MEASURING THE TECHNICAL EFFICIENCY OF INPATIENT CARE SERVICES IN TURKISH PUBLIC HOSPITALS USING STOCHASTIC FRONTIER ANALYSIS

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I certify that this thesis satisfies all the requirements as a thesis for the degree of Master of Science

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This is to certify that I have read this thesis and that it in my opinion is fully adequate, in scope and quality, as a thesis for the Degree of Master of Science in the field of Economics of the Graduate School of Social Sciences.

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I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

Alper MORTAŞ

ABSTRACT

MEASURING THE TECHNICAL EFFICIENCY OF INPATIENT CARE SERVICES IN TURKISH PUBLIC HOSPITALS USING STOCHASTIC FRONTIER ANALYSIS

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In this study, we measure the technical efficiency of inpatient care services of Turkish public hospitals using Stochastic Frontier Analysis (SFA). In the analysis, cross-sectional data on 495 general hospitals in 2016 are used. According to the parameters estimated with SFA, a hospital with high role group and in a region with a low development index has higher efficiency than those of other hospitals. The contribution of this thesis to the previous studies on hospital efficiency in Turkey is to use case-mix index reflecting the clinical level of all cases in a hospital. We adjust output of inpatient service with case mix index and remove the heterogeneity between cases in order to get better estimates by SFA. After using CMI, it has been observed that the inefficiency parameters of role group of hospital and development index are approach to zero whereas parameter of health index loose its significance.

Keywords: Stochastic Frontier Analysis, Technical Efficiency, Hospital Efficiency, Case-mix Index, Inpatient Care Services

ÖZ

STOKASTİK SINIR ANALİZİ İLE TÜRKİYE KAMU HASTANELERİNDE YATARAK TEDAVİ HİZMETLERİ TEKNİK ETKİNLİĞİNİN ÖLÇÜLMESİ

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Bu tezde, Türk kamu hastanelerinin yatarak tedavi hizmetlerinin, Stokastik Sınır Analizini (SSA) kullanarak teknik etkinliği ölçülmektedir. Analizde, 2016 yılında 495 genel hastaneye ait kesitsel veriler kullanılmıştır. SFA ile hesaplanan parametrelere göre, yüksek rol grubuna sahip ve düşük bir gelişmişlik endeksine sahip bir bölgede bulunan bir hastanenin etkinliği diğer hastanelere göre daha yüksektir. Bu tezin Türkiye'de hastane etkinliği üzerine olan önceki çalışmalara katkısı, bir hastanedeki tüm vakaların klinik düzeyini yansıtan vaka-karma endeksinin kullanılmasıdır. SFA tarafından daha iyi tahminler elde etmek için yatarak tedavi hizmeti çıktısını vaka karma endeksi ile ayarlayarak vakalar arasındaki heterojenlik ortadan kaldırılmaktadır. Vaka-karma endeksi kullanıldıktan sonra hastane rol grubu ve gelişmişlik indeksi parametrelerin sıfıra yaklaştığı, sağlık indeksinin ise anlamlılığını kaybettiği gözlenmiştir.

Anahtar Kelimeler: Stokastik Sınır Analizi, Teknik Etkinlik, Hastane Etkinliği, Vaka-karma İndeksi, Yatarak Tedavi Hizmetleri

ACKNOWLEDGMENTS

I would like to thank my valuable adviser Asst. Prof. Güneş AŞIK for her patience and goodwill, who helped me through her contributions throughout my thesis work.

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ABBREVIATION LIST

CMI	: Case-mix Index
DEA	: Data Envelopment Analysis
DMU	: Decision Maker Unit
DRG	: Diagnosis Related Groups
HTP	: Health Transformation Program
LR	: Likelihood Ratio
MoH	: Ministry of Health
ML	: Maximum Likelihood
NUTS	: Nomenclature of Territorial Units for Statistics
OECD	: Organization for Economic Co-operation and Development
OLS	: Ordinary Least Squares
RTS	: Returns to Scale
SFA	: Stochastic Frontier Analysis
TPHI	: Turkish Public Hospitals Institution

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CHAPTER I

INTRODUCTION

Nowadays, performance measurement of health systems is becoming a fundamental issue for developing countries. With economic developments in these countries, expenditures on health services are increasing, and policy makers desire to plan their investments responsively and in accordance with the citizens' preferences. Thus, health expenditures are aimed to be financially sustainable with public resources (Jacobs et al. 2006). Health care services efficiency and productivity measurement is of great importance for researchers and policy makers, as the health system and the public will benefit from the increased efficiency of health services that will be provided in this way.

In Turkey, after the Health Transformation Program (HTP) (2003) was put in place, a significant increase in health spending was observed. Especially, increase in health spending in the public sector is thought to be one of the determinants of public expenditure increase. When considering the scarcity of resources in addition to this increase, it is necessary to discuss the problem of effective resource allocation and the use of service production units in the health care system (Atılgan, 2012).

A number of reference points and evaluation criteria have been developed for the use of resources in hospitals in the approach developed for institutional performance evaluation in hospitals affiliated to Ministry of Health (MoH) (Turkish Public Hospitals Institution, 2012). Administrative performance criteria including evaluation of medical, administrative, financial, quality, patient and employee satisfaction of health facilities, was created for performance evaluations of contracted managers by adapting the Balanced Score Card approach developed by Norton & Kaplan (1992). Regarding the Balanced Scorecard criteria for inpatient care services, there is an efficiency score calculated by the stochastic frontier analysis where the output is the day spent in the inpatient service, the inputs are the bed and the staff, and appropriate control and inefficiency variables are used (Turkish Public Hospitals Institution, no date). In addition to inpatient services elements of MoH Balanced Scorecard, case mix index is used as a component of efficiency model in this study. Case-mix index, which is a coefficient that allows us to compare the case production of a hospital with another hospital through diagnosis related groups, has an important place in the literature of efficiency analysis. For that reason, we use case mix index in order to remove the heterogeneity between cases and get better estimates by Stochastic Frontier Analysis (SFA) in this thesis.

As a measurement method of technical efficiency, SFA presents a parametric structure and tests the decision maker units against a determined frontier for efficiency measurement. It requires the use of a theoretically defined production frontier function form. The greatest advantage of SFA over other methods is that it allows the model to be affected by random errors. The method divides the deviations from the frontiers of the defined production technology into two parts, measured by error terms. The first part is the randomness (or statistical error) and the second part is the ineffectiveness.

In this study, we measure the technical efficiency of inpatient care services of Turkish public hospitals using Stochastic Frontier Analysis (SFA). In the analysis, cross-sectional data on 495 general hospitals in 2016 were used. In addition to of input-output relations, we evaluate the impact of hospital-specific and environmental factors on efficiency scores by using SFA. The contribution of this thesis to the previous studies on Turkish hospitals is to use case-mix index reflecting the clinical complexity of all cases in a hospital. The main objective is to monitor the change in parameters and efficiency scores after adjusting the case-mix index with the comparison of models.

In the second chapter, the Turkish health system is considered. Firstly, the principles and aims of Health Transformation Program are considered. Then, the developments provided in inpatient services and in regional distribution of human resource with this transformation framework are explained. It is further explained how the general hospitals, which are not branch hospitals, are grouped by MoH according to the resources used and the services they have.

In the third chapter, the foundation of "efficiency" is described by production technology, input and output sets, production frontier function, output distance function and output oriented technical efficiency concepts.

In the fourth chapter, firstly the need for SFA has been demonstrated by showing the missing aspects of the deterministic frontier models. Then, the methodology of calculating technical efficiency and estimating the parameters, and its translog functional form are presented. At the end, the hypothesis tests are described in order to choose the most appropriate model for measuring the efficiency.

In the fifth chapter, we search the literature and choose the unit of analysis and variables according to the information available in the literature review and available data. Then, we obtain the parameters after deciding empirical model according to hypothesis tests. In the last section, we classify the technical efficiencies among role groups, bed capacities and regions of hospitals, then interpret in accordance with the parameters obtained.

In the conclusion that is the last part of the study, we interpret the results obtained and make suggestions for future studies.

CHAPTER II

TURKISH HEALTH SYSTEM

2.1. Health Transformation Program

Since the year of 2003, the structure of Turkish health system has been changed evidently with the Health Transformation Program (HTP) aiming to organize, finance and provide health services effectively, efficiently and fairly (Ministry of Health of Turkey 2003). Effectiveness refers to the aim of the policies to be implemented to raise the level of public health. Efficiency is to reduce costs by using resources appropriately and to produce more services with the same source. Equity is to ensure that people reach health care services to the extent they need and that they contribute to the financing of services in proportion to their financial strength (Ministery of Health of Turkey 2012).

The basic principles of the Health Transformation Program are listed below (Ministry of Health of Turkey 2003):

Human centricity: This principle refers to taking into consideration the needs, demands and expectations of the individual, the individual, who will benefit from the service in the planning of the system and in the presentation of the service.

Sustainability: It means that the system to be developed is in harmony with the country's conditions and resources, and it is a principle that it sustains itself by nurturing itself.

Continuous quality improvement: This principle focuses on creating a feedback system that will provide lessons from outcomes and mistakes.

Participation: Taking all the views and suggestions of all interested parties during the development and implementation of the system means creating platforms to provide a constructive discussion environment.

Reconciliation: As a requirement of a democratic administration, it refers to the search for meeting in common points, taking into account the mutual interests between the different sections of the sector.

Volunteerism: It means that the people who produce and serve the service in the system do not voluntarily take part in the direction of the incentive measures rather than the forced ones.

Separation of powers: The principle of financing healthcare services, planning, supervising, and generating services.

Decentralization: Institutions should get rid of the cumbersome structure formed by the central government. It is aimed to pass the misconception of management principle in accordance with changing and developing conditions and contemporary understanding. Autonomous entities from the administrative and financial side will have a quick decision mechanism and will use the resources more efficiently.

Competition in service: Health service provision is the principle of eliminating monopoly and competing with service providers in accordance with certain standards.

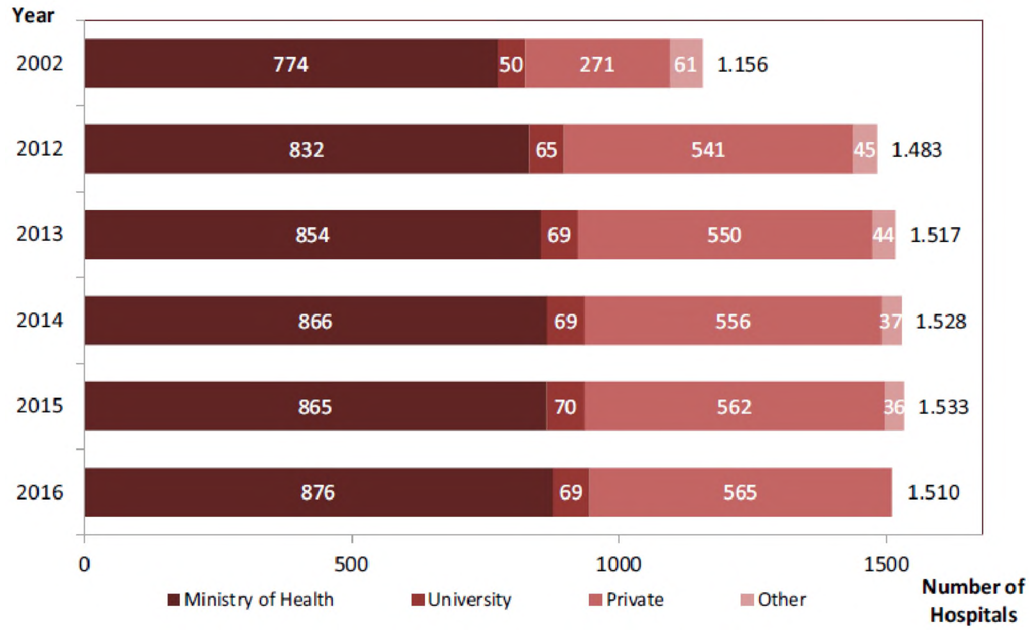
Within the framework of these principles HTP consists of 8 components, which have been formed to cover the health sector with all its dimensions (Ministry of Health of Turkey 2003:

- The Ministry of Health as the Planner and Controller
- General Health Insurance Gathering Everybody under a Single Umbrella
- Widespread, Easily Accessible and Friendly Health Service System
- Health Manpower Equipped with Knowledge and Competence and Working with High Motivation
- Education and Science Institutions Supporting the System
- Quality and Accreditation for Qualified and Effective Health Services
- Institutional Structure in the Management of Rational Medicine and Equipment
- Access to Effective Information at Decision Making Process

2.2. Inpatient Services

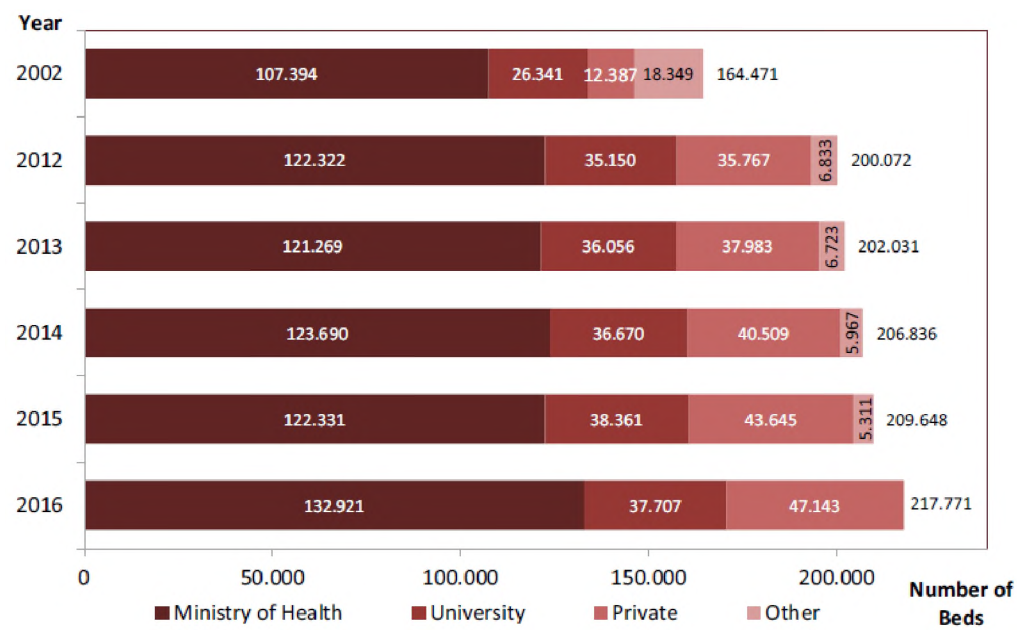
Provision of health services in Turkey mostly publicly funded. Preventive, curative, rehabilitative and developmental health services are actors of the health system. The main service providers include the MoH, university hospitals and the private sector. MoH operating hospitals, clinics, family health centers, community health centers, dispensaries. Public hospitals were technologically renewed and capacities increased by HTP. University hospitals are able to provide all the health services in practice and the private sector contributes to the production of health services through hospitals, clinics and outpatient clinics, examination rooms, pharmacies, laboratories, medical devices and pharmaceutical companies.

Figure 2. 1. Number of Hospitals by Years and Sectors



Between 2012 and 2016, there is a significant increase in hospitals by 30%. Although MoH hospitals have the largest share in the total number of hospitals, private hospitals have paved the way for the expansion of health infrastructure (Keskin 2017, 25).

Figure 2. 2. Number of Hospital Beds by Years and Sectors



Between 2012 and 2016 there is a 32% increase in hospital beds. In particular, the increase in intensive care and qualified beds has led to an improvement in the quality of inpatient services as well as a quantitative increase in services provided in hospitals.

	2002	2012	2013	2014	2015	2016
Ministry of Health	4.169.779	6.891.857	7.023.313	7.396.239	7.404.570	7.561.989
University	781.990	1.601.878	1.630.464	1.737.627	1.891.094	1.842.001
Private	556.494	3.485.092	3.719.780	3.900.407	4.237.453	4.048.696
Total	5.508.263	11.978.827	12.373.557	13.034.273	13.533.117	13.452.686

Table 2. 1. Number of Inpatients by Years and Sectors

The expansion in health care delivery contributed to improved health care utilization and physician productivity (Ministry of Health of Turkey 2012). Between 2012 and 2016, there is an increase of two quarts in the total number of inpatients. The highest increase was in the private sector with an increase of about seven times.

