct hospitals based on economic tools and methodologies.

There is a strong theory that while services have been decentralized, SDH's are still referring a large number of patients to tertiary hospitals as their capacity to manage cases within may be constrained by resources such as appropriate technologies and staffing numbers including space issues.

- **Population Density** - is the number of people living per unit of an area (e.g. per square mile) or the number of people relative to the space occupied by them**.** The higher the population density the higher the degree of people utilising services in SDH's.

"For a one unit change in the ***population density****, the change in productivity is expected to improve by .000345 percent, holding other independent variable constant".*

The coefficient reflects my resentment that there has been a general increase in population per area over a decade. The Ministry and Government has to ensure that these population remain and utilise services in their medical area to ensure productivity of hospitals improve.

Dependent Variable: LOG(Y)

Method: Least Squares

Date: 06/18/15 Time: 09:31

Sample: 1 153

Included observations: 153

Variable	Coefficient	Std. Error	t-Statistic	Prob.
BUD	-1.25E-07	1.14E-07	-1.094757	0.2755
EP	0.000108	7.16E-05	1.511957	0.1328
HB	-0.004683	0.005558	-0.842587	0.4009
NB	0.140797	0.212887	0.661369	0.5095
NPOP	-0.089962	0.067823	-1.326407	0.1868
NUR	-0.003418	0.005832	-0.586063	0.5588
OR01	-0.003052	0.002333	-1.308604	0.1928
PB	-0.735852	1.018071	-0.722790	0.4710
PD	0.000345	0.000382	0.903269	0.3679
PHY	0.010649	0.028481	0.373901	0.7090
PPOP	0.325317	0.313811	1.036665	0.3017
C	0.681644	0.205666	3.314328	0.0012

R-squared	0.150531	Mean dependent var	0.114362
Adjusted R-squared	0.084260	S.D. dependent var	0.310670
S.E. of regression	0.297294	Akaike info criterion	0.486993
Sum squared resid	12.46209	Schwarz criterion	0.724675
Log likelihood	-25.25500	Hannan-Quinn criter.	0.583544
F-statistic	2.271457	Durbin-Watson stat	1.650892
Prob(F-statistic)	0.013958		

6.4 Tobit Regression of DEA multistage Technical Efficiency

Apart from regressing the Malmquist Productivity Indices, the Technical Efficiency scores computed with DEA multi stages method using the most recent data 2014 was also regressed to derive the scores and efficiency on the part of the paper. The Tobit model was used to regress technical efficiency scores. The dependent latent variable (Technical Efficiency Scores) was regressed against independent variables aligned to institutional factors which are at the discretion of the hospital management and elected contextual/environmental (non-discretionary) factors that are beyond their control to estimate their impacts on efficiency.

The interpretation of the Tobit model should not be interpreted similar to an Ordinary Least Square model where the relationship of the effect of the independent variable $\boldsymbol{x}\mathbf{i}$ on $\boldsymbol{\gamma}^*$ is computed. It is interpreted as the combination of two parts:

The first been the change in $\boldsymbol{\gamma}^*$ of those above the limit, weighted by the probability of being above the limit; and secondly the change in the probability of being above the limit, weighted by the expected value of $\boldsymbol{\gamma}^*$ if above.

The interpretation of the Tobit model is read as "on average or the marginal effect of an additional unit of independent variable $\boldsymbol{x}\mathbf{i}$ on the latent dependable variable $\boldsymbol{\gamma}^*$.

6.4.1 Output Oriented Model (CRS)

Table 17 Output Oriented DEA Regression results (CRS)

Technical Efficiency (CRS)	*Constant*	*Coefficient*	*Standard Error*	*z-Statistic*	*Probability*
Operational Budget	0.332364	8.17E-08	0.000000087	0.93917	0.3476
No. of Physicians	0.393584	0.002563	0.004112	0.62323	0.5331
No. of Nurses	0.393584	0.000623	0.001	0.62323	0.5331
Hospital Beds	0.057193	0.012823	0.003316	3.86672	0.0001*
Physicians to Bed ratio	0.719106	-0.199773	0.108753	-1.836939	0.0662
Nurses to Bed ratio	0.719106	-0.048593	0.026453	-1.836939	0.0662
Phy/ 1000 Pop	0.780133	-0.157913	0.034493	-4.578175	0*
Nur/ 1000 Pop	0.780133	-0.038411	0.00839	-4.578175	0*
Occupancy Rate	-0.000872	0.016384	0.003288	4.983358	0*
Elderly Population	0.209143	0.000171	0.0000505	3.382504	0.0007*
Population Density	0.43667	0.000393	0.000629	0.624798	0.5321

Notes (1) * p-value ≤ 0.05

The coefficients indicate how one unit change in an independent variable xi alters the latent dependent variable y*.

Under the Constant Returns to Scale assumption, apart from independent variables of Physicians to Bed, Nurses to Bed ratio, Physicians and Nurses per 1000 Population, the coefficients of all other independent variables indicate a positive relationship to the latent dependent variable.

For instance, the No. pf Physicians and Nurses **coefficient** could be interpreted as a unit change in one of the two variables would alter the technical efficiency positively by 0.002563 and 0.000623 respectively. This outcome was expected as new growth in staffing numbers has lagged behind in the Public Health sector over a decade. But note that the growth is marginally very small and not statistically significant as reflected in the z-Statistics and the P-value.

An increase in Hospital Beds significantly increases the technical efficiency scores. This implies that an increase in number of beds will improve the hospitals ability to provide services in a more efficient manner. The coefficient is also statistically significant reflected in the P-Value been lower than the 95% significant level.

As for the ratio of Physicians to 1000 Population, an increase in physicians could possibly have a negative effect on the technical efficiency of the hospital if the population growth remains stagnant. Appropriate analysis must be undertaken on the comparison of population growth and the need for additional physicians in SDH's to avoid overstaffing. The same implies for the ratio for Nurses. The variables are also statistically significant but it seems that SDH's may have become less efficient due to access staffing.

Occupancy rate is also statistically significant indicating that a unit change in Occupancy rate has a positive impact on technical efficiency by 0.016384 units. Based on empirical evidence, hospitals with a higher occupancy rate imply a more efficient system as beds are utilized to the maximum. Beds as inputs are used efficiently to produce maximum treatment as outputs.

6.4.2 Output Oriented Model (VRS)

Table 18 Output Oriented DEA Regression Results (VRS)

Technical Efficiency (VRS)	*Constant*	*Coefficient*	*Standard Error*	*z-Statistic*	*Probability*
Operational Budget	0.704832	-4.13E-08	9.70E-08	-0.426182	0.6700
No. of Physicians	0.74024	-0.003161	0.004482	-0.705193	0.4807
No. of Nurses	0.74024	-0.000769	0.00109	-0.705193	0.4807
Hospital Beds	0.389851	0.007131	0.004652	1.532994	0.1253
Physicians to Bed ratio	0.954924	-0.280273	0.107242	-2.613465	0.009*
Nurses to Bed ratio	0.954924	-0.068175	0.026086	-2.613465	0.009*
Phy/ 1000 Pop	0.779049	-0.080995	0.054036	-1.498905	0.1339
Nur/ 1000 Pop	0.779049	-0.011334	0.010734	-1.055872	0.291
Occupancy Rate	0.315328	0.010519	0.00501	2.099668	0.0358*
Elderly Population	0.450269	0.00011	6.58E-05	1.666595	0.0956
Population Density	0.531335	7.74E-04	0.000647	1.196275	0.2316

Notes (1) * p-value ≤ 0.05

Under the output oriented mode with Variable Returns to Scale assumption, Physicians and Nurses to Bed ratio along with Occupancy rate are statistically significant. With the increase in hospital size or scale of operation, these independent variables would certainly have an impact on technical efficiency levels.

Table 19 Output Oriented DEA Regression Results of SE

Scale Efficiency	*Constant*	*Coefficient*	*Standard Error*	*z-Statistic*	*Probability*
Operational Budget	0.634234	1.12E-07	7.24E-08	1.541611	0.1232
No. of Physicians	0.669911	0.00484	0.003389	1.42815	0.1532
No. of Nurses	0.669911	0.001177	0.000824	1.42815	0.1532
Hospital Beds	0.550479	0.008933	0.003697	2.416395	0.0157*
Physicians to Bed ratio	0.825367	0.014528	0.103515	0.14035	0.8884
Nurses to Bed ratio	0.825367	0.003534	0.025179	0.14035	0.8884
Phy/ 1000 Pop	1.024018	-0.094767	0.040944	-2.314557	0.0206*

Nur/ 1000 Pop	1.024018	-0.023052	0.009959	-2.314557	0.0206*
Occupancy Rate	0.553992	0.009983	0.004317	2.31226	0.0208*
Elderly Population	0.688298	9.83E-05	5.54E-05	1.776684	0.0756
Population Density	0.899818	-4.76E-04	0.000536	-0.888327	0.3744

Notes (1) * p-value ≤ 0.05

As for the determinants of scale efficiency, the number of hospital beds, number of hospital beds, Physicians and Nurses Ratio to 1000 population and Occupancy rate are statistically significant therefore these determinants are to be carefully assessed by policy analysts and decision makers.

The number of hospital beds is an important component during the service and functional planning phase of infrastructure development. The right number of beds has a positive impact on hospital efficiency thus proper analysis should be undertaken in determining the "right" number of beds the hospitals should accommodate.

Also the deployment of appropriate number of doctors and nurses to SDH's is critical in ensuring that services are provided as per the population of the catchment area. Given its statistically significant, implication for policy analysts and decision makers is to always account for population growth when deciding on the "adequate" or "right" number of doctors and nurses that needs to be deployed to SDH's. Shortage or access could have potential negative impact on Scale efficiency.

