# Performance Evaluation of Iranian Private Banks Using Data Envelopment Analysis (DEA)

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# ABSTRACT

Assessing performance of any organizations is necessary in guiding their future strategic decisions. Banks also are no exception. The purpose of this study is to evaluate the performance of 15 Iranian private banks using data envelopment analysis in 5 years period using Data Envelopment Analysis (DEA). The result will help these banks to improve their performances by focusing on inadequate factors and evaluate their efficiency among the competitors.

In the process of evaluating the banks, all of the important indicators are verified and inputs and outputs have been selected in order to assess the efficiency of the banks based on previous studies and the views of experts in this field. Then, the efficient and inefficient banks and their operational rank were determined. Also, reasons for inefficiency of banks would have been detected and proposal for improvements would be discussed.

**Keywords:** Private Banks, Banking efficiency, DEA, Iranian Banks, Privatization

# ÖZ

Herhangi bir kurumun yapacaği performans değerlendirmesi o kurumun gelecekteki stratejik kararlarını belirtemede büyük önem taşimaktadir. Bankalar bu çalişmanın amacı 15 özel Iran bankasının 5 yıllık bir süre icindeki performansını DEA (Veri Zarflama Analizi) kullanarak değerlendirmek.

Sonuçlar bankaların yetersizliklerine odaklanarak performanslarını geliştirme fırsatı yaratacak. Ayrıca rakipleri ile kıyasla araştırma ve araştirmadaki bankaların ne kadar etkili olduklarını analiz etme firsatı verecektir.

Bankaların analizi esnasında tüm önemli göstergeler belirlenmiş ve onaylanmıştır, Ayrıca girdi ve çıktılar da onceki araştırmalara ve alanında uzman kişilerin fikirlerine başvurularak gerçekleşmiştir. Bunun üzerine yeterli ve yetersiz bankalar belirlenmiş ve operasyonel sıralamaları oluşturulmuştur.

Buna ek olarak bankaların yetersizlik sebepleri saptanmiş ve iyileştirici projeler için önerilerde bulunulmuştur.

# DEDICATION

TO MY FAMILY

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# INTRODUCTION

Nowadays evaluating efficiency in any organization is a must in order to know how selected strategies are affected and how plans should be chosen to compete with other rivals. Banks, which are playing vital role in any economic system of a country, are not an exception. Therefore, evaluating banks efficiencies and detecting effective factors for them are necessary because of the mentioned reasons. In this chapter, after describing the problem, the problem identification will be discussed. In the last section of this chapter, the aim and purpose of this study will be explained.

## 1.1 Problem Description

A bank is a financial institution that accepts deposits from the public and creates credit. In any country, banks have the most critical role in its economy. After entering private banks in the financial market, public demands for different types of bank services grow. Therefore, banks try to use any method that can improve their efficiency to attract more customers. For that reason, evaluating the performance of banks is very important to detect the efficient and inefficient factors.

Following the Iranian revolution (1979), the government had no other choice but to make all banks run by the government, because of distrust of people and investors to the banks and financial institutes, the government had to create trust by guaranteeing the obligations of banks.

For this reason, the government-run banking system in Iran made by merging small private banks. However, the lack of competition among banks caused an inefficient banking system and dissatisfaction of customers and the government.

With worldwide changing economy, the growth of world trade, presence of international banks in neighbor countries, spread of internet and traveling out of borders caused banks and people to know more about the performance of the banks in other countries and their services to customers. The significant difference between Iranian banks and banks all over the world was revealed.

When the war between Iran and Iraq finished, Iran got more stability. In 1998, the government decided to begin to privatize bank sector. It was started by offering part of shares to the stock market. The process of privatizing banks done during years. Banks slowly offered their shares in the market.

After 18 years of starting privatization, currently there are 20 private banks, eight government banks, and 5 Interest-free banks. 16 out of 20 private banks founded by the private or public sector and the rest privatized by offering their shares in the stock market. As time passed, the number of private banks increase. The chart below shows the growth of private banks in Iran after starting the privatization program.

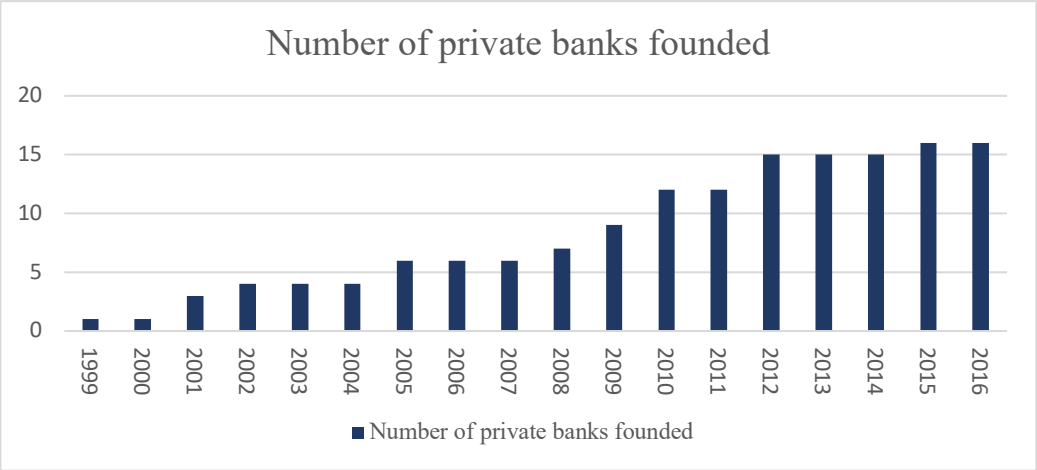

Figure 1.1: Number of Founded Private Banks per Year

One of the reasons that the number of private banks grows is because of different types of sanctions against Iran. After a wave of sanctions in 2006, the first banks that were sanctioned were government banks. In this era, private banks helped a lot in transferring money and trade with other countries.

## 1.2 Problem Identification

As the number of private banks increases, the competition between them getting harder. Therefore, evaluating the performance of these banks is critical to lead them to a better place.

Nowadays the owners of banks are looking for a trustable method to evaluate the performance of their banks to be sure that their strategies have appropriately executed, to know their place at present and make further plans.

The main problem in any bank or organization with many branches is what method should be used to evaluate correct performance. Owners using the proper evaluating method can put their resources into the essential targets of the organization. Proper performance evaluation helps owners, managers, and stuffs to know the weaknesses of their work and start to adapt necessary actions for improving performance.

In order to compare banks, because of the complexity of the banking system and variation of inputs and outputs, we need a method that can accept more than one input and output.

Data envelopment analysis (DEA) is a linear programming based non-parametric technique for evaluating the relative efficiency of homogeneous Decision-Making Units (DMU) based on multiple inputs and multiple outputs. There exist radial and non-radial models in DEA [1].

In this survey, we are trying to evaluate the efficiency of private banks in Iran. Evaluating the efficiency and assessing the performance will be done by DEA method over a five years period (2011-2015). The banks that reach better amounts of output giving a specific amount of input will be known as efficient banks and all other banks will be compared with each other.

One of the essential roles in any comparison is selecting criteria. many elements involved in the efficiency of any banks. Therefore, inputs and outputs should be selected carefully. In this case, inputs and outputs are selected by studying previous and similar research and using experts' opinions.

In any organization the amount of assets used is an essential criterion as an input. Number of branches and number of workers for each bank is the other inputs that are selected for this study. The main reason for existing any organization is to make a benefit. Therefore, the amount of benefit for each bank is a critical output. The other selected outputs are given facilities and total deposits. We will discuss more in the next chapter.

## 1.3 Aims and Scopes

In this study, we try to determine efficient and inefficient banks based on inputs and outputs and ranking them by efficiency. Every bank specifically will be studied, and the reasons for being an efficient or inefficient bank will be explained. The studied banks are compared, and analyzed by using the collected data and DEA method. Then, suggestions will be proposed to improve the performance of the inefficient banks. efficiency of programs, processes, and workers, is a sign of a pioneer organization.

In this study, after determining the general field, we started to study about different type of banks in Iran. Based on their importance and speed of growing in the market, we decided to study the private banks. In the next step, determining inputs and outputs based on previous studies and the view of experts was started. After That, the needed data extracted mostly by using annual reports of the banks under study.

In the next stage, data envelopment analysis (DEA) was used to analyze the given data (inputs and outputs) and rank banks by their efficiencies. At the end, we compare and analyze the results and suggest adjustments for improvements.

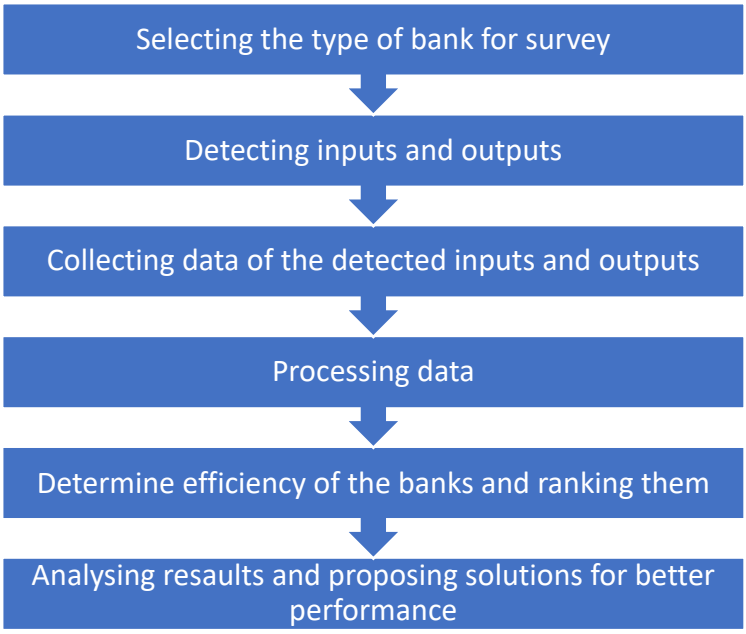

Figure 1.2: Stages of the Thesis

## 1.4 Structure of the thesis

So far in this report, a general view of the subject and the method that are used to solve this problem were described. In the next chapter, previous related studies will be reviewed. In chapter 3, the method that we used for this thesis is explained. In chapter 4, we will start to analyze and compare the results gained from chapter 3 to find efficient and inefficient banks and rank them. In the last chapter, we propose suggestions to improve the performance of the banks and make a conclusion.

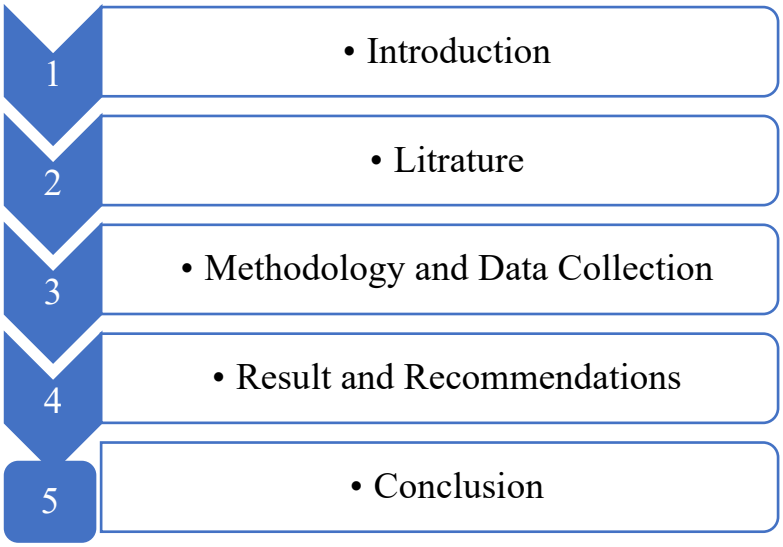

Figure 1.3: Structure of the Thesis

# Chapter 2

# LITERATURE

Evaluating performance issues have been considered for a long time by researchers. Without study and knowing the amount of progress and getting feedback about how applied strategies were effective, improving efficiency is not possible. All of these actions cannot be done without measuring and evaluating. For this reason, evaluate performance system is a must for any organization.

In the first section of this chapter, we will review different methods that previous researchers used in the banking industry. In the next section, we have a short history of DEA method. In the last section of this chapter, we study different types of DEA method used in previous researches.

## 2.1 Different types of methods used for evaluating efficiency

### 2.1.1 Stochastic Frontier Analyses (SFA)

In 2018, an article published by Mokhamad Anwar, about cost efficiency performance of Indonesian banks, after the economic crisis period in this country. The considered period is between 2002 and 2010, and the method has been used is stochastic frontier analysis (SFA) to estimate bank cost efficiency. In this paper, TOBIT regression is also used to reveal the determinants of Indonesian banks' cost efficiency [2].

There is an article written by Thiago Christiano Silva, Benjamin Miranda Tabak published in 2017 that compares two methods of evaluating efficiency. They

compare DEA method with stochastic Frontier model (SFA). The used data was collected from Chinese local banks. The primary purpose of this study is comparing a parametric and a non-parametric method. The result of this article is the similarity between DEA and SFA estimation for efficiency, but the difference in the bank-level estimations [3].

Yizhe Dong and Michael Firth et al., studied the performance of Chinese commercial banks in 2016. The selected period for this survey was between 2002 to 2013, and the used method was single frontier approach (SFA) as developed by Aigner, Lovell, and Schmidt (1977) to estimate cost and profit efficiencies. The result of their study was that the cost and profit efficiencies had improvements over time. Also, these banks are more profit-efficient than cost-efficient. However, foreign banks are the most cost-efficient and the least profit efficient. They conclude that the gap between domestic banks and foreign banks has gotten more after the World Trade Organization transition period (2007–2013) [4].

A study was done by Thi Lam Anh Nguyen in 2018 about Diversification and bank efficiency in six members of the Association of Southeast Asian Nations (ASEAN) countries in 2007-2014. The used method is Stochastic Frontier Approach (SFA). The criteria for this study are asset, funding, and income. The results show that more income-diversified banks have lower cost efficiency while more asset-diversified banks have only lower persistent cost efficiency. More funding-diversified banks caused higher profit efficiency, while more asset-diversified banks caused only higher persistent profit efficiency [5].

In 2017, Oscar Carvallo and Adnan Kasman, used SFA to determine the convergence of cost and profit efficiency in Latin American Banks. They surveyed banks in 19 Latin American and the Caribbean countries over the period 1999–2013[6].

In 2017, an article about comparing banking efficiency between EU members and candidate countries. They compared banks in ten South East European countries and find out how differences in efficiency are related to EU membership. the other issue that they concerned about is how the financial crisis in 2008 affect the banks' efficiency in these ten south east European countries. The used method in this article is SFA, and the conclusions are that the efficiency gap is closing because of adjustments of the less efficient banks. And during the financial crisis, the efficiency of south east European countries banks has been improved [7].

An article was published in April 2019, Mohamed Chaffai and Paolo Coccorese compared MENA (middle east and north African) banks with international banks. Their criteria are cost and revenue efficiency, and they compared banks in 52 countries in 2000-2012 period. They used stochastic meta frontier, made two models and identified two inefficiency components, managerial inefficiency, and technology inefficiency. The results show that banks costs could be reduced by 13%, while revenue could be increased by 17% if their banking systems [8].

### 2.1.2 Other Methods for Evaluating Efficiency

In February 2019, Christos Alexakis and Marwan Izzeldin worked on productivity in Islamic and conventional banks. They used Malmquist productivity index (MPI) to asses performance in this type of banks in Gulf Cooperation Council (GCC) countries. They mainly focus on the financial crisis period (2006-2012), and their criteria were financial ratios like cost, revenue, and profit. What they concluded is

that Islamic banks are not as good as conventional banks in term of cost performance, but share equal revenue performance with the conventional ones [9].

In March 2019, Xiang Chena and Tsu-Tan Fu studied profit inefficiency and productivity convergence between Taiwanese and Chinese banks. They believed that Malmquist productivity index has a problem because it cannot model the distance function with input contraction and output expansion. Therefore, they developed the difference based Luenberger productivity indicator (LPI) with the directional distance function. The duality between the directional distance function and the profit function provides the LPI to be a useful mean for performance assessment when profitability is the overall goal of firms [10].

In 2016, Abdul Rashid and Sana Jabeen worked on an article about comparing Conventional banks with Islamic banks in Pakistan. In this study, at first, they chose the determinants of performance by constructing the financial performance index (FPI) based on CAMELS' ratios. The used data was collected in 2006-2012 period. By using the GLS regression, the results show that conventional banks are better in operating efficiency, reserves, and overheads than Islamic banks, whereas deposits and market concentration are better in Islamic banks [11].

Sunil K.Mohanty and Hong-Jen Lin et al., surveyed comparing the efficiency of banks in Gulf Cooperation Council (GCC) countries. What they did was comparing cost and profit efficiencies of Islamic banks with that of conventional banks. They used heteroskedastic stochastic frontier (HSF) models to compare these banks in 6 countries membered in GCC. The results show that measures of cost and profit efficiencies of banks vary widely across the six Gulf countries over the same period.

Based on this survey, the essential factors in the efficiency of these banks are country-specific variables [12].