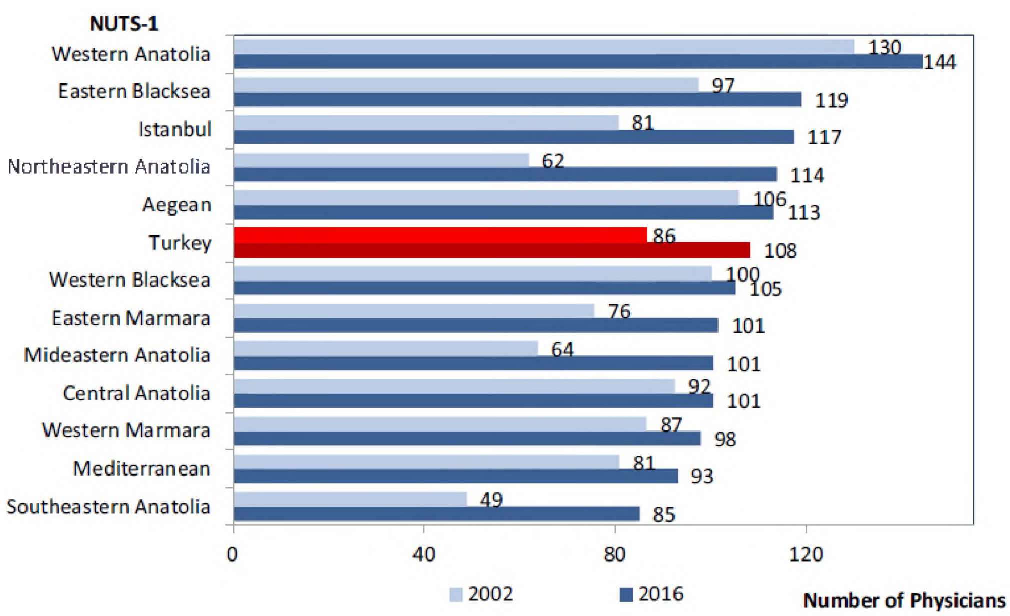
2.3. Human Resources

Before HTP, access to health services in rural areas was more difficult and expensive. As a result of resource constraints of large public health organizations, poor training of staff, low wages, low level of professional incentives, and lack of skilled personnel in rural areas and geographical misallocation of personnel, there is a huge difference in efficiency in health services among regions. Also, there was a geographically serious imbalance in the distribution of staff (OECD and World Bank 2008). For example, MoH statistics (2000) indicated that 12 % of health centers did not have physicians and two-thirds of rural health posts did not have midwives.

Within the framework of "Basic Law on Health Services, Law on Compensation and Working Principles of Health Personnel" (2005), a balanced distribution of health personnel throughout the country has been started with the regulation of State Service Liability. Thus, a new, more acceptable and sustainable regulation was introduced that provided different durations and higher wages in deprivation areas. Assignment and transfer of personnel began according to the 'service point', which varies according to the nature of the place where they work and the length of time they have worked (Ministry of Health of Turkey 2012).

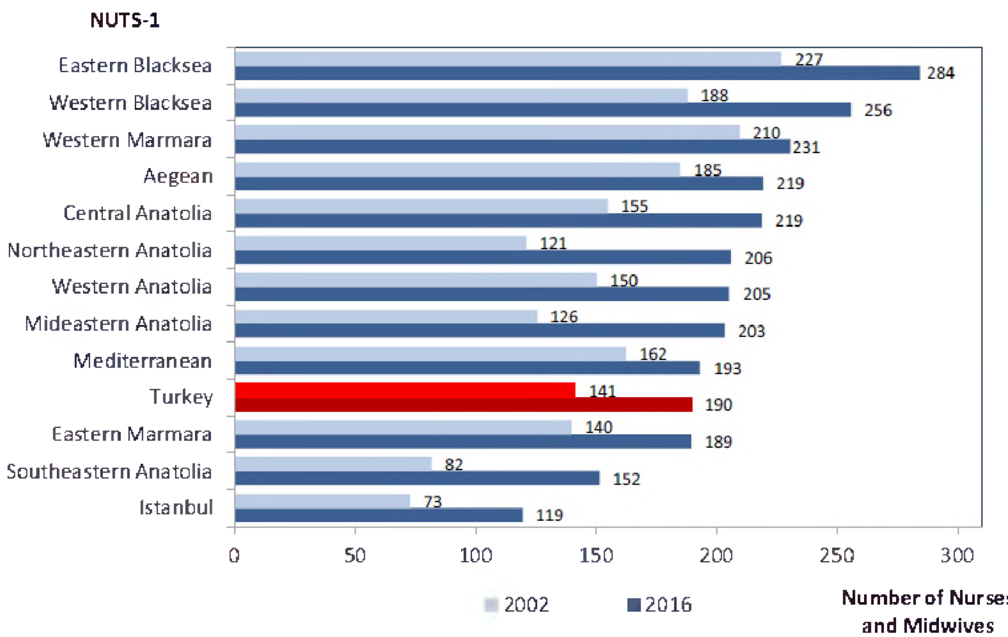
In the graphs, Regional Distribution of Human Resources according to Nomenclature of Territorial Units for Statistics (NUTS) is shown for regional comparisons. The NUTS with level 1 presented in Appendix-A was formed by the grouping of neighboring countries, which are similar in economic, social and geographical direction, by Turkish Statistics Institution.

Figure 2. 3. Number of Total Physicians per 100.000 Population by NUTS-1, MoH, 2002, 2016



Between 2012 and 2016, significant improvements have been made in physician distribution in addition to increase in the number of physicians per capita. In particular, the need for physicians has been met in Anatolian regions where the number of doctors are low.

Figure 2.4. Number of Nurses and Midwives per 100.000 Population by NUTS-1, MoH, 2002, 2016



When we look at the total number of physicians, nurses and midwives per capita, it is observed that the increase in the number of nurses and midwives in particular is more than the increase in the number of physicians.

2.4. The Role Groups of General Hospitals

Hospitals are planned according to building, physical conditions, equipment and medical technological needs, health human power criteria (Circular Letter of Health Region Planning Practices 2010):

Group A1

A-I Group hospitals are called treatment institutions in which at least five branches have been given education authority and education staff have been completed, tertiary care and rehabilitation services are provided, educational research activities are carried out and at the same time specialist and subsidiary specialist subjects have been trained. The following criteria are searched:

1- Education authority is granted according to the related legislation of the Ministry,

2- Completion of the education cadres in the branches of expertise given by the Ministry,

3- Establishment of Training Planning and Coordination Council in its context,

4- The advanced examination and treatment services required by the status of the hospital and the availability of imaging services within the institution or through service procurement,

5- With a minimum of four branches, it is possible to have a specialist doctor and to arrange an independent emergency branch in the branches of internal medicine, general surgery, women's health, child health and diseases (these branches are exempted if there is a branch hospital in women's-birth and child branches), neurosurgery, orthopedics and traumatology, cardiology, anesthesiology and reanimation,

6- In the presence of 3rd stage intensive care unit and 3rd level Emergency Service.

Group A2

Definition: General hospitals operating The district operates in the provinces in the region health center status or in the provinces connected to these centers and without education-research status and meeting the following criteria are called A-II Group Hospitals. Criteria:

1- In the provinces with the center of the health zone or with the sub-region center connected to these provinces; second stage, in-patient health facility status,

2- In the presence of at least four branches, including internal medicine, general surgery, gynecological diseases and childhood, pediatric diseases, have six or more specialist doctors and to arrange an independent emergency branch,

3- To provide follow-up and treatment of patients with severe and high risk admission, acceptance and treatment of complicated patients,

4- In the presence of 3rd Level Emergency Service,

5- In the presence of 3rd Level step-intensive care unit,

6- The inspection and treatment services required by the status of the hospital and imaging services can be met within the institution or through external service.

Group B

Definition: General hospitals operating outside the A-I and A-II Group hospitals, operating in provincial centers and reinforced districts and meeting the following criteria are called B-Group hospitals. Criteria:

1. To operate in the province center or in the districts which are in the position of strengthened district center.

2. Internal branch emergency pool watch and surgical branch emergency pool watch can be held based on 24-hour basis.

3. There should be at least 2nd level Emergency Service and 2nd stage Intensive Care Unit.

Group C

Definition: Group C hospitals are general hospitals grouped according to the following criteria. Criteria:

1- To operate in the strengthened districts or in the districts connected with the district centers strengthened in the health district planning in terms of health service provision.

2- In the presence of service of a specialist doctor in four main branches and additionally at least two specialist doctors from other branches.

3- In the presence of at least the first stage intensive care unit and the first level emergency services are available.

Group D

Definition: General hospitals with at least 25 patient beds that are enforced in accordance with the following criteria and are active in the districts connected to the districts strengthened by health zone planning. Criteria:

1- In four main branches; the planning of at least 1 specialist medicine for each branch and the presence of more than one specialist physician including the family physician,

2- Providing specialist policlinic examination services in existing specialist branches and providing follow-up and treatment at the expert level of the hospitalized patients,

3- Emergency health services can be presented in the first level emergency service structure,

4- In the presence of operating room, post-operative care room, dental policlinic, delivery room, observation room with monitors,

5- The dialysis unit can be configured according to need.

Group E

Definition: General hospitals are the integrated district hospitals whose beds are under 25 beds. It is the health facilities that are presented in the same structure in the health services provided in the first step together with diagnosis and treatment services.

CHAPTER III

THEORETICAL BACKGROUND

Although the concepts of productivity and efficiency do not mean the same thing, unfortunately they are used interchangeably in the literature. Productivity is the measure of the effective use of resources and refers to the proportion of the amount of output and the corresponding inputs used to produce that output. The efficiency is the comparison of the most appropriate output quantity with the observed output quantity or the comparison of the observed input quantity with the most suitable input quantity in the production made in a specific quality.

The notion of "Technical efficiency" is first defined by Koopmans (1951):

A producer is technical efficient if, and only if, it is impossible to produce more of any output without producing less of other output or using more of some input.

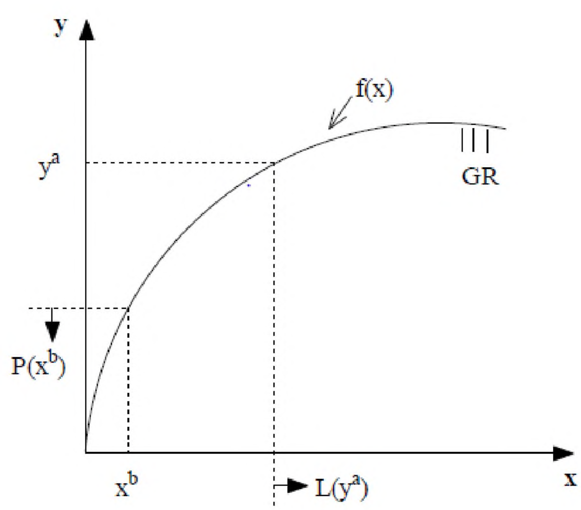
The starting point of stochastic frontier modeling and efficiency measurement is the approach put forward by Farrell (1957). He proposes two elements to measure the efficiency of a decision maker unit (DMU). The first one is technical efficiency, the second is allocation efficiency. Technical efficiency is a measure that determines the maximum output level that a DMU can obtain from the current set of inputs in its hands. Allocation efficiency shows the ability of the DMU to use these inputs at appropriate rates while the prices of the inputs are available.

In this thesis, we aim to apply a study based on measurement of technical efficiency. Before discussing the measurement method of technical efficiency, it is needed to present some background information about production technology and production function. In this chapter, analytic foundations of production theory for the measurement method of technical efficiency with stochastic frontier analysis will be discussed.

3.1. The Production Technology, Input and Output Sets of Production

It is assumed that producers use a non-negative vector of inputs $x = (x_1, \ldots\ldots, x_N)$, to produce a nonnegative vector of outputs $y = (y_1, \ldots\ldots, y_M)$. In the figure 3.1, the production technology in a single input-output case is represented. The graph of production technology, *GR* is the set of input-output combinations bounded below x-axis and bounded above by the curve emanating from the origin. $L(y^A)$ is the set of inputs and $P(x^B)$ is the set of outputs.

Figure 3. 1. Production Technology, Input and Output Sets of Production



$GR = \{(y, x) : x\ can\ produce\ y\}$ denotes the set of feasible input-output vectors. GR is assumed to satisfy the following properties (Kumbhakar & Lovell 2000, 18; Coelli et al. 2005, 42):

G1: $(0, x) \in GR$ and $(y, 0) \in GR \Rightarrow y = 0$

G2: GR is a closed set.

G3: GR is bounded for each $x \in R_+^N$.

G4: $(y, x) \in GR \Rightarrow (y, \lambda x) \in GR$ for $\lambda \geq 1$.

G5: $(y, x) \in GR \Rightarrow (\lambda y, x) \in GR$ for $0 \geq \lambda \geq 1$.

Property G1 indicates that any nonnegative input can produce at least zero output. G2 is the guarantee of existence of efficiency, since input and upper vectors lies on the upper boundary of GR. G3 assures that finite input cannot produce infinite output. G4 and G5 are weak monotonicity properties that guarantee the input expansion and output contraction.

$L(y) = \{x : (y, x) \in GR\}$ describes the sets of feasible input vectors for each output vector $y \in R_+^M$. In Figure 3.1, $L(y^A)$ is the set of inputs on the interval $[x^A, +\infty)$. $L(y)$ is assumed to satisfy the following properties (Kumbhakar & Lovell 2000, 21; Coelli et al. 2005, 43):

L1: $0 \notin L(y)$ for $y \geq 0$ and $L(0) = R_+^N$.

L2: The sets $L(y)$ are closed.

L3: x is finite $\Rightarrow x \notin L(y)$ if y is infinite.

L4: $x \in L(y) \Rightarrow \lambda x \in L(y)$ for $\lambda \geq 1$.

L5: $L(\lambda y) \subseteq L(y)$ for $\lambda \geq 1$.

Property L1 indicates that any input cannot produce zero output. Property L2 guarantees the existence of technical efficiency input given a level of output. Property L3 states that finite input cannot produce an infinite output. L4 and L5 are related to the output contraction and input expansion.

$P(x) = \{y : (y, x) \in GR\}$ describes the sets of output vectors that are feasible for each output vectors that are feasible for each output vector $y \in R_+^N$. In Figure 3.1, $P(x^B)$ is the set of outputs on the interval $[0, y^B)$. $P(x)$ is assumed to satisfy the following properties (Kumbhakar & Lovell 2000, 22; Coelli et al. 2005, 42):

P1: $P(0) = \{0\}$

P2: $P(x)$ is a closed.

P3: $P(x)$ is bounded for $x \in R_+^N$.

P4: $P(\lambda x) \supseteq P(x)$ for $\lambda \geq 1$.

P5: $y \in P(x) \Rightarrow \lambda y \in P(x)$ for $\lambda \in [0, 1]$.

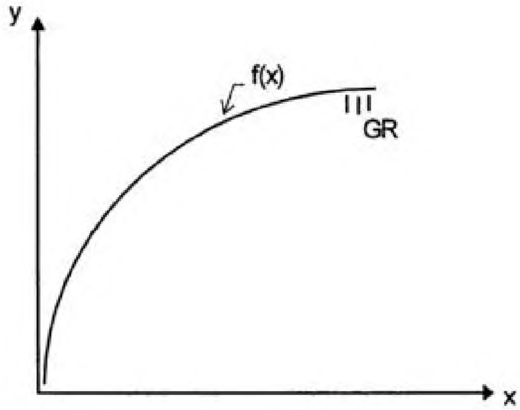
Property P1 indicates that zero input produce zero output. Property P2 guarantees the existence of technical efficiency given a level of input. Property P3 states that finite input cannot produce an infinite output. P4 and P5 are related to the output contraction and input expansion.

3.2. Production Frontier

The production frontier function expresses the maximum output that can be generated by the given input vector. A production frontier is a function:

$$f(x) = \max\{y : y \in P(x)\} = \max\{y : x \in L(y)\} \tag{3.1}$$

Figure 3. 2. Production Frontier



In figure 3.2, the production frontier function f (x) is located at the upper limit of production possibilities. Other input-output combinations are under this curve. $f(x)$ is assumed to satisfy the following properties (Kumbhakar & Lovell 2000, 26; Coelli et al. 2005, 12):

f1: $f(0) = 0$

f2: f is upper semi continuous on R_{+}^{N}.

f3: $f(0) > 0 \Rightarrow f(\lambda x) \rightarrow +\infty \ as \ \lambda \rightarrow +\infty$

f4: $f(\lambda x) \geq f(\lambda x), \lambda \geq 1$ for $x \in R_{+}^{N}$

The production frontier $f(x)$ defines the maximum feasible output produced with any given input. It gives the upper boundary of production possibilities, thus each producer can be located on production frontier with an input-output combination (Kumbhakar & Lovell 2000, 27).

