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MEASURING EFFICIENCY OF PUBLIC HOSPITALS IN MYANMAR

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ABSTRACT

The health care costs are increasing time to time. Enhancing health care productivity is important for the best use of its resources so that the health care costs are efficiently managed. The investment in health care and addressing its efficiency are significant for robust health system. Myanmar has two tiers health system; public and private health sectors to serve the people. The public hospitals occupy 80% of Myanmar health system, it is worthy to study the public hospitals' efficiency. This study aims to estimate the public hospitals' technical efficiency and to examine the effects of input variables on technical efficiency. The Cobb- Douglas function and translog production function models were tested for model fit to measure the technical efficiency. The data from seventy-nine public hospitals for the period 2005-2018, over fourteen years were analyzed in which number of patients is dependent variable, and number of health workforce (labor) and number of beds (capital) are explanatory variables. The public hospitals production function has 93 % technical efficiency and the gamma value 0.99 indicates high variabilities in hospital production. This study found that there is substitutability between hospital beds (capital) and midwives, and other health staff (labor). With existing number of doctors and nurses can increase the maximum output of hospital production function. Doubling the number of other health staff contributes to increasing hospital technical efficiency. The findings provide useful information for making decision on strengthening health system by allocating human and capital resources effectively.

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LIST OF ABBREVIATIONS

AE	Allocative Efficiency
ASEAN	Association of Southeast Asia Nations
BLUE	Best Linear Unbiased Estimator
CES	Constant Elasticity of Substitution
CHE	Catastrophic Health Expenditure
CNLRM	Classical Normal Linear Regression Model
CSO	Central Statistical Organization
DEA	Data Envelopment Analysis
EE	Economic Efficiency
GDP	Gross Domestic Product
HALE	Healthy Adjusted Life Expectancy
ISR	Infant Survival Rate
LHV	Lady Health Visitor
LRT	Likelihood Ratio Test
ML	Maximum Likelihood
MLE	Maximum-likelihood Estimation
MLF	Maximum Likelihood Function
OEDC	Economic Cooperation and Development Countries
OLS	Ordinary Least Square
OOP	Out of Pocket Payment
QALY	Quality-Adjusted Life Year
SFA	Stochastic Frontier Analysis
SFM	Stochastic Frontier Model
TE	Technical Efficiency
UHC	Universal Health Coverage
WHO	World Health Organization

CHAPTER I

INTRODUCTION

Everyone admit that “Health is wealth”. Health is a durable good that can give us happiness and meaningful life. Health care is an input into health. Efficient healthcare services facilitate to advance health and increase access to health services without further growth in spending. In developing countries, the public sector hospitals’ consumption in healthcare is between 50% to 80% (Ahmadi, et al., 2015). Healthcare efficiency is evaluated from different perspectives like service quality indicators, workload indicators for staffing needs and patient waiting time etc. The investment in healthcare and addressing its efficiency is important for robust health system across the globe.

1.1 Rationale of the Study

The production function is a fundamental component of economics; therefore, health economists use it to study efficiency of health care services provided by hospitals. The term production function refers to the physical relationship between the productive resources and the result, in the form of goods or services per unit of time (Francisco, et al., 2020). The higher production needs the higher cost for more capital and labor. Similarly, the reduction of mortality rates may be fewer when contribution to health care is insufficient. It is challenging to control hospitals productivity, but essential to respond the demand of hospital services. Determining various inputs to hospital functions and maximize the hospital output increases hospitals’ productivity and leveraging the service demand. The hospital production function estimates the effectiveness of hospitals’ operation to be able to manage hospitals’ resources for caring the patients’ health.

The health care costs are increasing time to time due to technology used, emerging new diseases and quality improvement procedures. Enhancing productivity of health care is important for the best use of its resources so that the health care costs are efficiently managed. The resource efficiency of the health sector needs to analyse financial and non-financial resources and the factors affecting their health production function. Some countries manage to receive their health outcomes by reducing the inputs such as number of health staffs, per capita total health expenditure (Hadad, et al., 2013). On the other hand, lack of efficiency leads to declining productivity in terms of workforce, capital and management. There are many variables that effect to health production function such as life style, environmental factors, genetics, occupation, education, income level, number of health staff, hospital resources etc. Given that these variables effect to health and healthcare production function, it is critical to assess the optimal production and correlations between input and output variables.

According to worldometer (2022), Myanmar population is 55,109,033 and it is 0.7% of the total world population. Population density in Myanmar is 83 per Km^2 with the total land area of 653,290 Km^2 (252,237 square miles). Population staying in urban is 31.4%, stating that most of the population are residing in rural areas. Total health expenditure is 4.68% of gross domestic product (World Bank, 2019). Myanmar has two tiers health system; public and private health sectors to serve the population. Under the Ministry of Health, there are six departments: department of public health, department of medical services, department of human resources for health, department of medical research, department of traditional medicine, department of food and drug administration. A total of 16 medical and allied health universities produces medical, nursing, allied health and traditional medicine providers. The department of medical services and the department of public health are governing body of primary, secondary and tertiary health care services of public and private hospitals in Myanmar.

According to Statistical Yearbook 2020, total number of public and private hospitals is 1,134 with active beds 61,811, number of hospital admission is 2,971,102 and number of deaths is 44,075 in 2018. Since the number of private hospitals across the country are steadily growing, more than 249 private hospitals, 200 private specialist clinics, 5,000 private general clinics, and 800 private dental clinics are serving Myanmar population (Department of Medical Services, 2014). Hence, the public hospitals occupy 80% of Myanmar health system, it is worthy to study the public hospitals’ efficiency.

Like global health care environment, Myanmar is facing the human resources shortage in health sector as well. Enhancing quality of health care services, production of health workforce and strengthening infrastructures including medical equipment and supplies have been taking into account for resilience country health system. The productive function for hospital will also need to study for economic viability of health care services and provide more information on strengthening health system. The number of beds is a measure of utilization of the available bed capacity in the hospital and number of health workforce are defined to measure the hospital production function (Sattar, 2016). Similarly, well-trained, well-distributed and productive health workers are crucial for access to high-quality, cost-effective healthcare. As the technical efficiency analysis is an important review tool to make decision on allocation of human and capital resources, this study will measure the technical efficiency of public hospitals in Myanmar.

1.2 Objectives of the Study

The objectives of the study are;

(i) To estimate the technical efficiency of public hospitals in Myanmar.

(ii) To examine the effects of input variables (health workforce and number of beds) on technical efficiency of public hospitals in Myanmar.

1.3 Method of Study

The number of health workforce, number of beds and number of patients were analyzed by descriptive statistics. Cobb-Douglas and translog production functions were applied to estimate the technical efficiency of public hospitals in Myanmar. Then, the best suitable model was used to examine the effects of number of beds, doctors, nurses, midwives and other health staff on technical efficiency of public hospitals in Myanmar. The dependent variable in this study was number of patients and the independent variables were number of health workforce and number of beds. The health workforce represented the labor and number of beds represented the capital goods.

1.4 Scope and Limitations of the Study

This study analyzes the secondary data from public hospitals in Myanmar. The time series data on technical efficiency of public hospitals from the period 2005-2018, over fourteen years. The data contained information about the number of patients (inpatients and outpatients), number of beds, doctors, nurses and other medical staffs. The data are obtained from Myanmar Statistical Yearbooks published by Central Statistical Organization, Ministry of Planning, Finance and Industry. This study included the number of in-patient and outpatient who have taken services from public hospitals across Myanmar, but, due to limitation in data availability, healthcare services provided at community and home-based settings were excluded.

1.5 Organization of the Study

This study is presented in five chapters. Chapter one is introduction about the study which includes rationale of the study, objectives of the study, method of study, scope and limitations of the study and organization of the study. Chapter two comprises literature reviews of related studies. Chapter three covers the methodology that used in this study and chapter four presents the analysis of data. Chapter five describes the findings, discussions, and recommendations of the study as well as needs for further research.

CHAPTER II
LITERATURE REVIEW

This chapter comprises the efficiency of global healthcare, health care efficiency in Asian countries and Myanmar, review of literatures related to study and the conceptual framework developed for this study.

2.1 Efficiency of Global Healthcare

Healthcare market is different from economy where consumer preferences direct to produce valued outputs. This mechanism does not work in health sector since inappropriate care with high prices can occur if policy action is not taken (Briggs & Gray, 2000). Hence, policymakers and managers are encouraged for understanding efficiency and measuring healthcare efficiency. According to WHO estimation in 2014, globally 20%-40% of total health spending which is around 1.5 trillion monetary value is being wasted every year because of health system inefficiency. In general, high healthcare spending seems to have the best health outcomes, however, countries spend more on their healthcare could not receive the best outcomes. Poor performance in healthcare is related to inefficiency (Mobely et al., 2002).

The quality healthcare does not mean efficiency (Singaroyan et al., 2006), however increasing efficiency improves healthcare quality (Helling et al., 2006). The technical efficiency is ability to achieve a higher level of output with similar level of inputs. Measuring healthcare efficiency in appropriate method and introduce the findings for policy and managerial decision are still challenging. With regard to healthcare efficiency, hospital technical efficiency is mostly measured. The hospital production factors (inputs) can be medical equipment and labor which are used to produce the outputs such as number of patients, mortality rates and healthy life styles (Baten et al., 2016).

Inefficiency can happen any stage of the above transformation process. The first stage is the transformation of money into physical inputs. From the efficiency perspective, procuring inputs should be in minimum cost (material cost and wages with market rate) and right mix of professionals (doctors, nurses, administrators, etc.). When the production process continues to the creation of activities produced from physical inputs (diagnostic tests or surgical procedures), use of highly skillful staff should efficiently use. The next stage, episodes of care which include many actions such as diagnostic tests, procedures, nursing care and physician consultations. A great scope of waste (inefficiency) can be seen in this step such as unnecessary tests, use of branded drugs, or unreasonable long length of stay. The final stage of the health system production process is the quality of the outputs produced which usually measure with the clinical outcomes achieved and the patient experience (WHO, 2016). The following figure gives the above assertion.

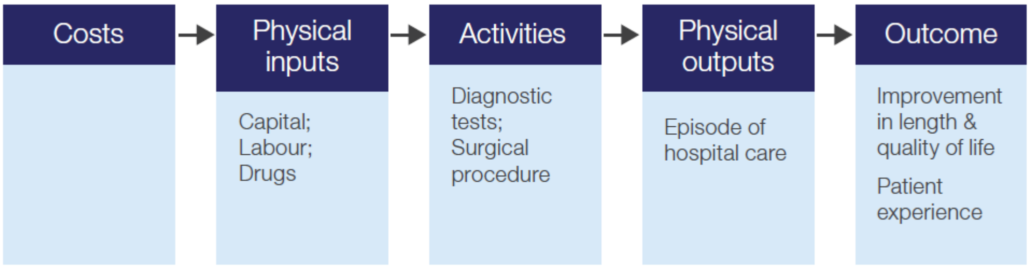

Figure (2.1) Hospital Production Process

Source: Extracted from WHO Health System Efficiency, 2016

There are two types of risk in measuring the efficiency of health systems. The first risk is decision-makers thought that identifying and addressing inefficiency is impossible. This concept hinders to measure the inefficiency that allow to persist poor performance and adverse actions. When the situation needs to trades off healthcare expenditures, untargeted across-the-board cost reduction can occur. The second risk is inadequate analysis or interpretation of information. When addressing the quality of care, reducing the hospital stay of inpatient is initiated for more efficient use of hospital resources. But in some circumstances, additional costs for ambulatory health services or hospital readmissions may happen (Smith, 2009). Any failure to attain that maximum output is an indication of inefficiency (Jacobs et al., 2006). One of the common causes of inefficiency in healthcare is inappropriate and ineffective use of healthcare resources (WHO, 2010). Since efficiency and inefficiency are inversely related, decreasing efficiency can conclude as increasing inefficiency.