## 2.2 Different Types of DEA Method

### 2.2.1 Multi-Stage DEA

A study was done by Xiaoyang Zhouac and Zhongwen Xu in June 2019 about evaluating efficiency of banks under uncertainty. They used a multi-period DEA model in three stages: capital organization, capital allocation, and profitability. The selected banks for this study are inefficient in China over 2014 to 2016 period. Study in three stages helps the authors to identify efficiencies and weaker stages. The results show that or all the evaluated banks, the capital allocation stage performed relatively better, while the capital organization and profitability stages were relatively weak across the whole banking system [13].

In 2016, Fadzlan Sufian and Fakarudin Kamarudin researched about determinants of efficiency in the Malaysian banks. They used a two-stage method. In the first stage, they calculated the efficiency of individual banks during 1999-2008 by using bootstrap data envelopment analysis. In the next stage, they used bootstrap regression to find the effect of origins in banks efficiency. The results indicated that the efficiency of these banks improved during the period. Also, banks from Asian countries are more efficient in comparison to foreign banks [14].

There is an article published in 2017 by Hirofumi Fukuyama and Roman Matousek. In this article, they developed a bank network revenue function to evaluate banks' network revenue performance. They researched Japenese banks operating from 2000 to 2013. Two-stage network DEA was used for this survey and what they concluded is that these banks did not reach the optimal levels in their production process and

they suggested expanding the banks' activities in securities and other earning assets [15].

Another article was written in 2014 by Ke Wang and Wei Huang et al., about the efficiency of the Chinese commercial banking system. The used method in this paper is additive two-stage DEA, and they studied 16 major Chinese banks in 2003-2011. In this survey, the authors utilized network DEA to research selected banks. They believed that in order to detect the inefficiency of the banking system, two-stage DEA is more effective than conventional DEA. The results show that the overall efficiency of selected banks to research improved during the study period [16].

### 2.2.2 Bootstrapped DEA

An article published in 2018 by Filipa Da Silva Fernandes and Charalampos Stasinaks, they surveyed the efficiency of peripheral European domestic banks over 2007-2014. The used method is DEA-Double Bootstrapped Truncated Regression. They utilized data envelopment analysis on a Malmquist Productivity Index to evaluate efficiencies. After that, a Double Bootstrapped Truncated Regression is applied to obtain bias-corrected scores and examine whether changes in the financial conditions affect banks' efficiency levels differently. They concluded that higher levels of liquidity and credit risk exert a negative effect on banks [17].

A research was done in 2019 by Hien Thu Phan, Sajid Anwar at al., about competition and stability in East Asian commercial banks. They studied banks in 4 East Asian countries (China, Hong Kong, Malaysia, and Vietnam) in ten years starting in 2004. They used SFA, DEA, and Sub-sampling bootstrapped DEA. The results show that increased competition may result in a decrease in stability. Also, it

shows bank size, credit risk, and market concentration have a positive effect on stability [18].

In 2016, Chris Stewart and Roman Matousek et al., did a survey on efficiency in the Vietnamese banking system. They considered 48 Vietnamese banks in 1999-2009 period. They applied DEA and bootstrapped DEA in two stages. In the first stage, relative efficiency scores were determined. In the next stage, they bootstrapped the DEA scores with a truncated bootstrapped regression. They concluded that large banks are more efficient than smaller banks. Also, non-state-owned commercial banks are more efficient than state-owned commercial banks [19].

### 2.2.3 Network DEA

A study assessed management efficiency in Japanese regional banks. This study was done by Satoshi Ohsato and Masako Takahashi in 2015, and they used Network DEA because they believed that because of diversification in management situations in Japanese banks, simple DEA has limitations. Their aim for this study is evaluating the overall and divisional efficiencies of Japanese regional banks [20].

Peter Wanke and Carlos Barros researched Brazilian banks in 2014, using two-stage Network DEA. In the first stage, they measured cost efficiency by considering the number of branches and employees. In the next stage, they assessed productivity efficiency by equity and permanent assets. They compared 40 Brazilian banks in 2012. What they concluded is that Brazilian banks are heterogeneous. This means some of the banks are cost efficiency, and the others are productive efficiency [21].

### 2.2.4 Other Methods of DEA

In 2015, He-Boong Kwon and Jooh Lee did research on production modeling of large U.S. banks. They used a new method by combining DEA and back propagation

neural network (BPNN). They believed that two-stage DEA model lacks predictive capacity. Therefore, they developed this method to add predictive power [22].

In 2016, Peter Wanke  Md. Abul Kalam Azad et al., did research over 114 Islamic banks from 24 countries by using TOPSIS and neural networks in two stages. First, TOPSIS is used in a two-stage approach to assessing the relative efficiency of selected banks. Then, in the second stage, neural networks are combined with TOPSIS results as part of an attempt to produce a model for banking performance with effective predictive ability. The result of this study shows that variables that are related to country and cost structure are very useful in efficiency [23].

In March 2018, Meiqin Wu and Changhong Li et al., surveyed the global productive efficiency of Chinese banks. They used DEA cross-efficiency method to evaluate 16 Chinese commercial banks' performance between 2007-2014. Also, a model named VIKOR aggregates used to measure the productive efficiency of the selected banks. This model helps to compare the solution with the attitude index, which ranks all of the banks. The results indicate that the cross-efficiency interval can provide more information than the traditional DEA model, that the banking system efficiency of China has been improved during the study period [24].

## 2.3 DEA in Other Researches

Because of the ability of DEA method for accepting multiple input and output, it is a common way to evaluate bank efficiencies all over the world. Table 2.1 shows how authors chose their factors as inputs and outputs. Because of popularity of DEA method, many researchers use this method to evaluate banking system’s efficiency.

Table 2.1: Recent researches using DEA method

| Authors | Year Published | Country | Number of researched banks | Inputs | Outputs |
|---|---|---|---|---|---|
| -Simona Alfiero -Alfredo Esposito -Emmanuel Kwasi Mensah -Mehdi Toloo [25] | 2019 | Europe | 250 | -Employees -Assets -Equity -Personnel Expenses | -Deposits Banks -Loans -Net income revenue -Net fees commission |
| -Ning Zhu -Jens Leth Hougaard -Zhiqian Yu -Bing Wang [26] | 2019 | China | 16 | - Operational expenses | -Non-performing loans - Interest income -Non-interest income |
| -Iago Cotrim Henriques -Vinicius Amorim Sobreiro -Herbert Kimura [27] | 2018 | Brazil | 37 | -Fixed assets -Total deposits -Personnel expenses | Total loans |
| Rachita Gulati Sunil Kumarb [28] | 2016 | India | 76 | -Price of physical capital -Price of labor -Price of loanable funds | -Advances -Investments -Non-interest income |
| -Ovidiu Stocia -Seyed Mehdian -Alina Sargu [29] | 2015 | Romania | 24 | -Deposits -Total cost -Employees -Owned equipment | -Net total revenues -Daily average rate |
| -Amir Moradi Motlagh -Alperhan Babacan [30] | 2015 | Australia | 8 | -Interest expense -Non-interest expense | -Interest income -Non-interest income |
| Efehan Ulas Burak Keskin [32] | 2015 | Turkey | 47 | -No. of branches -No. of employees -Total assets | -Total deposit -net profit -Net interest income |

Table 2.1 (continued)

| Authors | Year Published | Country | Number of researched banks | Inputs | Outputs |
|---|---|---|---|---|---|
| Iveta Řepková [33] | 2014 | Czech | 11 | -Labor<br>-Deposits | -Loans<br>-Net interest income |
| Emília Zimková [34] | 2014 | Slovakia | 16 | -Employees<br>-Deposits<br>-Fixed assets | -Earning assets |
| -Romzie Rosman<br>-Norazlina Abd Wahab<br>- ZairyZainol [35] | 2014 | Middle Eastern and Asian | 79 | -Deposits<br>-Fixed assets<br>-Personnel expenses | -Loans<br>-Earning asset |
| Georgios E. Chortareas Claudia Girardone AlexiaVentouri [36] | 2012 | Europe | 22 | -Personnel expenses<br>-Total fixed assets<br>-Deposits | -Total loans<br>-Total other earning assets<br>-Fee-based income |
| -Hirofumi Fukuyama<br>-Roman Matousek [37] | 2011 | Turkey | 25 | -Employees<br>-Capital<br>-Deposits | -Securities<br>-Loans |
| -Qiang Deng<br>-Wai Peng Wong<br>-Hooy Chee Wooi<br>-Cui Ming Xiong [38] | 2011 | Malaysia | 12 | -Branches<br>-Staff<br>-Deposits | -Loans<br>-Profit |
| -Roberta B.Staub<br>-Geraldoda Silva e Souzab<br>-Benjamin M.Tabak [39] | 2010 | Brazil | 127 | -Interest expenses<br>-Operational expenses<br>-Personnel expenses | -Investments<br>-Total loans<br>-Deposits |
| -Rajiv D.Banker<br>-HsihuiChang<br>-Seok-Young Lee [40] | 2010 | Korea | 14 | -Yearly deflated interest revenue<br>-Yearly deflated other operating revenue | -Yearly deflated interest expense<br>-Yearly deflated other operating expense |

Table 2.1 (continued)

| Authors | Year Published | Country | Number of researched banks | Inputs | Outputs |
|---|---|---|---|---|---|
| -Tyrone T.Lin -Chia-Chi Lee -Tsui-Fen Chiu [41] | 2009 | Taiwan | 117 | -Employees -Interest expense -Deposits -Current deposit | -Loans -Earning -Revenue -Interest revenue |
| -Göran Bergendahl -Ted Lindblom [42] | 2008 | Sweden | 88 | -Credit losses -Personnel expenses -Non-interest expenses | -Loan -Deposit -Other earning assets |
| Olena Havrylchyk [43] | 2006 | Poland | 31-52 | -Deposits -Fixed assets -Labor | -Loans -Treasury bonds -off-balance items |
| -Xiaogang CHEN -Michael SKULLY -Kym BROWN [44] | 2005 | China | 43 | -Interest expenses -Non-interest expenses -Price of deposits -Price of capital | -Loans -Deposits -Non-interest income |
| -George E.Halkos -Dimitrios S.Salamouris [45] | 2004 | Greek | 20 | -Interest expenditures -Total assets -Employees -Operating expenditures | -Interest Income -Net Profit |
| -Chiang Kao -Shiang-Tai Liu [46] | 2004 | Taiwan | 24 | -Total deposits -Interest expenses -Non-interest expenses | -Total Loans -Interest Income -Non-Interest Income |
| -Leigh Drake -Maximilian J.BHall [47] | 2003 | Japan | 145 | -General and administrative expenses -Fixed assets -Retail and wholesale deposits | -Total loans -Liquid assets and other investments -Other income |
| Milind Sathye [48] | 2002 | Australia | 29 | -Labor -Capital -Loanable funds | -Loans -Demand Deposits |

# Chapter 3

# METHODOLOGY

This chapter contains three sections. In the first section, we have a review on DEA method, its advantages and CCR model. Then, the inputs and outputs characteristics for this thesis are explained. In the last section, the collected data in a table form is shown.

## 3.1 Data Envelopment Analysis

Measuring efficiency had been considered all the time by researchers because of its importance in evaluating the performance of any organization. In 1957, Farrell used a non-parametric method for assessing a small factory. Later on, Charnes et al[49] developed the Farrells' theory and presented a model named Data Envelopment Analysis. In recent years in many countries all over the world in order to evaluate performance and other common activities in different fields, different functions of DEA have been seen.

The reason for the popularity of this method in comparison to other methods is the possibility of studying complicated connections and mostly unknown between multiple inputs and outputs that usually exist in studied issues. DEA gives the possibility to reconsider the problems that have been solved before in other ways. For example, the possibility of assessment using this method to detect inefficient sources in high-profit companies.

DEA is based on a series of improvement using linear programming. In this method efficiency curve is formed by points that are produced by linear programming. To determinate these points constant return to scale or variable return to scale can be used. After some improvements, linear programming determines that if selected Decision-Making Unit (DMU) is placed on the efficiency curve or not. In this way, efficient and inefficient DMUs separated.

### 3.1.1 Advantages and Disadvantages

Some of the advantages of DEA, as listed by Bhat et al. [50], are as follows:

- It can handle multiple inputs and multiple outputs
- It is unnecessary to have an assumption of a functional form relating inputs to outputs
- DMUs are directly contrasted against a contemporary or combination of contemporaries
- Inputs and outputs do not need to have similar units

Meanwhile, once again according to Bhat et al[50]., the disadvantages are:

- Results are sample specific
- Since it is an extreme point technique, measurement error can cause noteworthy problems
- It can tell you how well you are doing compared to your peers but not compared to a theoretical maximum
- It is a non-parametric technique, thus, statistical hypothesis tests are difficult
- Large problems can be computationally intensive because a standard formulation creates a separate LP for each DMU

### 3.1.2 CCR Model

CCR model is the basic DEA model as introduced by Charnes et al. (1978)[49]. This model was modified by Banker et al. (1984) and became the BCC model which accommodates variable returns to scale. The CCR model presupposes that there is no significant relationship between the scale of operations and efficiency by assuming constant returns to scale (CRS) and it delivers the overall technical efficiency. The CRS assumption is only justifiable when all DMUs are operating at an optimal scale. However, firms or DMUs in practice might face either economies or diseconomies to scale. Thus, if one makes the CRS assumption when not all DMUs are operating at the optimal scale, the computed measures of technical efficiency will be contaminated with scale efficiencies.

Every multiple for inputs, produce the same multiple for outputs. If input X produces output Y, then Input λX Produces λY for λ>0. In the other words, if point (X,Y) is feasible, then (λX, λY) is feasible. If input X produce output Y, then input λX produce output λY for λ>0 and efficiency ratio for (X,Y) and (λX, λY) is identical. Therefore, any changes in inputs results in the same changes for outputs which means increasing in inputs does not cause saving or increasing costs. CCR model uses constant return to scale. For variable return to scale, any multiple for inputs can produce more or less in outputs. When increasing in outputs is more than increasing in inputs, the return to scale is increasing and when increasing in outputs less than increasing in inputs, return to scale is decreasing.

For the CCR model, it is of the assumption that there are *n* DMUs to be evaluated, of which each DMU consumes varying amounts of *m* different inputs to produce *s* different outputs. Particularly, $DMU_j$ consumes $x_{ij}$ amount of input *i* and produces $y_{rj}$ amount of output *r.* Furthermore, it is of the assumption that $x_{ij} \geq 0$ and $y_{rj} \geq 0$,

and that each DMU has at least one positive input and one positive output value. In the ratio-form of DEA, the ratio of outputs to inputs is used to measure the relative efficiency of the $DMU_j = DMU_o$ to be evaluated relative to the ratios of all the $j$ = 1, 2, …, $n$ $DMU_j$. The CCR construction can be interpreted as the reduction of the multiple-output/multiple-input situation (for each DMU) to that of a single 'virtual' output and 'virtual' input. In mathematical programming speech, this ratio, which is to be maximized, forms the objective function for the particular DMU being evaluated, so that symbolically:

$$\max h_o(u, v) = \sum_r u_r y_{ro} / \sum_i v_i x_{io} \qquad (3.1)$$

in which the variables are the $u_r$'s and the $v_i$'s, while the $y_{ro}$'s and $x_{io}$'s are the observed output and input values of $DMU_o$, which is the DMU to be evaluated. Without further additional constraints, displayed below, (1.1) is unbounded. A set of normalizing constraints, of which there is one for each DMU, reflects the condition that the virtual output to virtual input ratio of every DMU, including $DMU_j = DMU_o$, should be less than or equal to unity. As such, the mathematical programming problem may be stated as:

$$\max h_o(u, v) = \sum_r u_r y_{ro} / \sum_i v_i x_{io} \qquad (3.2)$$

subject to

$\sum_r u_r y_{rj} / \sum_i v_i x_{ij} \leq 1$ for $j$ = 1, …, $n$

$u_r, v_i \geq 0$ for all $i$ and $r$

The transformation for linear fractional programming selects the solution $(u, v)$ for which $\sum_{i=1}^{m} v_i x_{io}$ = 1, and produces the equivalent LP problem in which the change of variables from $(u, v)$ to $(\mu, \nu)$ is a result of the Charnes-Cooper transformation[49]:

$$\max \; z = \sum_{r=1}^{s} \mu_r y_{ro}$$

$$S.t. \quad \sum_{i=1}^{m} v_i x_{io} = 1$$

$$\sum_{r=1}^{s} \mu_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} \le 0 \quad j = 1,...,n$$

$$\mu_r \ge 0 \quad r = 1,...,s$$

$$v_i \ge 0 \quad i = 1,...,m$$

$$\max z = \sum_{r=1}^{s} \mu_r y_{ro}$$

subject to

$$\sum_{r=1}^{s} \mu_r y_{ro} - \sum_{i=1}^{m} v_i x_{ij} \le 0 \qquad (3.3)$$

$$\sum_{i=1}^{m} v_i x_{io} = 1$$

$$\mu_r, v_i \ge 0$$

for which the LP dual problem is:

$$\theta^* = min\theta$$

subject to

$$\sum_{j=1}^{n} x_{ij}\lambda_j \le \theta x_{io} \qquad i = 1, 2, \ldots, m; \qquad (3.4)$$

$$\sum_{j=1}^{n} y_{rj}\lambda_j \ge y_{ro} \qquad r = 1, 2, \ldots, s;$$

$$\lambda_j \ge 0 \quad j = 1, 2, \ldots, n;$$

## 3.2 Inputs and Outputs Characteristics

### 3.2.1 Inputs

#### 3.2.1.1 Number of Employees

Cost of human resources in banks is a considerable part of bank costs. Determination exact amount of these costs in each bank included personnel's salaries is difficult and complicated. For this reason, in this thesis, instead of using cost of employee, number of employees is used. This factor determined as an input.