Occupancy rate is also statistically significant confirming that depending on the hospital size decided by number of beds; the occupancy rate could also dictate how scale efficient the SDH's are. The higher the number of beds as input would require higher occupancy rate as an output.

6.4.3 "Slacks"

In an output oriented DEA model, (T. Coelli, 2008) defines that in a piece wise form of the non-parametric DEA can cause a few difficulty in efficiency measurement. Some DMU's that do not fall in the production frontier but are enveloped onto the frontier due to the frontier running parallely to the axes, these DMU;s may not be fully efficient but provides a radial measure of augmenting output to move to efficiency points on the frontier.

Simply, the values provided by DEA in terms of output slacks provides DMU's numerical answers of the quantity of outputs that needs to be increased to move from an inefficient to an efficient point on the frontier. It represents only the leftover portions of inefficiencies after proportional reductions in inputs or outputs. If a DMU cannot reach the efficiency frontier, SLACKS are needed to push the DMU to the frontier.

6.4.3.1 Output Slacks (CRS)

Table 20 Output Slacks under Constant Returns to Scale

DMU	*Outpatient Visits*	*Inpatient Days*
1	0	0
2	0	0
3	0	0
4	0	0
5	0	0
6	0	0
7	0	0
8	0	0
9	0	0
10	0	0

11	0	0
12	0	0
13	0	0
14	50617.11	0
15	0	0
16	0	0
17	24704.816	0
mean	4430.702	0

Using the assumption of a Constant Returns to Scale, the output slacks provides only two firms that need to increase their outputs as they are producing below full capacity. Hospital 14 and 17 need to increase their outputs by 50,617.11 visits and 24,704.81 visits respectively.

6.4.3.2 Output Slacks (VRS)

Table 21 Output Slacks under Variable Returns to Scale

DMU	*Outpatient Visits*	*Inpatient Days*
1	0	2143.378
2	0	1974.954
3	0	271.322
4	0	0
5	0	0
6	0	678.974
7	0	0
8	0	1330.851
9	0	0
10	0	0
11	0	0
12	0	661.743

13	0	0
14	43796.273	0
15	0	0
16	0	310.722
17	23375.432	0
mean	3951.277	433.644

Under the VRS, DMU' 14 and 17 again need to increase outpatient visits by 43,796.27 and 23,375.43 respectively. On the other hand, when relaxing the assumption of CRS and implying that scale of operations could determine output levels, DMU;s 1,2 3,6, 8, 12 and 16 reflect the levels by which Inpatient days needs to be increased to move to the efficient frontier. The result to a large extent is obvious as evident in the low occupancy rates recorded in majority of the SDH's.

CHAPTER VII

CONCLUSION AND RECOMMENDATION

Fiji' by default of its size face a daunting task of increasing efficiency and productivity of public services, in particular health services. The tasks of creating economies of scale, reducing average and marginal costs, minimizing wastage, minimizing health expenditure, optimizing benefits from funded programs and projects using economics and econometric tools in assessing performance is very limited or does not exist at all. While many reforms have been put in place to improve services, the benefit and costs are not taking into consideration due to lack of such technical expertise within the Ministry to do such an analysis using tools such as DEA.

This study thus is the first attempt to measure and evaluate health services performance based on economic and mathematical engineering concepts of efficiency and productivity. It does have its limitations and further studies would be necessary to verify results and use recent data to update the results of this study.

Firstly, it is important to ask of whether the study has met its objectives or not. The objectives of the study were aimed at:

1 To measure the change in total factor productivity from 2005-2014 and decomposing total factor productivity into technical efficiency change or the "catching up effect" and technical change or the "true technological change".

2 Identifying the determinants or variables that have influenced total factor productivity and technical efficiency changes in Fiji over period of the study.

3 To determine the technical and Scale efficiency of sub-divisional hospitals in Fiji in 2014 and identifying the determinants or variables that influenced technical and scale efficiency in SDH's in Fiji in 2014.

4 To identify "benchmark" hospitals and "best practices" for standardization of services.

7.1 Objective 1

The objective of exploring the change in total factor productivity of SDH's in Fiji over a decade was to provide decision makers and policy analysts an actual glimpse of what factors influenced productivity more. Productivity change is a product of a change in technical efficiency of the firm in moving towards the most efficient production frontier and technological change which reflect movement of the whole frontier due to new innovation or methods of treating patients that increases outputs to a totally new level. Therefore, the computation of the productivity index was necessary.

The results in summary reflected that the total factor productivity has fallen drastically since 2005 and now for the last period 2013-2014 decreased by a substantial 14.3 percent. In the last period of the study i.e between 2013 to 2014, out of 17 hospitals only 4 had shown coefficients of positive growth indicating productivity gains and the rest had productivity losses.

While technological change has seen a slow but improving growth especially in the last period, technical inefficiency seems to be the major contributor towards the slow progress in producing more outputs within the resources allocated by Government. It is alarming to note that all 17 hospitals had indices below 1 which indicated productivity losses due to technical inefficiency in all hospitals.

As Per literature Technical inefficiencies can be influenced by many factors. It could be largely due to the lack of financial resources in particular for operational purposes to ensure services are delivered; other factors also have a major impact on the degree of efficiency of service provision.

Factors such as hospital size may affect resource inputs and overall production of outputs. Some large bed numbered SDH's may have greater efficiency than small bed hospitals. Economies of scale are greatest in hospitals that are large. Furthermore, the status of the hospital (Public or Private) may influence service delivery performance. As we are all aware globally, the public health system lack incentives, in particular finance, to drive health workers to work smarter. The Service mix or the range of services available within the hospital may differ from hospital to hospital even if standards are implemented. Some SDH's case mix are very narrow therefore been inefficient as compared to increased or higher service mix. Finally, the importance of Labour is a major factor in determining hospital technical efficiency.

Recommendation – As the gist of the problem appears to be as a direct result of high technical inefficiencies, the SDH's would need to **review the current mix of clinical role delineation** and assign or delegate services based on factor such as size of operational budget.

Based on the above assignment than an assessment must be made on the proportionate of other services that could be delegated to SDH's to ensure services are provided to the most isolated community in Fiji. Factors such as Labour recruitment and deployment, financing of services and providers are discussed everyday.

7.2 Objective 2

It is interesting to note that many factors were insignificant in determining hospital efficiency and productivity measures apart from Population density. While the provision of operational budget was significant, it had results that depicted that there was some form of wastage or loss in the manner of how resources were allocated and utilized.

Predominantly, reasons that had deteriorated the technical efficiency should have been a result of the limited key inputs, either financial or in the form of human resources or technological. While technological efficiency may have deteriorated due to scale of operations as mentioned, it is not easy to influence to Governments of using economic rational as the only basis for making decisions on resource allocation or hospital size, capital investment etc. Therefore focus is diverted to reason for deterioration of technical efficiency and means of improving it.

Recommendation – As the gist of the problem appears to be as a direct result of high technical inefficiencies, the SDH's would need to **review the current mix of clinical role delineation** and assign or delegate services based on factor such as size of operational budget. Furthermore, some signs reflect unexpected results highlighting further investigation into matters such as increase in operational budget expected to get a positive sign on influencing efficiency but results reflected a negative growth in technical efficiency. Those coefficients as illustrated in Table …… that reflect opposite signs needs to be investigated. Operational budget, Elderly population, Hospital Beds, Number of Physicians reflected an opposite sign which needs to be further investigated.

7.3 Objective 3

The DEA multistage analysis provided some answers to our output. The first Output oriented measure illustrated that there were 13 hospitals that were producing with the possibility of increasing returns to scale. This indicated that 13 out of 17 hospitals were still producing less output with the given input resources and there were possibilities of reaching the optimum output without additional input resources.

Under the output oriented, out of 17 hospitals 8 represent a Decreasing Returns to Scale (DRS). This means that an additional unit of input is unable to provide the same marginal benefit as at the optimum point of output and still produce less than optimum. Policy makers could reallocate funding from firms reflecting a Decreasing Returns to Scale to those reflecting an Increasing Rate of Returns.

Recommendation – policy makers needs to identify hospitals that are reflecting a DRS to spend less and move towards optimum level of productivity. Ministry will also identify those hospitals that need to increase its productivity to move to its optimal level.

7.4 Objective 4

Only two hospitals, namely hospital 11 and 13 depicted hospitals that were producing at the optimal level given the resources allocated. The result ensures that the two respective hospitals need to investigate what determinants have influenced their scores and what were some good service practices and bench marking of standard of care within that allowed them to be productively efficient. Policy makers need to explore the standards and practices further and adopt these new found standards and quality of care into other inefficient hospitals.

Recommendation – as a further study, the Ministry could explore and adopt the benchmarking standards and practices of the two most efficient firms and replicate it into all other officials.

7.5 Limitations of the Study

The following issues may limit the full potential of the study:

1. **Data Availability** – economic studies using the DEA methodology or any production frontier studies have never been done in Fiji and therefore data collection are not aligned parallely to fully meet data requirements.

2. **Relative measure** – the DEA efficiency scores are calculated for a homogenous set of DMU's therefore all observations and conclusions are generalised for the respective DMU's under the study. It does not reflect on the efficiency of other type of health facilities.

3. **No quality measure** - due to unavailability or completeness of quality data, no observation or statement is made on the qualitative aspect of hospital efficiency.

4. **Focussed on TE and SE only**, not allocative efficiency due to unavailability of price of input data.