The study conducted at organization for economic cooperation and development (OECD) countries over three periods: 2000, 2008 and 2016 at the members of OECD countries: Australia, Austria, Belgium, Canada, Chile, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Japan, Portugal, Slovak, Republic Slovenia, Spain, Sweden, Switzerland, Turkey, United Kingdom and United States found that average efficiencies were 0.8801, 0.8807 and 0.8472 for year 2000, 2008 and 2016 respectively. The overall average efficiency is 0.8693 during that period (Gavurova et al., 2021)

The study of healthcare system of the United States of America with utilizing gross domestic product (GDP), inflation, wage and population growth observed that healthcare system of the United States of America is considered as the world's most expensive but least effective compared with other nations. Main causes of the expensive healthcare costs are institutionalized medical practices and reimbursement policies, technology-induced costs and consumer behavior (Kumar et al., 2011).

2.2 Healthcare Efficiency in Asian Countries

WHO highlighted that people in some Asian countries spends more than 70% of out-of-pocket payment (OOP) for healthcare which leads to catastrophic and exacerbate poverty. The studies about technical efficiency are useful for economic viability and making decision on strengthening health system. According to study in Asian countries, total 42 of 46 countries (91.3%) were technically inefficient in using healthcare system resources. The study found that the high-income countries are most efficient such as Cyprus, Japan and Singapore. Compare to these high-income countries, one lower middle-income country; Bangladesh has efficient health system because of prioritizing in community health services. (Ahmed et al.,2019).

The secondary analysis on Association of Southeast Asia Nations (ASEAN) countries health system found that all the countries are challenging to achieve Universal Health Coverage (UHC) due to low levels of overall and government spending on health; inadequate numbers of health workers; and increasing burdens diseases include non-communicable diseases and infectious diseases. Although healthcare services are more available, health and healthcare inequities will likely worsen. Political commitments to increasing health budgets will reduce the risks to health equity as well as migration and population aging which will increase demand on health systems (Minh et al., 2014).

The comparative study of technical efficiency taken among twenty-eight Asian countries using Data Envelopment Analysis (DEA) method found that eleven out of twenty-eight countries were technically efficient. Bangladesh, Cambodia, China, Jordan, Kyrgyzstan, Lebanon, Malaysia, Maldives, Sri Lanka, Thailand and Vietnam- demonstrated pure technical efficiency. Pakistan was the least efficient country. The efficient countries have high healthy adjusted life expectancy (HALE) and infant survival rate (ISR). Bangladesh and Cambodia slightly low HALE but they were on efficiency frontier because of their very low inputs. (Win and Lofgren, 2020). The researchers recommended that Myanmar should learn from Bangladesh how they structure their community health for improving efficiency of health system.

2.3 Healthcare Efficiency in Myanmar

The output of a hospital can be determined by its facilities and services. The outputs of hospital services are number of patients treated and number of operations/services conducted. The number of beds, number of workforces, their salaries, financial investment on infrastructures, medical equipment and supplies are inputs of hospital production (WHO, 2015). The catastrophic health expenditure (CHE) characterizes the amount of out-of-pocket (OOP) payments for health care exceeding to a specified threshold of household's income. The World Health Organization (WHO) defined financial catastrophe as the OOP expenditure exceeding 40% of the household income net of subsistence needs (WHO, 2005). The collaborative survey of Ministry of Health Myanmar and WHO indicated that the incidence of catastrophic health expenditure is 34% of urban and 28% of rural households in Yangon, 23% of urban and 32% of rural households in Mandalay, and 36% of urban and 21% of rural households in Mon State (MOH & WHO, 2008).

According to the study of Win, Z. M. and Lofgren, C., conducted in 2020 found that Myanmar is in the list of inefficient countries. The study of health system from technical efficiency perspective is very rare, and no studies have been made on national level hospitals efficiency with SFA for estimating the hospital inefficiency frontier. To estimate the technical efficiency, different health personnel working under the Myanmar public health system is disaggregated according to their different roles in serving population. The different health personnel are described in the following:

2.3.1 Number of Doctors

A doctor is a person who has completed studies in medicine and surgery from basic medical education program in Myanmar. After completion of basic medical education, post graduate specialties, master program to doctorate programs train the general practitioners to become specialist doctors. All the doctors who are general practitioners or specialist are counted as medical doctors in this study.

2.3.2 Number of Nurses

Nursing Education in Myanmar has diploma program and direct entry bachelor program. A graduate who completed diploma or bachelor program in nursing have been recognized as a nurse and granted practicing license. The highest nursing education is Doctorate program and several post graduate specialties in nursing such as intensive care, pediatric care, cardiac care are delivered. Nurses are taking different roles in Myanmar health system such as nurse practitioners who provides care to patients, nurse administrators who manage hospital/school administration or central Ministerial administration, and teachers who train the new nursing professionals. Their role is interchangeable depends on government granted designation, therefore, different roles of nurses are collectively counted in this study.

2.3.3 Number of Midwives

Midwives are the one who care mothers, babies and families. A graduate who completed diploma in midwifery program has been recognized as midwife and granted practicing license. The highest education is diploma program but senior midwives are eligible to attend lady health visitor (LHV) course to take supervisory and administrative role. As such, LHV are not represent as midwife in this study due to totally changing their role to administration.

2.3.4 Number of Other Health Staff

Learning the public health system as a whole, there are different health cadres working under Myanmar health system. In this study, dental surgeons, health assistants, lady health visitors, public health supervisor I, public health supervisor II, and indigenous medical practitioners are combined as ‘other health staff’.

2.3.5 Number of Hospital Beds

The hospital beds are capital investment which occupy the admitted patients for taking treatment at hospital. When number of patients increases, the hospital beds should increase or effectively manage patient’s hospital stay. WHO defines a hospital bed as a bed that is regularly maintained and staffed for the accommodation and full-time care of a succession of inpatients and is situated in wards or a part of the hospital where continuous medical care for inpatients is provided.

2.3.6 Number of Patients

The number of patients is presented as hospital services which is output variable of hospital production function. The patients who are taking outpatient services or inpatient services under public hospitals are counted as total number of patients who receiving care from health personnel.

2.4 Review of Literatures Related to this Study

Baten et al. (2010) measured that the tea industries from seven tea regions of Bangladesh studied with fifteen years of data for production efficiency. The study observed that Translog production function was more preferable compared to Cobb-Douglas production function. This study discovered a negative relationship between size and tea yield. The findings highlighted that tea yield exists 49% technical inefficiency. The inefficiency effects depend on the labor-specific variables and time of observations.

Boris et al. (2010) studied at Honduras, Central America to compare technical efficiency across treatment and control groups of farm households. The cross-sectional data collected for a total of 371 farm households for the agricultural year 2007-2008 was used to estimate production frontier by using Translog model. The results reveal that average technical efficiency is consistently higher for beneficiary farmers than the control group while the presence of selectivity bias cannot be rejected. The technical efficiencies are ranges from 0.67 to 0.75 for beneficiaries and from 0.40 to 0.65 for the control depends on selectivity biases were controlled or not.

Mehraban, & Raghfar (2016) conducted a study that estimation of production function of direct health care services delivered by Iranian Social Security Organization, Ministry of Health and Medical Education. Direct health care service production was analyzed with Cobb-Douglas function using seven-year time series data from 2008- 2015. There is negative elasticity of bed restoration interval while active beds, physicians and nurses were positive. The capital intensive was found with highly dependent on active beds. The technical efficiency was with the range 0.762 to 0. 776.

Hamidi (2016) analyzed that measuring efficiency of governmental hospitals in Palestine using stochastic frontier analysis with balanced panel data from 22 governmental hospitals over a period of 6 years. In this research, the Cobb–Douglas function, translog function, and multi-output distance function were used for estimating hospital technical efficiency. The explanatory variables are number of beds, number of doctors, number of nurses, and number of non-medical staff while inpatients and outpatients were uses as output variable. The study found that translog function was more appropriate than Cobb-Douglas function. Hospitals production has a decrease return to scale and the average technical efficiency was approximately 55 %. Doctors and nurses (labor) seem to be the most important factors in hospital production.

Baten et al. (2016) studied that Gender-specific stochastic frontier health efficiency model in Malaysia governmental hospitals. The study was analyzed with life expectancy as output variable and number of doctors, number of nurses, total health expenditure, GDP in prices are contributed as inputs. The secondary data of study variables are taken from Ministry of Health Malaysia. The Cobb-Douglas and translog production functions were tested for appropriate hospital production output. The study concluded that translog stochastic frontier gender-specific health efficiency model is appropriate. GDP in prices has a negative effect on life expectancy and statistically significant. Increase in total health expenditures will increase the overall health outcome (life expectancy). number of hospitals, number of beds, and demographic rates like crude birth rate, crude death rate, infant mortality rate, and maternal mortality rate are expected to reduce the inefficiency of hospital production; in this case; life expectancy. The average health efficiency for male and female was 0.9321 and 0.9946 respectively.

Pechrova & Simpach (2020) analysed that the Czech Republic agricultural sector with 517 farms with 1708 observations for years 2013 to 2016. The research found that the technical efficiency in Cobb-Douglas model was slightly higher (85.69%) than in translog model (85.12%), but there were found statistically significant differences. The likelihood value in Cobb-Douglas was lesser than Translog analysis that make decision to select translog model as appropriate model, and effect on the technical efficiency is mild and almost negligible.

Sielska & Nojszewska (2022) examined that production function for modeling hospital activities: the case of Polish county for the period 2012-2018. In this study used Cobb-Douglas (two factors & three factor inputs) and translog (two factors & three factor inputs) production functions. The aim of study is to identify the most useful inputs for the health production. Total number of patient days was output variable and number of beds, number of doctors and nurses in full time equivalent and cost of materials, electricity & services were production factors. The total number of beds contributed to the best and each type of production function resulted diversified results in showing properties of production function.

2.5 The Conceptual Framework

The conceptual framework of this study depicts how hospital service is offered by production factors (labour and capital) are described in following Figure (2.2).

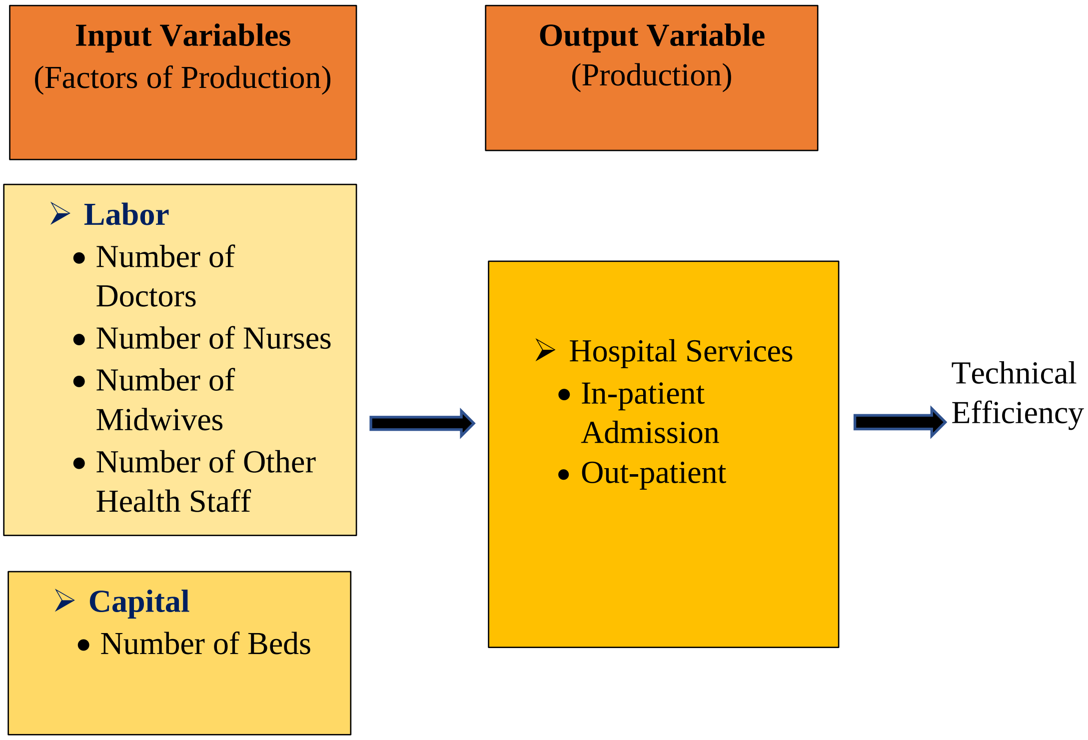

Figure (2.2) Conceptual Framework of the Study

Source: Self Compilation (2022)

The measurement of items for labour includes number of doctors, number of nurses, number of midwives and number of other health staff. The measurement of item for capital is number of hospital beds. The measurement items for production output is number of in-patient admissions and number of out-patients.