#### 3.2.1.2 Number of Branches

One of the most important factors in cost and efficiency for banks is the number of branches. Increasing number of branches cause attracting more customers and transactions but on the other hand, add a new branch has a lot of costs for banks. Although nowadays electronic banking has been extended, lots of banking transactions needed to be done in bank branches and existing branches is necessary for banks and customers.

#### 3.2.1.3 Total Assets

Assets, based on economic science, is every properties and rights that have a monetary value. Some of the assets are objectives, like lands, buildings, facilities, equipment, vehicles, assets in a storehouse, or cash. Alternatively, it can be financial rights.

Also, assets are divided into two general groups. Current assets are the items that are expected in a year on any time to turn into cash, consumed or sold. Usually, current assets categorized by the period needed to turn to cash. For example, funds, office equipment, debtors, inventory are current assets. The other type of assets is fixed assets that usually have a long life. Like lands, buildings, facilities, machinery, and equipment, vehicles. For this type of assets always depreciation cost is considered (except land).

### 3.2.2 Outputs

#### 3.2.2.1 Total Deposit

Deposit is money that is paid to banks by a natural or juridical person under specific circumstances. Banks use this collected money to pay as a loan to intrapreneurs, industries, business owners, and generally any applicant. One of the main goals of

any banks is attracting more deposits. In this thesis, we consider total deposits as an output.

#### 3.2.2.2 Net Annual Profit

Net annual profit is gained profit in an accounting period time, which is calculated by subtracting costs and taxes from total income. Being positive or negative, this amount depends on the performance of the considered system. This factor is an output in this study.

#### 3.2.2.3 Bank Facilities

Banks are specialized in providing financing to their customers, and the various options offered in the market, for example overdraft services, deferred payment plans, lines of credit, revolving credit, term loans, letters of credit, and swingline loans. This factor is considered as an output in this thesis.

## 3.3 Collected Data

The needed data for inputs and outputs, were extracted mostly from banks annual reports. In table a in appendix 1 (page 63) the data for 15 banks in 5 years have been shown.

# Chapter 4

# RESAULTS AND ANALYSES

After reviewing previous studies in this filed and acquainting with expert's opinions, we select inputs and outputs for this study. Then, we collect the needed data to evaluate 15 private bank efficiencies during Iran in a five years period between 2011-2015. All the data extracted from annual reports from each bank. The collected data is shown in appendix 1.

## 4.1 Bank efficiencies

In this chapter, we start analyzing the collected data using DEA method. The data have been analyzed by PIM-DEA software. The efficiencies of the banks are shown in table 4.1.

Table 4.1: Efficiencies of the researched banks

| No | Name | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|
| 1 | Mellat | 67.21 | 73.75 | 64.22 | 100 | 61.18 |
| 2 | Tejarat | 61.24 | 64.95 | 58.65 | 53.4 | 55.04 |
| 3 | Saderat | 45.4 | 50.84 | 45.44 | 42.93 | 48.37 |
| 4 | Parsian | 100 | 100 | 86.88 | 84.09 | 90.88 |
| 5 | EghtesadNovin | 100 | 99.62 | 93.39 | 88.99 | 82.65 |
| 6 | Pasargad | 91.4 | 100 | 92.63 | 85.34 | 100 |
| 7 | Karafarin | 78.4 | 79.13 | 72.36 | 68 | 75.41 |
| 8 | Sarmaye | 58.37 | 76.91 | 65.66 | 52.5 | 68.46 |
| 9 | Shahr | 80.66 | 89.51 | 81.53 | 76.29 | 94.03 |
| 10 | Saman | 82.46 | 90.05 | 88.16 | 82.54 | 86.39 |
| 11 | Sina | 72.88 | 75.93 | 65.79 | 69.02 | 67.68 |
| 12 | Ghavamin | 100 | 100 | 79 | 77.32 | 84.27 |
| 13 | Ansar | 74.49 | 80.93 | 74.21 | 65.15 | 63.64 |
| 14 | Iran Zamin | 77.56 | 26.94 | 13.19 | 9.02 | 9.05 |
| 15 | Khavar miane | 100 | 100 | 63.42 | 97.45 | 71.66 |

In order to rank the banks by their efficiencies, we calculate the average of efficiencies for each bank for 5 years and then we ranked them by average efficiency. Pasargad Bank is the most efficient bank among the researched banks by 93.87% efficiency in average. Eghtesad Novin Bank and Parsian bank are second and third bank in ranking with similar results, 92.93% and 92.37% respectively. The results are shown in figure 4.1:

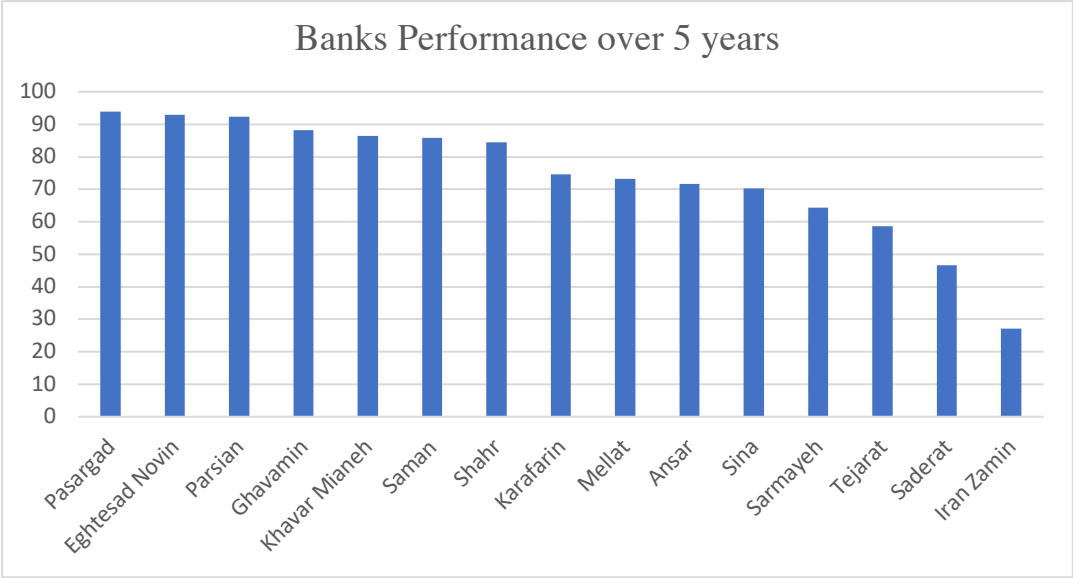


Figure 4.1: Ranking banks by their efficiencies

By using table 4.1 we can find the number of efficient and inefficient banks, and categorize them by the amount of their efficiencies. Most of the banks have more than 90% efficiency, and only 4 out of 75 DMUs have efficiency less than 50%. The results are shown in figure 4.2.

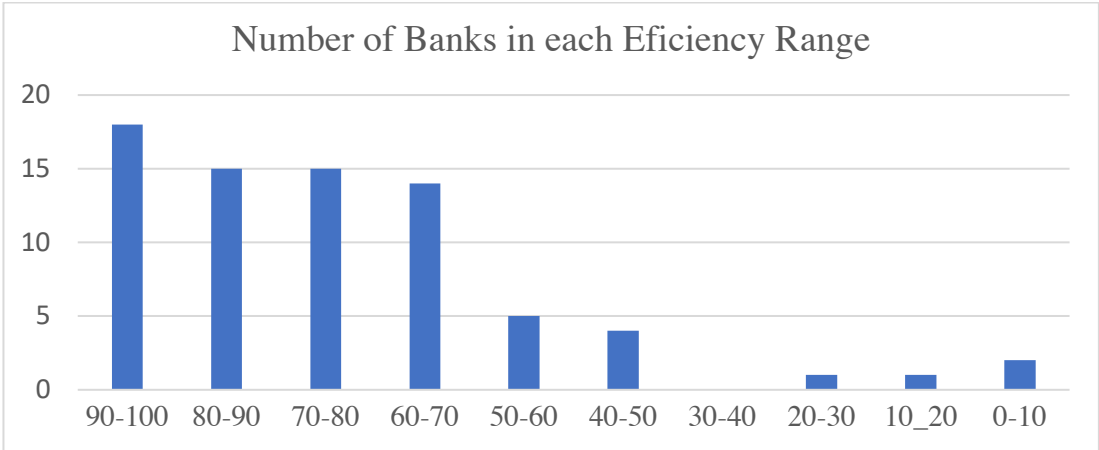


Figure 4.2: Number of Banks Based on Their Efficiencies

The charts below show the efficiency of each bank during the five years. These banks selected as samples. As you can see, most of the banks improved their

efficiencies during the study period, Except for Iran Zamin bank. 10 out of 75 DMUs are 100% which means 10 banks in different years were efficient banks.

- Bank Mellat

Mellat Bank was founded from merging 10 commercial banks after Iran revolution, started privatizing in 2009. This bank is the biggest private bank in Iran based on assets. As it is shown in figure 4.3, two years after starting privatization this bank started to improve its performance. In the fourth year, this bank was an efficient bank but in the last year of the period, efficiency decreased. We will find the reason for this problem in the next chapter.

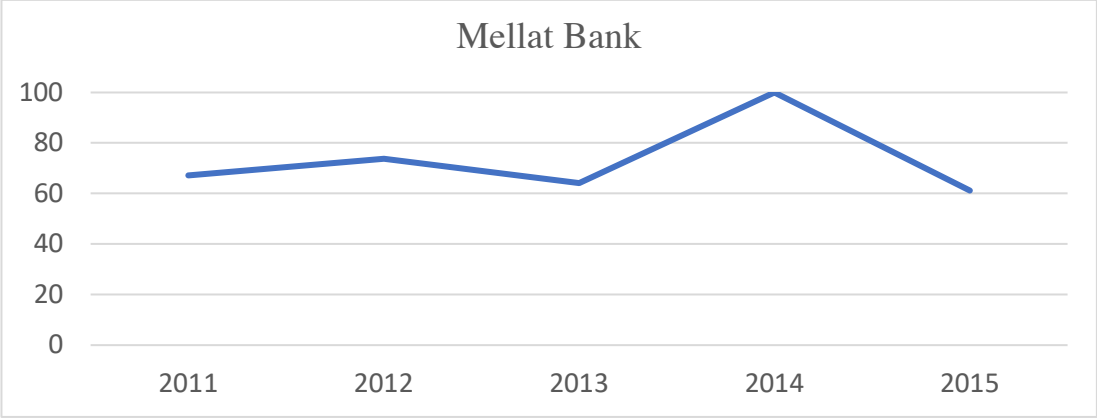


Figure 4.3: Bank Mellat Efficiency

- Tejarat Bank

Tejarat bank is the first Iranian bank founded in 1887. In the beginning, this bank is named Shahi bank and after Iran revolution, it changed to Tejarat bank. This bank started to privatization from 2009. Figure 4.4 demonstrated the performance of this bank during a period, you can see that the efficiency of this bank slightly changed each year, but it still far away from an efficient bank. The average efficiency is 58.65%.

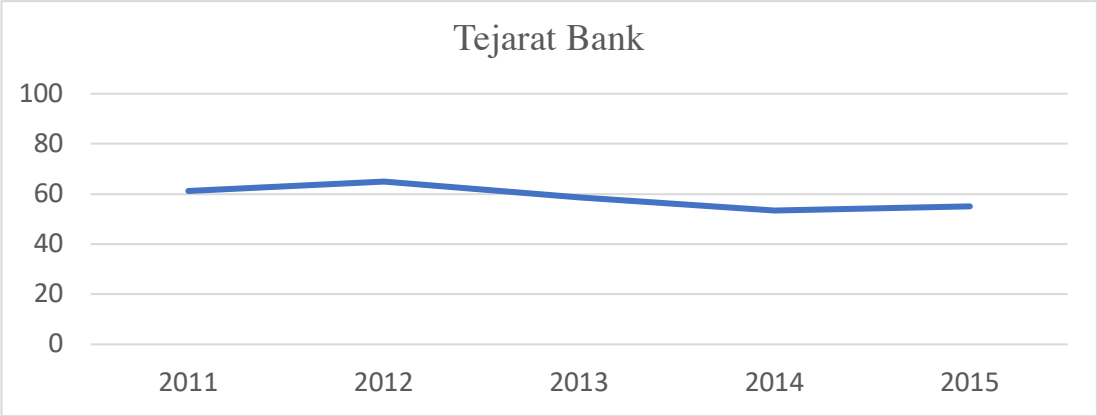

Figure 4.4: Bank Tejarat Efficiency

- Bank Saderat

Bank Saderat is the first in number of branches, founded in 1952. This bank has been privatized starting 2008. in figure 4.5 you can see that efficiency did not change a lot, and it is far away from an efficient bank.

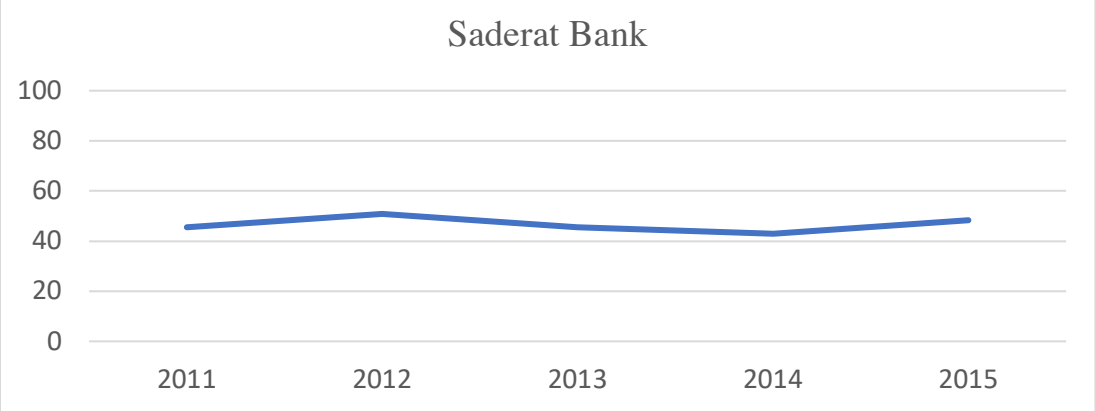

Figure 4.5: Bank Saderat Efficiency

- Parsian Bank

Parsian Bank founded in 2001 and started working 2002, is the second private bank in Iran. This bank is one of the three banks that can turn to an efficient bank in the last year of the period. The efficiency was 100% in 2011 and 2012, but it decreased in 2013. The efficient amount for inputs will be proposed in the next chapter.

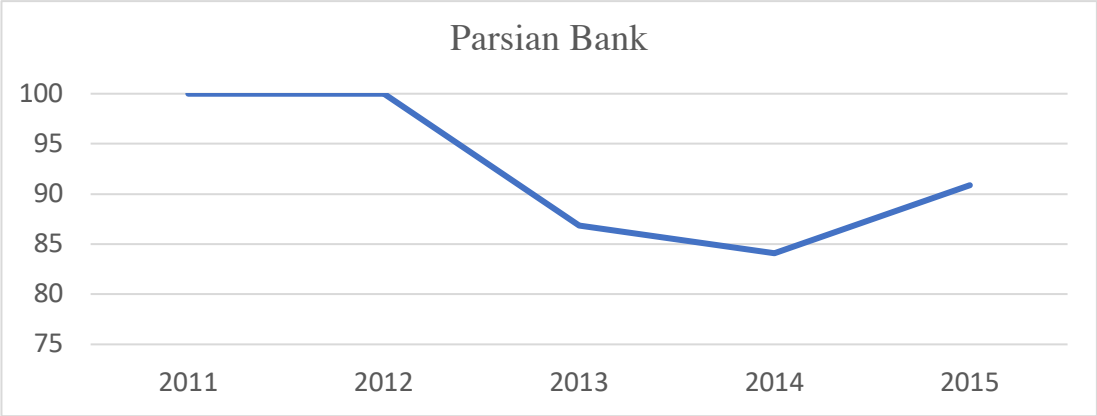

Figure 4.6: Parsian Bank Efficiency

- Bank Iran Zamin

Bank Iran Zamin got the last place in the bank ranking in figure 4.7, with 27.15% average efficiency in the period. This bank founded by giving permission to a financial institute, named Mola Al Movahedin Financial institutions, to promote as a bank in 2011. As you can see in table 1 in appendix 1 (page 63), this bank had minus value in annual net profit in the last three years of the period. This is one of the main reasons for the low efficiency of this bank.