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APPENDIX

APPENDIX A: Total Factor Productivity decomposed by Efficiency and Technological change for 4 major Divisions

Table 1: Central Division

Central				
	Rewa	Naitasiri	Serua/Namosi	Tailevu
2005-2006				
Efficiency Change	1.103	1.137	1.024	0.997
Technological Change	1.863	1.846	1.85	1.863
2006-2007				
Efficiency Change	0.943	1.045	0.964	0.986
Technological Change	1.53	1.543	1.533	1.53
2007-2008				
Efficiency	0.997	0.876	0.998	0.99

Change				
Technological Change	1.493	1.638	1.448	1.493
2008-2009				
Efficiency Change	1.026	2.13	0.949	0.963
Technological Change	1.159	1.3	1.159	1.159
2009-2010				
Efficiency Change	0.985	0.466	2.548	1.021
Technological Change	1.259	1.278	1.789	1.229
2010-2011				
Efficiency Change	0.854	0.872	0.36	0.83
Technological Change	1.411	1.411	0.819	1.411

2011-2012				
Efficiency Change	1.315	1.384	1.353	1.381
Technological Change	0.988	0.988	0.988	0.988
2012-2013				
Efficiency Change	0.834	0.881	0.882	1.022
Technological Change	0.957	0.957	0.957	0.957
2013-2014				
Efficiency Change	0.756	0.587	0.968	0.97
Technological Change	1.132	1.132	1.132	1.132

Table 2: Eastern Division

	Eastern				
	Lomaiviti	Kadavu	Lomaloma	Lakeba	Rotuma

2005-2006					
Efficiency Change	0.97	1.108	1	1.123	1
Technological Change	1.767	1.572	1.038	1.121	1.235
2006-2007					
Efficiency Change	0.943	0.933	1	1.67	1
Technological Change	1.552	1.55	1.128	1.018	1.324
2007-2008					
Efficiency Change	0.991	0.964	0.871	0.726	1
Technological Change	1.504	1.558	1.462	1.718	0.883
2008-2009					
Efficiency Change	1.001	1.046	1.148	0.835	1
Technological Change	1.159	1.12	1.239	1.208	1.283
2009-2010					
Efficiency Change	1.008	0.958	1	1.093	1
Technological Change	1.259	1.285	1.002	0.714	0.639
2010-2011					
Efficiency Change	0.849	0.979	1	0.74	1

Technological Change	1.411	1.411	1.194	1.39	1.132
2011-2012					
Efficiency Change	1.71	1.412	1	1.724	1
Technological Change	0.988	1.027	1.749	0.923	1.315
2012-2013					
Efficiency Change	0.96	0.928	1	0.793	1
Technological Change	0.957	0.957	0.767	0.979	1.021
2013-2014					
Efficiency Change	0.892	0.496	0.937	0.62	1
Technological Change	1.132	1.132	1.196	1.087	3.087

Table 3: Western Division

	Western				
	Ra	Tavua	Ba	Nadi	Nadroga
2005-2006					
Efficiency Change	0.981	0.986	0.988	1.155	1.037
Technological Change	1.25	1.191	1.141	1.096	1.056
2006-2007					

Efficiency Change	0.946	0.944	0.884	0.944	0.955
Technological Change	1.185	1.13	1.082	1.04	1.02
2007-2008					
Efficiency Change	0.994	0.99	0.992	0.9	0.992
Technological Change	1.227	1.17	1.12	1.12	1.12
2008-2009					
Efficiency Change	0.982	0.962	1.026	0.972	0.949
Technological Change	0.983	0.938	0.927	0.927	0.927
2009-2010					
Efficiency Change	1.015	1.025	0.986	1.02	1.07
Technological Change	1.09	1.01	1.049	1.049	0.93
2010-2011					
Efficiency Change	0.897	0.922	1.039	0.977	0.901
Technological Change	1.264	1.21	1.21	1.21	1.226
2011-2012					
Efficiency Change	1.538	1.415	2.054	1.076	1.491
Technological Change	0.821	0.818	0.824	0.829	0.831
2012-2013					
Efficiency Change	0.927	1.045	0.595	0.947	0.895
Technological Change	0.921	0.909	0.902	0.896	0.891
2013-2014					
Efficiency Change	0.997	0.965	0.952	0.937	0.66

Technological Change	1.019	1.019	1.019	1.019	1.998

Table 4: Northern Division

	Northern		
	Bua	Cakaudrove	Taveuni
2005-2006			
Efficiency Change	1.033	1.016	1.164
Technological Change	1.02	0.988	0.958
2006-2007			
Efficiency Change	0.937	0.988	0.906
Technological Change	1.02	1.02	1.02
2007-2008			
Efficiency Change	0.983	0.968	0.989
Technological Change	1.12	1.12	1.12
2008-2009			
Efficiency Change	0.985	0.94	0.986
Technological Change	0.927	0.927	0.927
2009-2010			
Efficiency Change	1.019	1.054	1.015
Technological Change	1.049	1.049	1.049
2010-2011			
Efficiency Change	0.901	0.946	0.995
Technological Change	1.21	1.21	1.21

2011-2012			
Efficiency Change	1.432	1.31	0.978
Technological Change	0.828	0.826	0.822
2012-2013			
Efficiency Change	0.866	0.893	1.102
Technological Change			
2013-2014			
Efficiency Change	0.948	0.907	0.607
Technological Change			

APPENDIX B: Data for Malmquist Productivity Index

TABLE 1: Panel Data for Malmquist Productivity Index

		Output		Input		
Hospital No. (DMU)	Time (Year)	Inpatient days	Outpatient Visits	Operational Budget	No. of Doctors	No of Nurses
1	2005	2505	184480	2717462	46	201
2	2005	677	21206	1311278	22	95
3	2005	742	30124	1403269	23	102
4	2005	844	23117	1166524	17	75
5	2005	1310	44592	1374415	19	84
6	2005	601	20854	1137368	18	77
7	2005	101	7313	651122	8	36
8	2005	380	26115	1177697	18	80
9	2005	318	2431	587479	7	30
10	2005	2980	61734	1631432	24	106

11	2005	2031	48778	1392797	20	86
12	2005	2415	128621	2205899	34	152
13	2005	3221	95982	2395080	42	183
14	2005	2434	88913	2414428	39	173
15	2005	727	38851	1203650	17	76
16	2005	2090	75157	1838405	29	127
17	2005	1231	29238	1391662	23	101
1	2006	2530	131450	2645683	40	201
2	2006	675	20897	1235225	19	95
3	2006	804	25027	1472694	20	102
4	2006	798	31483	1256102	15	75
5	2006	1003	48689	1520912	17	84
6	2006	541	12657	1149437	15	77
7	2006	171	6654	768173	7	36
8	2006	345	19686	1414067	16	80
9	2006	349	2970	630770	6	30
10	2006	3011	94423	1785676	21	106
11	2006	1813	39486	1517042	17	86
12	2006	2293	139427	2398307	30	152
13	2006	3557	105816	2227401	37	183
14	2006	2815	70318	2499881	35	173
15	2006	801	35024	1251621	15	76
16	2006	2502	69012	1942202	25	127
17	2006	1331	26787	1283887	20	101
1	2007	2438	82934	2751678	45	201
2	2007	414	23201	1305119	21	95
3	2007	843	15659	1492236	23	102
4	2007	771	32472	1248508	17	75
5	2007	763	34759	1604880	19	84
6	2007	530	17881	1196420	17	77
7	2007	214	6217	706598	8	36
8	2007	218	15780	1221873	18	80
9	2007	308	2592	618360	7	30
10	2007	2700	90469	1849762	23	106
11	2007	1493	46536	1575327	19	86

12	2007	2173	116053	2658392	34	152
13	2007	3670	66052	2313436	41	183
14	2007	2530	55796	2566097	38	173
15	2007	801	32512	1309905	17	76
16	2007	2524	70878	1926872	28	127
17	2007	1164	24160	1388651	22	101
1	2008	2438	120095	2465557	45	206
2	2008	474	21080	1175888	21	98
3	2008	908	35590	1335268	23	104
4	2008	748	16987	1125908	17	77
5	2008	890	32146	1424466	19	86
6	2008	452	26240	1069062	17	79
7	2008	222	9156	633911	8	37
8	2008	212	12885	1070246	18	82
9	2008	154	6165	552150	7	31
10	2008	2701	74917	1662243	23	108
11	2008	1957	46650	1421253	19	88
12	2008	2771	104218	2391802	34	155
13	2008	3092	86238	2296503	41	188
14	2008	2530	57828	2310897	38	177
15	2008	1364	24918	1190394	17	78
16	2008	2442	62809	1777508	28	130
17	2008	1205	38117	1253389	23	104
1	2009	1989	95091	2592029	47	223
2	2009	131	19186	1302230	22	105
3	2009	696	49981	1517395	24	113
4	2009	745	24253	1261020	18	83
5	2009	987	35486	1535638	20	93
6	2009	376	23682	1180233	18	85
7	2009	135	7552	704038	8	39
8	2009	328	8536	1291465	19	88
9	2009	246	3439	595574	7	33
10	2009	2310	47040	1825586	25	117
11	2009	1826	31263	1592851	20	95
12	2009	2106	102475	2515126	35	168