CHAPTER III

RESEARCH METHODOLOGY

This chapter describes the data and variables of the study and approaches to measuring technical efficiency, developing hypothesis, and statistical methods that used to test the hypothesis for achieving research objectives.

3.1 Source of Data and Variables

The time series data over a period of fourteen years, 2005- 2018 were collected from Myanmar Statistical Yearbook published by Central Statistical Organization, Ministry of Planning, Finance and Industry. Number of patients (in-patient and out-patient) from seventy-nine public hospitals were measured as output variable, and number health workforce and hospital beds were measured as input variables to estimate the public hospitals technical efficiency. Data represents the different levels of public hospitals; primary, secondary and tertiary public hospitals across Myanmar. The number of doctors, nurses and midwives were abstracted separately for the reason that they are large health workforce of health system and possess different expertise in caring patients. Dental surgeon, health assistant, lady health visitor, public health supervisor I, public health supervisor II and indigenous medical practitioner are collectively presented as other health workforce. Specialist doctors are counted as doctors since data has no categorization on specialty of patient care.

3.2 Measuring Efficiency

Efficiency can be defined as the best use of available resources for achieving optimum output level. In other word efficiency means maximizing the output without increasing the inputs or increasing/maintaining the output by decreasing the existing inputs. Conversely, inefficiency can be stated as failure to achieve possible maximum output with input resources. The optimum possible output is determined by the frontier of production. Efficiency analysis included the distance to the boundary from the data point measured (Coelli et al. 2005). The terms efficiency and productivity are used interchangeably, in fact, they are not the same. Productivity is an absolute term while efficiency is a relative term. Productivity is calculated by the proportion of outputs to inputs and efficiency is described by comparing the total quality to input ratio with the optimal performance to input ratio. Ferrell (1957) defined that efficiency measures the performance of the firm in producing maximum output from a given set of inputs.

A production function defined by economists is the transformation of inputs into valued output to achieve maximum feasible level of output for a given set of inputs. The efficiency of production function categorizes as technical efficiency, allocative efficiency and economic efficiency (Farrell, 1957). The technical efficiency studies how inputs variables are used for producing output. The output oriented technical efficiency is the analysis of farm's capacity to attain optimum production from a given set of inputs, whereas, input orientated technical efficiency analyses the farm's capacity to achieve optimum production from the least possible volume of inputs. The allocative efficiency means how organization is able to select optimal combination of inputs to produce greatest level of output. Allocative efficiency examines the farm's capacity to make efficient use of resources in terms of their respective costs and processing technologies. The economic efficiency can direct the combined impact of technical efficiency and allocative efficiency. Technical efficiency is a prerequisite of allocative efficiency and allocative efficiency is required for optimal allocation of resources. Economic efficiency is the result of technological efficiency and allocative effectiveness. A technically and allocatively productive firm is considered to be an economically efficient industry.

3.3 Statistical Methods for Measuring Efficiency

There are two approaches: parametric and non-parametric methods. There is the difference between parametric and non-parametric methods. Parametric method defines the basic functional type for the output or cost function while non-parametric method could not (Vasilis, 2002). Parametric method relies on econometric that can be used as deterministic or stochastic analysis. Non-parametric method is mathematical programming method that can be used data envelopment analysis (DEA). Parametric methods emphasize on economic optimization while non-parametric methods test the technological optimization. DEA method is non-stochastic and does not capture random noise such as strikes, and any deviation from the estimated frontier is interpreted as due to inefficiency. DEA could not conduct statistical tests of the hypothesis regarding the inefficiencies scores, but, DEA can analysis output oriented and input oriented efficiency.

The stochastic frontier model (SFM) is mostly used for measuring hospital efficiency. It can explain boundary, frontier or optimal behavior rather than average behavior explained by ordinary regression models. SFA demonstrates a production function of the standard regression model with a composite disturbance term which is the sum of the two errors components; standard noise and inefficiency. The loglikelihood function required for the maximum likelihood estimation of the parameters of the model was first given by Stevenson (1980). In summary, DEA does not disperse out the effects of a stochastic error term while SFA separates the two sources of error, due to inefficiency and random noise.

Among the SFA, Cobb-Douglas and Translog models are the most commonly used models for estimating production functions. Both models can be linearized by natural logarithms. The Cobb-Douglas has been popular because of simple calculation, but validity of Cobb-Douglas is questioned to represent the healthcare production (Lopez, 1988). Translog model is more flexible model than Cobb-Douglas. The translog production function has many advantages from the theoretical point of view. To make operational the concept of translog production function has constraints on the result feasibility since occurrence of an extended collinearity is favored. As such, both models should be tested for the best fit of data set before estimating the technical efficiency. Figure (3.1) demonstrated the statistical methods used in measuring efficiency.

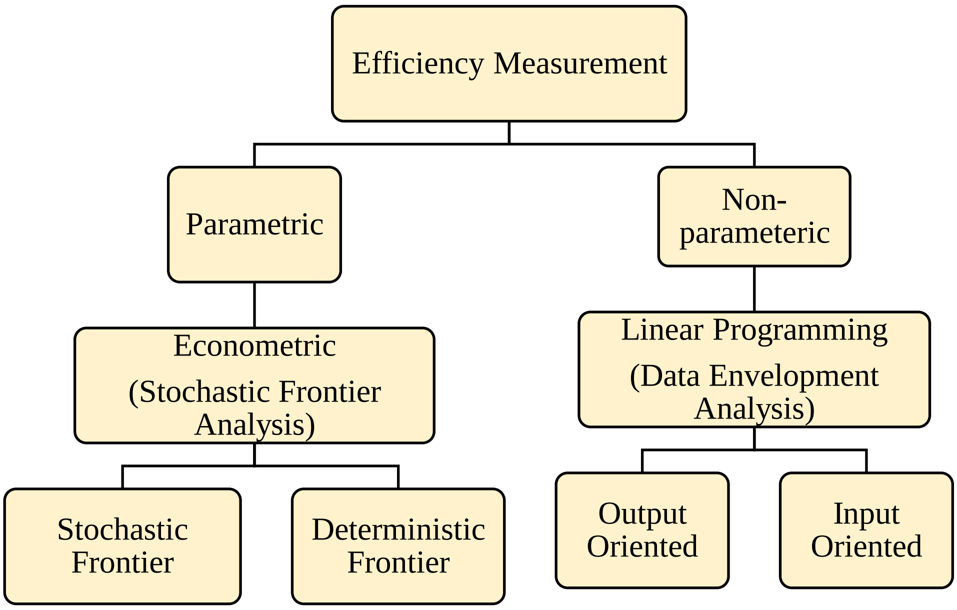

Figure (3.1) Statistical Methods for Measuring Efficiency

Source: Vasilis (2002)

3.3.1 Cobb-Douglas Production Model

In 1928, the economists Paul Douglas and Charles Cobb identified "A Theory of Production" which is now well known as Cobb-Douglas function. It is a mathematical representation of the relationship between capital, labor, and output. The Cobb-Douglas production model fulfils the basic economic law and it is easy to interpret. The Cobb-Douglas form is simply derived as an algebraic transformation of the identity (Gujarati & Porter, 2009). This transformation embodies the result that the estimated parameters must be the factor shares. The Cobb-Douglas model is

$$Y_i = \beta_1 X_i^{\beta_2} e^{u_i} \tag{3.1}$$

where, Y_i = output

X_i = input

β_1= intercept

β_2= coefficient

Taking the logarithms on both sides of Equation (3.1) are obtained

$$\ln Y_i = \ln \beta_1 + \beta_2 \ln X_i + u_i \tag{3.2}$$

$$\ln Y_i = \alpha + \beta_2 \ln X_i + u_i \tag{3.3}$$

where $\alpha = \ln \beta_1$.

Equations (3.1) is linear regression model and can be estimated by ordinary least squares (OLS) or maximum likelihood (ML), that have to be careful about the properties of the stochastic error term that enters these models. Remember that the Best Linear Unbiased Estimator (BLUE) property of Ordinary Least Square (OLS) requires that u_i has zero mean value, constant variance, and zero autocorrelation. For hypothesis testing, we further assume that u_i follows the normal distribution with mean and variance values. In short, it is assumed that $u_i \sim N(0, \sigma^2)$.

The statistical counterpart of Equation (3.1) is given in Equation (3.2). To use the classical normal linear regression model (CNLRM), and assume that $\ln u_i \sim N(0, \sigma^2)$. As the preceding analysis shows, one has to pay very careful attention to the error term in transforming a model for regression analysis. Equation (3.3) should not pose any problems for estimation, where $\alpha = \ln \beta_1$, this model is linear in the parameters α and β_2, linear in the logarithms of the variables Y and X, and can be estimated by OLS regression. Because of this linearity, such models are called log-log, double-log, or log-linear models. If the assumptions of the classical linear regression model are fulfilled, the parameters can be estimated by the OLS method by letting

$$Y_i^* = \alpha + \beta_2 \ln X_i^* + u_i \tag{3.4}$$

where $Y_i^* = \ln Y_i$ and $X^* = \ln X_i$. The OLS estimators $\widehat{\alpha}$ and $\widehat{\beta}$ obtained will be best linear unbiased estimators of α and β_2, respectively.

In stochastic form, Cobb–Douglas production function with two factors may be expressed as

$$Y_i = \beta_1 X_{2i}^{\beta_2} \quad X_{3i}^{\beta_3} e^{u_i} \tag{3.5}$$

where; Y_i = output

X_{2i}= labor input

X_{3i}= capital input

β_2 = coefficient of X_{2i}

β_3 = coefficient of X_{3i}

u = stochastic disturbance term

e = base of natural logarithm.

The relationship between output and input variables is nonlinear. If log-transform this model, linear in the logs of these variables.

$$\ln Y_i = \ln \beta_1 + \beta_2 \ln X_{2i} + \beta_3 \ln X_{3i} + u_i \tag{3.6}$$

$$= \beta_0 + \beta_2 \ln X_{2i} + \beta_3 \ln X_{3i} + u_{i,}, \text{ where } \beta_0 = \ln \beta_1$$

The properties of the Cobb–Douglas production function are:

1. β_2 is the (partial) elasticity of output with respect to the labor input, that is, it measures the percentage change in output for, a 1 percent change in the labor input, holding the capital input constant.
2. β_3 is the (partial) elasticity of output with respect to the capital input, where the labor input constant.
3. $(\beta_2 + \beta_3)$ gives information about the returns to scale, that is, the response of output to a proportionate change in the inputs. If this sum is 1, then there are constant returns to scale, that is, doubling the inputs will double the output, tripling the inputs will triple the output, and so on. If the sum is less than 1, there are decreasing returns to scale doubling the inputs will less than double the output. If the sum is greater than 1, there are increasing returns to scale—doubling the inputs will more than double the output.