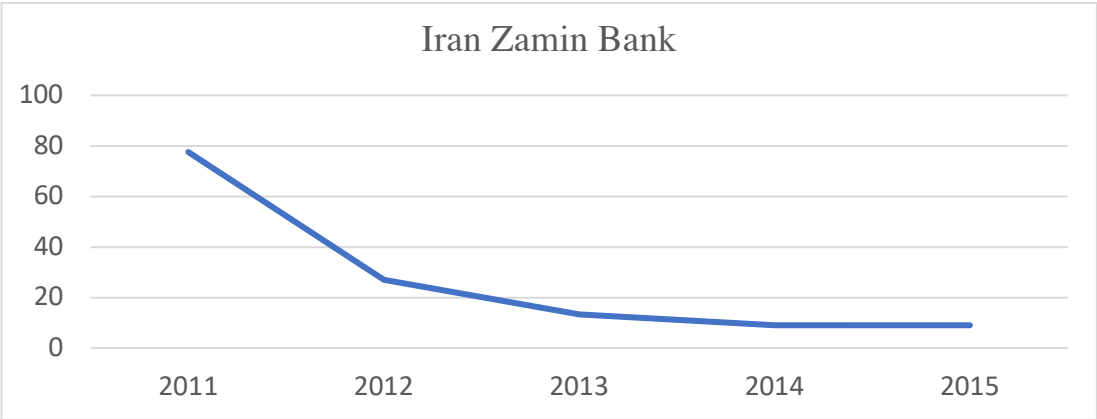

Figure 4.7: Bank Iran Zamin Efficiency

- Bank Ghavamin

Bank Ghavamin founded in 2000 as a financial and credit institution. Ghavamin Bank is the first bank in the country with the aim of helping to enhance the living quality and financial support of working staff of Iran police forces. Figure 4.8 demonstrates that this bank was efficient in 2011 and 2012, but it decreased significantly in 2013.

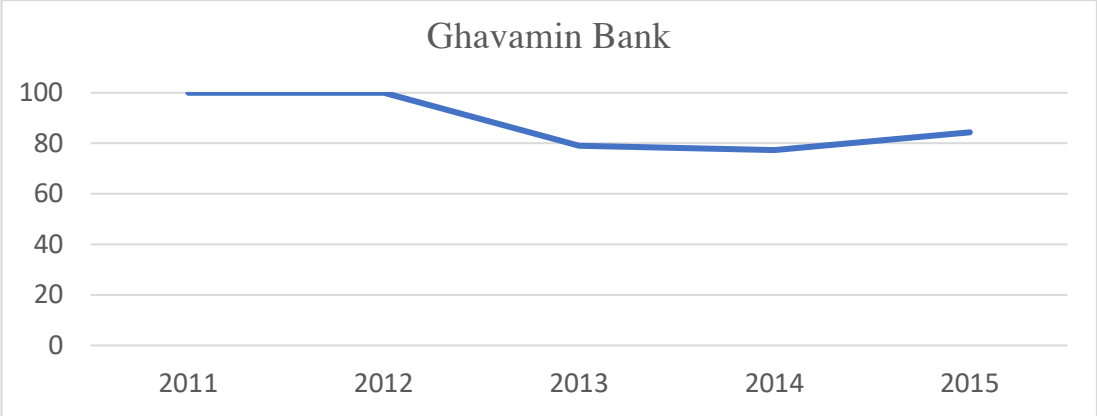


Figure 4.8: Bank Ghavamin Efficiency

- Eghtesad Novin Bank

Eghtesad Novin Bank is the first private bank in Iran Founded in 2001. This bank had an overall improvement in performance and it is very close to being an efficient bank. This banks efficiency slightly decreased during 5 years.

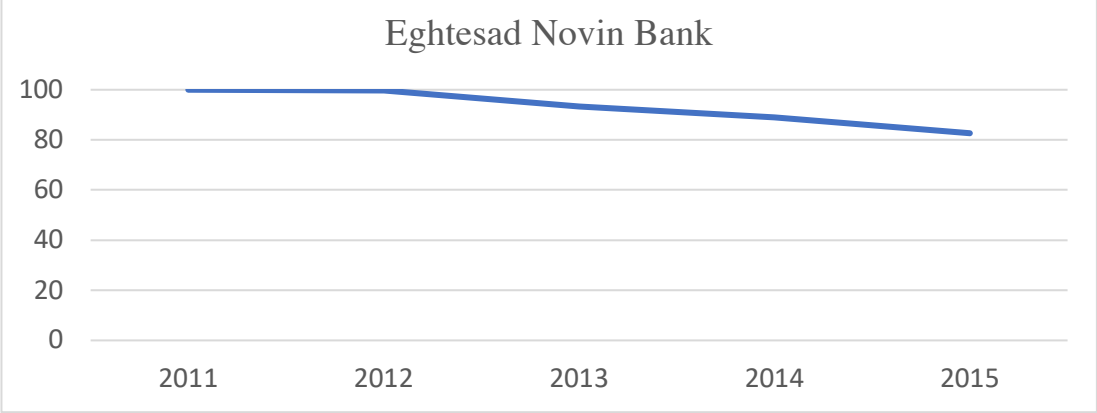


Figure 4.9: Eghtesad Novin Bank Efficiency

- Bank Pasargad

Bank Pasargad unlike the previous banks, started working as a complete private bank in 2006. Figure 4.10 demonstrates this bank was an efficient bank in 2012 and 2015, but efficiency decreased in 2013 and 2014.

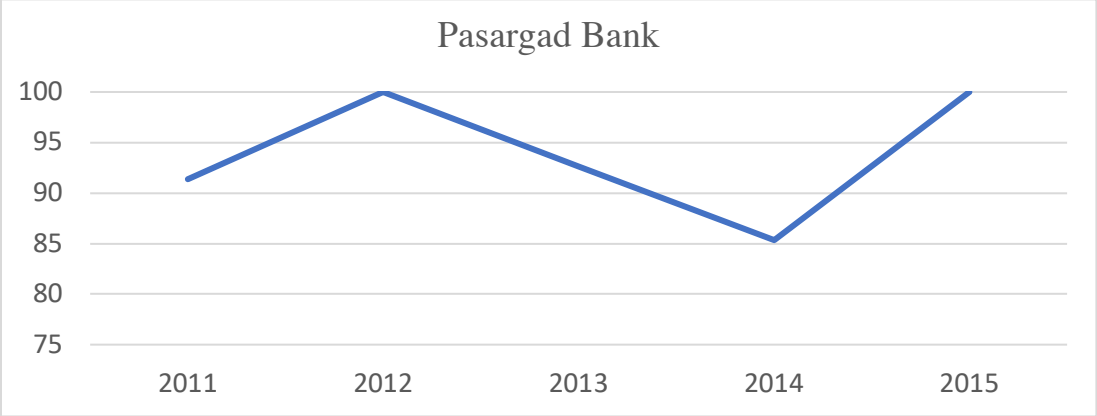


Figure 4.10: Bank Pasargad Efficiency

- Karafarin Bank

Karafarin bank, which is translated to Entrepreneurship Bank established in 2001 is one of the leading banks in this section. As it is shown in figure 4.11, this bank still far away from an efficient bank and during these years it has not been improved.

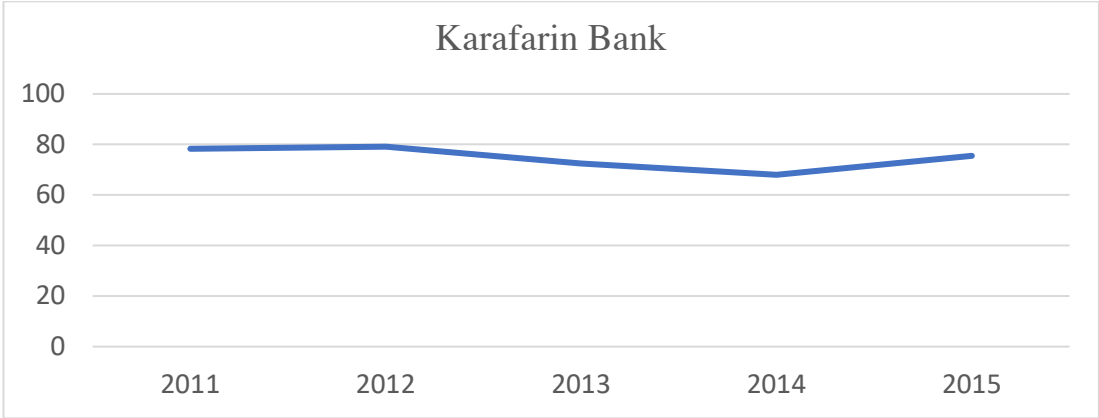


Figure 4.11: Karafarin Bank Efficiency

- Sarmayeh Bank

Sarmayeh Bank is the sixth private bank in Iran founded in 2005. Efficiency in the first year was 58.37%, and it have been changed during the period. Efficient amount of inputs to be an efficient bank will be proposed in the next chapter.

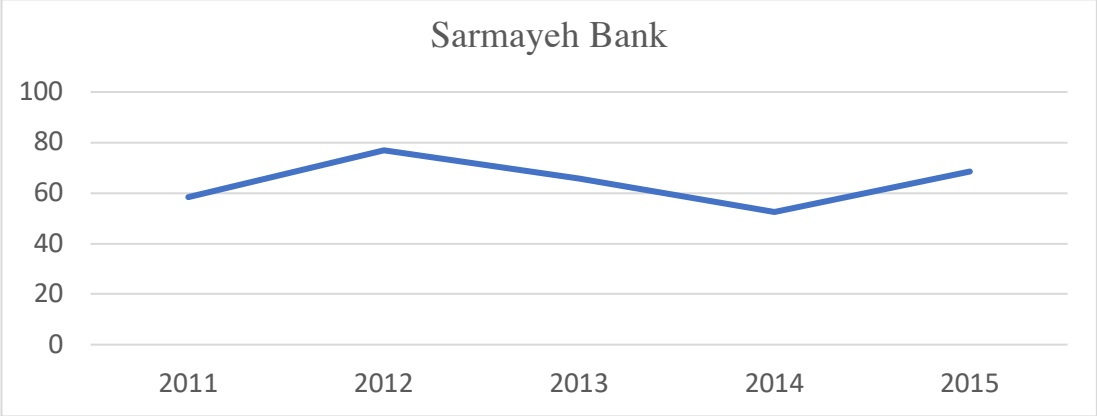


Figure 4.12: Sarmayeh Bank Efficiency

- Shahr Bank

Shahr Bank founded in 2009 by Tehran municipality. Most of the shareholders are the municipality of big cities in Iran. Figure 4.13 demonstrates that this bank had significantly improved during five years. Shahr bank became an efficient bank in the last year of the period. The efficiency in 2011 was 80.66% and they could reach to 94.03% in the last year.


Figure 4.13: Shahr Bank Efficiency

- Saman Bank

This bank started its activities as a Credit Institution in September 1999. Subsequently, on August 2002, it received a full banking license and changed its name to Saman Bank. This bank's efficiency was 82.46% in the first year, and it did not change much during the period, they could manage to keep the efficiency more than 80%. The needed changes will be proposed in the next chapter.

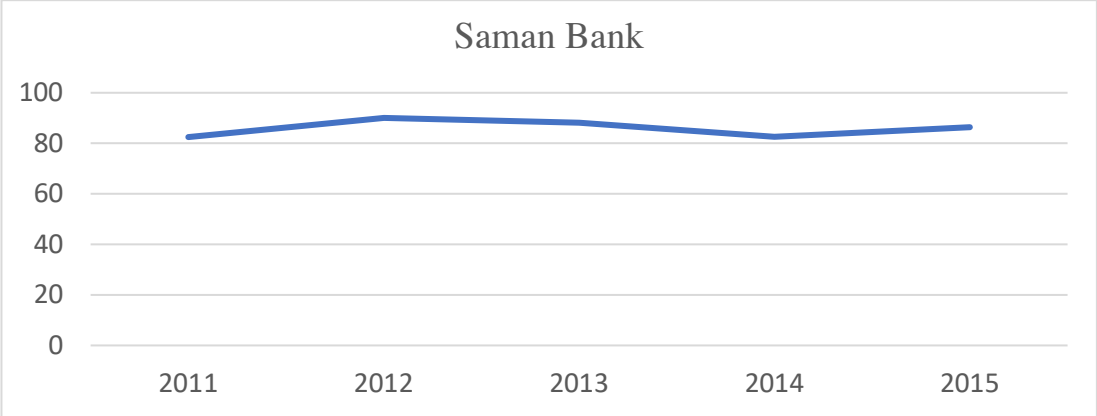


Figure 4.14: Saman Bank Efficiency

- Sina Bank

This bank did not have a lot of changes in its efficiency during the period. all the efficiencies for this bank were between 60% to 80%. Efficient amount of each input will be suggested in the next chapter.

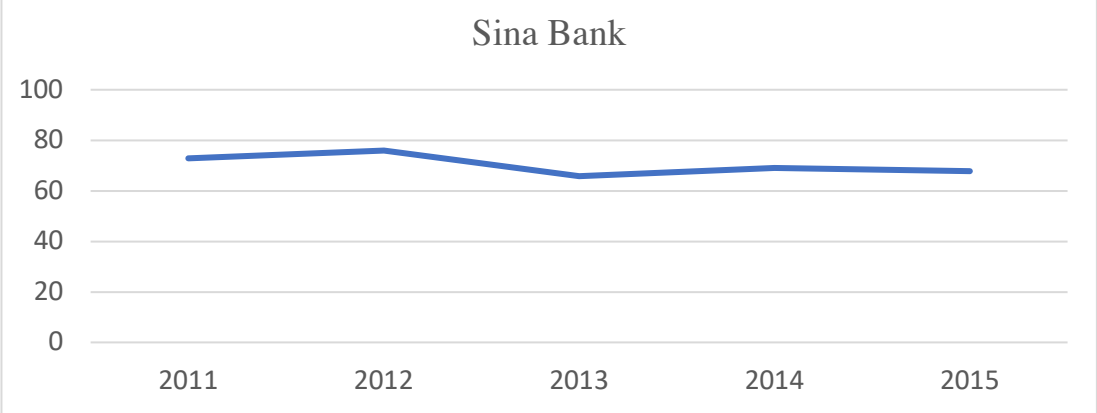


Figure 4.15: Sina Bank Efficiency

- Ansar Bank

Ansar bank had improvements during the study period. This bank was 74.49% efficient in the first year, it improved next year but the efficiency decreased in the last three years.

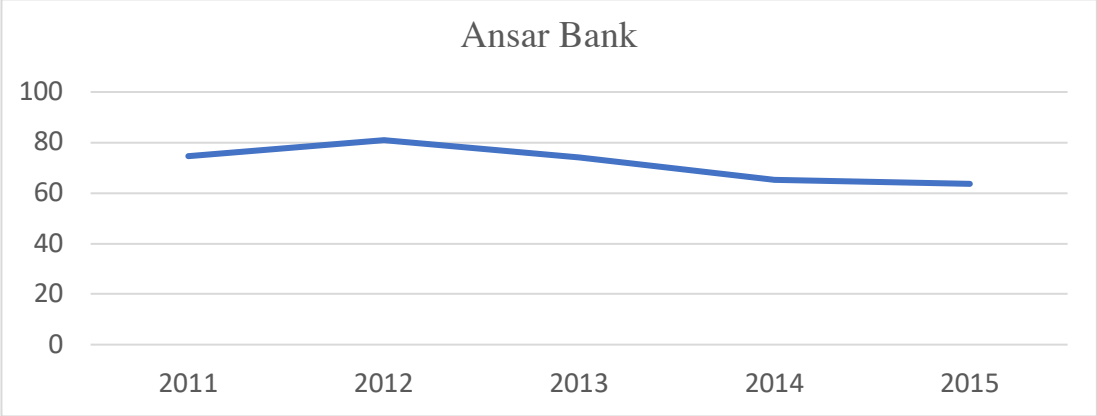


Figure 4.16: Ansar Bank Efficiency

## 4.2 Detect Significant Input Indexes

After an overall analysis on the results, we try to find out which input (number of employees, number of branches and total assets) has more effect on the efficiency of each bank. There are two ways to solve this problem. The first method is using weights of each input indexes and their averages. The other method is eliminating an input and get the results with the remaining two input. And repeat the test for all three inputs. Then we compare the result to see which input has more effect on the efficiencies of the banks. First, we use weights to detect the most effective input.

### 4.2.1 Weights Method

in this method, we collect weights of each DMU for a specific input, calculate average and compare the results for all three inputs. Based on table 2 shown in appendix 2, the results are shown in table 4.2.

Table 4.2: Comparing weights of the inputs

| Number | Input 1 | Input 2 | Input 3 |
|---|---|---|---|
| Name | No. of Employees | No. of Branches | Total Assets |
| Total weights | 367.93 | 264.89 | 950.36 |
| Average | 4.90 | 3.53 | 12.67 |

By looking at the results, we can see that the average weights for input 3 is much higher than the others. The averages for input 1 and 2 are nearly close. Which means the effect of input 3 (total asset) is more than input 1 and input 2. To verify the result, we test by another method mentioned before.

### 4.2.2 Eliminate Inputs Method

In this method, we eliminate one input and get results with the remaining two inputs. We repeat the test three times and each time, we eliminate an input to see the effect of that input on the results. Table 4.3 is a sample of how the calculation is done.