13	2009	3099	61007	2548246	43	203
14	2009	2226	44825	2625606	40	191
15	2009	861	29735	1303812	18	84
16	2009	2225	64589	2040258	30	140
17	2009	1495	37073	1371396	24	112
1	2010	2816	135668	2508228	47	223
2	2010	514	30635	1218430	22	105
3	2010	62	40624	1405662	24	113
4	2010	756	32168	1177220	18	83
5	2010	1133	44287	1451838	20	93
6	2010	482	24928	1096434	18	85
7	2010	140	10414	648156	8	39
8	2010	323	16913	1123866	19	88
9	2010	139	12022	567610	7	33
10	2010	1822	58928	1713854	25	117
11	2010	1458	61899	1481119	20	95
12	2010	2184	123742	2431325	35	168
13	2010	2898	80254	2380648	43	203
14	2010	2951	49543	2402142	40	191
15	2010	949	38969	1220013	18	84
16	2010	2242	74838	1844726	30	140
17	2010	1713	39588	1287597	24	112
1	2011	3287	131314	2429197	50	244
2	2011	647	26610	1155669	21	103
3	2011	957	38224	1303213	25	122
4	2011	802	31756	1173068	20	96
5	2011	1269	50822	1414170	26	128
6	2011	474	23885	925602	17	84
7	2011	152	9031	549432	9	43
8	2011	484	22876	956430	17	85
9	2011	159	9223	469285	7	34
10	2011	2101	31241	1580151	30	148
11	2011	1360	38344	1328176	26	125
12	2011	1996	89495	1934737	37	183
13	2011	4811	108613	2014821	37	180

14	2011	2827	71650	2146083	42	206
15	2011	847	34447	1119749	19	95
16	2011	1652	52222	1612277	29	144
17	2011	1583	30655	1069997	22	107
1	2012	3296	149271	2137356	33	169
2	2012	613	32066	966091	20	100
3	2012	887	45239	1113963	28	140
4	2012	946	34108	982752	21	108
5	2012	1028	25293	956683	20	101
6	2012	508	13653	758207	15	78
7	2012	63	7965	542896	9	48
8	2012	301	24493	668897	18	89
9	2012	99	4849	588831	8	43
10	2012	1545	59221	1274825	27	139
11	2012	1466	40096	1154493	23	119
12	2012	2048	108069	1149725	43	219
13	2012	4453	112405	2269977	57	289
14	2012	3052	97276	1735955	42	213
15	2012	921	31690	938435	20	99
16	2012	1033	37727	1500099	40	203
17	2012	1056	30421	1337736	25	129
1	2013	3333	144066	3012871	58	294
2	2013	550	39108	1288427	22	114
3	2013	969	39720	1483828	28	140
4	2013	882	44031	1130288	19	98
5	2013	1020	48811	1171870	20	101
6	2013	499	22153	960232	16	80
7	2013	107	7210	638089	10	49
8	2013	350	19496	950881	16	82
9	2013	143	3703	638261	8	41
10	2013	1630	81870	1507003	27	137
11	2013	1368	100915	1222055	21	106
12	2013	3096	130938	2153159	39	199
13	2013	5323	145779	2688351	50	256
14	2013	3681	113049	2188234	41	207

15	2013	793	33078	1227859	20	103
16	2013	1982	60457	1873579	32	161
17	2013	1473	34422	1349523	22	113
1	2014	2860	139550	3914560	82	336
2	2014	448	32644	2154419	44	179
3	2014	772	49544	1505165	29	120
4	2014	919	49849	1143852	20	82
5	2014	819	50529	1289281	24	100
6	2014	477	25479	1900681	39	161
7	2014	181	7794	668804	11	44
8	2014	298	20996	1901544	39	160
9	2014	124	5818	626471	9	35
10	2014	1424	62239	1483784	28	114
11	2014	1328	104342	1242853	21	88
12	2014	3353	147528	2220514	42	173
13	2014	6203	198084	2816339	52	215
14	2014	3845	95637	3254956	64	264
15	2014	746	39212	1271064	22	91
16	2014	2029	96102	2028125	34	140
17	2014	1170	31350	2182784	43	176

APPENDIX C: Results of Malmquist Productivity Indices

Table 1: Technical Efficiency Change Indices (2005-2014)

DMU	*05-06*	*06-07*	*07-08*	*08-09*	*09-10*	*10-11*	*11-12*	*12-13*	*13-14*
1	1.103	0.943	0.997	1.026	0.985	0.854	1.315	0.834	0.756
2	1.137	1.045	0.876	2.13	0.466	0.872	1.384	0.881	0.587
3	1.024	0.964	0.998	0.949	2.548	0.36	1.353	0.882	0.968
4	0.997	0.986	0.99	0.963	1.021	0.83	1.381	1.022	0.97
5	0.97	0.943	0.991	1.001	1.008	0.849	1.71	0.96	0.892
6	1.108	0.933	0.964	1.046	0.958	0.979	1.412	0.928	0.496
7	1	1	0.871	1.148	1	1	1	1	0.937
8	1.123	1.67	0.726	0.835	1.093	0.74	1.724	0.793	0.62

9	1	1	1	1	1	1	1	1	1
10	0.981	0.946	0.994	0.982	1.015	0.897	1.538	0.927	0.997
11	0.986	0.944	0.99	0.962	1.025	0.922	1.415	1.045	0.965
12	0.988	0.884	0.992	1.026	0.986	1.039	2.054	0.595	0.952
13	1.155	0.944	0.9	0.972	1.02	0.977	1.076	0.947	0.937
14	1.037	0.955	0.992	0.949	1.07	0.901	1.491	0.895	0.66
15	1.033	0.937	0.983	0.985	1.019	0.901	1.432	0.866	0.948
16	1.016	0.988	0.968	0.94	1.054	0.946	1.31	0.893	0.907
17	1.164	0.906	0.989	0.986	1.015	0.995	0.978	1.102	0.607

Table 2: Technical (Technological) Change Indices (2005-2014)

DMU	*05-06*	*06-07*	*07-08*	*08-09*	*09-10*	*10-11*	*11-12*	*12-13*	*13-14*
1	1.863	1.53	1.493	1.159	1.259	1.411	0.988	0.957	1.132
2	1.846	1.543	1.638	1.3	1.278	1.411	0.988	0.957	1.132
3	1.85	1.533	1.448	1.159	1.789	0.819	0.988	0.957	1.132
4	1.863	1.53	1.493	1.159	1.229	1.411	0.988	0.957	1.132
5	1.767	1.552	1.504	1.159	1.259	1.411	0.988	0.957	1.132
6	1.572	1.55	1.558	1.12	1.285	1.411	1.027	0.957	1.132
7	1.038	1.128	1.462	1.239	1.002	1.194	1.749	0.767	1.042
8	1.121	1.018	1.718	1.208	0.714	1.39	0.923	0.979	1.057
9	1.235	1.324	0.883	1.283	0.639	1.132	1.315	1.021	0.85
10	1.25	1.185	1.227	0.983	1.09	1.264	0.821	0.921	1.019
11	1.191	1.13	1.17	0.938	1.01	1.21	0.818	0.909	1.019
12	1.141	1.082	1.12	0.927	1.049	1.21	0.824	0.902	1.019
13	1.096	1.04	1.12	0.927	1.049	1.21	0.829	0.896	1.019
14	1.056	1.02	1.12	0.927	0.93	1.226	0.831	0.891	1.019
15	1.02	1.02	1.12	0.927	1.049	1.21	0.828	0.89	1.019
16	0.988	1.02	1.12	0.927	1.049	1.21	0.826	0.891	1.019
17	0.958	1.02	1.12	0.927	1.049	1.21	0.822	0.897	1.019

Table 3: Total Factor Productivity Change Indices (2005-2014)

DMU	*05-06*	*06-07*	*07-08*	*08-09*	*9-10*	*10-11*	*11-12*	*12-13*	*13-14*
1	2.054	1.442	1.488	1.189	1.240	1.205	1.299	0.798	0.855
2	2.099	1.613	1.436	2.769	0.596	1.230	1.367	0.844	0.664
3	1.894	1.477	1.445	1.100	4.559	0.295	1.337	0.845	1.095
4	1.857	1.509	1.479	1.116	1.255	1.171	1.364	0.978	1.098
5	1.715	1.463	1.491	1.160	1.269	1.198	1.689	0.918	1.010
6	1.742	1.445	1.502	1.171	1.231	1.382	1.450	0.888	0.561
7	1.038	1.128	1.274	1.422	1.002	1.194	1.749	0.767	0.976
8	1.259	1.699	1.248	1.009	0.780	1.028	1.591	0.777	0.655
9	1.235	1.324	0.883	1.283	0.639	1.132	1.315	1.021	0.850
10	1.226	1.122	1.219	0.966	1.107	1.134	1.263	0.854	1.016
11	1.174	1.067	1.158	0.902	1.035	1.115	1.157	0.950	0.983
12	1.126	0.957	1.111	0.951	1.034	1.257	1.692	0.537	0.970
13	1.265	0.981	1.007	0.901	1.070	1.182	0.892	0.849	0.955
14	1.095	0.974	1.110	0.880	0.994	1.105	1.239	0.797	0.672
15	1.053	0.956	1.100	0.913	1.069	1.090	1.186	0.771	0.966
16	1.004	1.008	1.084	0.871	1.106	1.144	1.082	0.796	0.924
17	1.115	0.925	1.108	0.914	1.065	1.203	0.804	0.989	0.618

APPENDIX D: Log Linear Regression Data for Malmquist Productivity Index

Table 1: (Technical Efficiency Change Index)

Technical Efficiency Change (Y) Dependent Variable regressed against many Independent variable.

i	t	Y	Bud	Phy	Nur	HB	PB	NB	PPOP	NPOP	OR	EP	PD
1	2	1.103	2645683	40	201	29	1.4	6.9	0.55	2.8	65.0	3399	463
2	2	1.137	1235225	19	95	21	0.9	4.5	0.96	4.8	25.8	737	52
3	2	1.024	1472694	20	102	12	1.7	8.5	0.84	4.2	37.7	2098	48