For log–linear regression model involving any number of variables, the coefficient of each of the X variables measures the (partial) elasticity of the dependent variable Y with respect to that variable. For a k-variable log–linear model:

$$\ln Y_i = \beta_0 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + \cdot \cdot \cdot + \beta_k \ln X_k + u_i \qquad (3.7)$$

each of the (partial) regression coefficients, β_2 through β_k, is the (partial) elasticity of Y with respect to variables X_2 through X_k.

The actual performance is modelled as the frontier model plus an error term which composed of two parts; equation error (disturbance term) and measurement error term. The first error part is normally distributed with mean zero and unknown variance σ_v^2. The second error part is a nonnegative one, representing a measure of inefficiency error with variance σ_u^2 (Coelli et al.,1998).

$$\ln Y_i = \beta_0 + \sum_{j=1}^{k} \beta_i \ln X_i + \varepsilon_i \qquad (3.8)$$

The error term in mathematical form:

$$\varepsilon_i = v_i - u_i \qquad (3.9)$$

The structural random error component ‘v’ is assumed to be distributed with zero mean and variance, N $(0, \sigma_v^2)$ independently and identically. The asymmetric non-negative random error component that measures technical inefficiency is denoted by ‘u’ which are independently and identically distributed truncations at zero from below of the distribution N $(0, \sigma_u^2)$.

$$\ln Y_i = \beta_0 + \sum_{i=1}^{k} \beta_j \ln X_i + (v_i - u_i) \quad (3.10)$$

where; Y_i = number of patients
X_i = number of beds, doctors, nurses, midwives and other health staff
ln = natural logarithm
v = systematic random error (standard noise)
u = non-negative random variables associate with technical inefficiency

3.3.2 Transcendental Logarithmic (Translog) Functional Model

Christiansen, Jorgensn and Lau published two papers in 1971 and 1973 about transcendental logarithmic production function which has strong separability and homogeneity of Cobb-Douglas and CES production functions and their implications for the production frontier. The translog production function permits to pass from a linear relationship between the output and the production factors, which are considered to a nonlinear one. Due to its properties, the translog production function can be used for the second order approximation of a linear-homogenous production.

Limitation of translog production function is multicollinearity effect due to number of parameters increase or explode as the number of inputs increases (Boisvert, 1982). There may be having opposing signs to the expected sign of the coefficient of the correlation between output variable and the explanatory variables (Pavelescu, 2010). Limiting the number of factors of production (independent variables) to production function that can affect the behavior of the output and /or increasing the number of observations or sample size are the remediation measures of multicollinearity effect (Boisvert, 1982 and Pavelescu, 2010).

The choice of the appropriate function form for empirical analysis depends on theoretical consistency, domain applicability, flexibility, factual conformity and computation facility, though, no single function satisfies all the requirements (Lau, 1986). Multi-collinearity may lead to unexpected signs of the parameters, unstable parameter estimates and high variance. If the main purpose of analysis is to interpret the precise effect of the predictors, multi variables translog production function should not be used to avoid the harmful collinearity. The first form of a translog production was proposed in 1967 by Kmenta for constant elasticity of substitution (CES) production function estimation with a second order Taylor series, when the elasticity of substitution is very close to the unitary value, which is the case of Cobb-Douglas production function. The form of the translog production function is:

$$\ln Y_i = \ln \beta_3 + \alpha_3 \ln X_i + \beta_3 \ln Xj + \gamma_3 \ln^2 (X_i / X_j) \qquad (3.11)$$

where; ln= natural logarithm

Y_i= Output (Gross domestic product)

X_i = Capital

X_j = Labor.

α_3, β_3, γ_3= parameters to be estimated

In 1971, Grilichs and Ringstad proposed new forms of production function. The first one was obtained by imposing the condition that $\alpha+\beta=1$. This way, the production function became in fact a labour productivity function:

$$\ln (Y_i / X_j) = \ln \beta_2 + \alpha_2 \ln(X_i / X_j) + \gamma_3 \ln^2 (X_i / X_j) \qquad (3.12)$$

It is to be noticed that the above-mentioned function is one of a second order polynomial in the logarithms of the single input considered, capital-labour ratio, respectively. The second form of production function was defined in conditions of relaxing the constraints imposed to the parameters in the Kmenta function, in order to test the homotheticity assumptions, and was written as:

$$\ln(Y_i) = \ln \beta_{ij} + \propto_i \ln X_i + \propto_j \ln X_j + \beta_i^2 \ln^2 X_i + \beta_j^2 \ln^2 X_j + \beta_{ij} \ln X_i \ln X_j \qquad (3.13)$$

The generalized form of translog production function, which takes into account a number of n inputs (production factors), can be expressed as:

$$\ln(Y_i) = \ln \beta_{ij} + \sum_{i=1}^{n} a_i \ln X_i + ½ \sum_{i=1}^{n} \sum_{j=1}^{n} \beta_{ij} \ln X_i \ln X_j \qquad (3.14)$$

Translog production function can be written in stochastic frontier model as

$$\ln(Y_i) = \ln \beta_{ij} + \sum_{i=1}^{n} a_i \ln X_i + ½ \sum_{i=1}^{n} \sum_{j=1}^{n} \beta_{ij} \ln X_i \ln X_j + (v_i - u_i) \qquad (3.15)$$

where; Y_i = number of patients

X_i = number of beds

X_j = number of health work force

ln = natural logarithm.

v = systematic random error (standard noise)

u = non-negative random variables associate with technical inefficiency

3.4 Estimating Parameters

The number of the parameters practically detonates as the number of production factors, which are considered increase. If the number of production factors is equal to n, the number of estimated parameters is

$$n=\frac{n(n+3)}{2} \tag{3.16}$$

Ordinary least square (OLS) estimates the parameters in a regression model by minimizing the sum of the squared residuals.If the OLS method is used in estimation of even three production factors, the probability of the occurrence of the harmful collinearity is very high. The stochastic frontier production function and the technical inefficiency models are jointly estimated by the maximum-likelihood method.

3.5 Measuring Technical Efficiency

The technical efficiency of public hospitals is calculated as ratio of observed output (Y) to the maximum possible output defined by certain level of inputs used.

$$\text{Technical efficiency (TE)}=\frac{Observed\ output}{Maximum\ possible\ output} \tag{3.17}$$

$$\text{TE} \quad =\text{E}\left[\ \frac{\exp(u_i)}{(v_i-u_i)}\ \right]$$

where, u_i = nonnegative random variable, technical efficiency lies between zero and unity which indicates the hospital is technically efficient. The value of u_i is positive and it reduces the efficiency of output.

The maximum likelihood method is used to estimate the unknown parameters, with stochastic frontier and the inefficiency effects simultaneously estimated. If v_i=0, hospitals have maximum output.

The variance parameters are also estimated as σ^2 and gamma γ. The gamma γ values are used to assess the efficiency. The gamma γ value gives the proportion of the deviation from hospital production function that caused by technical inefficiency. Therefore, the gamma value may be measured the existence of efficiency. If gamma is zero. u_i is absent from the model and deviations from the frontier are attributed to noise, the technical inefficiency is absent from the estimation. The gamma value close to zero can be interpreted that the productive function is technically efficient and the error is due to statistical noise. If gamma value is close to one, there is variation in technical efficiency that means technical inefficiency exists. If sigma square value is used to evaluate the effect of efficiency is correctly defined. The variance parameter is defined as:

$$\sigma^2 = \sigma_v^2 + \sigma_u^2 \tag{3.18}$$

$$\gamma = \frac{\sigma_u^2}{\sigma^2}, \qquad 0 \leq \gamma \leq 1 \tag{3.19}$$

where σ^2 is total variance of error terms, gamma parameter is the effect of efficiency on production.

3.6 Testing the Technical Efficiency

The following hypotheses will be tested to estimate the technical efficiency of public hospitals across Myanmar.

(i) Hypotheses

Null Hypothesis

H_0: $\gamma = 0$, the production function is technically efficient

Alternative Hypothesis

H_A: $\gamma \neq 0$, the production function has technical inefficiency.

(ii) Test Statistics

$$\chi^2 = \sum_{i=1}^{n} \frac{(O_i - E_i)^2}{E_i}$$

where; O_i = observed frequency

E_i = expected frequency

(iii) Critical Value

$$K = \chi^2_{(\alpha, n-1)}$$

(iv) Decision Rule

If $\chi^2 \geq K$; reject H_0.

Otherwise; accept H_0.

(v) Decision

(vi) Conclusion

CHAPTER IV

ANALYSIS OF DATA

This chapter presents the statistical methods used in this study. The descriptive statistics explains the basic structures of study variables. Data analysis by Cobb-Douglas production model and Translog production model, model selection and estimating technical efficiency are presented.

4.1 Descriptive Method

The data of production factors and production output are collected from Statistical Yearbooks published by Central Statistical Organization in 2006, 2008 and 2010. The summary data for the year 2005 to 2018 is presented in Table (4.1).

Table (4.1)

Summary Data of Production Factors and Production Output for the Year 2005 to 2018

Year	Number of beds	Number of health workforce				Number of Patients (000)	
		Doctor	Nurses	Midwives	Other Health Staff	In patient	Out patient
2005	42513	17564	18123	16201	8615	1006	2755
2006	43128	18584	19776	16745	9097	1005	2834
2007	43288	20501	21075	17703	9459	1084	2949
2008	43749	21799	22027	18098	9770	1107	3243
2009	44255	23740	22885	18543	10115	1208	3381
2010	45904	24536	24242	19051	10495	1340	3627
2011	45346	26435	25644	19556	11300	1327	3660
2012	45040	28077	26928	20044	11249	1530	4166
2013	48035	29832	28254	20617	11823	1793	5519
2014	48721	31542	29532	21435	15410	2095	7318
2015	51487	32861	32609	22258	15626	2562	9301
2016	55895	8436	21598	13811	18875	2754	10190
2017	59283	10479	20881	13651	18679	2912	10737
2018	61811	17343	20887	14110	18182	2971	11489

Source: Statistical Yearbooks, Ministry of Planning, Finance and Industry (2006, 2008, 2020)

According to Table (4.1) the minimum number of hospital beds can be seen in 2005 and the maximum number of beds in 2018. The investment in hospital beds is gradually increasing due to increasing number of inpatients. In regards to health workforce, number of doctors, nurses and midwives are increasing every year till 2015 and start decreasing in 2016 onwards. Latt. et al (2016) mentioned in 'Health Care in Myanmar' article that the enrollment of medical students was reduced to half of former enrollment in 2012 onwards to ensure the quality of medical education. There may be policy action for other health cadre production which effect to decreasing number of health workforce in 2016. The least number of doctors, nurses and midwives in 2016 are 8436, 21598 and 13811 respectively. However, combination of other health staff is steadily increasing year by year with minimum 8615 and maximum 18182. The number of inpatients and outpatients are also increasing each year. The minimum number of outpatients is 2755 and maximum 11489. Correspondingly, the minimum number of inpatients is 1006 and maximum number of inpatients is 2971.

The data of production factors and production output were expressed in Table (4.2).