Table 4.3: Sample of calculating for detecting significant indexes

| Name | Efficiency | Efficiency without input 1 | Difference |
|---|---|---|---|
| DMU01 | 40.21 | 42.31 | 2.1 |
| DMU02 | 30.71 | 36.25 | 5.54 |
| DMU03 | 21.33 | 25.31 | 3.98 |
| DMU04 | 76.95 | 77.54 | 0.59 |
| DMU05 | 67.05 | 74.34 | 7.29 |

As it is shown in table 4.3, we eliminate input 1 and do the calculations by input 2, input 3 and the same three output. After calculating without input 1, we calculate the difference between the efficiency with all three inputs and the efficiency with just input 2 and input 3 without input 1. Then, we calculate total differences and average difference for all DMUs. As it is shown in table 4.4, when we eliminate input 1 and do the test with two remaining inputs, each DMU has an increase in efficiency 7.73% on average. We recalculate efficiencies for each DMU but this time, we eliminate

input 2 and use input 1 and input 3. This time, the efficiency of each DMU increase by 2.39% averagely.

Table 4.4: Comparing the effect of each input on efficiency

| | without Input 1 | without Input 2 | without input 3 |
|---|---|---|---|
| Total Difference | 575.55 | 160.17 | 1850.88 |
| Average | 7.67 | 2.13 | 24.67 |

We do the same calculations without input 3 and with input 1 and input 2. As you can see in table 4.4, the amount of change in each DMU is 22.58% averagely, which is much higher than the results without input 1 and results without input 2. This means that the effect of input 3 on the efficiency is much higher than the two other inputs. In other words, if we increase the amount of input 3, we get more improvement in efficiency than the two other inputs.

This method approved the previous method's result in section 2.1. after detecting the most significant input index, we will find the most significant output index in the next section.

## 4.3 Detect Significant Output Indexes

It is one of the main factors for any organization to know which one of their outputs is more important and should be more considered because it can affect decisions about plans and strategies. Like section 2, we will detect significant output indexes by two methods. First, we use DMU weights and in the other method, one output will be eliminated and calculations will be done again. First, we start by weights method.

### 4.3.1 Weights Method

in this method, the weight of each DMU is calculated and it is shown in table 2 in appendix. We calculate total weights for each output, average and then by comparing the average weights for each output, we will find out which output is more important.

Table 4.5: Comparing weights of the outputs

| Number | Output 1 | Output 2 | Output 3 |
|---|---|---|---|
| Name | Total Deposits | Annual Net Profit | Given Facilities |
| Total weights | 684.92 | 128.07 | 18.18 |
| average | 9.13 | 1.70 | 0.24 |

As it is shown in table 4.5, output 1 has more weights on average than the other two outputs. In other words, Total deposit should be more considered by banks because by increasing output 1, efficiency will be more improved more than by increasing output 2 or output 3.

### 4.3.2 Eliminate Output Method

In order to find the most significant output indexes, by using this method, we eliminate one of the outputs, recalculate the process by all three inputs and the remaining two outputs and then, comparing the created difference in all DMU efficiencies.

First, we eliminate output 1 and do the calculations to find efficiencies by all three input, and output 2 and output 3. As it is demonstrated in table 4.6, when we eliminate output 1 and calculate the efficiency of each DMUs using three inputs and the remaining two outputs, each DMU changes 41.51% averagely. Now, we do the same process with output 2 and output 3. We eliminate output 2 and using output 1 and output 3 and with all three inputs, the efficiency of each DMU changes 2.03% averagely. Similarly, by eliminating output 3 and using output 1 and output 2 the efficiency of each DMU changes by 0.28% on the average.

Table 4.6: Comparing the effect of each output on efficiency

| | Without output 1 | Without output 2 | Without output 3 |
|---|---|---|---|
| Total Difference | 3113.93 | 152.74 | 21.25 |
| Average | 41.51 | 2.03 | 0.28 |

The results show that changes in output 1 which is total deposit, has more effect on the efficiency than the other two outputs. In other words, changes in output 1 cause more change in efficiency. The result of this method approved the previous method's result.

## 4.4 Comparison Criteria

After evaluating efficiency of each bank and finding significant input and output indexes, now we need to find the reasons for inefficient banks. For this reason, we need to know how we should compare banks with each other.

Efficient banks can be known as a benchmark for inefficient banks. Each efficient bank has a weight and we name it λ. As you can see in chapter 3, the amount of λ is calculated by solving the dual model of linear programming DEA for efficient banks. These weights show us how efficient performance of a bank should be, and efficient amount of inputs and outputs can be calculated as a linear combination. Therefore, by using this Knowledge we can present a better evaluation of inefficient banks.

For example, based on table 4.7, DMU068 which is an inefficient bank should be compared to DMU5, DMU12, and DMU15 which have the following weights 0.13, 0.09 and 0.14 respectively. When we have more than one bank as a benchmark, the benchmark with more weight should be chosen.

Table 4.7: Benchmark banks and their weights for inefficient banks

| Name | DMU4 | DMU5 | DMU12 | DMU15 | DMU19 | DMU21 | DMU27 | DMU30 | DMU45 |
|---|---|---|---|---|---|---|---|---|---|
| DMU01 | 0.19 | 2.51 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| DMU18 | 0 | 1.12 | 0 | 0 | 0 | 0 | 0.39 | 0 | 0 |
| DMU32 | 0 | 0.94 | 0 | 0 | 0 | 0 | 0.47 | 0 | 0 |
| DMU54 | 0 | 0.08 | 0.3 | 0.02 | 0 | 0 | 0 | 0 | 0 |
| DMU61 | 0.45 | 1.34 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| DMU68 | 0 | 0.13 | 0.09 | 0.14 | 0 | 0 | 0 | 0 | 0 |
| DMU73 | 0 | 0 | 0 | 0.15 | 0 | 0 | 0.2 | 0 | 0 |

# Chapter 5

# CONCLUSION AND SUGGESTIONS

In this chapter, first each inefficient bank is compared with the benchmark bank with the greatest λ. After that, the main reasons for inefficiency in Iranian Private banks will be discussed. At the end, we have some suggestions for further studies.

After calculating efficiencies for each bank and determination of efficient and inefficient banks, now we must find solutions to turn inefficient banks into efficient banks.

## 5.1 Suggest Improvements and Comparison

When a bank is detected as an inefficient bank, that means this bank uses unbalanced sources (inputs). in the other word, by adjusting inputs in the right way we can change efficiency and make it more efficient.

Assume that ($X_0$, $Y_0$) is an inefficient DMU by $\theta$ efficiency then for ($\theta X_0$, $Y_0$), That DMU will be efficient. In other words, if we multiply inputs times $\theta$, then the efficiency will be 1. The amount of efficiency ($\theta$) is always between 0 to 1. Which means if we multiply inputs to efficiency value, it is always less than the initial inputs( $\theta X_0 < X_0$ ). This means to turn an inefficient bank into an efficient bank, we have to decrease inputs as we keep the outputs the same.

For example, DMU61, which is bank Mellat in 2015, was 61.18% efficient. The inputs for this DMU were 21342 employees, 1590 Branches and 60,950,842,453 U.S

Dollar total assets. If we use just 61.18% of each input, the efficiency will be 100% as table 5.1 shows.

Table 5.1 Suggestions for Mellat Bank

| Bank | DMU | No. of employees | No. of branches | Total Assets | efficiency |
|---|---|---|---|---|---|
| Mellat | DMU61 | 21,342 | 1,590 | 60,950,842,453 | 61.18% |
| Suggested changes | | 0.6118×(21,342) =13,053 | 0.6118×(1,590) =972 | 0.6118×(60,950,842,453) =37,277,535,244 | 100% |

If an inefficient DMU needs a benchmark to know how it should be to be an efficient bank, we have to find a benchmark so that DMU can compare itself with it. To do this, we use λ to find the best benchmark. An inefficient bank can compare itself with any benchmark with λ more than 0. But DMUs with greater λ are better benchmarks for that inefficient DMU.

Table 5.2 λ values for each bank in last year

| Name | DMU4 | DMU5 | DMU12 | DMU15 | DMU19 | DMU21 | DMU27 | DMU30 | DMU45 | DMU46 | DMU66 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| DMU61 | 0.45 | 1.34 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.33 | 0 |
| DMU62 | 0 | 0.61 | 0 | 0 | 0 | 0 | 0.37 | 0 | 0 | 0.32 | 0 |
| DMU63 | 0 | 0.77 | 0 | 0 | 0 | 0 | 0.32 | 0 | 0 | 0.52 | 0 |
| DMU64 | 0.64 | 0.08 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.04 | 0 |
| DMU65 | 0.09 | 0.56 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.03 | 0 |
| DMU66 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| DMU67 | 0.08 | 0 | 0 | 0 | 0 | 0 | 0 | 0.28 | 0.04 | 0.03 | 0 |
| DMU68 | 0 | 0.13 | 0.09 | 0.14 | 0 | 0 | 0 | 0 | 0 | 0.01 | 0 |
| DMU69 | 0 | 0.44 | 0 | 0 | 0 | 0 | 0.19 | 0 | 0 | 0 | 0 |
| DMU70 | 0.25 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.19 | 0.03 | 0 |
| DMU71 | 0 | 0.01 | 0.22 | 0.13 | 0 | 0 | 0 | 0 | 0 | 0.04 | 0 |
| DMU72 | 0 | 0.43 | 0 | 0 | 0 | 0 | 0.4 | 0 | 0 | 0.12 | 0.01 |
| DMU73 | 0 | 0 | 0 | 0.15 | 0 | 0 | 0.2 | 0 | 0 | 0.11 | 0 |
| DMU74 | 0 | 0 | 0 | 0.36 | 0 | 0 | 0.01 | 0 | 0 | 0.01 | 0 |
| DMU75 | 0.01 | 0 | 0 | 0 | 0 | 0 | 0 | 0.83 | 0 | 0 | 0.01 |

To compare DMU61, the best benchmark should be selected. Benchmarks for this bank can be DMU4 and DMU5. The amount of λ for these DMUs are 0.45 and 1.34 respectively. We can compare DMU61 to any of these benchmarks, but for better result we suggest that the inefficient DMU be compared with the benchmark with greater λ.

Table 5.3 Comparison Table for Mellat Bank

| Bank | DMU | No. of employees | No. of branches | Total Assets | Total Deposits | Annual Net Profit | Given Facilities |
|---|---|---|---|---|---|---|---|
| Mellat | DMU61 | 21,342 | 1,590 | 60950842453 | 41815841489 | 42493676844 | 27888739904 |
| Parsian | DMU5 | 2,662 | 233 | 16582218885 | 14211995387 | 16063885991 | 11522489456 |

By looking at table 5.2, we see that the DMU61 is much bigger bank than DMU5. This difference in the size of these two banks makes them incomparable. To solve this problem, by comparing number of branches, it can be seen that number of branches for DMU61 is nearly 7 times greater than number of branches in DMU5. Thus, if we multiply DMU64 data to seven, then the comparison is more reasonable because of being data in the same range. Noting that, the number of branches is selected because it is a proper criterion to estimate the size of a bank.

Table 5.4 Comparison Table for Mellat bank

| Bank | DMU | No. of employees | No. of branches | Total Assets | Total Deposits | Annual Net Profit | Given Facilities |
|---|---|---|---|---|---|---|---|
| Mellat | DMU61 | 21,342 | 1,590 | 60950842453 | 41815841489 | 42493676844 | 27888739904 |
| Eghtesad Novin | DMU5 | 2,662 | 233 | 16582218885 | 14211995387 | 16063885991 | 11522489456 |
| DMU5×7 | | 18,634 | 1631 | 116075532195 | 99483967709 | 112447201937 | 80657426192 |

Bank Tejarat did not change much during 5 year, started 61.24% efficiency and in the last year the efficiency was 55.04%. Suggested inputs for this bank is proposed in table 5.5.

Table 5.5 Comparison for Tejarat Bank

| Bank | DMU | No. of employees | No. of branches | Total Assets | efficiency |
|---|---|---|---|---|---|
| Tejarat | DMU62 | 18,913 | 1715 | 36074214680 | 59.62% |
| Suggested Inputs | | 11348 | 1029 | 628124226 | 100% |

We compare the performance of Tejarat Bank in the last year of the period with Bank Eghtesad Novin in the first year, according to the amount of λ in a similar manner explained before (Table 5.6).

Table 5.6 Comparison Table for Bank Tejarat

| Bank | DMU | No. of employees | No. of branches | Total Assets | Total Deposits | Annual Net Profit | Given Facilities |
|---|---|---|---|---|---|---|---|
| Tejarat | DMU 62 | 18,913 | 1715 | 36074214680 | 27766470159 | 28444305513 | 15712049345 |
| Eghtesad Novin | DMU 5 | 2,662 | 233 | 16582218885 | 14211995387 | 16063885991 | 11522489456 |
| DMU5×7 | | 18,634 | 1631 | 116075532195 | 99483967709 | 112447201937 | 80657426192 |

Table 5.7 shows the comparison between Saderat Bank and the best benchmark for it determined by λ.

Table 5.7 Comparison for Saderat Bank

| Bank | DMU | No. of employees | No. of branches | Total Assets | Total Deposits | Annual Net Profit | Given Facilities |
|---|---|---|---|---|---|---|---|
| Saderat | DMU63 | 31,138 | 2,600 | 46525571020 | 36105013542 | 36782848897 | 22261607719 |
| Eghtesad Novin | DMU5 | 2,662 | 233 | 16582218885 | 14211995387 | 16063885991 | 11522489456 |
| DMU5×11 | | 29282 | 2563 | 182404407735 | 156331949257 | 176702745901 | 126747384016 |

Eghtesad Novin Bank has had a satisfying performance, this bank was efficient in first and second year, after that the efficiency is slightly decreased to 82.65%.

Table 5.8 Suggestions for Eghtesad Novin Bank

| Bank | DMU | No. of employees | No. of branches | Total Assets | efficiency |
|---|---|---|---|---|---|
| Eghtesad Novin | DMU65 | 3,162 | 251 | 14546518160 | 82.65% |
| Suggested inputs | | 2613 | 207 | 12022697259 | 100% |

Based on table 5.2 and amount of λ, Eghtesad Novin bank should compare with itself in first year. The table below shows the amount of inputs and outputs for each bank. The collected data are shown in table 1 in appendix.

Table 5.9 Comparison for Eghtesad Novin Bank

| Bank | DMU | No. of employees | No. of branches | Total Assets | Total Deposits | Annual Net Profit | Given Facilities |
|---|---|---|---|---|---|---|---|
| Eghtesad Novin | DMU65 | 3,162 | 251 | 422,139,957 | 325,471,535 | 2,399,545 | 268,402,751 |
| Parsian | DMU5 | 2,662 | 233 | 16582218885 | 14211995387 | 16063885991 | 11522489456 |

Karafarin Bank could not improve during the period, started from 78.4% to 75.41% in the last year. Suggested inputs for the last year are proposed in table 5.10.

Table 5.10 Suggestions for Karafarin Bank

| Bank | DMU | No. of employees | No. of branches | Total Assets | efficiency |
|---|---|---|---|---|---|
| Karafarin | DMU67 | 1,673 | 107 | 4249043591 | 75.41% |
| Suggested inputs | | 1262 | 81 | 3204203772 | 100% |

Table5.11 Comparison for Karafarin Bank

| Bank | DMU | No. of employees | No. of branches | Total Assets | Total Deposits | Annual Net Profit | Given Facilities |
|---|---|---|---|---|---|---|---|
| Karafarin | DMU67 | 1,673 | 107 | 123,307,245 | 104,602,671 | 2,667,863 | 81,260,142 |
| Khavar miane | DMU30 | 216 | 8 | 1744462990 | 1167348433 | 2781559987 | 1042850894 |
| DMU30×13 | | 2808 | 104 | 22678018874 | 15175529624 | 36160279829 | 13557061628 |

Suggested inputs for Sarmaye bank are shown in table 5.12.

Table 5.12 Suggestions for Sarmayeh Bank

| Bank | DMU | No. of employees | No. of branches | Total Assets | efficiency |
|---|---|---|---|---|---|
| Sarmaye | DMU68 | 1,361 | 140 | 161,308,204 | 74.26% |
| Suggested inputs | | 1,010 | 104 | 119,787,472 | 100% |

Based on λ values, it is better to compare this bank with DMU15. Table 5.13 compares these two banks.

Table 5.13 Comparison for Sarmayeh bank

| Bank | DMU | No. of employees | No. of branches | Total Assets | Total Deposits | Annual Net Profit | Given Facilities |
|---|---|---|---|---|---|---|---|
| Sarmaye | DMU68 | 1,361 | 140 | 5558518401 | 3710560613 | 4388395968 | 3613531185 |
| Khavar miane | DMU15 | 599 | 101 | 526321879.1 | 80673225.38 | 1932563830 | 242442383 |

Saman Bank is famous for its internet banking services. This bank was the first bank to provide internet banking to its customers. The efficiency of Saman Bank is more than 80% in every year of the period. therefore, by number of changes it can be an efficient bank.