4	2	0.997	1256102	15	75	17	0.9	4.4	0.65	3.3	26.0	1156	64
5	2	0.970	1520912	17	84	40	0.4	2.1	0.99	5.0	17.7	904	107
6	2	1.108	1149437	15	77	22	0.7	3.5	1.51	7.5	26.3	664	60
7	2	1.000	768173	7	36	16	0.4	2.2	2.22	11.1	10.9	318	161
8	2	1.123	1414067	16	80	17	0.9	4.7	2.05	10.2	21.8	633	95
9	2	1.000	630770	6	30	14	0.4	2.1	2.09	10.5	30.9	282	159
10	2	0.981	1785676	21	106	29	0.7	3.6	0.70	3.5	63.5	1756	68
11	2	0.986	1517042	17	86	42	0.4	2.1	0.59	3.0	21.4	1687	89
12	2	0.988	2398307	30	152	46	0.7	3.3	0.50	2.5	42.7	2649	283
13	2	1.155	2227401	37	183	85	0.4	2.2	0.45	2.2	37.2	4069	161
14	2	1.037	2499881	35	173	58	0.6	3.0	0.66	3.3	55.6	2603	73
15	2	1.033	1251621	15	76	32	0.5	2.4	0.94	4.7	29.6	941	29
16	2	1.016	1942202	25	127	58	0.4	2.2	0.73	3.7	44.9	1817	51
17	2	1.164	1283887	20	101	33	0.6	3.1	1.35	6.8	34.9	782	80
1	3	0.943	2751678	45	201	29	1.5	6.9	0.60	2.7	55.3	3479	474
2	3	1.045	1305119	21	95	21	1.0	4.5	1.04	4.7	18.4	753	54
3	3	0.964	1492236	23	102	12	1.9	8.5	0.90	4.1	38.1	2156	49
4	3	0.986	1248508	17	75	17	1.0	4.4	0.76	3.4	23.9	1098	61
5	3	0.943	1604880	19	84	40	0.5	2.1	1.11	5.0	12.0	901	107
6	3	0.933	1196420	17	77	22	0.8	3.5	1.68	7.6	18.8	662	60
7	3	1.000	706598	8	36	16	0.5	2.2	2.48	11.2	15.1	315	160
8	3	1.670	1221873	18	80	17	1.0	4.7	2.34	10.5	18.6	616	92
9	3	1.000	618360	7	30	14	0.5	2.1	3.32	15.0	20.3	197	111
10	3	0.946	1849762	23	106	31	0.8	3.4	0.77	3.5	59.4	1759	68
11	3	0.944	1575327	19	86	42	0.5	2.1	0.66	3.0	21.5	1662	88
12	3	0.884	2658392	34	152	36	0.9	4.2	0.55	2.5	46.9	2668	285
13	3	0.944	2313436	41	183	85	0.5	2.2	0.49	2.2	42.5	4115	163
14	3	0.955	2566097	38	173	58	0.7	3.0	0.74	3.3	45.6	2587	73
15	3	0.937	1309905	17	76	32	0.5	2.4	1.11	5.0	29.6	886	27
16	3	0.988	1926872	28	127	58	0.5	2.2	0.80	3.6	43.7	1836	51

17	3	0.906	1388651	22	101	33	0.7	3.1	1.45	6.5	45.4	812	83
1	4	0.997	2465557	45	206	29	1.5	7.1	0.59	2.7	74.6	3550	484
2	4	0.876	1175888	21	98	21	1.0	4.7	1.04	4.8	22.8	757	54
3	4	0.998	1335268	23	104	12	1.9	8.7	0.88	4.1	39.9	2214	50
4	4	0.990	1125908	17	77	17	1.0	4.5	0.75	3.4	33.5	1122	63
5	4	0.991	1424466	19	86	40	0.5	2.2	1.04	4.8	11.2	966	114
6	4	0.964	1069062	17	79	22	0.8	3.6	1.67	7.7	18.7	664	60
7	4	0.871	633911	8	37	16	0.5	2.3	2.43	11.2	14.9	324	164
8	4	0.726	1070246	18	82	17	1.0	4.8	2.42	11.1	11.3	595	89
9	4	1.000	552150	7	31	14	0.5	2.2	3.19	14.7	17.8	206	116
10	4	0.994	1662243	23	108	31	0.8	3.5	0.77	3.6	65.9	1760	69
11	4	0.990	1421253	19	88	42	0.5	2.1	0.65	3.0	28.2	1702	90
12	4	0.992	2391802	34	155	36	0.9	4.3	0.55	2.5	64.9	2684	286
13	4	0.900	2296503	41	188	85	0.5	2.2	0.49	2.2	67.3	4160	164
14	4	0.992	2310897	38	177	58	0.7	3.0	0.72	3.3	45.6	2637	74
15	4	0.983	1190394	17	78	32	0.5	2.4	1.04	4.8	46.1	949	29
16	4	0.968	1777508	28	130	58	0.5	2.2	0.81	3.7	71.9	1826	51
17	4	0.989	1253389	23	104	33	0.7	3.1	1.43	6.6	67.0	825	84
1	5	1.026	2592029	47	223	29	1.6	7.7	0.61	2.9	51.3	3608	492
2	5	2.130	1302230	22	105	21	1.1	5.0	0.87	4.1	6.3	952	68
3	5	0.949	1517395	24	113	12	2.0	9.4	0.93	4.4	37.4	2202	50
4	5	0.963	1261020	18	83	17	1.0	4.9	0.79	3.7	40.6	1110	62
5	5	1.001	1535638	20	93	40	0.5	2.3	1.09	5.1	15.7	966	114
6	5	1.046	1180233	18	85	22	0.8	3.9	1.75	8.3	16.6	666	61
7	5	1.148	704038	8	39	16	0.5	2.5	2.47	11.7	8.0	335	169
8	5	0.835	1291465	19	88	17	1.1	5.2	2.41	11.4	9.5	627	94
9	5	1.000	595574	7	33	14	0.5	2.4	3.30	15.6	2.8	209	118
10	5	0.982	1825586	25	117	31	0.8	3.8	0.92	4.3	65.8	1556	61
11	5	0.962	1592851	20	95	42	0.5	2.3	0.68	3.2	29.5	1709	90
12	5	1.026	2515126	35	168	36	1.0	4.7	0.62	2.9	51.9	2504	267

13	5	0.972	2548246	43	203	85	0.5	2.4	0.49	2.3	36.9	4317	171
14	5	0.949	2625606	40	191	58	0.7	3.3	0.77	3.6	43.0	2602	73
15	5	0.985	1303812	18	84	32	0.6	2.6	1.12	5.3	23.3	920	28
16	5	0.940	2040258	30	140	58	0.5	2.4	0.87	4.1	30.6	1794	50
17	5	0.986	1371396	24	112	33	0.7	3.4	1.45	6.9	35.8	850	87
1	6	0.985	2508228	47	223	29	1.6	7.7	0.60	2.9	65.8	3633	495
2	6	0.466	1218430	22	105	21	1.1	5.0	1.13	5.4	19.7	730	52
3	6	2.548	1405662	24	113	12	2.0	9.4	0.94	4.4	37.4	2180	50
4	6	1.021	1177220	18	83	17	1.0	4.9	0.83	3.9	34.6	1065	59
5	6	1.008	1451838	20	93	40	0.5	2.3	1.14	5.4	16.0	925	110
6	6	0.958	1096434	18	85	22	0.8	3.9	1.75	8.3	20.9	669	61
7	6	1.000	648156	8	39	16	0.5	2.5	2.56	12.1	9.5	323	163
8	6	1.093	1123866	19	88	17	1.1	5.2	2.54	12.0	20.4	597	89
9	6	1.000	567610	7	33	14	0.5	2.4	3.66	17.3	8.1	189	106
10	6	1.015	1713854	25	117	31	0.8	3.8	0.82	3.9	58.0	1732	67
11	6	1.025	1481119	20	95	29	0.7	3.3	0.74	3.5	38.5	1570	83
12	6	0.986	2431325	35	168	55	0.6	3.0	0.61	2.9	36.0	2554	272
13	6	1.020	2380648	43	203	85	0.5	2.4	0.49	2.3	48.4	4332	171
14	6	1.070	2402142	40	191	58	0.7	3.3	0.75	3.5	57.0	2673	75
15	6	1.019	1220013	18	84	32	0.6	2.6	1.15	5.4	31.7	896	27
16	6	1.054	1844726	30	140	58	0.5	2.4	0.85	4.0	34.7	1821	51
17	6	1.015	1287597	24	112	33	0.7	3.4	1.45	6.9	29.9	852	87
1	7	0.854	2429197	50	244	29	1.7	8.4	0.61	3.0	53.7	3810	519
2	7	0.872	1155669	21	103	23	0.9	4.5	1.03	5.1	22.3	753	54
3	7	0.360	1303213	25	122	12	2.1	10.1	0.95	4.7	45.9	2246	51
4	7	0.830	1173068	20	96	17	1.2	5.7	0.92	4.5	36.0	1065	59
5	7	0.849	1414170	26	128	40	0.7	3.2	1.48	7.3	16.0	938	111
6	7	0.979	925602	17	84	22	0.8	3.8	1.59	7.8	25.5	698	63
7	7	1.000	549432	9	43	16	0.5	2.7	2.72	13.3	9.8	318	161
8	7	0.740	956430	17	85	17	1.0	5.0	2.36	11.6	24.1	597	89