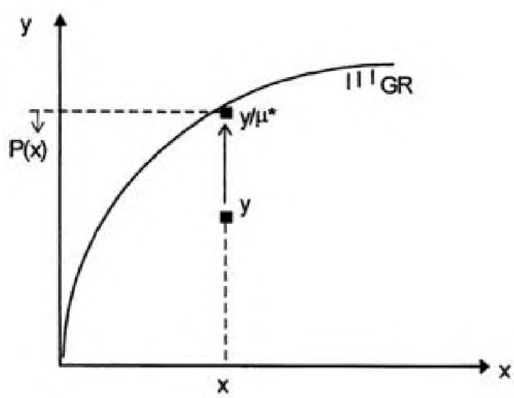
3.3. Output Distance Function

An output distance function:

$$D(x, y) = \min\{\mu : y/\mu \in P(x)\} \qquad (3.2)$$

is first introduced by Shephard (1953). An output distance function gives the minimum amount of the parameter μ which deflates the output with a given input vector. It depicts a distance from a producer to the frontier production.

Figure 3. 3. Measure of Technical Efficiency



In Figure 3.3, with input x, output y can be produced, but larger output (y/μ^{*}) can also be reached, so

$$D(x, y) = \mu^{*} \qquad (\text{where } \mu^{*} < 1) \qquad (3.3)$$

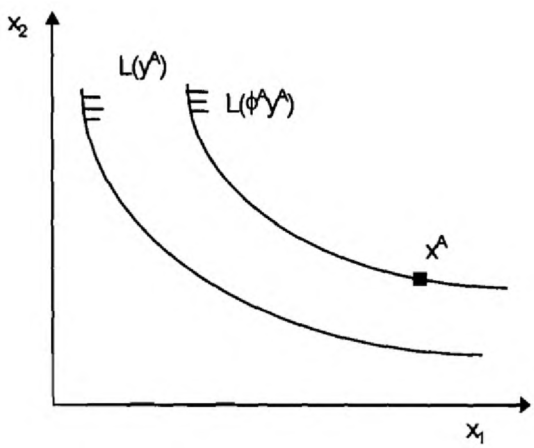
3.4. Output-Oriented Technical Efficiency

An output-oriented measure of technical efficiency:

$$TE(x, y) = [\max\{\Phi : \Phi y \in P(x)\}]^{-1} \tag{3.4}$$

is first proposed by Debreu (1951) and Farrell (1957). An output-oriented measure of technical efficiency gives the inverse of the maximum amount of the parameter Φ which cuts down the output vector with a given input vector. It refers to the ability to obtain maximum output from a given input vector.

Figure 3. 4. Output-Oriented Measure of Technical Efficiency



Since the distance function provides radial measures of the distance from an input bundle to the frontier production, it coincides with the distance function $D(x, y)$.

$$TE(x, y) = [D(x, y)]^{-1} \tag{3.5}$$

By using equation 3.3 and equation 3.5, we derive technical efficiency equation

$$TE = \frac{1}{\mu^*} = \frac{y}{y/\mu^*} = \frac{y}{y_{max}} \tag{3.6}$$

that is the ratio of the observed level of output (y) to the maximum feasible level of output (y/μ^*). $TE < 1$ means that the producer is inefficient and $TE = 1$ means that the producer is efficient.

CHAPTER IV

STOCHASTIC FRONTIER ANALYSIS

The stochastic frontier analysis was introduced for the first time by Aigner, Lovell, Schmidt (1977) and Meusen, Van den Broeck (1977). The stochastic frontier analysis is based on the idea that the deviations from the production frontier do not arise entirely from the production unit. The SFA assumes that there is a parametric function between production inputs and outputs. The greatest advantage of SFA over the deterministic approach where all deviations from the frontier are expressed as inefficiency is to take into account random situations that may develop outside of the manufacturer's control and affect output. The method divides the deviations from the frontiers of the defined production technology into two parts, measured by error terms. The first part is the randomness (or statistical error) and the second part is the ineffectiveness.

In this chapter, technical efficiency is evaluated in the context of production frontier models using cross-sectional data. Firstly, deterministic production model and its analysis methods are introduced, so the need of stochastic frontier model comes forward. In the second section, the calculations of SFA’s individual efficiency estimation are introduced under the different assumptions of inefficiency term. Then, the translog form and the properties its specific parameters are explained. Finally, the hypothesis test method for SFA appropriateness, translog form, truncated normal distribution, and inefficiency variables are introduced.

4.1. Deterministic Production Frontier Model

A deterministic production frontier model can be written as:

$$y_i = f(x_i, \beta).TE_i \quad (4.1)$$

where y_i is the scalar output of producer (hospital) i, $i = 1, \ldots, I$, x_i is a vector of N inputs used by producer i, $f(x_i, \beta)$ is the production frontier and β is the vector of parameters to be estimated. Now, we write output oriented technical efficiency in terms of production function:

$$TE_i = \frac{y_i}{f(x_i, \beta)} \quad (4.2)$$

which is the shortfall of observed output y_i from maximum feasible output $f(x_i, \beta)$. y_i takes the maximum value of $f(x_i, \beta)$ if , and only if, $TE_i = 1$. Otherwise $TE_i < 1$ measures the shortfall which is less than 1.

Since we require that $TE_i \leq 1$, define that $TE_i = \exp(u_i)$ where $u_i \geq 0$. So, we rewrite the equation 4.1 as:

$$y_i = f(x_i, \beta).\exp(-u_i) \quad (4.3)$$

In order to estimate the parameter vector β and $(-u_i)$ in equation 4.3, Aigner & Chu (1968) proposed that $f(x_i, \beta)$ takes log-linear Cobb-Douglas form. Then, the deterministic model is written as:

$$\ln(y_i) = \beta_0 + \sum_{j=1}^{k} \beta_j \, lnx_{ji} - u_i \quad (4.4)$$

The model is called as 'deterministic' because the only deviating factors are entirely contained in the inefficiency term u_i. Greene (2008) suggests that random factors such as luck or unexpected disturbances in a related market cannot play role in determining maximum feasible output of deterministic models. This is in contrast to the specification of the frontier in which the maximum output that a producer can obtain is assumed to be determined both by the production function and by random external factors.

In order to get the technical efficiency, the estimates of the parameters β and the error term u_i are needed. To obtain the estimation of the parameters, the methods based on Ordinary Least Squares (OLS) were developed. OLS makes the parameters estimated consistently since it is robust to non-normality (Greene 2008) .The OLS methods are corrected ordinary least squares (COLS) introduced by Winsten (1957) and modified ordinary least squares (MOLS) introduced by Afriat (1972) and Richmond (1974).

4.1.a. Corrected Ordinary Least Square (COLS)

Winstein (1957) suggested a two stage method to estimate parameters of deterministic production frontier model. First stage is to obtain estimates of the slope coefficients and the intercept parameter of the model. Then, the OLS intercept is shifted up to the extent that frontier bounds all the observations below.

An OLS regression of $\ln y_i$ on lnx_{ji} is employed:

$$\ln y_i = \hat{\beta}_0 + \sum_{j=1}^{k} \hat{\beta}_j \, lnx_{ji} - \hat{e}_i \tag{4.5}$$

where $\hat{e}_i$ are the OLS residuals. Since $E(e_i) \neq 0$, the $\hat{\beta}_0$ is a biased estimate of β_0. However, $\hat{\beta}_j$ is a consistent estimate of β_j. We write OLS regression residual as:

$$\hat{e}_i = \ln y_i - \hat{\beta}_0 + \sum_{j=1}^{k} \hat{\beta}_j \, lnx_{ji} \tag{4.6}$$

The OLS intercept is adjusted up ("corrected") by the $\max\{\hat{e}_i\}$,so that frontier bounds all the observations below;

$$\hat{e}_i - \max\{\hat{e}_i\} = \ln y_i - \{[\hat{\beta}_0 + \max\{\hat{e}_i\}] + \sum_{j=1}^{k} \hat{\beta}_j \, ln x_{ji}\} \leq 0 \qquad (4.7)$$

Then

$$\hat{\beta}_{COLS} = \hat{\beta}_0 + \max\{\hat{e}_i\} \qquad (4.8)$$

and

$$\hat{u}_i \equiv -(\hat{e}_i - \max\{\hat{e}_i\}) \geq 0 \qquad (4.9)$$

where $\hat{\beta}_{COLS}$ is corrected OLS intercept and $\widehat{u_i}$ is the estimated inefficiency. It provides consistent estimates of technical efficiency for each producer as $\widehat{TE} = \exp(-\widehat{u_i})$. Kumbhakar et al. (2015) points out, as the disadvantage of this method, that the inefficiencies are highly sensitive to outliers. An unduly large value of y_i can cause overestimating the technical inefficiencies than they would be.

4.1.b. Modified Ordinary Least Square

MOLS is proposed as a variation on COLS by Afriat (1972) and Richmond (1974). They suggested that the model could be estimated by OLS, under the assumption that the disturbances follow an explicit one-sided distribution about the inefficiency term u_i, such as exponential or half-normal. The motivation for such distributional assumptions is that increasing technical inefficiency becomes increasingly unlikely (Kumbhakar & Lovell 2000, 71). A central moment of the residuals may be utilized to yield a consistent estimator of the mean of the inefficiency $E[u_i]$ (Hokkanen 2014, 25). After estimation by OLS, the estimated intercept is shifted up ("modified") by $E[u_i]$. Then

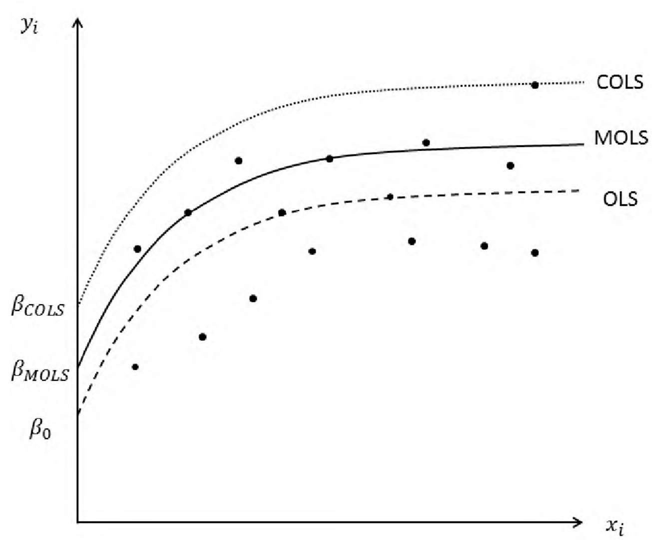
$$\hat{\beta}_{MOLS} = \hat{\beta}_0 + E[u_i] \tag{4.10}$$

and

$$\widehat{u_i} \equiv -(\hat{e}_i - E[u_i]) \geq 0 \tag{4.11}$$

The figure 4.1 shows OLS-based production frontiers. Since the estimation of technical efficiency of COLS and MOLS are based on OLS, the frontier line is parallel to the OLS regression line, which causes both frontier lines to have the same structure.

Figure 4. 1. OLS-based production frontiers



The COLS and MOLS methods do not take into account the random error, but in reality there are stochastic effects and neglecting them points out a major problem. The addition of a stochastic element at the estimated frontier is seen as the most important innovation to be introduced in the next chapter in the stochastic frontier model.

4.2. Stochastic Production Frontier Model

The stochastic production frontier model was first proposed by Aigner, Lovell and Schmidt (1977) and Meeusen and van den Broeck (1977) for Cobb-Douglas case as following:

$$\ln y_i = \beta_0 + \sum_j \beta_j \, lnx_{ji} - u_i + v_i \quad (4.12)$$

y_i: Dependent variable

x_{ji}: Vector of the independent variables,

u_i: Inefficiency component,

v_i: Random error term, N ~ $(0,\sigma_v^2)$

The u_i inefficiency terms indicates the amount that is less than the production level that was expected, while the v_i terms captures random variations across DMUs. The v_i terms could arise from measurement error or omitted factors (Coelli et al. 2005). The main idea given with stochastic frontier model is that the production 'frontier' could be under the influence of non-deterministic factors. Many unsuccessful random factors, even weather conditions, are able to appear as inefficiency (Greene 2008).

If we use a single input x and output y in the model, the Cobb-Douglas stochastic frontier model consists of:

$$lny_i = \beta_0 + \beta_1 lnx_i - u_i + v_i$$

or

$$y_i = exp(\beta_0 + \beta_1 lnx_i - u_i + v_i)$$

or

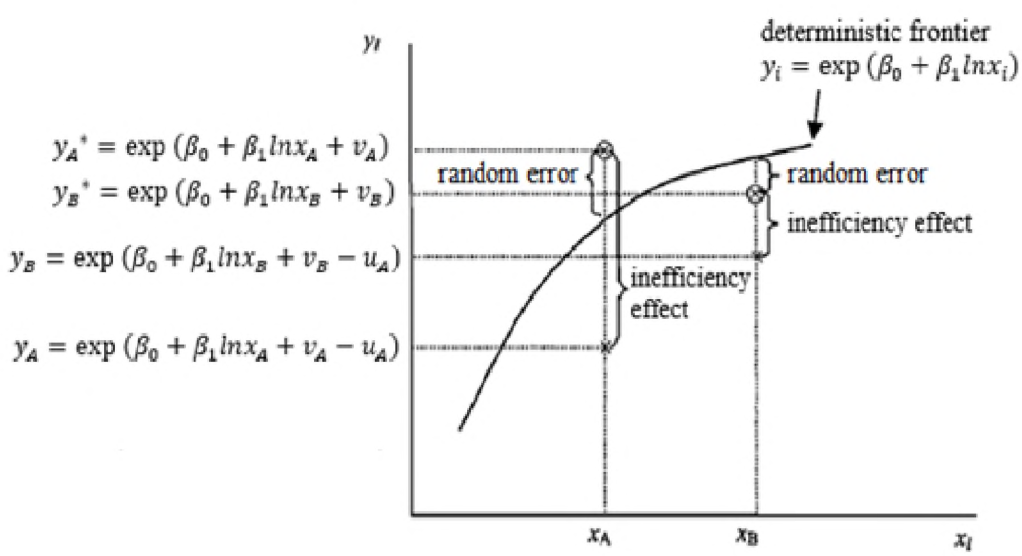
$$y_i = exp(\beta_0 + \beta_1 lnx_i)\ exp(v_i)\ exp(-u_i) \quad (4.13)$$

In the figure 4.2, the input values are shown horizontally, and the output values are shown in the vertical axis. The DMU A uses the input x_A to produce the output y_A, while the DMU B uses the input x_B to generate the output y_B. If the DMU's are 100% efficient $(u_A = 0, u_B = 0)$ then the boundary outputs are as follows:

$$y_A{}^* = \exp(\beta_0 + \beta_1 lnx_A + v_A) \qquad y_B{}^* = \exp(\beta_0 + \beta_1 lnx_B + v_B) \quad (4.14)$$

Figure 4. 2. Stochastic Frontier Model

Source: Coelli et al., (2005, p. 244)



Actually, the determination of the technical efficiency at the stochastic production frontier is represented in the Figure 4.2. For DMU A, the deviation of the frontier output $(y_A{}^*)$ from the deterministic production frontier gives the random error and the deviation of the observed output (y_A) from the frontier output $(y_A{}^*)$ gives the inefficiency. The same applies to DMU B.

4.2.a. Technical Efficiency

The output oriented technical efficiency, the ratio of observed output to the corresponding frontier output, is calculated by using equation 4.2:

$$TE_i = \frac{y_i}{\exp[\beta_0 + \sum_j \beta_j lnx_{ji} + v_i]} \quad (4.15)$$

The denominator of the equation 4.15, $\exp[\beta_0 + \sum_{j=1}^{k} \beta_j \, lnx_{ji} + v_i]$ indicates the maximum potential of production where the inefficiency score of the firm is zero (u_i=0) that is called frontier production. As for the nominator part we use equation 4.13;

$$TE_i = \frac{exp[\beta_0 + \sum_j \beta_j lnx_{ji} - u_i + v_i]}{exp[\beta_0 + \sum_j \beta_j lnx_{ji} + v_i]} = exp(-u_i) \quad (4.16)$$

TE_i measures the observed output relative to the maximum potential of output by using the amount of input. The formula of technical efficiency of stochastic frontier model is similar with deterministic, but onwards, the error terms assumptions will provide efficiency scores with new parameters containing individual-specific information.