Table 5.14 Suggestions for Saman Bank

| Bank | DMU | No. of employees | No. of branches | Total Assets | efficiency |
|---|---|---|---|---|---|
| Saman | DMU70 | 2,475 | 143 | 8915124604 | 86.39% |
| Suggested inputs | | 2138 | 124 | 7701776145 | 100% |

Table 5.15 Comparison for Saman bank

| Bank | DMU | No. of employees | No. of branches | Total Assets | Total Deposits | Annual Net Profit | Given Facilities |
|---|---|---|---|---|---|---|---|
| Saman | DMU70 | 2,475 | 143 | 8915124604 | 7282805376 | 7960640731 | 4393517195 |
| Parsian | DMU4 | 4,531 | 288 | 29434510921 | 24126128601 | 25978019205 | 19659156844 |

The efficient amounts of inputs needed to be an efficient bank for Sina bank are proposed in table 5.16.

Table 5.16 Suggestions for Sina Bank

| Bank | DMU | No. of employees | No. of branches | Total Assets | efficiency |
|---|---|---|---|---|---|
| Sina | DMU71 | 2,424 | 257 | 169,134,175 | 67.78% |
| Suggested inputs | | 1643 | 174 | 114,639,144 | 100% |

Table 5.17 Comparison for Sina Bank

| Bank | DMU | No. of employees | No. of branches | Total Assets | Total Deposits | Annual Net Profit | Given Facilities |
|---|---|---|---|---|---|---|---|
| Sina | DMU71 | 2,424 | 257 | 5828193487 | 4886054721 | 5563890076 | 3508212750 |
| Ghavamin | DMU12 | 3,498 | 507 | 16303006778 | 15621705140 | 17473595745 | 14231050744 |
| DMU12×0.5 | | 1749 | 254 | 8151503389 | 7810852570 | 8736797873 | 7115525372 |

Ghavamin Bank was an efficient bank in the first year and second year, but after that the efficiency decreased down to 80%. In table 5.18 efficient amount of inputs are suggested.

Table 5.18 Suggestions for Ghavamin Bank

| Bank | DMU | No. of employees | No. of branches | Total Assets | efficiency |
|---|---|---|---|---|---|
| Ghavamin | DMU72 | 6,783 | 734 | 576,865,042 | 84.27% |
| Suggested inputs | | 5,716 | 618 | 486,124,171 | 100% |

Table5.19 Comparison for Ghavamin Bank

| Bank | DMU | No. of employees | No. of branches | Total Assets | Total Deposits | Annual Net Profit | Given Facilities |
|---|---|---|---|---|---|---|---|
| Ghavamin | DMU72 | 6,783 | 734 | 19878188904 | 19034555858 | 19712391213 | 16585507891 |
| Eghtesad Novin | DMU5 | 2,662 | 233 | 16582218885 | 14211995387 | 16063885991 | 11522489456 |
| DMU5×3 | | 7986 | 699 | 49746656656 | 42635986161 | 48191657974 | 34567468368 |

Ansar Bank had improvements every year, but it is still far away from an efficient bank (63.64% efficiency in the last year).

Table 5.20 Suggestions for Ansar Bank

| Bank | DMU | No. of employees | No. of branches | Total Assets | efficiency |
|---|---|---|---|---|---|
| Ansar | DMU73 | 5,232 | 642 | 7,746,412,543 | 63.64% |
| Suggested inputs | | 3329 | 409 | 4,929,816,942 | 100% |

Table 5.21 Comparison for Ansar Bank

| Bank | DMU | No. of employees | No. of branches | Total Assets | Total Deposits | Annual Net Profit | Given Facilities |
|---|---|---|---|---|---|---|---|
| Ansar | DMU73 | 5,232 | 642 | 7746412543 | 8012480979 | 8690316334 | 6469554549 |
| Khavar miane | DMU27 | 4,356 | 784 | 21293590350 | 20428235598 | 22042447152 | 16984632201 |

Bank Iran Zamin is the only bank with always decreasing efficiency. The efficiency of this bank in the last year of the period was only 9.05%. the collected data shown in table 1 in appendix demonstrated that this bank had minus value in annual profit output. The main problem of this bank is so much debts to the Central Bank of Iran.

Table 5.22 Suggestions for Iran Zamin Bank

| Bank | DMU | No. of employees | No. of branches | Total Assets | efficiency |
|---|---|---|---|---|---|
| Iran Zamin | DMU74 | 2,219 | 327 | 126,463,472 | 9.05% |
| Suggested inputs | | 200 | 30 | 392,202,360 | 100% |

Table 5.23 Comparison for Iran Zamin Bank

| Bank | DMU | No. of employees | No. of branches | Total Assets | Total Deposits | Annual Net Profit | Given Facilities |
|---|---|---|---|---|---|---|---|
| Iran Zamin | DMU74 | 2,219 | 327 | 126,463,472 | 12,850,012 | -813,093 | 17,721,494 |
| Khavar miane | DMU15 | 11 | 4 | 526321879 | 80673225 | 1932563830 | 242442383.7 |
| DMU15×82 | | 902 | 328 | 43158394088 | 6615204481 | 158470234043 | 19880275466 |

## 5.2 Conclusion

- Among the benchmark banks, Eghtesad Novin Bank is selected more than the others. is not only an efficient bank, but also is a good benchmark for inefficient banks.
- By calculating total deposits for all of the banks each year and the amount of changes each year, we will see a significant increase in the fourth year of the period. the cause of this sudden increase in deposits is the government policy that allowed banks to increase their interest rates up to 22%. Because of intense competition among banks, most of them presented the highest interest rates to their customers.

Another important reason that explains a sudden increase in total deposits is increasing foreign currency rates. By reason of increasing foreign currency rates, inflation is increased as well, and this set of factors led people to put their money in banks because investment under that situation had a lot of risks.

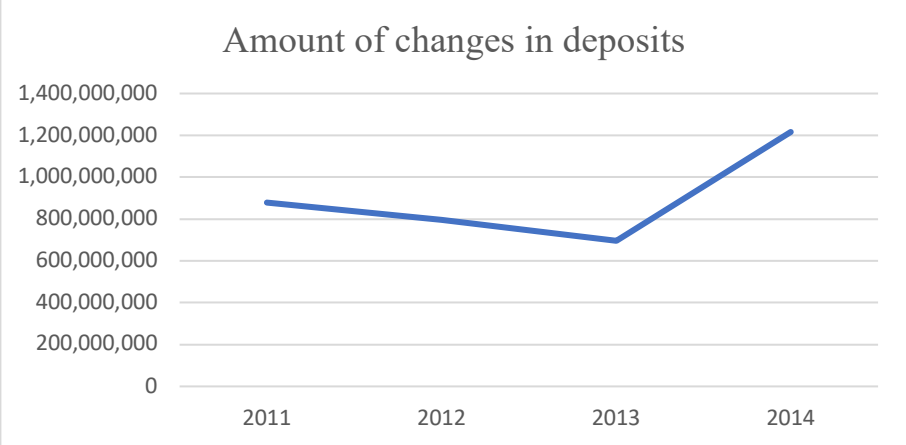


Figure 5.1 Amount of changes in deposits

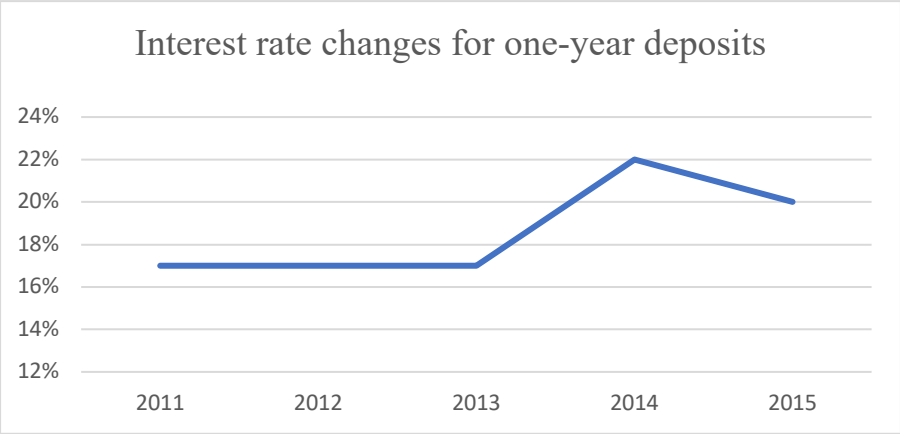


Figure 5.2 Interest rates during period

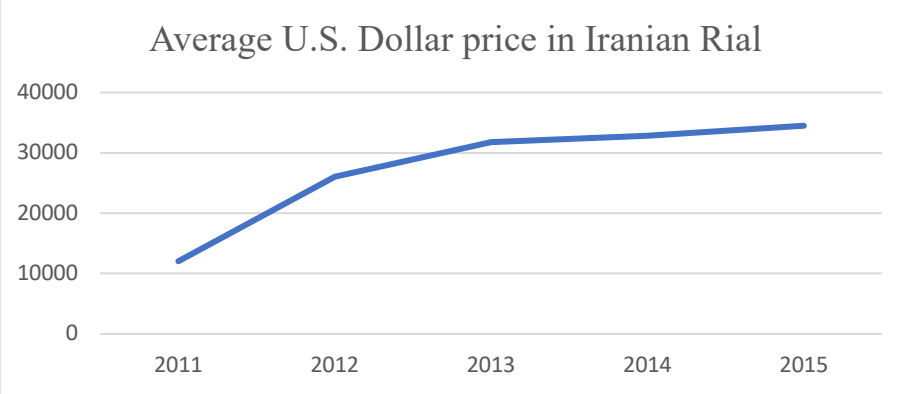


Figure 5.3 U.S Dollar price in Iranian Rial during period

- By extracting figures below from collected data, we will see that Given facilities are always significantly increased during these five years although the average interest rate for given facilities nearly still the same. One of the main causes of this issue is increasing demands. By increasing foreign currency rates and following that, increasing inflation, purchasing power of the community is significantly decreased. Therefore, to cover costs and increased prices, people intended to request for loan. This is one of the main reasons for increasing in total facilities.

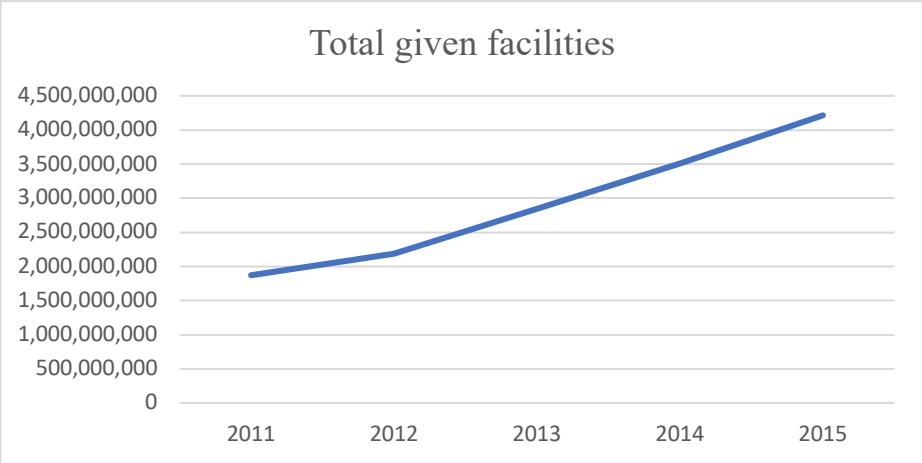


Figure 5.3 Total Private Banks Facilities

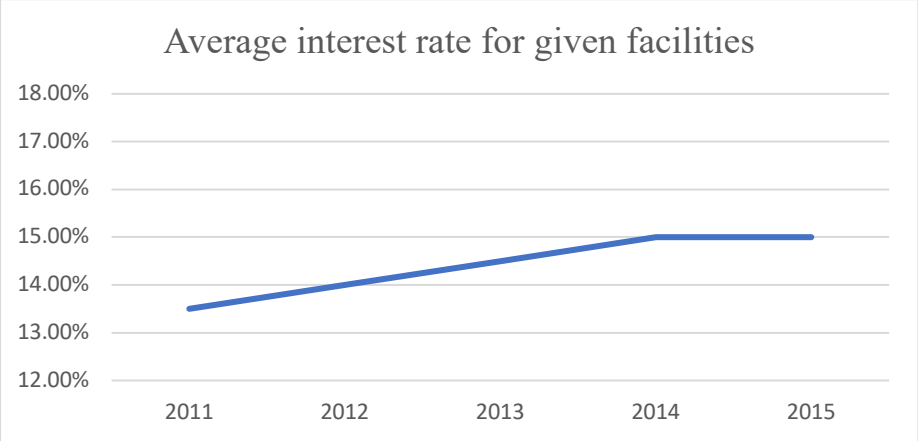


Figure5.4 Average Interest Rate

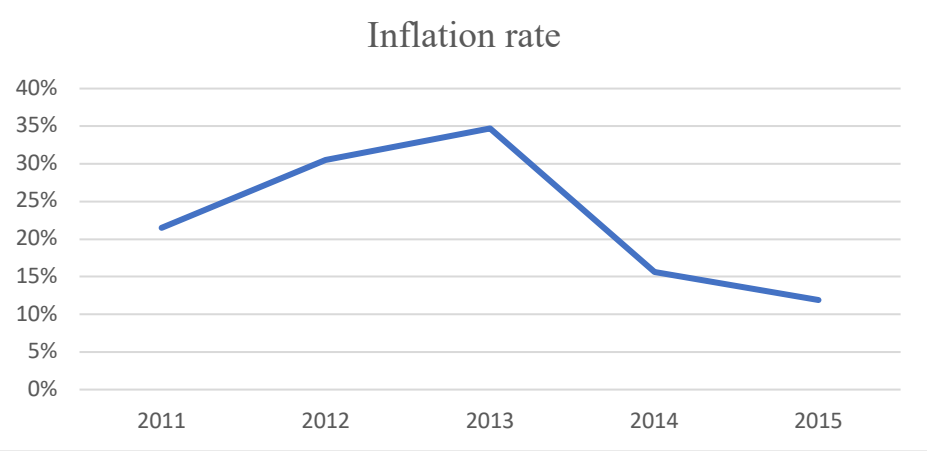


Figure 5.5 Inflation Rate During the period

- When foreign currency rates increased, private banks helped a lot to Iran economic system by attracting people's saving and money. As foreign currency rates increase, a lot of people want to invest in this field. and a great amount of Iranian Rial will turn to foreign currencies, which means the value of national currency will decrease in this situation.

What government and banks did was that the government allowed banks to increase their interest rates, and because of that, people tended to put their saving and money in banks with high-interest rate instead of buying foreign currencies with a lot of risk and tolerance in market. Therefore, banks could attract a lot of money and helped the government to manage the market.

# REFRENCES


[1] Puri, J., & Yadav, S. P. (2014). A fuzzy DEA model with undesirable fuzzy outputs and its application to the banking sector in India. *Expert Systems with Applications, 41*(14), 6419-6432.

[2] Anwar, M. (2018). Cost efficiency performance of Indonesian banks over the recovery period: A stochastic frontier analysis. *The Social Science Journal*.

[3] Silva, T. C., Tabak, B. M., Cajueiro, D. O., & Dias, M. V. B. (2017). A comparison of DEA and SFA using micro- and macro-level perspectives: Efficiency of Chinese local banks. *Physica A: Statistical Mechanics and its Applications, 469*, 216-223.

[4] Dong, Y., Firth, M., Hou, W., & Yang, W. (2016). Evaluating the performance of Chinese commercial banks: A comparative analysis of different types of banks. *European Journal of Operational Research, 252*(1), 280-295.

[5] Nguyen, T. L. A. (2018). Diversification and bank efficiency in six ASEAN countries. *Global Finance Journal, 37*, 57-78.

[6] Carvallo, O., & Kasman, A. (2017). Convergence in bank performance: Evidence from Latin American banking. *The North American Journal of Economics and Finance, 39*, 127-142.

[7] Nurboja, B., & Košak, M. (2017). Banking efficiency in South East Europe: Evidence for financial crises and the gap between new EU members and candidate countries. *Economic Systems, 41*(1), 122-138.

[8] Chaffai, M., & Coccorese, P. (2019). How far away is the MENA banking system? Efficiency comparisons with international banks. *The North American Journal of Economics and Finance, 49*, 378-395.

[9] Alexakis, C., Izzeldin, M., Johnes, J., & Pappas, V. (2019). Performance and productivity in Islamic and conventional banks: Evidence from the global financial crisis. *Economic Modelling, 79*, 1-14.

[10] Chen, X., Fu, T.-T., Juo, J.-C., & Yu, M.-M. (2019). A comparative analysis of profit inefficiency and productivity convergence between Taiwanese and Chinese banks. *BRQ Business Research Quarterly*.

[11] Rashid, A., & Jabeen, S. (2016). Analyzing performance determinants: Conventional versus Islamic Banks in Pakistan. *Borsa Istanbul Review, 16*(2), 92-107.

[12] Mohanty, S. K., Lin, H.-J., Aljuhani, E. A., & Bardesi, H. J. (2016). Banking efficiency in Gulf Cooperation Council (GCC) countries: A comparative study. *Review of Financial Economics, 31*, 99-107.

[13] Zhou, X., Xu, Z., Chai, J., Yao, L., Wang, S., & Lev, B. (2019). Efficiency evaluation for banking systems under uncertainty: A multi-period three-stage DEA model. *Omega, 85*, 68-82.