9	7	1.000	469285	7	34	14	0.5	2.4	3.62	17.7	12.2	189	106
10	7	0.897	1580151	30	148	31	1.0	4.8	1.00	4.9	32.4	1739	68
11	7	0.922	1328176	26	125	29	0.9	4.3	0.93	4.5	40.3	1595	84
12	7	1.039	1934737	37	183	55	0.7	3.3	0.67	3.3	29.6	2424	259
13	7	0.977	2014821	37	180	75	0.5	2.4	0.42	2.1	55.4	4318	171
14	7	0.901	2146083	42	206	58	0.7	3.6	0.84	4.1	46.1	2502	71
15	7	0.901	1119749	19	95	26	0.7	3.7	1.28	6.3	30.3	887	27
16	7	0.946	1612277	29	144	56	0.5	2.6	0.86	4.2	28.9	1780	50
17	7	0.995	1069997	22	107	33	0.7	3.2	1.33	6.5	34.9	859	88
1	8	1.315	2137356	33	169	29	1.1	5.8	0.39	2.0	48.0	3933	536
2	8	1.384	966091	20	100	23	0.9	4.4	0.94	4.7	18.0	783	56
3	8	1.353	1113963	28	140	12	2.3	11.6	0.93	4.7	66.8	2550	58
4	8	1.381	982752	21	108	17	1.3	6.4	1.05	5.3	44.9	1020	57
5	8	1.710	956683	20	101	40	0.5	2.5	1.29	6.5	16.0	825	98
6	8	1.412	758207	15	78	22	0.7	3.5	1.40	7.1	19.7	713	65
7	8	1.000	542896	9	48	16	0.6	3.0	2.90	14.7	4.1	321	162
8	8	1.724	668897	18	89	17	1.0	5.2	2.49	12.6	18.0	573	86
9	8	1.000	588831	8	43	14	0.6	3.1	4.33	21.9	7.7	193	108
10	8	1.538	1274825	27	139	31	0.9	4.5	0.92	4.7	42.5	1727	67
11	8	1.415	1154493	23	119	29	0.8	4.1	0.84	4.2	23.2	1614	85
12	8	2.054	1149725	43	219	55	0.8	4.0	0.78	3.9	28.2	2435	260
13	8	1.076	2269977	57	289	75	0.8	3.8	0.65	3.3	51.7	4360	172
14	8	1.491	1735955	42	213	58	0.7	3.7	0.82	4.2	52.0	2539	72
15	8	1.432	938435	20	99	26	0.8	3.8	1.27	6.4	37.9	897	27
16	8	1.310	1500099	40	203	56	0.7	3.6	1.25	6.3	6.6	1679	47
17	8	0.978	1337736	25	129	33	0.8	3.9	1.59	8.1	5.4	837	85
1	9	0.834	3012871	58	294	29	2.0	10.2	0.69	3.5	47.8	3932	536
2	9	0.881	1288427	22	114	24	0.9	4.7	1.12	5.7	22.2	742	53
3	9	0.882	1483828	28	140	22	1.3	6.4	0.93	4.7	50.0	2548	58
4	9	1.022	1130288	19	98	17	1.1	5.8	0.96	4.9	40.7	995	55

5	9	0.960	1171870	20	101	40	0.5	2.5	1.43	7.3	16.7	741	88
6	9	0.928	960232	16	80	22	0.7	3.6	1.42	7.2	22.0	713	65
7	9	1.000	638089	10	49	16	0.6	3.0	2.20	11.2	6.6	428	217
8	9	0.793	950881	16	82	17	0.9	4.8	2.20	11.2	20.0	593	89
9	9	1.000	638261	8	41	14	0.6	2.9	4.20	21.4	7.2	190	107
10	9	0.927	1507003	27	137	33	0.8	4.1	0.90	4.6	53.8	1729	67
11	9	1.045	1222055	21	106	29	0.7	3.6	0.78	4.0	32.7	1533	81
12	9	0.595	2153159	39	199	55	0.7	3.6	0.70	3.6	38.1	2435	260
13	9	0.947	2688351	50	256	75	0.7	3.4	0.55	2.8	61.5	4523	179
14	9	0.895	2188234	41	207	58	0.7	3.6	0.75	3.8	52.7	2683	76
15	9	0.866	1227859	20	103	26	0.8	4.0	1.27	6.4	20.8	930	28
16	9	0.893	1873579	32	161	56	0.6	2.9	0.97	4.9	31.4	1711	48
17	9	1.102	1349523	22	113	33	0.7	3.4	1.34	6.8	34.7	866	88
1	10	0.756	3914560	82	336	29	2.8	11.6	0.96	4.0	37.7	3953	539
2	10	0.587	2154419	44	179	24	1.8	7.5	2.16	8.9	13.4	751	53
3	10	0.968	1505165	29	120	22	1.3	5.5	0.99	4.1	23.2	2545	58
4	10	0.970	1143852	20	82	17	1.2	4.8	0.89	3.7	37.8	1115	62
5	10	0.892	1289281	24	100	40	0.6	2.5	1.51	6.2	18.4	863	102
6	10	0.496	1900681	39	161	22	1.8	7.3	3.59	14.7	20.2	709	64
7	10	0.937	668804	11	44	16	0.7	2.7	3.16	13.0	11.7	332	168
8	10	0.620	1901544	39	160	17	2.3	9.4	5.34	21.9	11.5	593	89
9	10	1.000	626471	9	35	14	0.6	2.5	4.59	18.9	9.2	185	104
10	10	0.997	1483784	28	114	33	0.8	3.4	0.95	3.9	42.1	1692	66
11	10	0.965	1242853	21	88	29	0.7	3.0	0.81	3.3	31.2	1525	81
12	10	0.952	2220514	42	173	55	0.8	3.1	0.75	3.1	49.1	2449	261
13	10	0.937	2816339	52	215	75	0.7	2.9	0.58	2.4	70.8	4514	178
14	10	0.660	3254956	64	264	58	1.1	4.6	1.22	5.0	42.8	2621	74
15	10	0.948	1271064	22	91	26	0.8	3.5	1.31	5.4	28.5	983	30
16	10	0.907	2028125	34	140	56	0.6	2.5	1.03	4.2	28.4	1728	48
17	10	0.607	2182784	43	176	33	1.3	5.3	2.57	10.6	29.0	871	89

Table 2: Log Linear Regression Data for Malmquist Productivity Index (Technological Change Index)

Technological Change (Y) Dependent Variable regressed against many Independent variable.													
i	t	Y	Bud	Phy	Nur	HB	PB	NB	PPOP	NPOP	OR	EP	PD
1	2	2.054	2645683	40	201	29	1.4	6.9	0.55	2.8	65.0	3399	463
2	2	2.099	1235225	19	95	21	0.9	4.5	0.96	4.8	25.8	737	52
3	2	1.894	1472694	20	102	12	1.7	8.5	0.84	4.2	37.7	2098	48
4	2	1.857	1256102	15	75	17	0.9	4.4	0.65	3.3	26.0	1156	64
5	2	1.715	1520912	17	84	40	0.4	2.1	0.99	5.0	17.7	904	107
6	2	1.742	1149437	15	77	22	0.7	3.5	1.51	7.5	26.3	664	60
7	2	1.038	768173	7	36	16	0.4	2.2	2.22	11.1	10.9	318	161
8	2	1.259	1414067	16	80	17	0.9	4.7	2.05	10.2	21.8	633	95
9	2	1.235	630770	6	30	14	0.4	2.1	2.09	10.5	30.9	282	159
10	2	1.226	1785676	21	106	29	0.7	3.6	0.70	3.5	63.5	1756	68
11	2	1.174	1517042	17	86	42	0.4	2.1	0.59	3.0	21.4	1687	89
12	2	1.126	2398307	30	152	46	0.7	3.3	0.50	2.5	42.7	2649	283
13	2	1.265	2227401	37	183	85	0.4	2.2	0.45	2.2	37.2	4069	161
14	2	1.095	2499881	35	173	58	0.6	3.0	0.66	3.3	55.6	2603	73
15	2	1.053	1251621	15	76	32	0.5	2.4	0.94	4.7	29.6	941	29
16	2	1.004	1942202	25	127	58	0.4	2.2	0.73	3.7	44.9	1817	51
17	2	1.115	1283887	20	101	33	0.6	3.1	1.35	6.8	34.9	782	80
1	3	1.442	2751678	45	201	29	1.5	6.9	0.60	2.7	55.3	3479	474
2	3	1.613	1305119	21	95	21	1.0	4.5	1.04	4.7	18.4	753	54
3	3	1.477	1492236	23	102	12	1.9	8.5	0.90	4.1	38.1	2156	49
4	3	1.509	1248508	17	75	17	1.0	4.4	0.76	3.4	23.9	1098	61
5	3	1.463	1604880	19	84	40	0.5	2.1	1.11	5.0	12.0	901	107
6	3	1.445	1196420	17	77	22	0.8	3.5	1.68	7.6	18.8	662	60