Table (4.2)

Descriptive Statistics of Output and Input Variables

Variables	Mean	Standard Error	Standard Deviation	Minimum	Maximum
Patients	7561571	1080179.52	4041661.68	3761000	14460000
Beds	48461	1687.74	6314.97	42513	61811
Doctors	22266	1971.57	7376.95	8436	32861
Nurses	23890	1112.46	4162.48	18123	32609
Midwives	17987	745.96	2791.16	13651	22258
Other Health Staff	12763	1007.98	3771.51	8615	18875

Source: Statistical Yearbooks, Ministry of Planning, Finance and Industry (2006, 2008, 2020)

Over the fourteen-year reference period (2005-2018) Myanmar public health sector provided in-patient and out-patient services with minimum 3,761,000 and maximum 14,460,000. The investment capital on hospital beds is spent to available 61,811 maximum beds for admitted patients. The labor inputs to the health system are different categories of health workforce. Table 4.2 shows that nurses are the highest number of workforces in Myanmar public health system followed by medical doctors, midwives and combination of other health staff (dental doctors, indigenous doctors, health assistant, lady health visitors, public health supervisor 1 and public health supervisor 2).

The composition of doctors, nurses, midwives and other health staff at Myanmar public health system was illustrated in Figure (4.1).

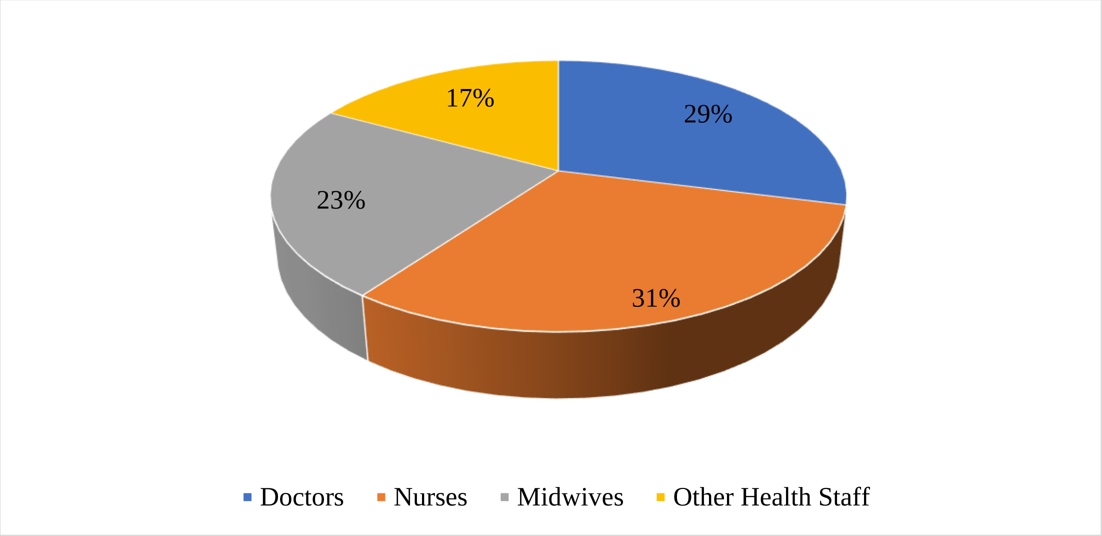

Figure (4.1) Health Workforce Composition in Myanmar Health System

Source: Statistical Yearbooks, Ministry of Planning, Finance and Industry (2007, 2008, 2020)

Myanmar public health system forms with 31% of nurses, 29 % of doctors, 23% of midwives and 17% of other health staff. Number of workforces in health system are increasing year by year which accommodate with increasing number of beds from 2005 to 2018. There is a remarkable decrease in number of doctors, nurses and midwives in 2016 due to government policy on reducing students' recruitment in 2012 for controlling health professional education quality. Though, number of hospital beds are steadily increasing from 2005-2018. The number of health workforce and hospital beds were described in Figure (4.2).

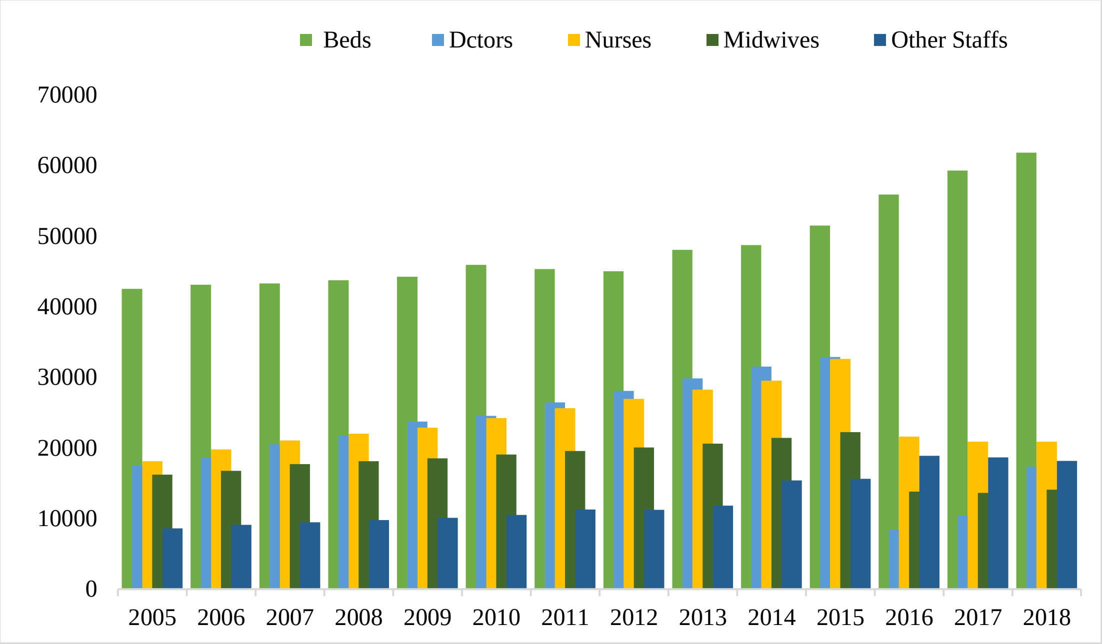

Figure (4.2) Number of Health Workforce and Hospital Beds during the Period from 2005 to 2018

Source: Statistical Yearbooks, Ministry of Planning, Finance and Industry (2006, 2008, 2020)

Number of in-patients and out-patients who taking services from public hospitals during fourteen years period are presented in Figure (4.3). The consumption of hospital services as admission and out-patient services are increasing. Even though, in-patient admission is steadily increasing, the out-patient services are noticeably rising compare to in-patient services starting from 2013.

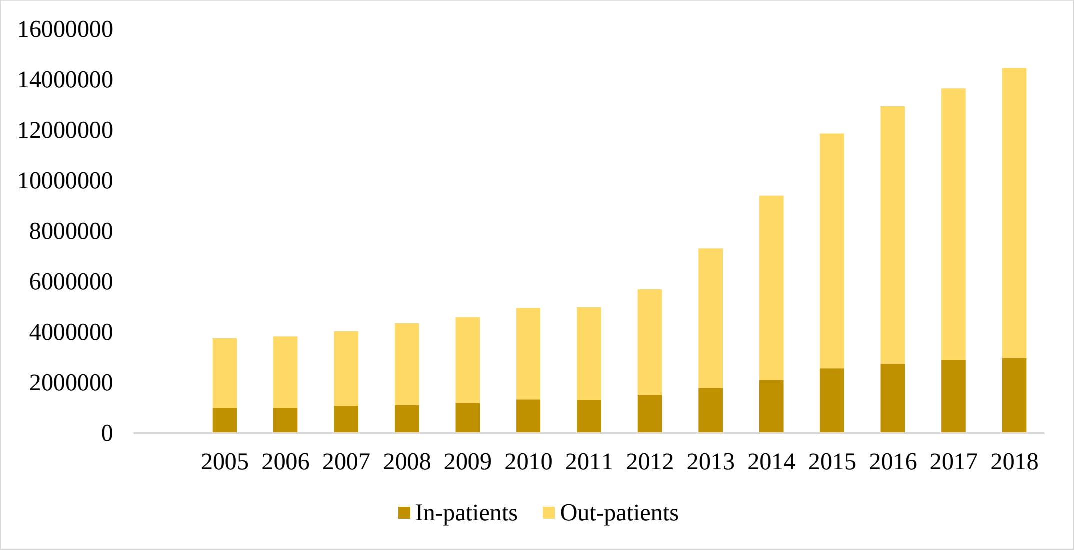

Figure (4.3) Number of In-patients and Out-patients during the Year 2005-2018

Source: Statistical Yearbooks, Ministry of Planning, Finance and Industry (2006, 2008, 2020)

4.2 Analysis of Cobb Douglas Production Model

The maximum likelihood estimation of Cobb-Douglas and Translog production models were calculated by using Frontier version 4.1 software developed by Tim Coelli in 2009 which is a modified version of Frontier 2.0 developed in1992. In this study, number of in-patient and out-patient were combined as total hospital output since the standard stochastic frontier model (SFM) allows only one output variable. The log of output and input variables are used for Cobb- Douglas Model. According to Equation (3.10), Cobb-Douglas Model is presented as

$$\ln(\text{Patients}) = \beta_0 + \beta_1 \ln(\text{Bed}) + \beta_2 \ln(\text{Doctor}) + \beta_3 \ln(\text{Nurse}) + \beta_4 \ln(\text{Midwife}) + \beta_5 \ln(\text{Other Health Staff}) + \varepsilon_i$$

where; ln (Patients) = log of inpatients and outpatients
ln (Beds) = log of beds
ln (Doctors) = log of doctors
ln (Nurses) = log of nurses
ln (Midwives) = log of midwives
ln (Other Health Staff) = log of other health staff

Table (4.3) shows the analysis of Cobb-Douglas Model for patients and other related input variables (beds, doctors, nurses, midwives and other health staff).

Table (4.3)

Parameter Estimates and Summary Statistic for Cobb-Douglas Production Function

Variables	Parameter	Coefficient	Standard Error	t- ratio
Constant	β_0	-39.395^{***}	0.999	-46.299
ln (Beds)	β_1	3.277^{***}	0.247	13.258
ln (Doctors)	β_2	-0.355^{***}	0.088	-4.008
ln (Nurses)	β_3	-0.872^{*}	0.468	-1.860
ln (Midwives)	β_4	2.448^{***}	0.467	5.234
ln (Other Health Staff)	β_5	0.863^{***}	0.255	3.379
Sigma Square (σ^2)	0.002^{***}			
Variance Ratio Parameter (γ)	0.000			
Log Likelihood Value	21.985			
Technical efficiency	0.999			

*** statistically significant at 1% level, * statistically significant at 10% level

Source: Frontier 4.1 output

The critical value of t ratio greater than 2.576 represent statistically significant at 1% level, 1.96 to 2.576 represent the statistically significant at 5% level and 1.64 to 1.96 represent the statistically significant at 10% level. According to the result, overall model is statistically significant at 1% level except input variable nurses is 10 % significant level. It indicates that all coefficients in the model are different from zero and it explains the goodness of fit for the model. Number of beds, doctors, midwives and other health staff are statistically significant at 1% level and number of nurses is statistically significant at 10 % level. The Cobb-Douglas model for patients can be expressed as follow;

$$\ln (\text{Patients}) = -39.395 + 3.277 \ln (\text{Bed}) -0.355) \ln (\text{Doctor}) -0.872 \ln (\text{Nurse})$$

$$+2.448 \ln (\text{Midwife}) + 0.863 (\text{Other Health Staff})$$

SE (0.999) (0.247) (0.088) (0.468) (0.467) (0.255)
t ratio (-46.299) (13.258) (-4.008) (-1.860) (5.234) (3.379)

The coefficients of beds, midwives and other health staff are positive and statistically significant at 1% level. The coefficient of doctors and nurses are negative. The sum of coefficients is greater than 1 and showing increasing return on scale of hospital production. One percent increase in number of beds, hospital production will increase 3.277% while other input variables remain constant. Similarly, 1% increase in midwife and other health staff, 2.448% and 0.863% increase in hospital production. One percent increase in doctors and nurses, 0.355% and 0.872% decrease in hospital production. It can be said that number of doctors and nurses are not necessary to increase with current hospital production. If increase the number of doctors and nurses, current production (number of patients) will decrease, that is, number of patients to look after by doctors and nurses will be reduced. The variance ratio parameter is very close to zero with the result 0.10000012E-07 and the log likelihood value is 21.985. The effect of efficiency on hospital production (γ) is not statistically significant and it can be interpreted that the production function is technically efficient. The public hospitals technical efficiency estimated by Cobb-Douglas model is 99%.