[14] Sufian, F., Kamarudin, F., & Nassir, A. m. (2016). Determinants of efficiency in the malaysian banking sector: Does bank origins matter? *Intellectual Economics, 10*(1), 38-54.

[15] Fukuyama, H., & Matousek, R. (2017). Modelling bank performance: A network DEA approach. *European Journal of Operational Research, 259*(2), 721-732.

[16] Wang, K., Huang, W., Wu, J., & Liu, Y.-N. (2014). Efficiency measures of the Chinese commercial banking system using an additive two-stage DEA. *Omega, 44*, 5-20.

[17] Fernandes, F. D. S., Stasinakis, C., & Bardarova, V. (2018). Two-stage DEA-Truncated Regression: Application in banking efficiency and financial development. *Expert Systems with Applications, 96*, 284-301.

[18] Phan, H. T., Anwar, S., Alexander, W. R. J., & Phan, H. T. M. (2019). Competition, efficiency and stability: An empirical study of East Asian commercial banks. *The North American Journal of Economics and Finance, 50*, 100990.

[19] Stewart, C., Matousek, R., & Nguyen, T. N. (2016). Efficiency in the Vietnamese banking system: A DEA double bootstrap approach. *Research in International Business and Finance, 36*, 96-111

[20] Ohsato, S., & Takahashi, M. (2015). Management Efficiency in Japanese Regional Banks: A Network DEA. *Procedia - Social and Behavioral Sciences, 172*, 511-518.

[21] Wanke, P., & Barros, C. (2014). Two-stage DEA: An application to major Brazilian banks. *Expert Systems with Applications, 41*(5), 2337-2344.

[22] Kwon, H.-B., & Lee, J. (2015). Two-stage production modeling of large U.S. banks: A DEA-neural network approach. *Expert Systems with Applications, 42*(19), 6758-6766.

[23] Wanke, P., Abul Kalam Azad, M., Emrouznejad, A., & Antunes, J. (2019). A dynamic network DEA model for accounting and financial indicators: A case of efficiency in MENA banking. *International Review of Economics & Finance, 61*, 52-68.

[24] Wu, M., Li, C., Fan, J., Wang, X., & Wu, Z. (2018). Assessing the global productive efficiency of Chinese banks using the cross-efficiency interval and VIKOR. *Emerging Markets Review, 34*, 77-86.

[25] Alfiero, S., Esposito, A., Mensah, E. K., & Toloo, M. (2019). A dataset of European banks in performance evaluation under uncertainty. *Data in Brief, 22*, 214-217.

[26] Zhu, N., Hougaard, J. L., Yu, Z., & Wang, B. (2019). Ranking Chinese commercial banks based on their expected impact on structural efficiency. *Omega*.

[27] Henriques, I. C., Sobreiro, V. A., Kimura, H., & Mariano, E. B. (2018). Efficiency in the Brazilian banking system using data envelopment analysis. *Future Business Journal, 4*(2), 157-178.

[28] Gulati, R., & Kumar, S. (2016). Assessing the impact of the global financial crisis on the profit efficiency of Indian banks. *Economic Modelling, 58*, 167-181.

[29] Stoica, O., Mehdian, S., & Sargu, A. (2015). The Impact of Internet Banking on the Performance of Romanian Banks: DEA and PCA Approach. *Procedia Economics and Finance, 20*, 610-622.

[30] Moradi-Motlagh, A., & Babacan, A. (2015). The impact of the global financial crisis on the efficiency of Australian banks. *Economic Modelling, 46*, 397-406.

[31] Zhao, H., & Kang, S. (2015). Banking Performance Evaluation in China Based on Non-radial Super-efficiency Data Envelopment Analysis. *Procedia Economics and Finance, 23*, 197-202.

[32] Ulas, E., & Keskin, B. (2015). Performance Evaluation and Ranking of Turkish Banking Sector. *Procedia Economics and Finance, 25*, 297-307.

[33] Řepková, I. (2014). Efficiency of the Czech Banking Sector Employing the DEA Window Analysis Approach. *Procedia Economics and Finance, 12*, 587-596.

[34] Zimková, E. (2014). Technical Efficiency and Super-efficiency of the Banking Sector in Slovakia. *Procedia Economics and Finance, 12*, 780-787.

[35] Rosman, R., Wahab, N. A., & Zainol, Z. (2014). Efficiency of Islamic banks during the financial crisis: An analysis of Middle Eastern and Asian countries. *Pacific-Basin Finance Journal, 28*, 76-90.

[36] Chortareas, G. E., Girardone, C., & Ventouri, A. (2012). Bank supervision, regulation, and efficiency: Evidence from the European Union. *Journal of Financial Stability, 8*(4), 292-302.

[37] Fukuyama, H., & Matousek, R. (2011). Efficiency of Turkish banking: Two-stage network system. Variable returns to scale model. *Journal of International Financial Markets, Institutions and Money, 21*(1), 75-91.

[38] Deng, Q., Wong, W. P., Wooi, H. C., & Xiong, C. M. (2011). An Engineering Method to Measure the Bank Productivity Effect in Malaysia during 2001-2008. *Systems Engineering Procedia, 2*, 1-11.

[39] Staub, R. B., da Silva e Souza, G., & Tabak, B. M. (2010). Evolution of bank efficiency in Brazil: A DEA approach. *European Journal of Operational Research, 202*(1), 204-213.

[40] Banker, R. D., Chang, H., & Lee, S.-Y. (2010). Differential impact of Korean banking system reforms on bank productivity. *Journal of Banking & Finance, 34*(7), 1450-1460.

[41] Lin, T. T., Lee, C.-C., & Chiu, T.-F. (2009). Application of DEA in analyzing a bank's operating performance. *Expert Systems with Applications, 36*(5), 8883-8891.

[42] Bergendahl, G., & Lindblom, T. (2008). Evaluating the performance of Swedish savings banks according to service efficiency. *European Journal of Operational Research, 185*(3), 1663-1673.

[43] Havrylchyk, O. (2006). Efficiency of the Polish banking industry: Foreign versus domestic banks. *Journal of Banking & Finance, 30*(7), 1975-1996.

[44] Chen, X., Skully, M., & Brown, K. (2005). Banking efficiency in China: Application of DEA to pre- and post-deregulation eras: 1993–2000. *China Economic Review, 16*(3), 229-245.

[45] Halkos, G. E., & Salamouris, D. S. (2004). Efficiency measurement of the Greek commercial banks with the use of financial ratios: a data envelopment analysis approach. *Management Accounting Research, 15*(2), 201-224.

[46] Kao, C., & Liu, S.-T. (2014). Measuring performance improvement of Taiwanese commercial banks under uncertainty. *European Journal of Operational Research, 235*(3), 755-764.

[47] Drake, L., & Hall, M. J. B. (2003). Efficiency in Japanese banking: An empirical analysis. *Journal of Banking & Finance, 27*(5), 891-917.

[48] Sathye, M. (2001). X-efficiency in Australian banking: An empirical investigation. *Journal of Banking & Finance, 25*(3), 613-630.

[49] Charnes, W.W. Cooper & E. Rhodes. (1978). Measuring the efficiency of decision-making units. *European Journal of Operational Research 2 (1978) 429-444.*

[50] Bhat, J. A., Haider, S., & Kamaiah, B. (2018). Interstate energy efficiency of Indian paper industry: A slack-based non-parametric approach. *Energy*, *161*, 284–298.

# APPENDICES

# Appendix 1: Collected data

| Year | Name of The Bank | DMU Number | No. of Employees | No. of Branches | Total Assets | Total Deposits | Annual Net Profit | Given Facilities |
|---|---|---|---|---|---|---|---|---|
| | | | I1 | I2 | I3 | O1 | O2 | O3 |
| 2011 | Mellat | DMU1 | 23,014 | 1,792 | 73221457729 | 52963105818 | 54814996423 | 34816844380 |
| | Tejarat | DMU2 | 20,724 | 1,866 | 48328747693 | 37175887686 | 39027778290 | 26956009885 |
| | Saderat | DMU3 | 33,465 | 2,972 | 57578695914 | 38706965449 | 40558856053 | 29957024572 |
| | Parsian | DMU4 | 4,531 | 288 | 29434510921 | 24126128601 | 25978019205 | 19659156844 |
| | Eghtesad Novin | DMU5 | 2,662 | 233 | 16582218885 | 14211995387 | 16063885991 | 11522489456 |
| | Pasargad | DMU6 | 3,251 | 296 | 20881985125 | 16109252118 | 17961142723 | 12928533139 |
| | Karafarin | DMU7 | 1,416 | 78 | 5668387686 | 3922011109 | 5773901713 | 2880201186 |
| | Sarmaye | DMU8 | 1,466 | 145 | 5508249106 | 3038310676 | 4890201280 | 3182483431 |
| | Shahr | DMU9 | 1,102 | 218 | 3604042553 | 2955134250 | 4807024854 | 1372027208 |
| | Saman | DMU10 | 1,953 | 153 | 10337279703 | 7475129072 | 9327019676 | 6306236302 |
| | Sina | DMU11 | 2,374 | 268 | 6286809264 | 5271688383 | 7123578987 | 4091360949 |
| | Ghavamin | DMU12 | 3,498 | 507 | 16303006778 | 15621705140 | 17473595745 | 14231050744 |
| | Ansar | DMU13 | 4,953 | 688 | 7776260403 | 8905488797 | 10757379401 | 8026967709 |
| | Iran Zamin | DMU14 | 599 | 101 | 548221709.7 | 40003106.76 | 1891893711 | 4952833.741 |
| | Khavar miane | DMU15 | 11 | 4 | 526321879.1 | 80673225.38 | 1932563830 | 242442383.7 |
| 2012 | Mellat | DMU16 | 22,495 | 1,714 | 96975145495 | 67938817824 | 69553029378 | 37669971279 |
| | Tejarat | DMU17 | 19,879 | 1,861 | 50446813146 | 39558610208 | 41172821763 | 26344608649 |
| | Saderat | DMU18 | 32,730 | 2,793 | 58675591006 | 43027923601 | 44642135155 | 28883605531 |
| | Parsian | DMU19 | 4,492 | 288 | 30322451584 | 24562884950 | 26177096504 | 19829606187 |
| | Eghtesad Novin | DMU20 | 3,029 | 233 | 18567355654 | 15689577794 | 17303789348 | 12890010586 |
| | Pasargad | DMU21 | 3,396 | 297 | 24377451666 | 19527125718 | 21141337272 | 14343445429 |
| | Karafarin | DMU22 | 1,487 | 88 | 6323230182 | 4451739455 | 6065951009 | 3700548498 |
| | Sarmaye | DMU23 | 1,444 | 144 | 6852272280 | 4778772854 | 6392984408 | 3898734367 |
| | Shahr | DMU24 | 1,467 | 260 | 6710314541 | 5701591991 | 7315803545 | 2518526834 |
| | Saman | DMU25 | 2,231 | 149 | 10855554161 | 8673651075 | 10287862629 | 6245730182 |
| | Sina | DMU26 | 2,420 | 275 | 7641485721 | 6251410963 | 7865622518 | 3988371984 |
| | Ghavamin | DMU27 | 4,356 | 784 | 21293590350 | 20428235598 | 22042447152 | 16984632201 |
| | Ansar | DMU28 | 5,124 | 688 | 9990924586 | 11185309207 | 12799520762 | 836584687.3 |
| | Iran Zamin | DMU29 | 2,075 | 352 | 1333708764 | 105305350.4 | 1719516905 | 209085097.7 |
| | Khavar miane | DMU30 | 216 | 8 | 1744462990 | 1167348433 | 2781559987 | 1042850894 |
| 2013 | Mellat | DMU31 | 22,157 | 1,633 | 74005758814 | 49656921603 | 50719001512 | 30632420334 |
| | Tejarat | DMU32 | 19,365 | 1,826 | 46497698828 | 33849449706 | 34911529615 | 20757464392 |
| | Saderat | DMU33 | 32,401 | 2,712 | 45503137250 | 34482731278 | 35544811187 | 22419105772 |
| | Parsian | DMU34 | 4,477 | 293 | 25274416392 | 18756346742 | 19818426651 | 15450463960 |

| | Name of The Bank | DMU Number | No. of Employees | No. of Branches | Total Assets | Total Deposits | Annual Net Profit | Given Facilities |
|---|---|---|---|---|---|---|---|---|
| | **Eghtesad Novin** | **DMU35** | 3,119 | 251 | 15818127045 | 13360334107 | 14422414017 | 10511946817 |
| | **Pasargad** | **DMU36** | 3,486 | 326 | 20369862858 | 16504993575 | 17567073484 | 11834743372 |
| | **Karafarin** | **DMU37** | 1,547 | 98 | 5413200853 | 3828010529 | 4890090438 | 3146775228 |
| | **Sarmaye** | **DMU38** | 1,419 | 143 | 6619246909 | 3975794989 | 5037874899 | 4577283246 |
| | **Shahr** | **DMU39** | 2,151 | 261 | 7073213109 | 6206897144 | 7268977053 | 2802725933 |
| | **Saman** | **DMU40** | 2,425 | 148 | 10882411695 | 8586350683 | 9648430592 | 5556550726 |
| | **Sina** | **DMU41** | 2,446 | 277 | 6640028778 | 5071626370 | 6133706279 | 3412537390 |
| | **Ghavamin** | **DMU42** | 6,512 | 774 | 18587304195 | 17012349711 | 18074429620 | 14108479888 |
| | **Ansar** | **DMU43** | 5,115 | 688 | 9333686356 | 9982310728 | 11044390638 | 7832250094 |
| | **Iran Zamin** | **DMU44** | 2,349 | 351 | 2141162356 | 195205388.5 | 1257285298 | 433550672.2 |
| | **Khavar miane** | **DMU45** | 282 | 11 | 1657113547 | 1208448734 | 2270528643 | 148534096.4 |
| **2014** | **Mellat** | **DMU46** | 22,478 | 1,602 | 5592564585 | 36002275813 | 36760974544 | 25431025880 |
| | **Tejarat** | **DMU47** | 19,065 | 1,809 | 36482946195 | 27279340842 | 28038039573 | 16113873722 |
| | **Saderat** | **DMU48** | 31,944 | 2,608 | 42367836155 | 31398834998 | 32157533729 | 20593393952 |
| | **Parsian** | **DMU49** | 4,241 | 293 | 21299175801 | 15952493308 | 16711192039 | 12564801558 |
| | **Eghtesad Novin** | **DMU50** | 3,126 | 251 | 13129539939 | 11276091179 | 12034789910 | 9531198480 |
| | **Pasargad** | **DMU51** | 3,685 | 327 | 17134405832 | 13719444440 | 14478143171 | 10611307942 |
| | **Karafarin** | **DMU52** | 1,640 | 101 | 4322638909 | 3185580437 | 3944279168 | 2666375092 |
| | **Sarmaye** | **DMU53** | 1,379 | 143 | 5376023682 | 2739721603 | 3498420334 | 3689199637 |
| | **Shahr** | **DMU54** | 2,180 | 261 | 8307640529 | 6472073321 | 7230772052 | 3167557951 |
| | **Saman** | **DMU55** | 2,509 | 145 | 8798485941 | 6926957882 | 7685656613 | 4706162070 |
| | **Sina** | **DMU56** | 2,363 | 255 | 5746892352 | 4878721063 | 5637419794 | 3266947005 |
| | **Ghavamin** | **DMU57** | 6,766 | 763 | 17459481544 | 16327423805 | 17086122536 | 14492546727 |
| | **Ansar** | **DMU58** | 5,230 | 677 | 8039929109 | 8319807189 | 9078505920 | 6743660855 |
| | **Iran Zamin** | **DMU59** | 2,338 | 353 | 3042766228 | 248987233.4 | 1007685964 | 623269988.8 |
| | **Khavar miane** | **DMU60** | 326 | 13 | 1596085856 | 1186057430 | 1944756162 | 1083639256 |
| **2015** | **Mellat** | **DMU61** | 21,342 | 1,590 | 60950842453 | 41815841489 | 42493676844 | 27888739904 |
| | **Tejarat** | **DMU62** | 18,913 | 1715 | 36074214680 | 27766470159 | 28444305513 | 15712049345 |
| | **Saderat** | **DMU63** | 31,138 | 2,600 | 46525571020 | 36105013542 | 36782848897 | 22261607719 |
| | **Parsian** | **DMU64** | 4,403 | 293 | 22571729669 | 18077129118 | 18754964473 | 13242326430 |
| | **Eghtesad Novin** | **DMU65** | 3,162 | 251 | 14546518160 | 11215421606 | 11893256961 | 9248888732 |
| | **Pasargad** | **DMU66** | 3,815 | 327 | 18426085045 | 14577851551 | 15255686906 | 1.18E+11 |
| | **Karafarin** | **DMU67** | 1,673 | 107 | 4249043591 | 3604502791 | 4282338146 | 2800142729 |
| | **Sarmaye** | **DMU68** | 1,361 | 140 | 5558518401 | 3710560613 | 4388395968 | 3613531185 |
| | **Shahr** | **DMU69** | 2,195 | 270 | 12003438387 | 10189931427 | 10867766782 | 5196648070 |
| | **Saman** | **DMU70** | 2,475 | 143 | 8915124604 | 7282805376 | 7960640731 | 4393517195 |
| | **Sina** | **DMU71** | 2,424 | 257 | 5828193487 | 4886054721 | 5563890076 | 3508212750 |
| | **Ghavamin** | **DMU72** | 6,783 | 734 | 19878188904 | 19034555858 | 19712391213 | 16585507891 |
| | **Ansar** | **DMU73** | 5,232 | 642 | 7746412543 | 8012480979 | 8690316334 | 6469554549 |
| | **Iran Zamin** | **DMU74** | 2,219 | 327 | 4357803997 | 442798483.8 | 1120633839 | 610664851.8 |
| | **Khavar miane** | **DMU75** | 349 | 16 | 2568719814 | 1286956168 | 1964791523 | 1847874431 |