4.2.b. Estimating The Parameters

In the SFA, v_i is assumed to be normally distributed, while distribution of u_i has been assumed to be Half-Normal, Truncated Normal, Exponential or Gamma. Since u_i is expected to be positive ($u_i \geq 0$) due to its distribution character, the composed error term $\varepsilon_i = v_i - u_i$ is asymmetric and negatively skewed. We assume that v_i and u_i are distributed independently of x_i, then we get again

$$E(\varepsilon_i) = -E(u_i) \quad (4.17)$$

like in COLS method. This means that OLS could provide consistent estimates of β_j, but not of β_0. Moreover it does not provide individual-specific technical efficiency. However, OLS could provide parameters about skewness for the presence technical inefficiency such that negatively skewed residuals suggest the presence of technical inefficiency. In order to test skewness, Schmidt & Lin (1984) proposed a test statistic $(b_1)^{1/2} = m_3/(m_2)^{1/2}$ formed by the second and third sample moments of the OLS residuals. On the other hand, Coelli (1995) proposed $m_3/(6{m_2}^3)^{1/2}$ which is a variant of this test. Although useful as screening devices, these tests do not use the information from the distribution functions of the random error (Kumbhakar et al. 2015, 65). The other method which will be introduced in Chapter 4.5 is Likelihood Ratio (LR) test conducted after the Maximum Likelihood (ML) estimation of the model are undertaken.

Mainly, the Maximum Likelihood (ML) method is used to estimate the parameters of the SFA model. In this approach, distributional assumptions are important in the estimation process. The random error term is normally distributed providing such features as OLS estimation. On the other hand, distribution of inefficiency error term is an important issue because u_i is assumed to be a one-sided error term with nonzero averages and the appropriate distribution assumption should be made. In this chapter, the parameters will be estimated according to error term components distributional assumptions by using ML method.

4.2.b.i. The Normal – Half Normal Model

This model developed by Aigner, Lovell and Smith (1977) uses the following distributional assumptions to obtain ML estimates of the stochastic production limit:

(i) $v_i \sim$ iid $N(0, \sigma_u^2)$

(ii) $u_i \sim$ iid $N^+(0, \sigma_u^2)$

(iii) v_i and u_i are distributed independently of each other and, of the regression coefficients

Assumption (ii) means that u_i has nonnegative half normal distribution. The independence of regression coefficients and u_i given in the assumption (iii) means that if producers have information about their technical efficiency, their choice of inputs may change (Kumbhakar & Lovell 2000, 75).

The density function of u is

$$f(u) = \frac{2}{\sqrt{2\pi}\sigma_u} exp\left\{-\frac{u^2}{2\sigma_u{}^2}\right\} \quad ,u_i \geq 0 \tag{4.18}$$

The density function of v is

$$f(v) = \frac{1}{\sqrt{2\pi}\sigma_v} exp\left\{-\frac{v^2}{2\sigma_v{}^2}\right\} \quad , -\infty < v_i < \infty \tag{4.19}$$

Under the independence assumption, we product their density functions in order to get the joint density function of u and v,

$$f(u, v) = \frac{2}{2\pi\sigma_u\sigma_v} exp\left\{-\frac{u^2}{2\sigma_u{}^2} - \frac{v^2}{2\sigma_v{}^2}\right\} \tag{4.20}$$

We want to derive the density function of ε, so we use the equation $v = \varepsilon + u$

$$f(u,\varepsilon) = \frac{2}{2\pi\sigma_u\sigma_v} exp\left\{-\frac{u^2}{2\sigma_u{}^2} - \frac{(\varepsilon+u)^2}{2\sigma_v{}^2}\right\} \quad (4.21)$$

By integrating u we finally obtain:

$$f(\varepsilon) = \int_0^\infty f(u,\varepsilon)du$$

$$= \frac{2}{\sqrt{2\pi}\sigma}\left[1 - \Phi\left(\frac{-\varepsilon\lambda}{\sigma}\right)\right] exp\left\{-\frac{\varepsilon^2}{2\sigma^2}\right\}$$

$$= \frac{2}{\sigma}\phi\left(\frac{\varepsilon}{\sigma}\right)\Phi\left(-\frac{\varepsilon\lambda}{\sigma}\right) \quad (4.22)$$

where $\sigma = (\sigma_u^2 + \sigma_v^2)^{1/2}, \lambda = \frac{\sigma_u}{\sigma_v}$, $\phi(.)$ and $\Phi(.)$ denotes the standard normal density and cumulative distribution functions are discussed by Aigner, Lovell and Schmidt (1977).

The marginal density function $f(\varepsilon)$ is asymmetrically distributed with mean and variance

$$E(\varepsilon) = -E(u) = -\sigma_u\sqrt{2\pi} \quad (4.23)$$

$$V(\varepsilon) = V(u) + V(v) = \frac{\pi-2}{\pi}\sigma_u^2 + \sigma_v^2 \quad (4.24)$$

The log-likelihood function for the marginal density function of the compound error term taking place in equation 4.22 for a sample of N producers is:

$$lnL(y|\beta,\lambda,\sigma^2) = constant - Nln\sigma + \sum_i ln\,\Phi\left(-\frac{\varepsilon_i\lambda}{\sigma}\right) - \frac{1}{2\sigma^2}\sum_i \varepsilon_i{}^2 \quad (4.25)$$

Thus, we can obtain maximum likelihood estimates of the parameters λ and σ by maximizing with respect to them. These estimates are consistent as $I \rightarrow +\infty$. Although with this way we can obtain information of ε_i containing information of u_i, it is not enough for individual specific information. After the estimation of the parameters, the inefficiency term u_i needs to be distinguished from the compound error term ε_i. In the context, Jondrow, Lovell, Materov, and Schmidt (1982) have proposed the JLMS technique to obtain individual specific inefficiencies. The JLMS technique displays the conditional distribution of the inefficiency error term according to the given compound error term as follows:

$$f(u|\varepsilon) = \frac{f(u,\varepsilon)}{f(\varepsilon)} \tag{4.26}$$

To calculate we use equation 4.14 and 4.15;

$$f(u|\varepsilon) = \frac{1}{\sqrt{2\pi}\sigma_*} exp\left\{-\frac{(u-\mu_*)^2}{2\sigma_*}\right\} / \left[1 - \Phi\left(-\frac{\mu_*}{\sigma_*}\right)\right] \tag{4.27}$$

where $\mu_* = -\varepsilon{\sigma_u}^2/\sigma^2$ and ${\sigma_*}^2 = \sigma_u^2\sigma_v^2/\sigma^2$. Since $f(u|\varepsilon)$ is distributed as $N^+(\mu_*, {\sigma_*}^2)$, the mean of the distribution can be used to get point estimator for u_i;

$$E(u_i|\varepsilon_i) = \mu_{*i} + \sigma_* \left[\frac{\phi(-\frac{\mu_{*i}}{\sigma_*})}{1 - \Phi(-\frac{\mu_{*i}}{\sigma_*})}\right]$$

$$= \sigma_* \left[\frac{\phi(\varepsilon_i\lambda/\sigma)}{1-\Phi(\varepsilon_i\lambda/\sigma)} - (\varepsilon_i\lambda/\sigma)\right] \tag{4.28}$$

By obtaining the point estimation of u_i, we can make estimation of technical efficiency of each producer by using equation 4.17,

$$TE_i = \exp(\widehat{u_i}) = E(u_i|\varepsilon_i) \tag{4.29}$$

where $\widehat{u_i}$ is $E(u_i|\varepsilon_i)$ obtained in equation 4.28.

On the other hand, Battesse and Coelli (1988) proposed the alternative point estimator for TE_i:

$$TE_i = E(\exp\{-u_i\}\,|\varepsilon_i)$$

$$= \left[\frac{1-\Phi(\sigma_* - \mu_{*i}/\sigma_*)}{1-\Phi(\mu_{*i}/\sigma_*)}\right] \exp\left\{-\mu_{*i} + \frac{1}{2}\sigma_*{}^2\right\} \tag{4.30}$$

Since the variation associated with the distribution of $(u_i|\varepsilon_i)$ is independent of i, all of the estimates of individual efficiency are inconsistent. Nonetheless, there is no alternative consistent estimator of individual efficiency when using cross-section data (Cornwell & Schmidt, 2008).

4.2.b.ii. The Normal – Truncated Normal Model

The normal-half normal model can be generalized by allowing u to follow a truncated normal distribution. The normal-truncated normal formulation introduced by Stevenson (1980) uses the following distributional assumptions to obtain ML estimates of the stochastic production limit:

(i) $v_i \sim$ iid $N(0, \sigma_u^2)$

(ii) $u_i \sim$ iid $N^+(\mu, \sigma_u^2)$

(iii) v_i and u_i are distributed independently of each other and, of the regression coefficients

In addition to half normal distribution, the mode of distribution μ is estimated as a new parameter. It provides a somewhat more flexible design of efficiency in the data (Kumbhakar & Lovell 2000, 83).

The density function of u is

$$f(u) = \frac{2}{\sqrt{2\pi}\sigma_u \Phi(-\mu/\sigma_u)} exp\left\{-\frac{(u-\mu)^2}{2\sigma_u{}^2}\right\} \qquad u_i \geq 0 \qquad (4.31)$$

where $\Phi(.)$ denotes the standard normal cumulative distribution function. As seen, $f(u)$ is also considered as the density of a normally distributed variable with nonzero mean μ and truncated below zero. If $\mu = 0$ the density function in equation 4.31 turns into the half normal density function.

Similarly, the joint density function of u and v_i is the product of their composite density function due to the independence assumption. The log likelihood function for a sample of N producers is calculated as:

$$lnL(y|\beta, \lambda, \sigma, \mu) = constant - Nln\sigma + Nln\Phi\left(-\frac{\mu}{\sigma_u}\right) + \sum_i ln\ \Phi\left(\frac{\mu}{\sigma\lambda} - \frac{\varepsilon_i \lambda}{\sigma}\right) - \frac{1}{2}\sum_i \left(\frac{\varepsilon_i + \mu}{\sigma}\right)^2 \qquad (4.32)$$

where $\sigma_u = \lambda\sigma/\sqrt{1+\lambda^2}$. By maximization of this function with respect to the unknown parameters, parameter estimates of the model are obtained. Here, as in the normal-half normal state, the point estimates of the efficiencies are obtained in the form of mode or average of the conditional distribution of u when ε is known.

4.2.b.iii. The Normal – Exponential Model

Since the assumption of half-normality is a very restrictive assumption, a number of alternative distribution assumptions have been proposed instead of this assumption.

(i) $v_i \sim$ iid $N(0, \sigma_u^2)$

(ii) $u_i \sim$ iid exponential

(iii) v_i and u_i are distributed independently of each other and, of the regression coefficients

Meeusen and van den Broeck (1977) and Aigner et al. (1977) have proposed the log-likelihood function assuming that the inefficiency error term is exponentially distributed.

$$f(u) = \theta \exp(-\theta u) \tag{4.33}$$

where $\theta > 0$ and $u > 0$. In the exponential model, the variance of the term inefficiency is obtained as $\sigma_u = 1/\theta$. Similarly, the joint density function of u and v_i is the product of their composite density function due to the independence assumption. The log likelihood function for a sample of N producers is calculated as:

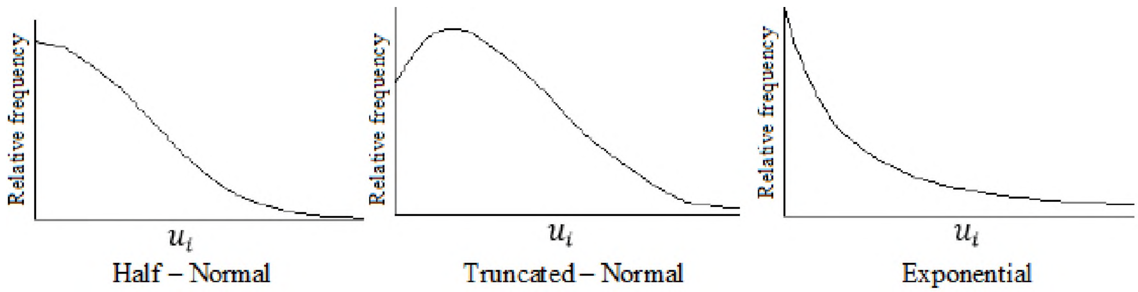
$$lnL(y|\beta, \sigma_u \sigma_v) = constant - Nln\sigma_u + N\frac{1}{2}\left(\frac{\sigma_v{}^2}{\sigma_u}\right) + \sum_i ln\,\Phi\left(\frac{-(\varepsilon_i + \sigma_v{}^2/\sigma_u)}{\sigma_v}\right) + \sum_i \frac{\varepsilon_i}{\sigma_u} \tag{4.34}$$

By maximization of this function with respect to the unknown parameters, parameter estimates of the model are obtained. Technical efficiency point estimates are also obtained in a similar way.

4.2.b.iv. Determination of the Distribution of Inefficiency Term

Regarding the distribution of inefficiency terms, half-normal, truncated normal and exponential distributions are available in the software STATA 14.2. Diagrams of the distributions are shown below. As can be seen, half-normal and exponential distribution have the mode at zero whereas truncated-normal distribution has a non-zero mode. In this regard, many researchers feel that the half-normal and exponential distributions are inappropriate because the density of efficiencies experience near 100% (Kimsey 2009). In addition, Atılgan (2016c) has found that the technical efficiency scores of Turkish hospitals according to alternative models are highly correlated in terms of size and order.

Figure 4. 3. Inefficiency Term Distribution



Since the half-normal represents a special case of the truncated-normal, a likelihood ratio test (LR) for the appropriateness of the additional parameter of truncated-normal distribution is possible. In case of obtaining a significant difference as a result of LR test which is presented in Chapter 4.4, the truncated-normal assumption allows for further investigation of factors influencing efficiency. On the other side, there is no statistical method to compare the convenience of exponential distribution with others. Rosko (2001) reported a high correlation between the inefficiency scores of models created using different distributions. For this reason, it has been suggested that making a different distribution assumption has had a small impact on efficiency estimates.

4.3. Translog Functional Form

The most widespread use of the production function, along with many functional forms, is the form of Translog after Cobb-Douglas. Translog production function (Christensen, Jorgenson & Lau 1971) is a generalization of the Cobb-Douglas function and a flexible functional form providing a second order approximation:

$$lny_i = \beta_0 + \sum_{j=1}^{h} \beta_j \, lnx_{ji} + \frac{1}{2}\sum_{j=1}^{h}\sum_{k=1}^{h} \beta_{jh} \, lnx_{ji} lnx_{ki} + (v_i - u_i) \qquad (4.35)$$

where $u_i = \delta_m \, z_{mi}$

$lnx_{ji} lnx_{hi}$: The interaction of the corresponding level of input j and input k

z_{mi}: inefficiency variable

δ_m: inefficiency parameter to be estimated

In addition to the Cobb-Douglas form, the cross-product and quadratic terms take place in the model. To test the new parameters of translog form LR test is used presented in Chapter 4.4.

The translog production model is preferred by the researchers in order to get flexibility in the specification of input-output relations. The cross-product and quadratic terms obtained from the translog model help to gain more degrees of freedom (Rosko & Mutter 2008). Moreover, Chirikos & Sear (2000) indicates that cross products included in the translog function increase the average efficiency scores due to increased elasticity of the function.

The first-order coefficients of the translog production function are not very informative to reflect the effect of the change in inputs on the outputs. However, they are necessary for the determination of output elasticities. The output elasticity of x_j of the translog production function:

$$e_j = \frac{\partial \ln y_i}{\partial \ln x_j} = \beta_j + \sum_k \beta_{jk} ln x_k \tag{4.36}$$

indicating the estimation of responsiveness of outputs to a change in inputs.

Returns to Scale is estimated as the sum of output elasticities for all inputs

$$RTS = \sum_j e_j = \sum_j (\beta_j + \sum_k \beta_{jk} ln x_k) \tag{4.37}$$

indicating the estimation of responsiveness of outputs to a change in all inputs.

4.4. Testing Hypotheses

The technical efficiency of a stochastic frontier model needs primarily one-sided error specification. The OLS-residual-based skewness tests satisfies the specification but it is not usable due to lack of the information from distribution functions of the random error (Parmeter & Kumbhakar 2017). To test the existence of no one-sided error u_i, Battese & Corra (1977) introduced a gamma parametrization:

$$\gamma = \frac{\sigma_u^2}{\sigma_u^2 + \sigma_v^2} \tag{4.38}$$

which has a value between 0 and 1. The parametrization has an advantage in the numerical maximization process because searches of maximizing values are restricted the parameter space (Kumbhakar et al. 2015, 66). It signifies the deterministic inefficiency portion of total error which involves computation.