4.3 Analysis of Translog Production Model

The translog production model is calculated as double log model of first order derivatives, second order derivatives and cross order derivatives.

In this study, the translog Model is presented as

$$\begin{aligned}
\ln(\text{Patients}) = {} & \beta_0 + \beta_1 (\ln \text{Bed}) + \beta_2 (\ln \text{Doctor}) + \beta_3 (\ln \text{Nurse}) \\
& + \beta_4 (\ln \text{Midwife}) + \beta_5 (\ln \text{Other Health Staff}) + \beta_{11}\, 0.5 (\ln \text{Bed} \times \ln \text{Bed}) \\
& + \beta_{22}\, 0.5 (\ln \text{Doctor} \times \ln \text{Doctor}) + \beta_{33}\, 0.5 (\ln \text{Nurse} \times \ln \text{Nurse}) \\
& + \beta_{44}\, 0.5 (\ln \text{Midwife} \times \ln \text{Midwife}) \\
& + \beta_{55}\, 0.5 (\ln \text{Other Health Staff} \times \ln \text{Other Health Staff}) \\
& + \beta_{12} (\ln \text{Beds} \times \ln \text{Doctor}) + \beta_{13} (\ln \text{Bed} \times \ln \text{Nurse}) \\
& + \beta_{14} (\ln \text{Bed} \times \ln \text{Midwife}) + \beta_{15} (\ln \text{Bed} \times \ln \text{Other Medical Staff}) \\
& + \beta_{23} (\ln \text{Doctor} \times \ln \text{Nurse}) + \beta_{24} (\ln \text{Doctor} \times \ln \text{Midwife}) \\
& + \beta_{25} (\ln \text{Doctor} \times \ln \text{Other Health Staff}) + \beta_{34} (\ln \text{Nurse} \times \ln \text{Midwife}) \\
& + \beta_{35} (\ln \text{Nurse} \times \ln \text{Other Health Staff}) \\
& + \beta_{45} (\ln \text{Midwife} \times \ln \text{Other Health Staff}) + \varepsilon_i
\end{aligned}$$

where;
ln (Patients) = log of inpatients and outpatients
ln (Beds) = log of beds
ln (Doctors) = log of doctors
ln (Nurses) = log of nurses
ln (Midwives) = log of midwives
ln (Other Health Staff) = log of other health staff
β_0 = intercept of constant term
$\beta_1, \beta_2, \beta_3, \beta_4, \beta_5$ = first order derivatives
$\beta_{11}, \beta_{22}, \beta_{33}, \beta_{44}, \beta_{55}$ = second order derivates
$\beta_{12}, \beta_{13}, \beta_{14}, \beta_{15}, \beta_{23}, \beta_{24}, \beta_{25}, \beta_{34}, \beta_{35}, \beta_{45}$ = cross order derivates

The analysis of first order, second order and cross order derivatives of Translog model for patients and other related input variables (beds, doctors, nurses, midwives and other health staff) are shown in Table (4.4).

Table (4.4)

Parameter Estimates and Summary Statistics for Translog Production Function

Variables	Parameter	Coefficient	Standard Error	t ratio
Constant	β_0	32.2***	0.93	34.45
ln (Beds)	β_1	34.7***	0.89	386.83
ln (Doctors)	β_2	-311***	0.89	-345.98
ln (Nurses)	β_3	-574***	0.89	-640.85
ln (Midwives)	β_4	123***	0.90	136.62
ln (Other health staff)	β_5	397***	0.90	439.53
ln (Bed) x ln (Bed)	β_{11}	-105***	0.69	-149.61
ln (Doctor) x ln (Doctor)	β_{22}	-76.2***	0.73	-103.29
ln (Nurse) x ln (Nurse)	β_{33}	-168***	0.69	-240.49
ln (Midwife) x ln (Midwife)	β_{44}	-26.7***	0.70	-37.66
ln (Other Health Staff) x ln (Other Health Staff)	β_{55}	164***	0.74	221.03
ln (Beds) x ln (Doctor)	β_{12}	247***	0.94	260.90
ln (Bed) x ln (Nurse)	β_{13}	215***	0.87	245.72
Ln (Bed) x ln (Midwife)	β_{14}	-129***	0.87	-147.54
ln (Bed) x ln (Other Health Staff)	β_{15}	-279***	0.90	-308.51
ln (Doctor) x ln (Nurse)	β_{23}	215***	0.88	242.26
ln (Doctor) x ln (Midwife)	β_{24}	-12***	0.90	-13.17
ln (Doctor) x ln (Other Health Staff)	β_{25}	-176***	0.98	-179.01
ln (Nurse) x ln (Midwife)	β_{34}	160***	0.87	182.39
ln (Nurse) x ln (Other Health Staff)	β_{35}	-8.77***	0.88	-9.91
ln (Midwife) x ln (Other Health Staff)	β_{45}	-18.5***	0.88	20.91
Sigma Square (σ^2)	147***			
Variance Ratio Parameter (γ)	0.99***			
Log likelihood	69.64			
Technical efficiency	0.933			

*** statistically significant at 1% level

Source: Frontier 4.1 output

The critical value of t ratio greater than 2.576 represent statistically significant at 1% level, 1.96 to 2.576 represent the statistically significant at 5% level and 1.64 to 1.96 represent the statistically significant at 10% level. According to Table (4.4), the results of production coefficients for Translog model are similar to Cobb Douglas model, i.e., the coefficients of beds, midwives and other health staff are positive and statistically significant at 1% level. The coefficient of doctors and nurses are negative and statistically significant at 1% level. The elasticities of number of beds, midwives and other health staff are positive. When number of beds increases by 1%, it could increase the hospital production by 34.7 % while others input variables remain constant. Similarly, 1% of midwives increases the patient services by 123 %, and 1% of other health staff increases the patient services by 397 % while other input variables are constant. If 1% of doctor increases 311 % of patient number decreases. Likewise, 1% of nurse increases 574 % of patient number decrease that can be concluded as increasing number of doctors and nurses will be reducing the number of patients to look after. The highest effect of production inputs is number of nurses followed by number of other health staff and number of doctors with the negative and positive relationship respectively. The elasticity of scale for each input is equal to marginal production. Since production factor: labor (health workforce) outweighs the capital (hospital beds), Myanmar public health industry can be concluded as labor intensive industry.

The second order derivative for patients and other related input variables (beds, doctors, nurses, midwives and other health staff) were analyzed by Translog production function. The second order derivative explain the changes in hospital productivity by doubling the inputs. According to the result, number of beds, doctors, nurses, midwives and other health staff are statistically significant at 1% level (Table 4.4). At the second order derivatives, the coefficients of doctors, nurses, midwives and hospital beds are negative, however the coefficient of other health staff is positive. Doubling the number of doctors, nurses, midwives and hospital beds are negative while doubling the number of other health staff resulted positive production function. Doubling the number of beds, number of doctors, number of nurses and number of midwives decrease the hospital output by 105%, 76.2%, 168% and 267 % respectively. Doubling the number of beds, doctors, nurses and midwives will not increase the hospital productivity. However, number of other health staff will increase 164 % of hospital production when they are doubled in number.

The analysis of cross order derivative of translog model for patients and other related input variables (beds, doctors, nurses, midwives and other health staff) were shown in Table (4.4). At the cross-order derivatives, the interaction between bed-doctors, beds-nurses, doctors-nurses and nurse-midwives are positive and statistically significant at 1% level. There is direct effect of input variable to output, and substitutability effect between beds and midwives, bed and other health staff, doctors and midwives, doctors and other health staff, and nurses, other health staff and midwives and other health staff.

The coefficient of interaction between number of beds and number of doctors, number of beds and number of nurses are statistically significant and positive while the interaction between number of beds and number of midwives, number of beds and number of other health staff are statistically significant and negative. The number of beds has dual effects on hospital output, as direct effects, number of beds have positive effect to output and by means of indirect effect, number of beds can change the effect of number of doctors, nurses on the output. If hospital increases 1% of bed, it should increase 247 % of doctor, increase 215 % of nurses. Increase 1% of bed should reduce 129 % of midwives and 279 % of other health staff since they possess negative coefficients. The negative coefficients can interpret as substitutability effect between two variables, for instance, number of bed and number of midwives are substitutable, and number of bed and number of other health staff also have substitutable effect. The coefficient of number of doctors and number of nurses are statistically significant at 1% level and positive. The number of doctors has dual effects on hospital production, as direct effect number of doctors have negative effect to hospital output and changes on the effect of number of nurses. If one percent of doctor increases, 215 %of nurses will need to increase. On the other hand, 1% of doctor can substitute with 12 % of midwives or 176 % of other health staffs.

The coefficient of number of nurses and number of midwives are statistically significant and positive, however, the interaction of number of nurses to number of other health staff is negative. Number of nurses has dual effects; as direct effect number of nurses shows negative effect to hospital output since nurses’ composition in current setting is sufficient. Therefore, increase in number of nurses may lead to reducing hospital productivity. As indirect effect, number of nurses can change on the effect of number of midwives. If hospital increase 1% of nurses, 160 % of midwives should increase. One percent of nurses can substitute 8.77 % of other health staff because the interaction between number of nurses and number of other health staff is negative. The interaction between number of midwives and number of other health staff are statistically significant and negative. Number of midwives has negative effect on hospital production concluded that additional number of midwives can reduce hospital output as their number is currently enough. For substitutability, 1% of midwives can substitute with 18.5 % of other health staff. It is implied that more substitutability may cause lesser complementarity.

The results from translog model (first order derivative, second order derivative and cross order derivative) illustrate that overall model is statistically significant at 1% level. It shows that all coefficients in the model are different from zero and it explains the goodness of fit for the model. Number of beds, doctors, nurses, midwives and other health staff are statistically significant at 1% level.

The maximum likelihood method estimated the stochastic frontier production function, technical efficiency and technical inefficiency. Table (4.4) shows that the variance ratio parameter, gamma (γ) is close to one (0.99) and its t ratio is statistically significant that can conclude that there is implication to technical inefficiency (u) and the differences in production is not only related to statistical noise (v). The gamma value indicated that 99% of variabilities in hospital production is attributed to hospital technical efficiency and equation error is only 1%.