7	3	1.128	706598	8	36	16	0.5	2.2	2.48	11.2	15.1	315	160
8	3	1.699	1221873	18	80	17	1.0	4.7	2.34	10.5	18.6	616	92
9	3	1.324	618360	7	30	14	0.5	2.1	3.32	15.0	20.3	197	111
10	3	1.122	1849762	23	106	31	0.8	3.4	0.77	3.5	59.4	1759	68
11	3	1.067	1575327	19	86	42	0.5	2.1	0.66	3.0	21.5	1662	88
12	3	0.957	2658392	34	152	36	0.9	4.2	0.55	2.5	46.9	2668	285
13	3	0.981	2313436	41	183	85	0.5	2.2	0.49	2.2	42.5	4115	163
14	3	0.974	2566097	38	173	58	0.7	3.0	0.74	3.3	45.6	2587	73
15	3	0.956	1309905	17	76	32	0.5	2.4	1.11	5.0	29.6	886	27
16	3	1.008	1926872	28	127	58	0.5	2.2	0.80	3.6	43.7	1836	51
17	3	0.925	1388651	22	101	33	0.7	3.1	1.45	6.5	45.4	812	83
1	4	1.488	2465557	45	206	29	1.5	7.1	0.59	2.7	74.6	3550	484
2	4	1.436	1175888	21	98	21	1.0	4.7	1.04	4.8	22.8	757	54
3	4	1.445	1335268	23	104	12	1.9	8.7	0.88	4.1	39.9	2214	50
4	4	1.479	1125908	17	77	17	1.0	4.5	0.75	3.4	33.5	1122	63
5	4	1.491	1424466	19	86	40	0.5	2.2	1.04	4.8	11.2	966	114
6	4	1.502	1069062	17	79	22	0.8	3.6	1.67	7.7	18.7	664	60
7	4	1.274	633911	8	37	16	0.5	2.3	2.43	11.2	14.9	324	164
8	4	1.248	1070246	18	82	17	1.0	4.8	2.42	11.1	11.3	595	89
9	4	0.883	552150	7	31	14	0.5	2.2	3.19	14.7	17.8	206	116
10	4	1.219	1662243	23	108	31	0.8	3.5	0.77	3.6	65.9	1760	69
11	4	1.158	1421253	19	88	42	0.5	2.1	0.65	3.0	28.2	1702	90
12	4	1.111	2391802	34	155	36	0.9	4.3	0.55	2.5	64.9	2684	286
13	4	1.007	2296503	41	188	85	0.5	2.2	0.49	2.2	67.3	4160	164
14	4	1.110	2310897	38	177	58	0.7	3.0	0.72	3.3	45.6	2637	74
15	4	1.100	1190394	17	78	32	0.5	2.4	1.04	4.8	46.1	949	29
16	4	1.084	1777508	28	130	58	0.5	2.2	0.81	3.7	71.9	1826	51
17	4	1.108	1253389	23	104	33	0.7	3.1	1.43	6.6	67.0	825	84
1	5	1.189	2592029	47	223	29	1.6	7.7	0.61	2.9	51.3	3608	492
2	5	2.769	1302230	22	105	21	1.1	5.0	0.87	4.1	6.3	952	68

3	5	1.100	1517395	24	113	12	2.0	9.4	0.93	4.4	37.4	2202	50
4	5	1.116	1261020	18	83	17	1.0	4.9	0.79	3.7	40.6	1110	62
5	5	1.160	1535638	20	93	40	0.5	2.3	1.09	5.1	15.7	966	114
6	5	1.171	1180233	18	85	22	0.8	3.9	1.75	8.3	16.6	666	61
7	5	1.422	704038	8	39	16	0.5	2.5	2.47	11.7	8.0	335	169
8	5	1.009	1291465	19	88	17	1.1	5.2	2.41	11.4	9.5	627	94
9	5	1.283	595574	7	33	14	0.5	2.4	3.30	15.6	2.8	209	118
10	5	0.966	1825586	25	117	31	0.8	3.8	0.92	4.3	65.8	1556	61
11	5	0.902	1592851	20	95	42	0.5	2.3	0.68	3.2	29.5	1709	90
12	5	0.951	2515126	35	168	36	1.0	4.7	0.62	2.9	51.9	2504	267
13	5	0.901	2548246	43	203	85	0.5	2.4	0.49	2.3	36.9	4317	171
14	5	0.880	2625606	40	191	58	0.7	3.3	0.77	3.6	43.0	2602	73
15	5	0.913	1303812	18	84	32	0.6	2.6	1.12	5.3	23.3	920	28
16	5	0.871	2040258	30	140	58	0.5	2.4	0.87	4.1	30.6	1794	50
17	5	0.914	1371396	24	112	33	0.7	3.4	1.45	6.9	35.8	850	87
1	6	1.240	2508228	47	223	29	1.6	7.7	0.60	2.9	65.8	3633	495
2	6	0.596	1218430	22	105	21	1.1	5.0	1.13	5.4	19.7	730	52
3	6	4.559	1405662	24	113	12	2.0	9.4	0.94	4.4	37.4	2180	50
4	6	1.255	1177220	18	83	17	1.0	4.9	0.83	3.9	34.6	1065	59
5	6	1.269	1451838	20	93	40	0.5	2.3	1.14	5.4	16.0	925	110
6	6	1.231	1096434	18	85	22	0.8	3.9	1.75	8.3	20.9	669	61
7	6	1.002	648156	8	39	16	0.5	2.5	2.56	12.1	9.5	323	163
8	6	0.780	1123866	19	88	17	1.1	5.2	2.54	12.0	20.4	597	89
9	6	0.639	567610	7	33	14	0.5	2.4	3.66	17.3	8.1	189	106
10	6	1.107	1713854	25	117	31	0.8	3.8	0.82	3.9	58.0	1732	67
11	6	1.035	1481119	20	95	29	0.7	3.3	0.74	3.5	38.5	1570	83
12	6	1.034	2431325	35	168	55	0.6	3.0	0.61	2.9	36.0	2554	272
13	6	1.070	2380648	43	203	85	0.5	2.4	0.49	2.3	48.4	4332	171
14	6	0.994	2402142	40	191	58	0.7	3.3	0.75	3.5	57.0	2673	75
15	6	1.069	1220013	18	84	32	0.6	2.6	1.15	5.4	31.7	896	27

16	6	1.106	1844726	30	140	58	0.5	2.4	0.85	4.0	34.7	1821	51
17	6	1.065	1287597	24	112	33	0.7	3.4	1.45	6.9	29.9	852	87
1	7	1.205	2429197	50	244	29	1.7	8.4	0.61	3.0	53.7	3810	519
2	7	1.230	1155669	21	103	23	0.9	4.5	1.03	5.1	22.3	753	54
3	7	0.295	1303213	25	122	12	2.1	10.1	0.95	4.7	45.9	2246	51
4	7	1.171	1173068	20	96	17	1.2	5.7	0.92	4.5	36.0	1065	59
5	7	1.198	1414170	26	128	40	0.7	3.2	1.48	7.3	16.0	938	111
6	7	1.382	925602	17	84	22	0.8	3.8	1.59	7.8	25.5	698	63
7	7	1.194	549432	9	43	16	0.5	2.7	2.72	13.3	9.8	318	161
8	7	1.028	956430	17	85	17	1.0	5.0	2.36	11.6	24.1	597	89
9	7	1.132	469285	7	34	14	0.5	2.4	3.62	17.7	12.2	189	106
10	7	1.134	1580151	30	148	31	1.0	4.8	1.00	4.9	32.4	1739	68
11	7	1.115	1328176	26	125	29	0.9	4.3	0.93	4.5	40.3	1595	84
12	7	1.257	1934737	37	183	55	0.7	3.3	0.67	3.3	29.6	2424	259
13	7	1.182	2014821	37	180	75	0.5	2.4	0.42	2.1	55.4	4318	171
14	7	1.105	2146083	42	206	58	0.7	3.6	0.84	4.1	46.1	2502	71
15	7	1.090	1119749	19	95	26	0.7	3.7	1.28	6.3	30.3	887	27
16	7	1.144	1612277	29	144	56	0.5	2.6	0.86	4.2	28.9	1780	50
17	7	1.203	1069997	22	107	33	0.7	3.2	1.33	6.5	34.9	859	88
1	8	1.299	2137356	33	169	29	1.1	5.8	0.39	2.0	48.0	3933	536
2	8	1.367	966091	20	100	23	0.9	4.4	0.94	4.7	18.0	783	56
3	8	1.337	1113963	28	140	12	2.3	11.6	0.93	4.7	66.8	2550	58
4	8	1.364	982752	21	108	17	1.3	6.4	1.05	5.3	44.9	1020	57
5	8	1.689	956683	20	101	40	0.5	2.5	1.29	6.5	16.0	825	98
6	8	1.450	758207	15	78	22	0.7	3.5	1.40	7.1	19.7	713	65
7	8	1.749	542896	9	48	16	0.6	3.0	2.90	14.7	4.1	321	162
8	8	1.591	668897	18	89	17	1.0	5.2	2.49	12.6	18.0	573	86
9	8	1.315	588831	8	43	14	0.6	3.1	4.33	21.9	7.7	193	108
10	8	1.263	1274825	27	139	31	0.9	4.5	0.92	4.7	42.5	1727	67
11	8	1.157	1154493	23	119	29	0.8	4.1	0.84	4.2	23.2	1614	85