The likelihood ratio (LR) test for the null hypotheses is defined:

$$\lambda = -2[L(H_0) - L(H_1)] \quad (4.39)$$

where $L(H_0)$ is log likelihood value of the restricted model and $L(H_1)$ is log-likelihood value of unrestricted model. LR has a mixed chi-square distribution, which is why the Kodde and the Palm (1986) table are used.

As it is mentioned earlier in this chapter, the likelihood ratio test can be also performed for μ parameter of truncated-normal distribution, translog production function coefficients of square and cross products, and inefficiency variable coefficients. All null hypotheses will be discussed and their inferences are presented below:

1) $H_0: \gamma = 0$, there is no one-sided error, SFA is not usable

2) $H_0: \mu = 0$, the parameter of truncated-normal model are not significant

3) $H_0: \beta_{jh} = 0$, coefficient terms of translog model are not significant

4) $H_0: \delta_m = 0$, coefficient terms of inefficiency variables are not significant.

CHAPTER V

MEASURING OF TECHNICAL EFFICIENCY

In this section, firstly efficiency measurement practices of health facilities in Turkey and in the world are summarized according to the purpose of using SFA. Then, the empirical model was established by determining the DMUs and the variables belonging to these DMUs based on the knowledge in the literature and working in the direction of the existing data. Finally, hypothesis tests, parameter estimates, maximum likelihood estimates and technical efficiency calculations for each inpatient care services were implemented.

5.1. Literature Review

When we look at the literature about efficiency measurement research on health care, the SFA method obviously constitutes a small part. Worthington (2004) and Hollingsworth & Peacock (2008) point to the deep theoretical background of the SFA, the computational difficulties of this method, the flexibility in handling multiple outputs, and the uncertainties in the distributional assumptions associated with the inefficiency terms are among the reasons for this. Rosko & Mutter (2011) remarks that using multi-output models in searching technical efficiency with SFA causes substantial information loss. To avoid the obstacles of SFA, the researches prefers non-parametric approaches such as Data Envelopment Analysis (DEA). However, non-parametric methods do not provide us usable parameter for developing policy about health-care resource planning. There has been researches about healthcare efficiency in the literature using these parametric and non-parametric methods. Chirikos & Sear (2000), supporting the estimation of comparable DEA and SFA models, has found that the efficiency scores diverge as reaching to maximum and minimum points. Katharakis et al. (2014) reached the same results in their research aiming to facilitate a common understanding about the adequacy of these methods by analyzing Greek hospitals. They concluded that divergent efficiency estimates arise from environmental variables, which is the component of SFA, such as being hospital status and geographical position. In case of Czech hospitals, Prochazkova (2011) has found that SFA and DEA give similar results due to significant rank correlation between them. Nevertheless, after adding inefficiency variables which are teaching status, hospital size, ownership type, population, unemployment rate and salary, the significance of rank correlation between SFA and DEA results does not exist anymore.

According to the current literature, investigating the effects of health policy on the efficiency of hospitals by using panel data, SFA has an important place. Particularly in Turkey, SFA studies have been conducted on measuring the success of the structural changes, that occur under the HTP, over hospital efficiency. Atılgan (2012) used Turkish MoH panel data of 2007-2009 years in his study where the cost effectiveness of General Hospitals was examined. According to the results of the study, the performance based additional payment system does not increase the cost effectiveness in hospitals. While ineffectiveness effects increase the bed occupancy rates efficiency scores according to model estimation results, hospital efficiency scores decrease in regions where population and development level are high. In addition to this research, Keskin (2017) analyzed Turkish health reforms between 2009-2014 years by using similar methods. It has founded that the cost effectiveness of the Ministry of Health hospitals increased except the 2010 and 2012 periods. Moreover, along with other reforms, the achievement of administrative and financial autonomy of public hospitals has resulted in a general increase in the cost-effectiveness of hospitals.

Besides estimating individual technical efficiency, the researchers also focus on investigating the inefficiency effects consisting of hospital specific factors and environmental factors which may influence the production process. Kimsey (2009) compared the technical efficiency of military, profit, non-profit, and other hospitals of USA. The results of analysis show there is no significant correlation between ownership and technical efficiency, but the inefficiency factors are found to be significantly correlated with greater technical efficiency. These factors are; younger average patient age, more female patients, percentage of surgical inpatient treatment, percentage of circulatory system based operation, accreditation, and having all credentialed physicians. In the study on inpatient care in Turkish hospitals carried out by Atılgan (2016b), it was found that the development index and role groups of Turkish hospitals affect the efficiency scores significantly. In other respects, Kawaguchi et al. (2012) preferred to evaluate the hospital specific factors as fixed effect estimators (advanced treatment hospital, case mix index, number of hospitals per unit of population, proportion aged over 65 years) in their search using panel data of Japanese hospitals.

How to represent inpatient care service output is one of the recent debates. Inpatient activities are commonly measured by discharge outputs in the recent line of research. However, since the dramatic variations of resource consumptions between patients classification, adjustment by a hospital service complexity-based index has become widespread in hospital efficiency analyses. Rosko M. D. (2001) adjusted discharge with case mix index in order to reflect cost variations associated with case-mix complexity. In the Kimsey's study (2009), inpatient and outpatient workloads are both adjusted with outpatient case mix index, since the case mix is assumed to reflect the complexity of outpatient work in addition to outpatient discharges. In this context, Ferreira & Marques (2016) carried out a study on appropriateness of output adjustment with complexity and severity for inpatient efficiency assessment based on locally convex order-m method. They concluded that CMI does not change efficiency scores and ranking of hospitals remarkably, but it generates efficiencies with higher consistency. This research is based using CMI on inpatient services of Turkish MoH hospitals. In the next sections, the effect of the CMI adjustment in the efficiency analysis will be investigated by creating two empirical models that one of them is CMI adjusted and the other one is not CMI adjusted.

5.2. The Data and Variables

To build a satisfactory empirical model of efficiency in the health care sector, the following criteria on which the following sections are based, are considered (Jacobs et al. 2006, 18):

- What is the appropriate unit of analysis?
- What are the outputs of health care?
- What value should be attached to these outputs?
- What inputs are used in the production of these outputs and how should these be valued?

- What environmental constraints are faced?

5.2.a. The Unit of Analysis

In order to perform a healthy efficiency analysis, the DMUs to be selected must have a homogeneous structure and produce similar outputs using similar inputs (Özgümüş 2012). Inpatient care services of public hospitals affiliated to the MoH have been designated as decision-making units in our work. The variables are not included in the scope of analysis if they are very small or very large at the level that disrupts the homogeneity of the decision-making units.

The data consists of 495 MoH general hospitals including the data of 2016. The hospitals which had incomplete data and group E hospitals, whose beds are under 25 beds, were extracted from the sample in order to provide a homogenous sample.

5.2.b. The Output and Input Variables

The technical efficiency of the presentation of health services refers to the physical relationship between resource used such as, capital used, human resources and equipment, and health outcome (Worthington 2004, 136). To measure the ultimate output of healthcare is difficult because of the marginal change in health status, so intermediate outputs such as inpatient discharges and outpatient visits, usually become the preferred outputs of the hospital production model by the researchers (Kimsey 2009). There are quite different opinions in the inpatient care literature about the choice of the output variable. However, the length of hospital staying has lost its importance due to the DRG system being implemented in developed countries. Instead, it is recommended to use number of patients that is CMI weighted discharge. Because the reduction in the patient's day of residence can be due to better patient discharge planning, quality improvement or the severity of the case. In addition, while the total number of treatments, the quality and the case rate are constant, the patient's daytime increase can show that the inefficiency increases, not the output. (Keskin 2017, 160).

Inpatient care activities differentiate in sub categories and results in change of the total workload levels of hospitals with same amount of discharges. For instance, the patients with chronic disease or severe cases need longer length of stay and more resource consumption (Atılgan 2016b). To account for the heterogeneity in workload of different cases of inpatients, case-mix index (CMI) adjustment based on Diagnosis Related Groups (DRG) is commonly used in the literature. Many parameters such as diagnosis and treatment of diseases, age, sex, discharge type, duration of hospitalization, complication and comorbidity status of the disease are assessed and the patient is assigned a specific group, the system automatically creates a patient specific DRG (General Directorate of Health Services 2014). Since each DRG represents a class of patients with similar clinical conditions, it is assumed that similar resource usage for treatment is required (Kimsey 2009). For each DRG, a cost weight (w_k) is determined by policy makers and reflects the cost to treat an average patient in a particular DRG, compared with the cost to treat an average patient in the entire system (Kuntz et al. 2008).

Then, case-mix index of hospital i is calculated by:

$$CMI_i = \frac{\sum_{k=1}^{m} w_k y_{ik}}{\sum_{k=1}^{m} y_{ik}} \tag{5.1}$$

y_{ik}: the invoiced cases in DRG k in hospital i

w_k: cost weight of DRG k

The CMI of a hospital reflects the clinical complexity and the need of resources. If a hospital has a CMI of "1", this means that it performs a work of average intensity. The smaller CMI than "1" means less resource intense, the vice versa, the more resource intense means.

The categorization of health workforce is made according to the different roles in patient care and deliver service: physician, ancillary staff, and non-medical staff (Hamidi 2016). As capital inputs, the number of beds, apart from that, the services and costs offered are assumed to be the inputs used in service production.

In this research, we used physicians, nurse staff and non-medical staff as labor inputs and the hospital bed as capital input. As the only output, we used discharge and adjusted with case-mix index. All variables used were selected by taking into consideration the current studies in the literature, Unity Evaluation Handbook of Turkish Public Hospitals Institution and the availability of data. The input and output variables are listed below:

- CMIxDISC: Discharge adjusted with case-mix index.
- PHYS: The total number of general practitioners, specialist physician and assistant physician.
- NURSE: The total number of nurses.
- NONMED: The total number of non-medical staff including administrative staff, technical staff, contracting out personnel and other non-medical staff.

- BED: The total number of hospital beds including intensive care beds. The beds in which inpatients were admitted for more than 24 hours to provide care and treatment, are placed in patient rooms or in units where the patient is provided with continuing medical care.

5.2.c. Control Variables

If the personnel differences among the hospitals, technology differences etc. are considered, the quality of hospitalization for these units will be different (Atilgan 2016a). The usage of control variables captures the quality of inputs in the model. Furthermore, SFA models become more specified, estimated average inefficiency is likely to decline as unexplained composite error is captured by the inclusion of additional explanatory or control variables (Rosko & Mutter 2011). In the empirical model, the following control variables are used to capture quality differences of inputs

- SPECRATE: The ratio of specialists is:

$$Specialist\ Rate = \frac{Specialists}{Total\ Physicians} \tag{5.2}$$

The proportion of specialist physicians in the total number of physicians is included as a control variable in the model to capture the quality difference in the input of the labor force used by the hospitals.

- TECH: Technology index denotes the use of high-tech diagnostics in the hospitals. The index was calculated by MoH in 2016 and consists of 39 medical device by adjusting according to its importance for hospital workload. It is a numerical variable with a range from 0 to 4. Hospitals with high technology levels, generally A group and large scale hospitals, it is expected that the demand for hospitals with high technology level will increase if the severity of illness is higher.

5.2.d. Inefficiency Variables

When measuring efficiency of a set of hospitals, the results might be specific to their nature or inherent characteristics, as well as the environment in which they are situated. There may be exogenous influences on production function independent from hospital managements. One of the greatest contribution to the hospital efficiency studies of the SFA method is to allow the determination of the impact of hospital-specific and environmental factors by estimating the parameters of inefficiency variables (Atılgan 2016b).

5.2.d.i. Hospital specific factors

- ROLE: The role group of hospital. A grouping made according to the amount of resources used and the availability of services is defined on the basis of MoH's hospital role classification which is classified into E, D, C, B, A2 and A1 groups. From group E to A1, the amount of resources used and the availability of services increase. In this study, we drop hospitals in group E because small hospitals with limited resources affect the efficiency scores negatively. In the previous SFA studies on Turkish public hospitals (Atılgan 2012; Keskin 2017), the role group variable is defined as an index taking to values of 1, 2, 3, 4, and 5 for the hospital role groups D, C, B, A2 and A1 respectively. Unlike these studies, we used dummy variables for each group. The role group of hospitals denotes availability of services and hospital capacity. The distribution of role groups of hospitals according to their CMI is presented below.

Hospital Roles	N	CMI Mean	CMI Std Dev
A1	50	1,09	0,20
A2	60	1,00	0,12
B	123	0,90	0,15
C	153	0,81	0,13
D	109	0,78	0,14
Total	495	0,87	0,18

Table 5. 1. The Relationship Between Hospital Roles and Case-Mix Index

As seen in the table 5.1, as the role group of the hospitals levels up, the mean of CMI increases and hospitals tends to set up a better service structure that provides more specialized care due to the provision of qualified care services. Since the output is weighted with CMI in our model, the output quality differences between role groups are captured. So, it is not need to use role group as control variable.

Another case represented by role groups is hospital capacity. The distribution of role groups of hospitals according to their number of hospital bed is presented below.

Hospital Roles	N	BED Mean	BED Std Dev
A1	50	703	292
A2	60	498	255
B	123	192	82
C	153	73	28
D	109	33	11
Total	495	212	257

Table 5. 2. The Relationship Between Hospital Roles and Hospital Beds

As seen in the table 5.2, as the role group of the hospitals levels up, the mean of BED increases and hospitals tends to have a higher bed capacity. The role group variable denotes the hospital capacity at the same time.

As a result of defining the role group variable as inefficiency factor, we aim to investigate the impact of role group which is independent from the management of the hospital.

5.2.d.ii. Environmental factors

The environmental impacts are the population over 65 years of age, the development index, and the health index of the province where the hospital is located.

- OVER65: Population Over 65 Years of Age. It is calculated as a proportion of population Over 65 Years of Age to the total population for 81 provinces. The data including 2016 information is provided from Turkish Statistics Institution. Age is the most important risk factor for heart health and it is assumed that more people over 65 in the province increase efficiency of hospitals since the elderly population demand more healthcare and costly treatments such as bypass, recovery after heart-attack, stroke, etc. (Prochazkova 2011).

- DEVINX: The data of development index is provided by Economic Policy Research Foundation of Turkey. Following the methodology which was applied at the level of the United Nations country Turkey's 2013 human development index is calculated on the basis of provincial cities. The DEVINX that is consists of three components: health, education, income (Özpınar & Koyuncu 2016). In Turkey, regional characteristics is considered one of the factors that hospital inefficiency in Turkey directly. In SFA studies, Atılgan (2012) and Keskin (2017) founded that the development index affects the hospital efficiency negatively. To use development index in the models is important in terms of revealing the effects of demand structure on inefficiency and exploring socio-economic differences.

- HEALTHINX: Health index is calculated by life expectancy at birth data of 2013 for 81 provinces and provided from Turkish Statistics Institution. Life expectancy at birth also reflects aggregated data denoting health behaviors which are determinants of life. The report of European Commission (2015) remarks that individual-level differences in lifestyle factors, such as smoking, alcohol consumption and body mass index would lead longer life expectancy. Additionally, it has found that these lifestyle factors can affect health care use and health spending.

5.2.e. Descriptive Statistics

All variables used in the study are grouped according to the definitions in the models and their descriptive statistics are given in Table 5.3.

Variable	Mean	Std. Dev.	Min	Max
Outputs				
CMIxDISC	12111	16670	250	96056
Inputs				
PHYS	88.8	143.1	3	885
NURSE	145.2	168.1	11	1020
NONMED	290.6	347.2	17	1848
BED	212.1	257.3	25	1627
Control variables				
SPECRATE	0.66	0.20	0.09	1
TECH	0.56	0.70	0.00	4.00
Inefficiency effects				
A1	0.11	0.30	0	1
A2	0.12	0.33	0	1
B	0.25	0.43	0	1
C	0.31	0.46	0	1
D	0.22	0.41	0	1
HEALTHINX	0.57	0.18	0.00	1.00
DEVINX	0.53	0.17	0.00	1.00
OVER65	0.09	0.03	0.03	0.18

Table 5. 3. Descriptive Statistics

5.3. Analysis Results and Discussions

In this chapter, hypothesis tests, parameter estimates, and technical efficiency scores for each hospital were calculated by using the STATA 14.2 software.

5.3.a. Hypothesis Testing

To test the hypotheses, we apply four LR tests between log likelihood values of restricted and unrestricted models, then we compare the test statistics with mixed chi-square distribution values (Kodde & Palm 1986) at the %95 confidence level.