According to Equation (3.15), the translog model for patients can be expressed as follow;

$$\begin{aligned}
\ln(\text{Patients}) = {} & 32.2 + 34.7 \ln(\text{Bed}) - 311 \ln(\text{Doctor}) - 574 \ln(\text{Nurse}) \\
& + 123 \ln(\text{Midwife}) + 397 \ln(\text{Other Health Staff}) - 105 \times 0.5 (\ln \text{Bed} \times \ln \text{Bed}) \\
& - 76.2 \times 0.5 (\ln \text{Doctor} \times \ln \text{Doctor}) - 168 \times 0.5 (\ln \text{Nurse} \times \ln \text{Nurse}) \\
& - 26.7 \times 0.5 (\ln \text{Midwife} \times \ln \text{Midwife}) \\
& + 164 \times 0.5 (\ln \text{Other Health Staff} \times \ln \text{Other Health Staff}) \\
& + 247 (\ln \text{Beds} \times \ln \text{Doctor}) + 215 (\ln \text{Bed} \times \ln \text{Nurse}) - 129 (\ln \text{Bed} \times \ln \text{Midwife}) \\
& - 279 (\ln \text{Bed} \times \ln \text{Other Medical Staff}) + 215 (\ln \text{Doctor} \times \ln \text{Nurse}) \\
& - 12 (\ln \text{Doctor} \times \ln \text{Midwife}) - 176 (\ln \text{Doctor} \times \ln \text{Other Health Staff}) \\
& + 160 (\ln \text{Nurse} \times \ln \text{Midwife}) - 8.77 (\ln \text{Nurse} \times \ln \text{Other Health Staff}) \\
& - 18.5 (\ln \text{Midwife} \times \ln \text{Other Health Staff})
\end{aligned}$$

SE (0.93) (0.89) (0.89) (0.89) (0.90) (0.90) (0.69) (0.73) (0.69) (0.70) (0.69) (0.70)
(0.74) (0.94) (0.87) (0.87) (0.90) (0.88) (0.90) (0.98) (0.87) (0.88) (0.88)

t ratio (34.45) (386.83) (-345.98) (-640.85) (136.62) (439.53) (-149.61) (-103.29)
(-240.49) (-37.66) (221.03) (260.90) (245.72) (-147.54) (-308.51) (242.26)
(-13.17) (-179.01) (182.39) (-9.91) (20.91)

4.4 Model Selection

The comparison between Cobb-Douglas Model and Translog Model by using log likelihood values is illustrated in the following Table (4.5).

Table (4.5)

Comparison between Cobb-Douglas and Translog Production Models

	Cobb- Douglas Model	**Translog Model**
Log Likelihood	21.985	69.64

Source: Frontier 4.1 output

The log-likelihood value for a given model can range from negative infinity to positive infinity. The actual log-likelihood value for a given model is mostly meaningless, but it's useful for comparing two or more models (Coelli, 2002). The log likelihood value from Cobb-Douglas model and translog model are 21.89 and 69.64 respectively. Since the higher the value of the log-likelihood, the better a model fits a data set. Therefore, the Translog production model was selected to estimate the technical efficiency of public hospitals in Myanmar.

4.5 Testing the Technical Efficiency of Public Hospitals

The hypotheses testing to estimate the technical efficiency of public hospitals across Myanmar are as follow.

(i) Hypotheses

Null Hypothesis

H_0: $\gamma = 0$, the production function is technically efficient

Alternative Hypothesis

H_A: $\gamma \neq 0$, the production function has technical inefficiency.

(ii) Test Statistics

$$\chi^2 = \sum_{i=1}^{n} \frac{(O_i - E_i)^2}{E_i}$$

where; O_i = observed frequency

E_i = expected frequency

(iii) Critical Value

$K = \chi^2_{(\alpha,n-1)}$

$K = \chi^2_{(0.01,19)} = 35.556$

(iv) Decision Rule

If $\chi^2 \geq K$; reject H_0.

Otherwise; accept H_0.

(v) Decision

$\chi^2 = 69.64 > K = 35.556$

$\therefore H_0$ is rejected.

(vi) Conclusion

It is concluded that production function of public hospitals in Myanmar has technical inefficiency.

4.6 Analysis of Technical Efficiency of Public Hospitals in Myanmar

Technical efficiency is the ratio of observed output to maximum possible output. If observed output is less than maximum possible output, the production function is not technically efficient, i.e., the production factors are not fully utilized. If the observed output is equal or greater than maximum possible output, the production function can be concluded as technically efficient. The production factors are fully utilized for the production. The analysis of the technical efficiency of public hospitals in Myanmar for the year 2005 to 2018 is described in Table (4.6) and Figure (4.4).

Table (4.6)

Technical Efficiency of Public Hospitals in Myanmar

Year	Technical Efficiency
2005	0.952
2006	0.95
2007	0.947
2008	0.945
2009	0.942
2010	0.939
2011	0.936
2012	0.932
2013	0.929
2014	0.925
2015	0.921
2016	0.917
2017	0.912
2018	0.908
Minimum	0.908
Maximum	0.952
Average	0.933

Source: Frontier 4.1 Output

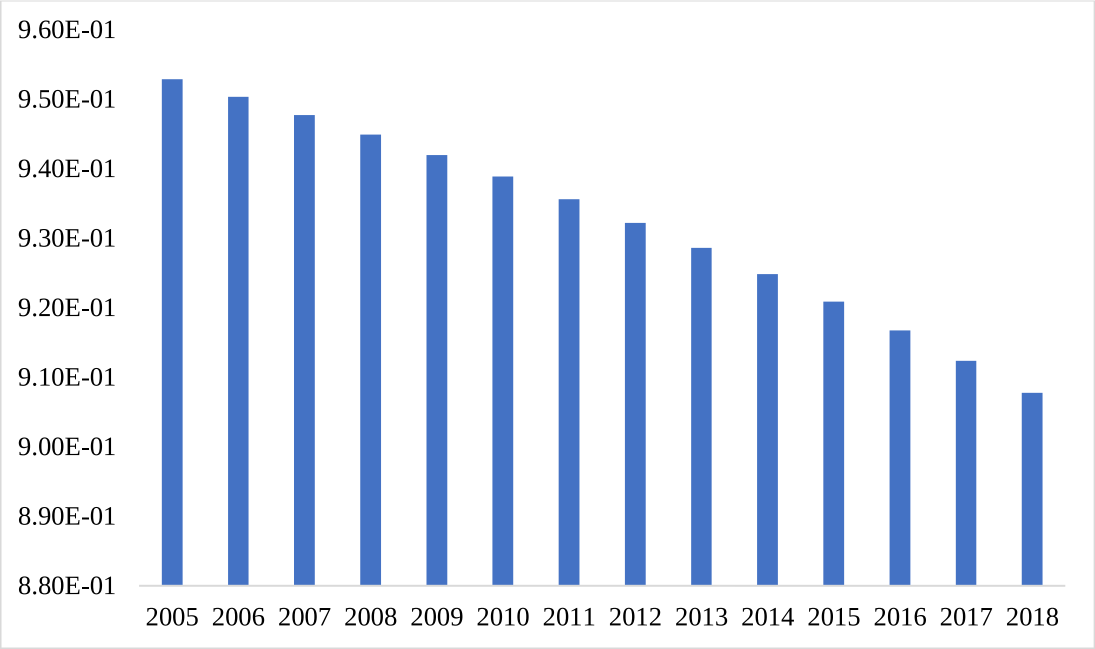

Figure (4.4) Hospitals’ Technical Efficiencies by Year (2005- 2018)

Source: Frontier 4.1 Output

Table (4.6) and Figure (4.4) show the technical efficiency of public hospitals in Myanmar. According to the result, the technical efficiency analyzed by translog model is 93% with a range of minimum technical efficiency 91% to maximum technical efficiency 95% and gradually decreasing per year.

CHAPTER V

CONCLUSION

This chapter reveals the findings from data analysis, discussion, recommendations and needs for further research.

5.1 Summary of Findings and Discussions

The descriptive analysis shows increasing demand of in-patient and out-patient services which is hospital output in this study. Since number of out-patients are higher than number of in-patients, hospitals may need infrastructures and supplies such as medical equipment, buildings, examination rooms and other outpatient department facilities in addition to increasing accessibility of service providers. In terms of study variables, it is found that number of beds, doctors, nurses, midwives and other health staff are rising with the increasing hospital output: the number of in-patients and out-patients. Increasing hospital service consumption may be due to more accessible to hospital services or improving patient satisfaction, but reversely, increase utilization of hospital services may be occurrence of more diseases or illness. The composition of health workforce expressed that nurses are the biggest occupational group which occupied 37% of Myanmar health workforce. This finding said that composition of nurses in Myanmar health system is similar to global nursing workforce contribution which is 59% of total health professionals (State of World’s Nursing Report, 2020).

This study compared the Cobb- Douglas and Translog Models for the best fit of data set. According to the results of higher likelihood estimate value computed by frontier software version 4.1, the translog production model was selected to estimate the technical efficiency of public hospitals in Myanmar. The model fit to translog production function is similar to the findings of Baten et al. (2009), Hamidi (2016), Baten et al. (2016) and Pechrova & Simpach (2021) which conducted in healthcare and agricultural sectors. Due to the nature of healthcare setting; importance of team members’ interaction in patient care can be seen in Translog model, therefore, Translog is the best fit to see the synergetic effect to hospital output than Cobb- Douglas model.

Analysis of Translog production function shows that increasing number of beds, midwives and other health staff will increase the hospital production while increasing number of doctors and nurses do not increase hospital production. It can also interpret that number of doctors and nurses are adequate at current situation, therefore, if doctors and nurses increase, the workload of looking after to patients will be reduced. This finding of negative relationship with health workforce and hospital production is similar findings with Hamidi (2016) which found number of patients has negative relationship with nurse and non-medical staff, and Mehraban & Raghfar (2016) which found number of patients has negative relationship with paraclinical staff.

The second order derivatives can interpret the output when doubling the individual input. All the second order coefficients in translog model are statistically significant at 1% level. Number of doctors and nurses are sufficient before increasing their number. Doubling the number of beds, doctors, nurses and midwives are statistically significant and show negative coefficients. Increasing the number in double to beds, doctors, nurses and midwives will not result to higher hospital production. This finding matches with the findings of Baten et al (2009) and Hamidi (2016) where doubling the number of health workforce do not contribute to enhancing hospital production.

Acknowledging doctors and nurses as key workforce in healthcare and increasing number of doctors and nurses anticipate to have more productivity. Nevertheless, this study highlighted that their composition is enough with current hospital production. Increasing doctors and nurses' recruitment found to be reduced hospital production. Number of beds has negative effect to hospital production stated that additional hospital beds are not needed for current hospital production. As a developing country with most population reside in rural areas, the finding does not mean Myanmar health system have enough doctors, nurses and hospital beds because accessibility of health services by rural population are not included in this study. This study can interpret as the health workforce and hospital beds are enough for the public hospitals in Myanmar over fourteen years period (2005-2018).

From the cross-order derivative, interaction and substitutability effects between input variables for hospital production can be analyzed. The positive interaction between beds and doctors, beds and nurses, doctors and nurses, and nurses and midwives. This finding highlighted the needs of health workforce when increasing one of them. It will be useful to form the harmonized healthcare team with appropriate skill mix based on their expertise in caring patients. The negative interaction between beds and midwives, beds and other health staff, doctors and midwives, doctors and other health staff, nurse and other health staff, and midwives and other health staff demonstrated the substitutability between these cadres. It is useful information for managing budget for health professional production to maintain or enhance hospital production. In this study, the higher production in labor force than capital can be concluded as Myanmar public hospitals industry is labor intensive. This finding is opposite to the study in Iranian direct healthcare services by Mehraban & Raghfar (2016) where more investment in hospital beds. However, these findings are logical because labour intensive industries are more suitable for developing countries while developed countries implement capital intensive.

The maximum likelihood method estimated the stochastic frontier production function, technical efficiency and technical inefficiency. The variance ratio parameter, gamma (γ) is close to one (0.99) and its t ratio is statistically significant that can conclude that there is implication to technical inefficiency (u) and the differences in production is not only related to statistical noise (v). Furthermore, gamma value directed the presence of technical inefficiency in hospital production function, the technical inefficiency was tested by maximum likelihood value. The log likelihood value is greater than critical Chi square value, and concluded that the technical inefficiency exists in hospital production. The gamma value indicated that 99% of variabilities in hospital production is attributed to hospital technical efficiency and equation error is only 1%. This finding reflects the ground situation as hospitals included in this study are varying from primary setting to tertiary hospitals where specialist services are available. According to best fit model, translog production function, technical efficiency of public hospital is estimated as 93% with minimum 91% and maximum 95%. During fourteen years period, the hospital production is above 90%, however there is slightly decreasing technical efficiency year by year, in other word, increase in inefficiency of hospital production. The hospital efficiency in this study (Cobb-Douglas- 99% and translog- 93%) is similar to the findings of Sielska & Nojszewska (2022) studied in Polish county hospitals in which Cobb-Douglas function (85.69%) was higher than translog function (84.57%).