12	8	1.692	1149725	43	219	55	0.8	4.0	0.78	3.9	28.2	2435	260
13	8	0.892	2269977	57	289	75	0.8	3.8	0.65	3.3	51.7	4360	172
14	8	1.239	1735955	42	213	58	0.7	3.7	0.82	4.2	52.0	2539	72
15	8	1.186	938435	20	99	26	0.8	3.8	1.27	6.4	37.9	897	27
16	8	1.082	1500099	40	203	56	0.7	3.6	1.25	6.3	6.6	1679	47
17	8	0.804	1337736	25	129	33	0.8	3.9	1.59	8.1	5.4	837	85
1	9	0.798	3012871	58	294	29	2.0	10.2	0.69	3.5	47.8	3932	536
2	9	0.844	1288427	22	114	24	0.9	4.7	1.12	5.7	22.2	742	53
3	9	0.845	1483828	28	140	22	1.3	6.4	0.93	4.7	50.0	2548	58
4	9	0.978	1130288	19	98	17	1.1	5.8	0.96	4.9	40.7	995	55
5	9	0.918	1171870	20	101	40	0.5	2.5	1.43	7.3	16.7	741	88
6	9	0.888	960232	16	80	22	0.7	3.6	1.42	7.2	22.0	713	65
7	9	0.767	638089	10	49	16	0.6	3.0	2.20	11.2	6.6	428	217
8	9	0.777	950881	16	82	17	0.9	4.8	2.20	11.2	20.0	593	89
9	9	1.021	638261	8	41	14	0.6	2.9	4.20	21.4	7.2	190	107
10	9	0.854	1507003	27	137	33	0.8	4.1	0.90	4.6	53.8	1729	67
11	9	0.950	1222055	21	106	29	0.7	3.6	0.78	4.0	32.7	1533	81
12	9	0.537	2153159	39	199	55	0.7	3.6	0.70	3.6	38.1	2435	260
13	9	0.849	2688351	50	256	75	0.7	3.4	0.55	2.8	61.5	4523	179
14	9	0.797	2188234	41	207	58	0.7	3.6	0.75	3.8	52.7	2683	76
15	9	0.771	1227859	20	103	26	0.8	4.0	1.27	6.4	20.8	930	28
16	9	0.796	1873579	32	161	56	0.6	2.9	0.97	4.9	31.4	1711	48
17	9	0.989	1349523	22	113	33	0.7	3.4	1.34	6.8	34.7	866	88
1	10	0.855	3914560	82	336	29	2.8	11.6	0.96	4.0	37.7	3953	539
2	10	0.665	2154419	44	179	24	1.8	7.5	2.16	8.9	13.4	751	53
3	10	1.095	1505165	29	120	22	1.3	5.5	0.99	4.1	23.2	2545	58
4	10	1.098	1143852	20	82	17	1.2	4.8	0.89	3.7	37.8	1115	62
5	10	1.010	1289281	24	100	40	0.6	2.5	1.51	6.2	18.4	863	102
6	10	0.561	1900681	39	161	22	1.8	7.3	3.59	14.7	20.2	709	64
7	10	1.120	668804	11	44	16	0.7	2.7	3.16	13.0	11.7	332	168

8	10	0.674	1901544	39	160	17	2.3	9.4	5.34	21.9	11.5	593	89
9	10	3.087	626471	9	35	14	0.6	2.5	4.59	18.9	9.2	185	104
10	10	1.016	1483784	28	114	33	0.8	3.4	0.95	3.9	42.1	1692	66
11	10	0.983	1242853	21	88	29	0.7	3.0	0.81	3.3	31.2	1525	81
12	10	0.970	2220514	42	173	55	0.8	3.1	0.75	3.1	49.1	2449	261
13	10	0.955	2816339	52	215	75	0.7	2.9	0.58	2.4	70.8	4514	178
14	10	1.319	3254956	64	264	58	1.1	4.6	1.22	5.0	42.8	2621	74
15	10	0.966	1271064	22	91	26	0.8	3.5	1.31	5.4	28.5	983	30
16	10	0.924	2028125	34	140	56	0.6	2.5	1.03	4.2	28.4	1728	48
17	10	0.618	2182784	43	176	33	1.3	5.3	2.57	10.6	29.0	871	89

APPENDIX E: Multi Stage DEA

Table 1: Output Input mix 2014 data for Multi Stage DEA

	Output		*Input*		
Hospital No. (DMU)	*Outpatient days*	*Inpatient Visits*	*Operational Budget*	*No. of Doctors*	*No of Nurses*
1	139550	2860	3914560	82	336
2	32644	448	2154419	44	179
3	49544	772	1505165	29	120
4	49849	919	1143852	20	82
5	50529	819	1289281	24	100
6	25479	477	1900681	39	161
7	7794	181	668804	11	44
8	20996	298	1901544	39	160
9	5818	124	626471	9	35

10	62239	1424	1483784	28	114
11	104342	1328	1242853	21	88
12	147528	3353	2220514	42	173
13	198084	6203	2816339	52	215
14	95637	3845	3254956	64	264
15	39212	746	1271064	22	91
16	96102	2029	2028125	34	140
17	31350	1170	2182784	43	176

Table 2: Output Oriented regression of TE under CRS against Independent Variables

DMU	CRS	Bud	Phy	Nur	HB	PB	NB	PPOP	NPOP	OR	EP	PD
1	0.459	3914560	82	336	29	2.8	11.6	0.96	4.0	37.7	3953	539
2	0.182	2154419	44	179	24	1.8	7.5	2.16	8.9	13.4	751	53
3	0.404	1505165	29	120	22	1.3	5.5	0.99	4.1	23.2	2545	58
4	0.558	1143852	20	82	17	1.2	4.8	0.89	3.7	37.8	1115	62
5	0.484	1289281	24	100	40	0.6	2.5	1.51	6.2	18.4	863	102
6	0.17	1900681	39	161	22	1.8	7.3	3.59	14.7	20.2	709	64
7	0.174	668804	11	44	16	0.7	2.7	3.16	13.0	11.7	332	168
8	0.134	1901544	39	160	17	2.3	9.4	5.34	21.9	11.5	593	89
9	0.159	626471	9	35	14	0.6	2.5	4.59	18.9	9.2	185	104
10	0.552	1483784	28	114	33	0.8	3.4	0.95	3.9	42.1	1692	66
11	1	1242853	21	88	29	0.7	3.0	0.81	3.3	31.2	1525	81
12	0.874	2220514	42	173	55	0.8	3.1	0.75	3.1	49.1	2449	261
13	1	2816339	52	215	75	0.7	2.9	0.58	2.4	70.8	4514	178
14	0.536	3254956	64	264	58	1.1	4.6	1.22	5.0	42.8	2621	74
15	0.399	1271064	22	91	26	0.8	3.5	1.31	5.4	28.5	983	30
16	0.654	2028125	34	140	56	0.6	2.5	1.03	4.2	28.4	1728	48
17	0.243	2182784	43	176	33	1.3	5.3	2.57	10.6	29.0	871	89

Table 3: Output Oriented regression of TE under VRS against Independent Variables

DMU	VRS	Bud	Phy	Nur	HB	PB	NB	PPOP	NPOP	OR	EP	PD
1	0.704	3914560	82	336	29	2.8	11.6	0.96	4.0	37.7	3953	539
2	0.206	2154419	44	179	24	1.8	7.5	2.16	8.9	13.4	751	53
3	0.413	1505165	29	120	22	1.3	5.5	0.99	4.1	23.2	2545	58
4	0.694	1143852	20	82	17	1.2	4.8	0.89	3.7	37.8	1115	62
5	0.518	1289281	24	100	40	0.6	2.5	1.51	6.2	18.4	863	102
6	0.178	1900681	39	161	22	1.8	7.3	3.59	14.7	20.2	709	64
7	0.771	668804	11	44	16	0.7	2.7	3.16	13.0	11.7	332	168
8	0.146	1901544	39	160	17	2.3	9.4	5.34	21.9	11.5	593	89
9	1	626471	9	35	14	0.6	2.5	4.59	18.9	9.2	185	104
10	0.622	1483784	28	114	33	0.8	3.4	0.95	3.9	42.1	1692	66
11	1	1242853	21	88	29	0.7	3.0	0.81	3.3	31.2	1525	81
12	0.907	2220514	42	173	55	0.8	3.1	0.75	3.1	49.1	2449	261
13	1	2816339	52	215	75	0.7	2.9	0.58	2.4	70.8	4514	178
14	0.62	3254956	64	264	58	1.1	4.6	1.22	5.0	42.8	2621	74
15	0.455	1271064	22	91	26	0.8	3.5	1.31	5.4	28.5	983	30
16	0.673	2028125	34	140	56	0.6	2.5	1.03	4.2	28.4	1728	48
17	0.263	2182784	43	176	33	1.3	5.3	2.57	10.6	29.0	871	89

Table 4: Output Oriented regression of SE against Independent Variables

DMU	SE	Bud	Phy	Nur	HB	PB	NB	PPOP	NPOP	OR	EP	PD
1	0.652	3914560	82	336	29	2.8	11.6	0.96	4.0	37.7	3953	539
2	0.886	2154419	44	179	24	1.8	7.5	2.16	8.9	13.4	751	53
3	0.978	1505165	29	120	22	1.3	5.5	0.99	4.1	23.2	2545	58
4	0.804	1143852	20	82	17	1.2	4.8	0.89	3.7	37.8	1115	62
5	0.934	1289281	24	100	40	0.6	2.5	1.51	6.2	18.4	863	102

6	0.956	1900681	39	161	22	1.8	7.3	3.59	14.7	20.2	709	64
7	0.225	668804	11	44	16	0.7	2.7	3.16	13.0	11.7	332	168
8	0.913	1901544	39	160	17	2.3	9.4	5.34	21.9	11.5	593	89
9	0.159	626471	9	35	14	0.6	2.5	4.59	18.9	9.2	185	104
10	0.888	1483784	28	114	33	0.8	3.4	0.95	3.9	42.1	1692	66
11	1	1242853	21	88	29	0.7	3.0	0.81	3.3	31.2	1525	81
12	0.963	2220514	42	173	55	0.8	3.1	0.75	3.1	49.1	2449	261
13	1	2816339	52	215	75	0.7	2.9	0.58	2.4	70.8	4514	178
14	0.865	3254956	64	264	58	1.1	4.6	1.22	5.0	42.8	2621	74
15	0.877	1271064	22	91	26	0.8	3.5	1.31	5.4	28.5	983	30
16	0.971	2028125	34	140	56	0.6	2.5	1.03	4.2	28.4	1728	48
17	0.924	2182784	43	176	33	1.3	5.3	2.57	10.6	29.0	871	89

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