Null Hypothesis	Test Statistic λ	$\chi^2_{0.95}$ Value	Decision	Implication
$\gamma = 0$	13.7	2,7	Reject	Stochastic Frontier Model
$\mu = 0$	3.33	2.7	Reject	Truncated Normal Distribution of u_i
$\beta_{jh} = 0$	38.7	17.7	Reject	Translog Production Function
$\delta_m = 0$	60.9	13.4	Reject	Include Inefficiency Terms

Table 5. 4. Hypothesis testing summary

According to first hypothesis test result, the H_0 hypothesis, which indicates that the gamma parameter given in equation 4.38 equals to zero, is rejected. In other words, there exists one-sided error in the model. Therefore, it is appropriate to use SSA in the analysis of technical efficiency of hospitals.

According to second hypothesis test result, the H_0 hypothesis, which indicates that the µ parameter of truncated normal distribution equals to zero, is rejected. Therefore, it is more appropriate to use truncated normal distribution for inefficiency term.

In the third test, the null hypothesis is rejected, which reduces the translog function to the Cobb-Douglas function. Therefore, it is more appropriate to use translog function.

The fourth test examines whether the ineffectiveness variables used to explain inefficiency are linear functions. This result implies that all explanatory variables are significant in explaining inefficiencies, but individual effects of one or more variables may not be statistically significant.

Consequently, all of the null hypotheses were rejected. SFA model for discharge and CMI adjusted discharge in the form of translog including u_i which is truncated normally distributed is presented below:

$$lny_i = \beta_0 + \beta_1 \ln(PHYS) + \beta_2 \ln(NURSE) + \beta_3 \ln(NONMED) + \beta_4 \ln(BED) + \beta_5 \frac{1}{2}[\ln(PHYS)]^2 + \beta_6 \frac{1}{2}[\ln(NURSE)]^2 + \beta_7 \frac{1}{2}[\ln(NONMED)]^2 + \beta_8 \frac{1}{2}[\ln(BED)]^2 + \beta_9 \ln(PHYS)\ln(NURSE) + \beta_{10} \ln(PHYS)\ln(NONMED) + \beta_{11} \ln(PHYS)\ln(BED) + \beta_{12} \ln(NURSE)\ln(NONMED) + \beta_{13} \ln(NURSE)\ln(BED) + \beta_{14} \ln(NONMED)\ln(BED) + \beta_{15} \ln(SPECRATE) + \beta_{16} \ln(TECH) + (v_i - u_i) \qquad (5.1)$$

and, $u_i \sim$ iid $N^+(\mu, \sigma_u^2)$, where

$$u_i = \delta_0 + \delta_1 A1_{ROLE} + \delta_2 A2_{ROLE} + \delta_3 B_{ROLE} + \delta_4 C_{ROLE} + \delta_5 HEALTHINX + \delta_6 DEVINX + \delta_7 OVER65 + \epsilon_i \qquad (5.2)$$

5.3.b. Parameter Estimating

Estimation results of coefficient parameters of the baseline model given in equations 5.1 and 5.2 obtained for CMI adjusted discharge model and discharge model are given in Table 5.5.

	CMIxDISC		DISC	
Variable	Coeff	Std Err	Coeff	Std Err
Constant	2.37***	0.67	3.19***	0.73
PHYS	0.003	0.47	-0.35	0.50
NURSE	0.77	0.47	1.02*	0.53
NONMED	1.32**	0.63	1.18*	0.69
BED	-0.45	0.47	-0.58	0.51
PHYSxPHYS	-0.39*	0.22	-0.50**	0.23
NURSExNURSE	0.77	0.47	0.77	0.48
NONMEDxNONMED	-0.97*	0.53	-1.01*	0.58
BEDxBED	-0.29	0.43	0.079	0.45
PHYSxNURSE	0.51**	0.23	0.46*	0.25
PHYSxNONMED	0.24	0.28	0.31	0.30
NURSExNONMED	-0.61	0.42	-0.37	0.44
BEDxPHYS	-0.39*	0.23	-0.26	0.24
BEDxNURSE	-0.56	0.35	-0.83**	0.36
BEDxNONMED	1.20***	0.39	1.01**	0.41
SPECRATE	0.035	0.16	0.19	0.17
TECH	0.003	0.06	-0.056	0.07
μ	-0.064	0.33	-0.35	0.46
σ_v^2	-3.13***	0.21	-2.53***	0.11
Log likelihood	-165.50		-183.12	
N	495		495	

Table 5. 5. Parameter Estimation

****:1%, **:5%, *:10% significance level*

First order coefficient indicates the direct effect of input on output. Non-medical staff have significant positive coefficient in both models. However, coefficient nurse staff is not significant in CMIxDISC model whereas it is significant in DISC model.

The quadratic coefficient indicates returns to scale information of input. The investment in physician and non-medical staff yields decreasing returns to scale in both models. It means that hospitals with higher number of physician or non-medical are less productive than hospitals with lower number of them.

The coefficient of interaction indicates complementarity or substitutability between input variables. The positive and significant coefficient means that there is complementarity property between physician and nurse staff, and also between bed and non-medical staff in both models. The results indicate that 1 % increase in physician staff should increase the nurse staff required by 0.51 % in CMIxDISC model and 0.46 % in DISC model. 1 % increase in number of bed should increase the non-medical staff required by 1.20 % in CMIxDISC model and 1.01 % in DISC model. The negative and significant coefficient means that there is substitutionary property between physician staff and bed in CMIxDISC model, and also between bed and nurse staff in DISC model. The hospital bed is the substitution of physician staff in CMIxDISC model whereas it is the substitution of nurse staff in DISC model. The results indicate that 1 % increase in number of hospital bed should reduce the physician staff required by 0.39 % in CMIxDISC model and reduce the nurse staff required by 0.83 % in DISC model.

Control variables indicates the input quality change. However, none of the control variables is significant. Technology index and specialist rate in a hospital has no effect on discharges which are adjusted with CMI or not.

The output elasticity given in equation 4.36 indicates the responsiveness of output to a change in inputs. Output elasticity of input variables are given in the Table 5.6. The sum of output elasticities indicates the scale efficiency.

Variable	Mean	Std. Dev.
e_PHYS	0.19	0.18
e_ANCI	0.29	0.28
e_NONMED	0.28	0.32
e_BED	0.38	0.24
RTS	1.14	0.12

Table 5. 6. Output Elasticity of Input Variables and Returns to Scale

The increase in hospital beds provides the highest response of output increase. If there is 1 % increase in number of beds holding other inputs constant, it will result 0.38% increase in production. It is the most important factor in hospital inpatient service production. Then nurse, non-medical staff, and physicians come respectively. The sum of output elasticities for all inputs supports the increase return to scale in both models ($RTS_{CMIxDISCHARGE} = 1.14,\ RTS_{DISCHARGE} = 1.05$).

	CMIxDISC		**DISC**	
Variable	Coeff	Std Err	Coeff	Std Err
constant	-0.74	0.48	-2.54**	0.11
A1	-2.79***	0.79	-3.21***	1.10
A2	-2.29***	0.57	-2.52***	0.68
B	-1.70***	0.36	-2.29***	0.50
C	-0.61***	0.22	-1.11***	0.28
HEALTHINX	0.016	0.59	-1.98**	0.91
DEVINX	1.32*	0.74	5.31***	1.56
OVER65	-4.58	.3.12	-0.66	3.66

Table 5. 7. Inefficiency Coefficients Estimation
****:1%, **:5%, *:10% significance level*

Inefficiency variables indicate the exogenous influences on production function independent from hospital managements. Estimation results of coefficient parameters obtained for CMI adjusted discharge model and discharge model are given in Table 5.7.

All role group of hospitals is significant for the production for inpatient services of hospitals. As the role group gets higher, the inefficiency parameter decreases in both model. In Turkey, the absence of a mandatory referral chain system allows patients to go directly to the top-level hospitals. Therefore, this leads to overcrowding especially in the high role group of hospitals. When we compare the models, the significances of group role parameters do not change, but all of the parameters approach to zero if the output is adjusted with CMI. The exogenous influence of role groups on hospital production does not disappear, but decrease by adjusting output with CMI.

The efficiency scores are positively related with health index (life expectancy at birth) of the province that hospital is located. If the output is adjusted with CMI, its significance is removed. So, CMI variable captures the deviation of health index.

The efficiency scores are inversely related with development index of the province that hospital is located. After using CMI, the coefficient and its significance are decrease.

5.3.c. Technical Efficiency

The technical efficiency scores obtained by the method of stochastic frontier analysis are given in Appendix-C. In this section, we aim to classify the scores and discuss them with parameters we estimated before. In Table 5.8, the hospitals are grouped according to the characteristics of the hospitals and the regions where they are located. The purpose of this classification is to show the variation of efficiency scores according to group role and bed capacity. In addition, the frequency plots of efficiency distribution according to the characteristics of the hospitals and the regions are represented in Appendix-B.

		CMIxDISC		**DISC**	
	N	Mean	Std. Dev.	Mean	Std. Dev.
	495	0.73	0.18	0.81	0.16
Role Group					
A1	50	0.87	0.05	0.93	0.03
A2	60	0.84	0.07	0.90	0.05
B	123	0.80	0.11	0.89	0.08
C	153	0.67	0.16	0.77	0.12
D	109	0.59	0.20	0.65	0.19
Bed Capacity					
0 - 100	232	0.62	0.19	0.71	0.17
100-200	97	0.78	0.12	0.86	0.10
200-300	48	0.80	0.09	0.90	0.05
300<	118	0.85	0.06	0.91	0.04
Regions					
South East Anatolia	49	0.79	0.16	0.92	0.10
North East Anatolia	19	0.77	0.13	0.88	0.11
İstanbul	35	0.75	0.16	0.87	0.09
Mediterranean	51	0.75	0.17	0.81	0.16
West Anatolia	41	0.73	0.17	0.78	0.16
East Black Sea	33	0.72	0.16	0.79	0.15
West Black Sea	47	0.72	0.18	0.79	0.15
Aegean	73	0.71	0.17	0.79	0.14
East Marmara	44	0.71	0.20	0.75	0.18
Central Anatolia	27	0.69	0.20	0.76	0.19
West Marmara	39	0.69	0.21	0.73	0.19
Central East Anatolia	37	0.67	0.16	0.85	0.12

Table 5. 8. Distribution of Efficiency Scores

The mean of the technical efficiency scores of 495 inpatient care services of MoH hospitals is 0.73 in CMIxDISC model and 0.81 in DISC model. About %27 of potential output in CMIxDISC model and %19 potential output in DISC model is lost due to the technical inefficiency. After using CMI, the standard deviation increase within groups and the mean of efficiency scores are decreases in all groups in Table 5.8. When discussing the models, it is necessary to pay particular attention to the efficiency decrease.

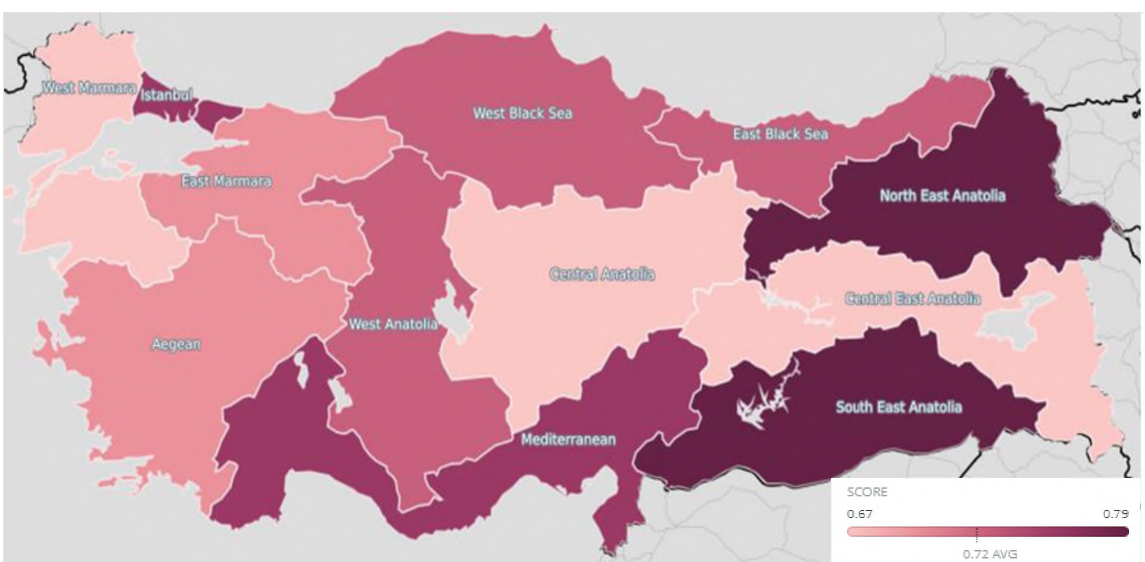
In table 5.8, it is observed that the average of efficiency scores decreases, as the role group of the hospitals levels up. Especially, when we look at group B and C, there is a big difference between the averages of the efficiencies. Group B hospitals operates in the province center or in the districts which are in the position of strengthened district center and have internal branch emergency pool watch and surgical branch emergency pool watch can be held based on 24-hour basis where Group C hospitals operate in the districts and do not have 24-hour basis emergency service. These hospital specific factors may increase dramatically the inpatient service efficiency.

We learned from the parameters that higher level role group means more qualified service availability resulting higher CMI and lower exogenous inefficiency factor. To have higher efficiency between role groups is explained by inefficiency factor in both models and by CMI level in CMIxDISC model.

In table 5.8, as the capacity of the hospitals levels up, the efficiency scores increases. This also supports our finding which the increasing RTS property of hospitals is. On the other hand, we previously showed that quadratic coefficient terms of non-medical and physician staff showed that investing to these inputs results decreasing returns to scale.

In table 5.8, we sorted the regions from highest to lowest score in CMIxDISC model. The rankings of regions do not remarkably change except Central East Anatolia. This region consists of hospitals mostly of C and D role group and has very low development index. We found before that the efficiency scores are inversely related with development index and after using CMI, coefficient of development index begins to affect efficiency less in the direction of increase. In the study on inpatient care services in Turkey, Atılgan (2016b) remarks that the lack of CMI may cause the severity of the case of hospitals not to be reflected in socioeconomically developed provinces and that's why the efficiency scores were seen to be low in there. However, Southeast Anatolia and North East Anatolia, which have low development index averages (0.28, 0.31), are in the first two places in both models. However, after Southeast Anatolia and North East Anatolia, Istanbul and Mediterranean region have high efficiency score average but do not have low development index averages. In Map 5.1, efficiency scores in CMIxDISC model according to NUTS-1 region is illustrated. The darker the regions the higher the score.

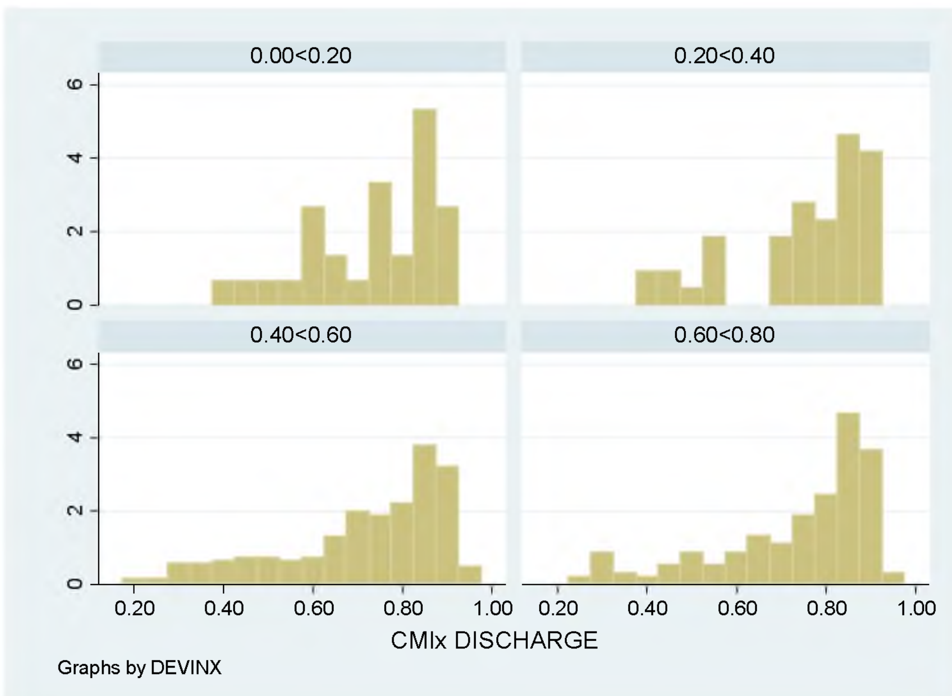
Map 5. 1. Efficiency Scores in CMIxDISC according to NUTS-1 Region



However, between regions there is no big difference in the average of the efficiency scores. Besides, within geographical regions, it seems that there are too many variations. It is not the right approach to make political outcomes by making cross-regional comparisons at this point.