5.2 Recommendations

The health care sector is improving time to time for providing healthy lives, the marginal contribution to health outcome is still relatively small. To measure the health care efficiency is quintessential for the best health care services with strategic investment. This study was conducted all the public hospitals data combined as one unit, hospital level performance cannot calculate. It would be useful to learn at hospital level efficiency so that management attention is specific and direct. Implementation research are recommended for measuring efficiency so that hospital level and policy maker level decisions are precise and fulfil the actual needs.

Technical efficiency of public hospitals during study period (2005-2018) was slightly decreasing each year. Decreasing technical efficiency means increasing technical inefficiency due to capital or labor inputs. This is a critical area to pay attention for addressing issues in time so that scared resources are efficiently manage for providing healthcare services. The accessibility of health services by rural population were not included in this study, and 70% of population are staying at rural areas. In order to effectively manage the whole health system, the data from community level health services, health workforce and capital investment should consider to study. The data related to community level healthcare services will be benefitted for researchers to estimate whole health system performance which will be very useful for policy makers.

There was reducing health workforce after political crisis 2021, technical efficiency of public hospitals should conduct with active number of health workforce to reflect current situation of hospital production which will provide information on situation of hospital efficiency and areas to be addressed by policy in terms of health workforce production or capital investment. Transolog production function analysis shows the substitutability between input variables. It is useful for managing production of health personals to achieve optimum hospital production with minimum input. The policy makers could prioritize the different health cadres' production according to the needs of production function and available budget, for example, the costly health professional like medical doctor can substitute with less costly one such as nurses or midwives.

Data quality and accessibility are important factors for making accurate decisions. When reliable data are available at hospital level, precise decision can be made for optimum hospital production. Implementation research on efficiencies measurement is encouraged for the best use of resources and making strategic decision on government health expenditures.

5.3 Further Research

This study measures the technical efficiency of public hospitals across the country. Since Myanmar has public and private health sectors, estimating technical efficiency of private hospitals should be conducted to understand the private health sector production function and able to learn the lessons from comparison between private and public hospital efficiencies. The stochastic frontier analysis of parametric method was applied in this study and it would be interesting to learn the results of non-parametric method such as data envelopment analysis that can provide information on input -oriented and output-oriented production function. There are many perspectives in estimating hospital outcome such as maternal and infant mortality rate, life expectancy, healthcare spending in gross domestic product, number of days for patient hospital stay, number of operations conducted by the health professionals should be considered to study. The quality healthcare does not mean efficiency, but efficiency can improve the quality, the quality measurement data, like patient satisfaction, patient waiting time for services should be consider to include for estimating efficiency.

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APPENDIX 1

Output of Cobb-Douglas Production Function by Frontier 4.1

```
Error Components Frontier (see B&C 1992)
The model is a production function
The dependent variable is logged
```

The final MLE estimates

```
                  coefficient             standard-error          t-ratio
beta 0          -0.39389830E+02          0.12842403E+01     -0.30671697E+02
beta 1           0.32768316E+01          0.21251133E+00      0.15419562E+02
beta 2           -0.35545878E+00          0.90810238E-01     -0.39143029E+01
beta 3          -0.87229500E+00          0.49071876E+00     -0.17775864E+01
beta 4           0.24483440E+01          0.52366142E+00      0.46754332E+01
beta 5           0.86373976E+00          0.24546303E+00      0.35188182E+01
sigma-squared  0.25323296E-02          0.93515608E-03      0.27079218E+01
gamma            0.10000012E-07          0.11994308E-03       0.83372977E-04
mu              -0.10064451E-04          0.31529168E-01     -0.31921080E-03
eta             -0.49552302E-03          0.58407176E+00     -0.84839408E-03
log likelihood =   0.21985184E+02
number of iterations =     21
(maximum number of iterations set at :   100)
number of cross-sections =      1
number of time periods =     14
total number of observations =     14
```

Technical Efficiency Estimates

efficiency estimates for year   1 :

```
     firm            eff.-est.
      1          0.99999813E+00
mean eff. in year   1 =  0.99999813E+00
```

efficiency estimates for year   2 :

```
    firm          eff.-est.
      1         0.99999813E+00
mean eff. in year   2 =  0.99999813E+00
efficiency estimates for year      3 :
    firm          eff.-est.
      1         0.99999813E+00
mean eff. in year   3 =  0.99999813E+00
efficiency estimates for year      4 :
    firm          eff.-est.
      1         0.99999813E+00
mean eff. in year   4 =  0.99999813E+00
efficiency estimates for year      5 :
    firm          eff.-est.
      1         0.99999813E+00
mean eff. in year   5 =  0.99999813E+00
efficiency estimates for year      6 :
   firm          eff.-est.
      1         0.99999813E+00
mean eff. in year   6 =  0.99999813E+00
efficiency estimates for year      7 :
    firm          eff.-est.
      1         0.99999813E+00
mean eff. in year   7 =  0.99999813E+00
efficiency estimates for year      8 :
    firm          eff.-est.
      1         0.99999813E+00
mean eff. in year   8 =  0.99999813E+00
efficiency estimates for year      9 :
    firm          eff.-est.
      1         0.99999813E+00
mean eff. in year   9 =  0.99999813E+00
efficiency estimates for year     10 :
    firm          eff.-est.
      1         0.99999813E+00
```

```
mean eff. in year  10 =  0.99999813E+00

efficiency estimates for year     11 :
     firm              eff.-est.
       1           0.99999812E+00
mean eff. in year  11 =  0.99999812E+00
efficiency estimates for year     12 :
     firm              eff.-est.
       1           0.99999812E+00
mean eff. in year  12 =  0.99999812E+00
efficiency estimates for year     13 :
     firm              eff.-est.
       1           0.99999812E+00
mean eff. in year  13 =  0.99999812E+00
efficiency estimates for year     14 :
     firm              eff.-est.
       1           0.99999812E+00
mean eff. in year  14 =  0.99999812E+00
summary of cross sectional  of observations:
(1 = observed, 0 = not observed)
  t:   1   2   3   4   5   6   7   8   9  10  11  12  13  14
  n    1   1   1   1   1   1   1   1   1   1   1   1   1   1   1  14
       1   1   1   1   1   1   1   1   1   1   1   1   1   1  14
```

APPENDIX 2

Output of Translog Production Function by Frontier 4.1

```
Error Components Frontier (see B&C 1992)
 The model is a production function
 The dependent variable is logged
The Final MLE Estimates
                     coefficient            standard-error           t-ratio
  beta 0        0.32202109E+02        0.93471827E+00        0.34451139E+02
  beta 1        0.34670094E+03        0.89623883E+00        0.38683990E+03
  beta 2       -0.31053654E+03        0.89753859E+00       - 0.34598684E+03
  beta 3       -0.57394666E+03        0.89559860E+00       -0.64085257E+03
  beta 4        0.12312534E+03        0.90120869E+00        0.13662245E+03
  beta 5        0.39676339E+03        0.90269099E+00        0.43953400E+03
  beta 6       -0.10461492E+03        0.69925066E+00       -0.14961005E+03
  beta 7       -0.76201126E+02        0.73768987E+00       -0.10329697E+03
  beta 8       -0.16789618E+03         0.69812994E+00      -0.24049417E+03
  beta 9       -0.26699345E+02        0.70884769E+00       -0.37665842E+02
  beta10        0.16440717E+03        0.74381664E+00        0.22103186E+03
  beta11        0.24663785E+03        0.94531076E+00        0.26090663E+03
  beta12        0.21478230E+03        0.87406653E+00        0.24572763E+03
  beta13       -0.12922003E+03        0.87579485E+00       -0.14754600E+03
  beta14       -0.27904542E+03        0.90447567E+00       -0.30851622E+03
  beta15        0.21537947E+03        0.88903210E+00        0.24226287E+03
  beta16       -0.11972045E+02        0.90853809E+00       -0.13177263E+02
  beta17       -0.17566142E+03        0.98127580E+00        -0.17901330E+03
  beta18        0.15999473E+03        0.87717105E+00         0.18239855E+03
  beta19       -0.87727560E+01        0.88489704E+00        -0.99138721E+01
  beta20       -0.18484358E+02        0.88357747E+00        -0.20919906E+02
  sigma-squared  0.14671674E+03       0.10005517E+01         0.14663585E+03
  gamma           0.99999999E+00      0.42089867E-08         0.23758687E+09
  mu             -0.25564757E+01      0.10098088E+01        -0.25316434E+01
  eta            -0.53514164E-01      0.97918827E-02        -0.54651558E+01
log likelihood =   0.69644247E+02
LR test of the one-sided error =   0.23585503E+03
with number of restrictions = 3
```

```
[note that this statistic has a mixed chi-square distribution]
number of iterations =     53
(maximum number of iterations set at :   100)
number of cross-sections =      1
number of time periods =     14
total number of observations =     14
```

Technical Efficiency Estimates

```
efficiency estimates for year      1 :
     firm             eff.-est.
       1          0.95289738E+00
mean eff. in year   1 =  0.95289738E+00
efficiency estimates for year      2 :
     firm             eff.-est.
       1          0.95037337E+00
mean eff. in year   2 =  0.95037337E+00
efficiency estimates for year      3 :
     firm             eff.-est.
       1          0.94771786E+00
mean eff. in year   3 =  0.94771786E+00
efficiency estimates for year      4 :
     firm             eff.-est.
       1          0.94492441E+00
mean eff. in year   4 =  0.94492441E+00
efficiency estimates for year      5 :
     firm             eff.-est.
      1          0.94198632E+00
mean eff. in year   5 =  0.94198632E+00
efficiency estimates for year      6 :
    firm             eff.-est.
       1          0.93889663E+00
mean eff. in year   6 =  0.93889663E+00
efficiency estimates for year      7 :
     firm             eff.-est.
       1          0.93564807E+00
mean eff. in year   7 =  0.93564807E+00
```

```
efficiency estimates for year      8 :
     firm             eff.-est.
       1           0.93223312E+00
mean eff. in year   8 =  0.93223312E+00
efficiency estimates for year      9 :
     firm             eff.-est.
       1           0.92864395E+00
mean eff. in year   9 =  0.92864395E+00
efficiency estimates for year     10 :
     firm             eff.-est.
       1           0.92487246E+00
mean eff. in year  10 =  0.92487246E+00
efficiency estimates for year     11 :
     firm             eff.-est.
       1           0.92091024E+00
mean eff. in year  11 =  0.92091024E+00
efficiency estimates for year     12 :
     firm             eff.-est.
       1           0.91674861E+00
mean eff. in year  12 =  0.91674861E+00
efficiency estimates for year     13 :
     firm             eff.-est.
       1           0.91237859E+00
mean eff. in year  13 =  0.91237859E+00
efficiency estimates for year     14 :
     firm             eff.-est.
       1           0.90779092E+00
mean eff. in year  14 =  0.90779092E+00
summary of cross sectional  of observations:
(1 = observed, 0 = not observed)
  t:   1   2   3   4   5   6   7   8   9  10  11  12  13  14
   n   1   1   1   1   1   1   1   1   1   1   1   1   1   1  14
       1   1   1   1   1   1   1   1   1   1   1   1   1  14p
```