# Appendix 2: Weights of each DMU of CCR model

| Name | Index1 | Index2 | Index3 | Index4 | Index5 | Index6 | Name | Index1 | Index2 | Index3 | Index4 | Index5 | Index6 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DMU01 | 0.39 | 0.28 | 0.74 | 0.86 | 0 | 0 | DMU38 | 5.73 | 0.59 | 7.95 | 7.4 | 1.33 | 0 |
| DMU02 | 0.72 | 0.1 | 0.99 | 1.12 | 0 | 0 | DMU39 | 0 | 6.16 | 6.18 | 6.62 | 0.33 | 0 |
| DMU03 | 0.51 | 0.07 | 0.71 | 0.78 | 0 | 0.03 | DMU40 | 5.63 | 0.58 | 7.81 | 7.27 | 1.31 | 0 |
| DMU04 | 1.29 | 0.9 | 2.43 | 2.82 | 0 | 0 | DMU41 | 2.02 | 0.28 | 2.79 | 3.09 | 0 | 0.13 |
| DMU05 | 3.08 | 0.41 | 4.23 | 4.78 | 0 | 0 | DMU42 | 3.52 | 0 | 4.8 | 4.19 | 0.8 | 0 |
| DMU06 | 5.2 | 0 | 2.3 | 3.75 | 0 | 0.22 | DMU43 | 2.55 | 0 | 37.19 | 0 | 7.3 | 0 |
| DMU07 | 0 | 11.78 | 11.82 | 12.51 | 0.7 | 0.15 | DMU44 | 2.98 | 43.87 | 47.55 | 50.43 | 3.15 | 0 |
| DMU08 | 7.66 | 1.02 | 10.82 | 9.92 | 1.79 | 0.52 | DMU45 | 1.22 | 0.16 | 1.67 | 1.89 | 0 | 0 |
| DMU09 | 11.96 | 0 | 16.31 | 14.22 | 2.72 | 0 | DMU46 | 0.86 | 0.11 | 1.18 | 1.33 | 0 | 0 |
| DMU10 | 3.04 | 2.72 | 6.4 | 6.5 | 0.69 | 0.32 | DMU47 | 0.6 | 0.08 | 0.82 | 0.93 | 0 | 0 |
| DMU11 | 5.88 | 0.6 | 8.15 | 7.59 | 1.37 | 0 | DMU48 | 1.64 | 1.15 | 3.09 | 3.58 | 0 | 0 |
| DMU12 | 2.78 | 0.37 | 3.85 | 4.08 | 0.16 | 0.18 | DMU49 | 2.44 | 1.71 | 4.63 | 5.25 | 0 | 0.22 |
| DMU13 | 3.88 | 0 | 5.32 | 4.5 | 0.87 | 0.3 | DMU50 | 2.72 | 0.36 | 3.74 | 4.23 | 0 | 0 |
| DMU14 | 9.96 | 0 | 145.37 | 0 | 28.51 | 0 | DMU51 | 0 | 12.67 | 12.77 | 13.21 | 0.74 | 0.82 |
| DMU15 | 125.04 | 12.86 | 173.49 | 161.44 | 29.09 | 0 | DMU52 | 7.94 | 1.06 | 11.22 | 10.28 | 1.86 | 0.54 |
| DMU16 | 0.34 | 0.24 | 0.64 | 0.74 | 0 | 0 | DMU53 | 5.13 | 0.6 | 7.15 | 6.7 | 1.2 | 0 |
| DMU17 | 0.72 | 0.1 | 0.99 | 1.12 | 0 | 0 | DMU54 | 0 | 7.16 | 7.17 | 7.69 | 0.38 | 0 |
| DMU18 | 0.52 | 0.07 | 0.71 | 0.8 | 0 | 0 | DMU55 | 6.19 | 0.64 | 8.58 | 7.99 | 1.44 | 0 |
| DMU19 | 1.8 | 0.81 | 2.17 | 2.77 | 0 | 0 | DMU56 | 2.06 | 0.28 | 2.84 | 3.15 | 0 | 0.13 |
| DMU20 | 1.97 | 1.38 | 3.73 | 4.23 | 0 | 0.18 | DMU57 | 3.7 | 0 | 5.08 | 4.3 | 0.83 | 0.28 |
| DMU21 | 4.52 | 0 | 2.15 | 3.48 | 0 | 0 | DMU58 | 2.84 | 0 | 25.54 | 0 | 4.72 | 4.14 |
| DMU22 | 0 | 10.49 | 10.57 | 10.94 | 0.61 | 0.68 | DMU59 | 0 | 47.72 | 48.08 | 49.73 | 2.79 | 3.1 |
| DMU23 | 6.78 | 0.8 | 9.46 | 8.86 | 1.59 | 0 | DMU60 | 0.45 | 0.32 | 0.86 | 0.99 | 0 | 0 |

| Name | Index1 | Index2 | Index3 | Index4 | Index5 | Index6 | Name | Index1 | Index2 | Index3 | Index4 | Index5 | Index6 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DMU24 | 7.24 | 0 | 9.87 | 8.6 | 1.65 | 0 | DMU61 | 0.87 | 0.12 | 1.19 | 1.35 | 0 | 0 |
| DMU25 | 2.88 | 2.59 | 6.06 | 6.28 | 0.66 | 0 | DMU62 | 0.59 | 0.08 | 0.8 | 0.91 | 0 | 0 |
| DMU26 | 5.18 | 0.61 | 7.22 | 6.76 | 1.21 | 0 | DMU63 | 1.56 | 1.1 | 2.95 | 3.42 | 0 | 0 |
| DMU27 | 2.14 | 0.29 | 2.94 | 3.33 | 0 | 0 | DMU64 | 2.28 | 1.6 | 4.33 | 4.91 | 0 | 0.21 |
| DMU28 | 3.41 | 0 | 4.64 | 4.05 | 0.77 | 0 | DMU65 | 2.55 | 0.35 | 3.53 | 3.91 | 0 | 0.16 |
| DMU29 | 3.8 | 0 | 55.56 | 0 | 10.9 | 0 | DMU66 | 0 | 12.51 | 12.55 | 13.28 | 0.75 | 0.16 |
| DMU30 | 31.13 | 4.1 | 43.81 | 41.05 | 7.37 | 0 | DMU67 | 7.81 | 1.04 | 11.05 | 10.13 | 1.83 | 0.53 |
| DMU31 | 0.4 | 0.28 | 0.76 | 0.88 | 0 | 0 | DMU68 | 4.04 | 0.54 | 5.54 | 6.27 | 0 | 0 |
| DMU32 | 0.76 | 0.1 | 1.04 | 1.18 | 0 | 0 | DMU69 | 0 | 7.13 | 7.14 | 7.66 | 0.38 | 0 |
| DMU33 | 0.58 | 0.08 | 0.79 | 0.9 | 0 | 0 | DMU70 | 6.01 | 0.71 | 8.38 | 7.85 | 1.41 | 0 |
| DMU34 | 1.43 | 1.01 | 2.72 | 3.09 | 0 | 0.13 | DMU71 | 1.93 | 0.26 | 2.66 | 2.95 | 0 | 0.12 |
| DMU35 | 2.17 | 1.52 | 4.1 | 4.75 | 0 | 0 | DMU72 | 3.76 | 0 | 5.16 | 4.37 | 0.84 | 0.29 |
| DMU36 | 2.46 | 0.33 | 3.37 | 3.81 | 0 | 0 | DMU73 | 7.81 | 0 | 10.72 | 9.08 | 1.76 | 0.6 |
| DMU37 | 0 | 11.21 | 11.29 | 11.68 | 0.65 | 0.73 | DMU74 | 0 | 45.91 | 28.42 | 35.49 | 0 | 2.84 |
| DMU38 | 6.88 | 0.92 | 9.73 | 8.92 | 1.61 | 0.47 | DMU75 | 5.73 | 0.59 | 7.95 | 7.4 | 1.33 | 0 |

# Appendix 3: Values of λ for each DMU

| Name | DMU4 | DMU5 | DMU12 | DMU15 | DMU19 | DMU21 | DMU27 | DMU30 | DMU45 | DMU46 | DMU66 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| DMU1 | 0.19 | 2.51 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.35 | 0 |
| DMU2 | 0 | 1.16 | 0 | 0 | 0 | 0 | 0.4 | 0 | 0 | 0.35 | 0 |
| DMU3 | 0 | 0.78 | 0 | 0 | 0 | 0 | 0.49 | 0 | 0 | 0.49 | 0 |
| DMU4 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| DMU5 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| DMU6 | 0 | 0.88 | 0 | 0 | 0 | 0.18 | 0 | 0 | 0 | 0 | 0 |
| DMU7 | 0.08 | 0 | 0 | 0 | 0 | 0 | 0 | 0.8 | 0.38 | 0.02 | 0 |
| DMU8 | 0 | 0.09 | 0.06 | 0.83 | 0 | 0 | 0 | 0 | 0 | 0.02 | 0 |
| DMU9 | 0 | 0 | 0 | 0.9 | 0 | 0 | 0.11 | 0 | 0 | 0.02 | 0 |
| DMU10 | 0.03 | 0.39 | 0 | 0 | 0 | 0 | 0 | 0.66 | 0 | 0.01 | 0 |
| DMU11 | 0 | 0 | 0.18 | 0.76 | 0 | 0 | 0.05 | 0 | 0 | 0.04 | 0 |
| DMU12 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| DMU13 | 0 | 0 | 0 | 0.76 | 0 | 0 | 0.21 | 0 | 0 | 0.12 | 0.01 |
| DMU14 | 0 | 0 | 0 | 0.59 | 0 | 0 | 0 | 0 | 0 | 0.02 | 0 |
| DMU15 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| DMU16 | 0.91 | 2.62 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.24 | 0 |
| DMU17 | 0 | 1.23 | 0 | 0 | 0 | 0 | 0.5 | 0 | 0 | 0.33 | 0 |
| DMU18 | 0 | 1.12 | 0 | 0 | 0 | 0 | 0.39 | 0 | 0 | 0.53 | 0 |
| DMU19 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| DMU20 | 0.28 | 0.62 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| DMU21 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| DMU22 | 0.12 | 0 | 0 | 0 | 0 | 0 | 0 | 0.86 | 0 | 0.02 | 0 |
| DMU23 | 0 | 0.22 | 0.08 | 0.57 | 0 | 0 | 0 | 0 | 0 | 0.01 | 0 |
| DMU24 | 0 | 0 | 0 | 0.64 | 0 | 0 | 0.26 | 0 | 0 | 0.01 | 0 |
| DMU25 | 0.24 | 0.09 | 0 | 0 | 0 | 0 | 0 | 0.61 | 0 | 0.02 | 0 |
| DMU26 | 0 | 0.04 | 0.29 | 0.53 | 0 | 0 | 0 | 0 | 0 | 0.03 | 0 |
| DMU27 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| DMU28 | 0 | 0 | 0 | 0.53 | 0 | 0 | 0.34 | 0 | 0 | 0.12 | 0 |
| DMU29 | 0 | 0 | 0 | 0.42 | 0 | 0 | 0 | 0 | 0 | 0.02 | 0 |
| DMU30 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| DMU31 | 0.76 | 1.41 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.31 | 0 |
| DMU32 | 0 | 0.94 | 0 | 0 | 0 | 0 | 0.47 | 0 | 0 | 0.3 | 0 |
| DMU33 | 0 | 0.65 | 0 | 0 | 0 | 0 | 0.33 | 0 | 0 | 0.51 | 0 |
| DMU34 | 0.71 | 0.05 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.02 | 0 |
| DMU35 | 0.1 | 0.7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.03 | 0 |
| DMU36 | 0 | 1.07 | 0 | 0 | 0 | 0 | 0.05 | 0 | 0 | 0.01 | 0 |
| DMU37 | 0.1 | 0 | 0 | 0 | 0 | 0 | 0 | 0.54 | 0 | 0.02 | 0 |
| DMU38 | 0 | 0.16 | 0.07 | 0.33 | 0 | 0 | 0 | 0 | 0 | 0.01 | 0.01 |
| DMU39 | 0 | 0 | 0.34 | 0.23 | 0 | 0 | 0 | 0 | 0 | 0.03 | 0 |

| Name | DMU4 | DMU5 | DMU12 | DMU15 | DMU19 | DMU21 | DMU27 | DMU30 | DMU45 | DMU46 | DMU66 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| DMU40 | 0.29 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.47 | 0.03 | 0 |
| DMU41 | 0 | 0 | 0.22 | 0.32 | 0 | 0 | 0.02 | 0 | 0 | 0.03 | 0 |
| DMU42 | 0 | 0.2 | 0 | 0 | 0 | 0 | 0.5 | 0 | 0 | 0.11 | 0 |
| DMU43 | 0 | 0 | 0 | 0.28 | 0 | 0 | 0.29 | 0 | 0 | 0.11 | 0 |
| DMU44 | 0 | 0 | 0 | 0.39 | 0 | 0 | 0 | 0 | 0 | 0.01 | 0 |
| DMU45 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| DMU46 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| DMU47 | 0 | 0.48 | 0 | 0 | 0 | 0 | 0.46 | 0 | 0 | 0.31 | 0 |
| DMU48 | 0 | 0.62 | 0 | 0 | 0 | 0 | 0.24 | 0 | 0 | 0.49 | 0 |
| DMU49 | 0.48 | 0.21 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.04 | 0 |
| DMU50 | 0.04 | 0.61 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.04 | 0.01 |
| DMU51 | 0 | 0.82 | 0 | 0 | 0 | 0 | 0.04 | 0 | 0 | 0.04 | 0 |
| DMU52 | 0.07 | 0 | 0 | 0 | 0 | 0 | 0 | 0.37 | 0 | 0.03 | 0 |
| DMU53 | 0 | 0.07 | 0.07 | 0.26 | 0 | 0 | 0 | 0 | 0 | 0.01 | 0.01 |
| DMU54 | 0 | 0.08 | 0.3 | 0.02 | 0 | 0 | 0 | 0 | 0 | 0.02 | 0 |
| DMU55 | 0.22 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.3 | 0.03 | 0 |
| DMU56 | 0 | 0 | 0.21 | 0.17 | 0 | 0 | 0.01 | 0 | 0 | 0.04 | 0 |
| DMU57 | 0 | 0.19 | 0 | 0 | 0 | 0 | 0.44 | 0 | 0 | 0.12 | 0.01 |
| DMU58 | 0 | 0 | 0 | 0.18 | 0 | 0 | 0.21 | 0 | 0 | 0.11 | 0 |
| DMU59 | 0 | 0 | 0 | 0.33 | 0 | 0 | 0 | 0 | 0 | 0.01 | 0 |
| DMU60 | 0.03 | 0 | 0 | 0 | 0 | 0 | 0 | 0.44 | 0 | 0 | 0 |
| DMU61 | 0.45 | 1.34 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.33 | 0 |
| DMU62 | 0 | 0.61 | 0 | 0 | 0 | 0 | 0.37 | 0 | 0 | 0.32 | 0 |
| DMU63 | 0 | 0.77 | 0 | 0 | 0 | 0 | 0.32 | 0 | 0 | 0.52 | 0 |
| DMU64 | 0.64 | 0.08 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.04 | 0 |
| DMU65 | 0.09 | 0.56 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.03 | 0 |
| DMU66 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| DMU67 | 0.08 | 0 | 0 | 0 | 0 | 0 | 0 | 0.28 | 0.04 | 0.03 | 0 |
| DMU68 | 0 | 0.13 | 0.09 | 0.14 | 0 | 0 | 0 | 0 | 0 | 0.01 | 0 |
| DMU69 | 0 | 0.44 | 0 | 0 | 0 | 0 | 0.19 | 0 | 0 | 0 | 0 |
| DMU70 | 0.25 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.19 | 0.03 | 0 |
| DMU71 | 0 | 0.01 | 0.22 | 0.13 | 0 | 0 | 0 | 0 | 0 | 0.04 | 0 |
| DMU72 | 0 | 0.43 | 0 | 0 | 0 | 0 | 0.4 | 0 | 0 | 0.12 | 0.01 |
| DMU73 | 0 | 0 | 0 | 0.15 | 0 | 0 | 0.2 | 0 | 0 | 0.11 | 0 |
| DMU74 | 0 | 0 | 0 | 0.36 | 0 | 0 | 0.01 | 0 | 0 | 0.01 | 0 |
| DMU75 | 0.01 | 0 | 0 | 0 | 0 | 0 | 0 | 0.83 | 0 | 0 | 0.01 |