Within the same geographical region, there are provinces with different developmental indices. Therefore, it is necessary to evaluate the efficacy scores according to the development index separately. In figure 5.1, four development index groups were generated and the distribution of the efficiency scores accordingly is illustrated.

Figure 5. 1. Frequency Plot of Efficiency Scores of CMIxDISCHARGE according to Development Index



The inefficiency coefficient of development index has been found significant and positive in both models. It means that the efficiency scores are inversely related with development index of the province that hospital is located. In figure 5.1, the frequency of low efficiency scores increase in high development index groups. This can be explained by a greater tendency to private hospitals in socioeconomically developed regions. Since one of the component of development index is income, high income group, which can afford private hospital, is in the provinces with high level development index.

CHAPTER VI

CONCLUSION

In the thesis study, the method of stochastic frontier analysis is introduced and basic concepts related to the method are given. The technical efficiency of 495 Turkish public hospitals is measured by using data of 2016 year. We constructed two empirical models that one of them is CMI adjusted and the other one is not CMI adjusted. According to the results, the mean of the technical efficiency scores is 0.73 in CMIxDISC model and 0.81 in DISC model. In other words, about %27 of potential output in CMIxDISC model and %19 potential output in DISC model are lost due to the technical inefficiency. These might be caused by hospital organization or exogenous factors. In addition to of input-output relations, we tested the impact of hospital-specific and environmental factors on inefficiency scores.

The inefficiency parameters of all role group of hospitals are significant for the production for inpatient services of hospitals. As the role group gets higher, the inefficiency parameter decreases in both model. In Turkey, the absence of a mandatory referral chain system allows patients to go directly to the top-level hospitals. Therefore, this leads to overcrowding especially in the high role group of hospitals. In addition, the efficiency scores are positively related with health index (life expectancy at birth) of the province that hospital is located and inversely related with development index of the province that hospital is located, but its significance is removed when the output is adjusted with CMI. After using CMI, role group and development index parameters of inefficiency variables are approach to zero whereas health index loose its significance. So, the efficiency of a hospital with A1 role group in a region with a low development index is higher than those of other hospitals for both models.

Southeast Anatolia and North East Anatolia, which have low development index averages, are in the first two places in both models. This supports other findings that the efficiency scores are inversely related with development index. However, between regions there is no big difference in the average of the efficiency scores. Besides, within geographical regions, it seems that there are too many variations.

The sum of elasticity of coefficients shows increase return to scale property. In addition, benchmarking according to the bed capacity groups shows that high-capacity hospitals are more efficient than others. In the last years, Turkish MoH makes high-capacity investments based on the Public-Private-Partnership (PPP) model. Our findings support that these investments are right in terms of ensuring technical efficiency.

CMI was disseminated by MoH in all public hospitals over time and was regularly checked to make it a reliable data source. As data accumulation is provided over years, panel data usage will be possible and more reliable results will be obtained in the future. The panel gives more information than the cross-section data on the time behavior of the data producers. For example, structural change takes into account fixed or random heterogeneities that vary from firm to firm and from time to time. Furthermore, panel data show how the inefficiency of each firm has changed over time (Kumbhakar et al. 2015, 96).

In the future, if the data is provided at the clinic level, Stochastic Frontier Analysis with CMI adjusted output will be very useful for evaluation of hospital clinics. The evaluation of the efficiency of the clinics with special features has great importance because the hospital-wide outcomes are not sufficiently descriptive. The analysis of the efficiency of the clinics, even all the units, and the evaluation of the results will bring more accurate and effective solutions in terms of hospitals leading to improvements. At present, the performance of clinically serving units of is determined according to the goals of reaching the generally determined standard rates by Turkish MoH. However, the performance measurements made according to the methods based on comparison with each other are more beneficial in terms of determining the achievable targets.

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APPENDIX-A

Nomenclature of Territorial Units for Statistics (NUTS)

Region	Provinces
Istanbul	Istanbul
West Marmara	Tekirdağ, Edirne, Kırklareli, Balıkesir, Çanakkale
Aegean	İzmir, Aydın, Denizli, Muğla, Manisa, Afyonkarahisar, Kütahya, Uşak
East Marmara	Bursa, Eskişehir, Bilecik, Kocaeli, Sakarya, Düzce, Bolu, Yalova
West Anatolia	Ankara, Konya, Karaman
Mediterranean	Antalya, Isparta , Burdur, Adana, Mersin, Hatay, Kahramanmaraş, Osmaniye
Central Anatolia	Kırıkkale, Aksaray, Niğde, Nevşehir, Kırşehir, Kayseri, Sivas, Yozgat
West Black Sea	Zonguldak, Karabük, Bartın, Kastamonu, Çankırı, Sinop, Samsun, Tokat, Çorum, Amasya
East Black Sea	Trabzon, Ordu, Giresun, Rize, Artvin, Gümüşhane
North East Anatolia	Erzurum, Erzincan, Bayburt, Ağrı, Kars, Iğdır, Ardahan
Central East Anatolia	Malatya, Elazığ, Bingöl, Tunceli, Van, Muş, Bitlis, Hakkari
South East Anatolia	Gaziantep, Adıyaman, Kilis, Şanlıurfa, Diyarbakır, Mardin, Batman, Şırnak, Siirt

Table A.1. Nomenclature of Territorial Units for Statistics (NUTS) Level 1

APPENDIX-B

Frequency Plots of Efficiency Scores

Figure B.1. Frequency Plot of Efficiency Scores of CMIxDISCHARGE according to Role Group

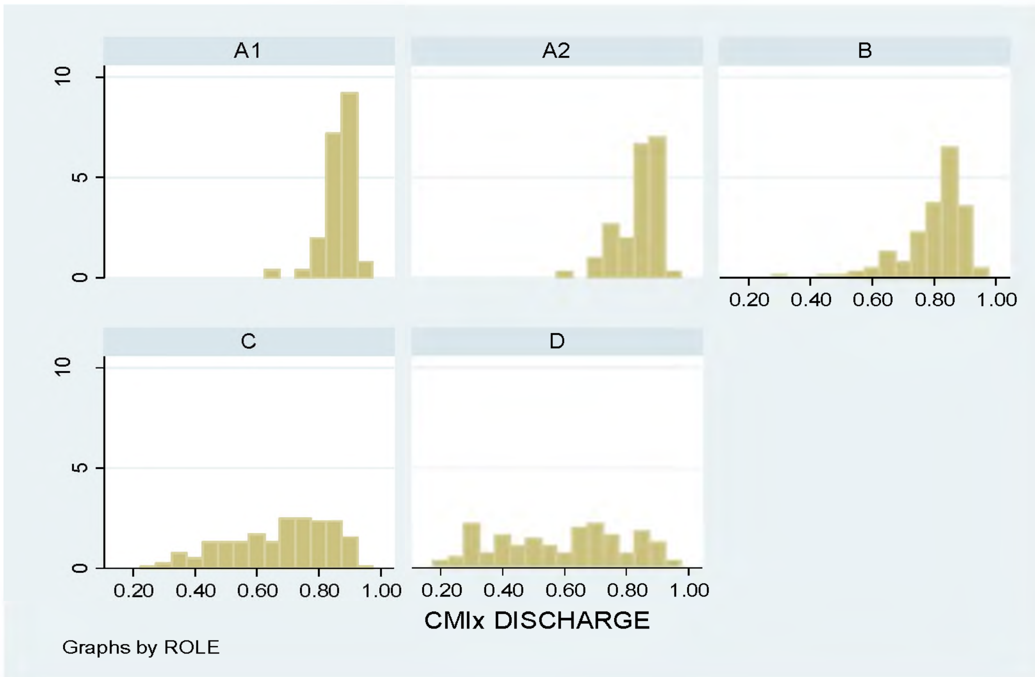


Figure B.2. Frequency Plot of Efficiency Scores of CMIxDISCHARGE according to Bed Capacity

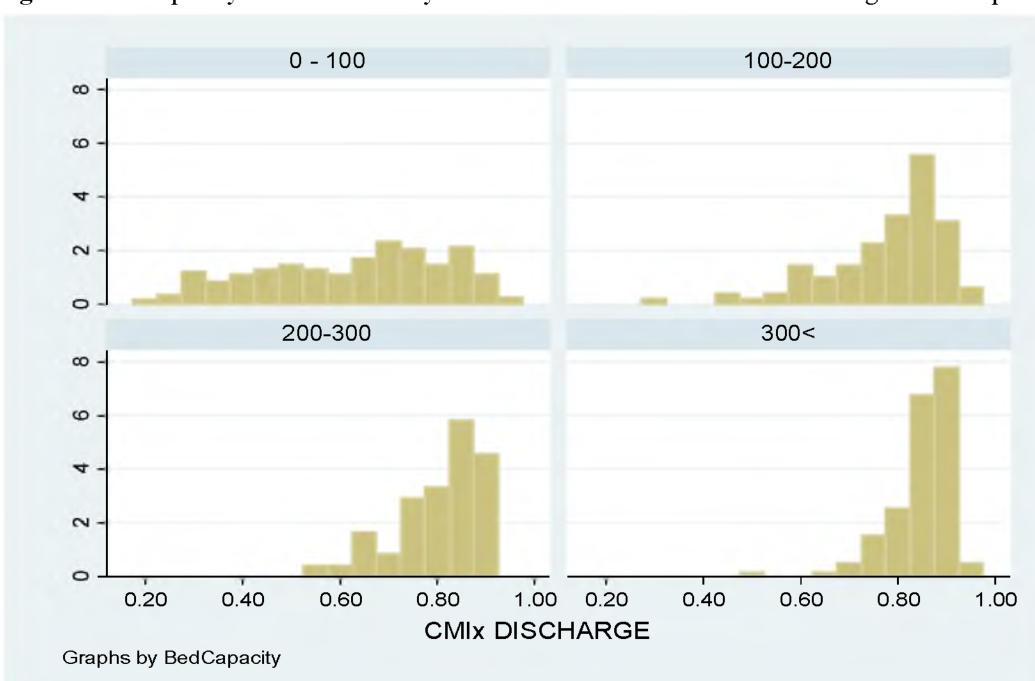
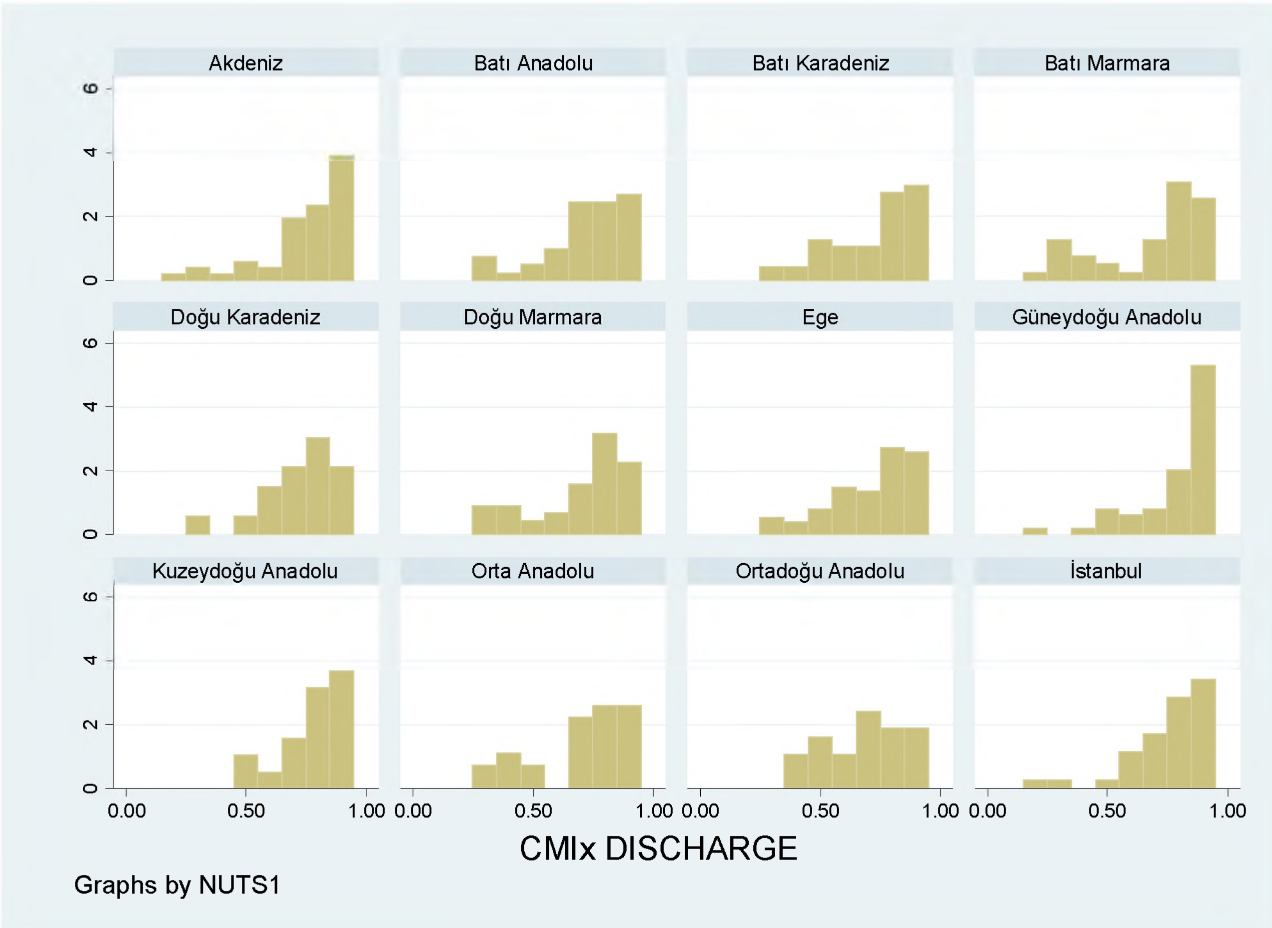


Figure B.3. Frequency Plot of Efficiency Scores of CMIxDISCHARGE according to NUTS-1 Region



APPENDIX-C

List of Efficiency Scores

HOSPITAL CODE	ROLE	CAPACITY	CMIx DISCHARGE	DISCHARGE	HOSPITAL CODE	ROLE	CAPACITY	CMIx DISCHARGE	DISCHARGE
141340	A1	200<	93%	95%	732388	A1	200<	90%	93%
220374	A1	200<	89%	97%	752173	A1	200<	89%	93%
995038	A1	200<	83%	94%	375502	A1	200<	79%	94%
864144	A1	200<	87%	91%	567614	A1	200<	92%	94%
620352	A1	200<	87%	90%	195104	A1	200<	86%	93%
388067	A1	200<	87%	86%	191451	A1	200<	81%	92%
254877	A1	200<	79%	88%	746026	A1	200<	84%	92%
880135	A1	200<	91%	90%	898950	A1	200<	84%	94%
369994	A1	200<	88%	90%	668217	A1	200<	67%	87%
893697	A1	200<	83%	88%	438515	A1	200<	87%	91%
700780	A1	200<	92%	95%	108584	A1	200<	78%	87%
141931	A1	200<	86%	91%	397643	A1	200<	88%	92%
384993	A1	200<	91%	94%	281695	A1	200<	87%	91%
529649	A1	200<	89%	95%	786539	A1	200<	88%	94%
982149	A1	200<	91%	98%	401163	A1	200<	89%	95%
161424	A1	200<	85%	94%	869446	A1	200<	87%	91%
584010	A1	200<	85%	95%	839799	A1	200<	89%	94%
708741	A1	200<	82%	94%	727165	A1	200<	88%	93%
896372	A1	200<	86%	93%	905864	A1	200<	86%	94%
842839	A1	200<	88%	94%	320877	A1	200<	90%	94%
874478	A1	200<	88%	94%	786006	A1	200<	90%	97%
390985	A1	200<	90%	94%	301054	A1	200<	90%	94%
631908	A1	200<	87%	93%	148897	A1	200<	94%	95%
573792	A1	200<	83%	93%	117537	A1	200<	86%	94%
918666	A1	200<	77%	91%	313457	A1	200<	92%	99%
343501	A2	200<	87%	91%	433863	A2	200<	83%	91%
321839	A2	200<	90%	93%	957903	A2	200<	87%	95%
344628	A2	200<	90%	98%	483216	A2	200<	84%	91%
545384	A2	200<	75%	81%	140234	A2	200<	88%	89%
431998	A2	200<	85%	91%	205788	A2	200<	84%	88%
791287	A2	200<	89%	91%	882098	A2	200<	82%	85%
584378	A2	200<	89%	91%	930835	A2	200<	76%	80%
874039	A2	200<	88%	92%	719822	A2	200<	77%	80%
170943	A2	200<	85%	89%	379494	A2	200<	71%	86%

HOSPITAL CODE	ROLE	CAPACITY	CMIx DISCHARGE	DISCHARGE	HOSPITAL CODE	ROLE	CAPACITY	CMIx DISCHARGE	DISCHARGE
936047	A2	200<	88%	96%	912642	A2	200<	87%	91%
144233	A2	200<	75%	96%	124883	A2	200<	85%	89%
214693	A2	200<	77%	82%	516805	A2	200<	81%	90%
996447	A2	200<	89%	90%	196727	A2	200<	93%	98%
542771	A2	200<	87%	89%	207591	A2	200<	90%	98%
484916	A2	200<	88%	91%	405961	A2	200<	86%	88%
560373	A2	200<	79%	86%	508891	A2	200<	85%	90%
429735	A2	200<	90%	92%	581014	A2	200<	85%	98%
817205	A2	200<	75%	91%	119337	A2	200<	90%	91%
413575	A2	200<	88%	90%	946713	A2	200<	90%	94%
145515	A2	200<	85%	88%	741537	A2	200<	89%	93%
202752	A2	200<	85%	84%	641680	A2	200<	80%	89%
675992	A2	200<	91%	93%	297282	A2	200<	79%	96%
706523	A2	200<	90%	94%	395750	A2	200<	80%	91%
660645	A2	200<	89%	93%	929909	A2	200<	92%	97%
711200	A2	200<	71%	86%	664733	A2	200<	84%	89%
391755	A2	200<	61%	81%	301644	A2	200<	86%	90%
778138	A2	100-200	85%	90%	329359	A2	200<	88%	93%
952557	A2	200<	74%	83%	593258	A2	200<	74%	81%
787834	A2	200<	68%	83%	552772	A2	200<	87%	97%
215746	A2	200<	89%	94%	857119	A2	200<	83%	86%
457925	B	100-200	87%	91%	181372	B	<100	91%	90%
164381	B	200<	77%	89%	306101	B	100-200	63%	79%
615885	B	200<	84%	89%	840039	B	200<	79%	86%
162147	B	100-200	84%	94%	924759	B	200<	85%	86%
581959	B	100-200	87%	98%	303994	B	200<	87%	87%
106714	B	100-200	85%	98%	228082	B	100-200	80%	88%
269679	B	200<	82%	89%	941785	B	100-200	80%	83%
638753	B	100-200	53%	44%	709118	B	100-200	90%	94%
438540	B	100-200	90%	88%	390232	B	200<	85%	94%
119194	B	100-200	87%	85%	977036	B	200<	90%	91%
236964	B	100-200	28%	44%	513650	B	200<	82%	87%
544857	B	100-200	72%	76%	604169	B	200<	90%	97%
203284	B	200<	77%	84%	752647	B	200<	72%	81%
506320	B	100-200	85%	85%	310654	B	200<	88%	93%
546951	B	200<	84%	90%	962834	B	100-200	74%	88%
371694	B	100-200	84%	90%	314457	B	<100	77%	86%
685295	B	100-200	83%	94%	496322	B	200<	83%	91%
385765	B	100-200	85%	87%	763146	B	100-200	94%	94%
969401	B	200<	65%	89%	814703	B	100-200	82%	88%

HOSPITAL CODE	ROLE	CAPACITY	CMIx DISCHARGE	DISCHARGE	HOSPITAL CODE	ROLE	CAPACITY	CMIx DISCHARGE	DISCHARGE
463331	B	200<	89%	91%	738739	B	200<	77%	85%
726546	B	200<	87%	90%	927140	B	200<	82%	89%
624860	B	200<	87%	90%	282629	B	200<	87%	89%
182639	B	200<	88%	93%	669741	B	200<	77%	89%
795321	B	200<	80%	91%	544808	B	200<	67%	86%
352304	B	100-200	81%	84%	913799	B	200<	81%	89%
519058	B	100-200	73%	78%	454141	B	100-200	87%	98%
398561	B	200<	88%	96%	724340	B	100-200	43%	97%
173896	B	200<	79%	96%	600937	B	100-200	84%	88%
760990	B	200<	89%	92%	289600	B	100-200	81%	86%
408093	B	200<	78%	88%	591248	B	100-200	83%	88%
304919	B	100-200	91%	90%	834975	B	<100	86%	91%
945640	B	100-200	79%	86%	810139	B	200<	64%	83%
254097	B	200<	79%	84%	953285	B	100-200	79%	88%
662394	B	100-200	80%	84%	132895	B	200<	83%	93%
670000	B	200<	89%	93%	286714	B	200<	91%	95%
105524	B	200<	88%	91%	476786	B	100-200	90%	94%
374825	B	100-200	83%	95%	753474	B	200<	78%	87%
891287	B	100-200	85%	95%	211399	B	100-200	61%	83%
162570	B	<100	86%	95%	103618	B	200<	83%	84%
473323	B	200<	48%	91%	721776	B	200<	89%	92%
343246	B	100-200	86%	87%	254394	B	100-200	87%	91%
671714	B	200<	65%	87%	597633	B	100-200	90%	93%
505551	B	100-200	86%	93%	846469	B	200<	86%	91%
621249	B	200<	86%	94%	150905	B	100-200	93%	97%
540193	B	100-200	84%	98%	518846	B	100-200	90%	97%
734191	B	100-200	69%	97%	608539	B	100-200	92%	97%
706695	B	100-200	79%	88%	678643	B	200<	91%	97%
389744	B	200<	75%	96%	678219	B	<100	94%	97%
111521	B	200<	84%	88%	781236	B	200<	89%	97%
746454	B	100-200	63%	80%	722274	B	200<	69%	99%
800855	B	200<	83%	90%	835114	B	200<	53%	99%
678949	B	100-200	72%	87%	594149	B	200<	82%	89%
573061	B	100-200	86%	90%	955952	B	100-200	84%	91%
833838	B	<100	60%	80%	153582	B	100-200	71%	88%
876769	B	100-200	76%	86%	987695	B	200<	87%	92%
929388	B	100-200	67%	83%	959268	B	200<	74%	85%
820867	B	<100	62%	87%	170005	B	100-200	66%	92%
258224	B	100-200	82%	90%	326133	B	100-200	84%	96%
442075	B	100-200	72%	85%	372178	B	200<	73%	85%

HOSPITAL CODE	ROLE	CAPACITY	CMIx DISCHARGE	DISCHARGE	HOSPITAL CODE	ROLE	CAPACITY	CMIx DISCHARGE	DISCHARGE
307717	B	200<	78%	88%	346153	B	100-200	74%	92%
842361	B	100-200	88%	91%	910156	B	200<	83%	87%
762389	B	100-200	81%	86%	755292	C	100-200	75%	88%
930972	C	<100	72%	87%	221828	C	<100	57%	59%
390340	C	<100	77%	87%	564029	C	<100	50%	67%
393147	C	100-200	79%	83%	926547	C	<100	49%	53%
546575	C	<100	63%	76%	203655	C	<100	81%	82%
494950	C	100-200	62%	72%	997245	C	<100	80%	87%
396471	C	<100	78%	84%	496805	C	100-200	86%	90%
835265	C	<100	77%	94%	308655	C	<100	69%	72%
500841	C	<100	75%	85%	596484	C	100-200	61%	75%
487094	C	<100	47%	67%	879954	C	<100	77%	89%
317761	C	<100	79%	78%	303381	C	<100	59%	83%
392253	C	<100	34%	40%	688182	C	<100	44%	66%
184719	C	<100	68%	68%	566429	C	<100	76%	77%
128640	C	<100	73%	72%	914424	C	<100	65%	76%
944590	C	<100	57%	48%	134172	C	<100	68%	83%
232161	C	<100	67%	77%	209257	C	<100	80%	77%
471960	C	<100	75%	76%	894930	C	100-200	72%	80%
737717	C	<100	86%	89%	678823	C	<100	30%	45%
233062	C	100-200	91%	90%	239791	C	<100	38%	55%
606757	C	<100	66%	79%	435185	C	<100	51%	55%
311023	C	<100	74%	81%	807720	C	<100	55%	69%
148267	C	<100	67%	76%	210399	C	<100	46%	58%
916914	C	100-200	60%	74%	261582	C	<100	61%	72%
486146	C	100-200	94%	91%	585521	C	100-200	74%	83%
809443	C	<100	65%	75%	964160	C	<100	76%	84%
163019	C	<100	71%	81%	620673	C	<100	59%	77%
429875	C	<100	69%	78%	269833	C	100-200	61%	73%
869568	C	100-200	83%	83%	550422	C	<100	54%	70%
647032	C	100-200	84%	83%	767756	C	<100	73%	80%
454207	C	<100	47%	60%	649521	C	<100	82%	88%
490244	C	100-200	90%	87%	944529	C	<100	55%	79%
595102	C	<100	47%	71%	506379	C	<100	54%	69%
891269	C	<100	76%	80%	211933	C	<100	42%	58%
751112	C	<100	38%	59%	381487	C	<100	34%	64%
805959	C	<100	79%	91%	862040	C	<100	89%	95%
853576	C	<100	29%	42%	682524	C	<100	70%	80%
152418	C	<100	74%	86%	516861	C	<100	69%	79%
842465	C	<100	72%	76%	581316	C	100-200	55%	70%

HOSPITAL CODE	ROLE	CAPACITY	CMIx DISCHARGE	DISCHARGE	HOSPITAL CODE	ROLE	CAPACITY	CMIx DISCHARGE	DISCHARGE
251542	C	<100	83%	87%	641843	C	<100	62%	79%
119419	C	<100	41%	43%	364151	C	<100	86%	87%
841356	C	<100	52%	61%	678096	C	100-200	68%	93%
597089	C	<100	92%	88%	844519	C	<100	81%	94%
307919	C	100-200	89%	85%	959144	C	<100	55%	92%
722436	C	100-200	80%	82%	931291	C	<100	47%	59%
739867	C	<100	35%	52%	737719	C	<100	85%	86%
176919	C	<100	48%	73%	985089	C	<100	83%	88%
139521	C	100-200	50%	66%	920035	C	<100	68%	77%
562144	C	100-200	65%	82%	818260	C	<100	83%	84%
926582	C	100-200	84%	89%	480095	C	<100	90%	77%
174135	C	100-200	88%	89%	544050	C	<100	35%	47%
834333	C	<100	72%	81%	275134	C	100-200	81%	86%
857388	C	100-200	59%	74%	405152	C	<100	59%	69%
513049	C	<100	86%	92%	774917	C	<100	77%	82%
814410	C	<100	44%	64%	512179	C	<100	62%	73%
313654	C	100-200	88%	86%	292625	C	100-200	75%	91%
548566	C	<100	46%	70%	675894	C	<100	81%	85%
987915	C	<100	48%	73%	798688	C	100-200	83%	87%
289122	C	<100	85%	89%	310957	C	<100	78%	82%
899120	C	<100	86%	89%	863327	C	<100	67%	81%
990140	C	100-200	74%	83%	687786	C	<100	88%	94%
771317	C	100-200	70%	85%	405908	C	<100	53%	97%
505136	C	<100	72%	80%	879523	C	<100	84%	97%
794319	C	<100	58%	71%	845538	C	<100	33%	49%
295942	C	<100	69%	82%	844919	C	100-200	82%	85%
519150	C	<100	80%	85%	680018	C	100-200	58%	67%
530881	C	<100	85%	88%	483530	C	<100	79%	79%
328129	C	<100	65%	93%	768264	C	100-200	82%	82%
857592	C	100-200	69%	83%	246206	C	<100	84%	87%
709283	C	100-200	89%	90%	544830	C	<100	44%	85%
541255	C	<100	91%	92%	285657	C	<100	72%	92%
989733	C	100-200	76%	77%	798989	C	<100	55%	87%
628913	C	<100	23%	48%	397184	C	<100	82%	88%
184606	C	<100	33%	66%	952252	C	<100	70%	85%
995924	C	<100	47%	73%	973434	C	<100	67%	80%
596399	C	<100	73%	80%	354641	C	<100	51%	80%
689735	C	<100	51%	65%	514489	C	100-200	89%	86%
593977	C	<100	84%	82%	573557	C	100-200	46%	63%
929220	D	<100	67%	76%	442054	D	<100	33%	38%

HOSPITAL CODE	ROLE	CAPACITY	CMIx DISCHARGE	DISCHARGE	HOSPITAL CODE	ROLE	CAPACITY	CMIx DISCHARGE	DISCHARGE
990779	D	<100	71%	81%	600220	D	<100	85%	87%
516124	D	<100	32%	35%	661170	D	<100	70%	74%
750705	D	<100	59%	75%	353074	D	<100	42%	48%
111631	D	<100	48%	58%	274291	D	<100	30%	31%
590551	D	<100	41%	42%	421937	D	<100	48%	62%
748034	D	<100	30%	39%	877697	D	<100	48%	47%
570390	D	<100	31%	31%	795383	D	<100	65%	63%
116651	D	<100	30%	40%	971030	D	<100	75%	71%
857420	D	<100	85%	85%	427231	D	<100	70%	77%
643968	D	<100	30%	33%	162440	D	<100	42%	51%
770840	D	<100	64%	69%	357230	D	<100	82%	74%
247872	D	<100	79%	82%	289847	D	<100	47%	40%
172421	D	<100	75%	75%	640075	D	<100	22%	25%
140585	D	<100	56%	55%	403411	D	<100	73%	68%
138878	D	<100	77%	77%	999679	D	<100	43%	80%
804750	D	<100	64%	78%	118773	D	<100	31%	34%
159618	D	<100	63%	80%	958764	D	<100	73%	75%
647209	D	<100	27%	27%	225717	D	<100	94%	91%
453622	D	<100	70%	64%	698856	D	<100	48%	75%
670113	D	<100	69%	85%	736145	D	<100	51%	61%
676663	D	<100	57%	77%	731058	D	<100	40%	46%
470605	D	<100	41%	75%	460317	D	<100	63%	70%
733217	D	<100	86%	90%	986760	D	<100	87%	81%
551920	D	<100	87%	90%	409125	D	<100	77%	84%
458446	D	<100	71%	85%	743326	D	<100	52%	70%
242353	D	<100	41%	70%	414473	D	<100	93%	93%
229782	D	<100	55%	70%	243280	D	<100	91%	87%
495859	D	<100	45%	36%	156952	D	<100	47%	61%
365623	D	<100	69%	58%	804904	D	<100	69%	75%
363440	D	<100	70%	71%	388203	D	<100	45%	45%
609572	D	<100	42%	45%	820821	D	<100	79%	74%
711464	D	<100	65%	69%	420042	D	<100	29%	27%
776076	D	<100	89%	88%	977065	D	<100	68%	70%
352194	D	<100	89%	91%	540594	D	<100	37%	39%
193291	D	<100	79%	87%	213292	D	<100	20%	41%
105495	D	<100	48%	62%	834463	D	<100	91%	93%
662504	D	<100	45%	61%	872523	D	<100	83%	90%
958265	D	<100	86%	85%	896197	D	<100	77%	94%
867253	D	<100	74%	72%	261315	D	<100	35%	47%
351143	D	<100	64%	55%	934970	D	<100	85%	90%

HOSPITAL CODE	ROLE	CAPACITY	CMIx DISCHARGE	DISCHARGE	HOSPITAL CODE	ROLE	CAPACITY	CMIx DISCHARGE	DISCHARGE
929937	D	<100	49%	70%	101036	D	<100	25%	30%
640079	D	<100	70%	60%	648296	D	<100	32%	45%
814912	D	<100	66%	77%	267686	D	<100	63%	65%
720509	D	<100	41%	54%	354177	D	<100	61%	65%
365767	D	<100	53%	69%	507062	D	<100	77%	67%
915844	D	<100	59%	64%	970560	D	<100	60%	72%
618051	D	<100	26%	39%	177604	D	<100	53%	80%
522389	D	<100	31%	40%	586541	D	<100	90%	90%
614462	D	<100	83%	79%	153324	D	<100	64%	79%
330217	D	<100	88%	88%	396107	D	<100	41%	32%
783524	D	<100	92%	91%	617926	D	<100	85%	88%
414865	D	<100	69%	72%	707183	D	<100	36%	41%
536459	D	<100	32%	35%	241631	D	<100	57%	68%
808601	D	<100	30%	36%					