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## ABBREVIATIONS

DEA: Data Envelopment Analysis  
FDH: Free Disposal Hull  
SFA: Stochastic Frontier Approach  
DFA: Distribution-Free Approach  
TFA: Thick Frontier Approach  
GLS: Generalized Least Squares  
OE: Overall Efficiency  
TE: Technical Efficiency  
AE: Allocative Efficiency  
SE: Scale Efficiency  
PTE: Pure Technical Efficiency  
USA: United States of America  
M&A: Mergers and Acquisitions  
DMUs: Decision Making Units  
CCR: Charnes, Cooper ve Rhodes  
CRS: Constant Return to Scale  
BCC: Banker, Charnes, and Cooper  
VRS: Variable Returns to Scale  
SDIF: Saving Deposit Insurance Fund of Turkey  
BAT: Bank Association of Turkey  
PBAT: Participation Banks Association of Turkey  
IRS: Increasing Returns to Scale  
DRS: Decreasing Returns to Scale  
ANOVA: Analysis of Variance

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## **ABSTRACT**

In this study, the efficiency of the banks operating in the Turkish Banking sector was measured for the years of 2015-2019. For efficiency measurement, input-oriented CCR and input-oriented BCC methods which are among DEA methods were applied separately. The result of the analysis was tested using statistical methods of ANOVA and t-test. When interpreting efficiency scores, banks are divided into groups as state banks, foreign-owned deposit banks, foreign-owned participation banks, private-owned state banks and state participation banks. While evaluating the efficiency of bank groups according to the results of DEA analysis, suggestions for potential improvements were made for the relevant bank groups.

## ÖZET

Bu çalışmada Türkiye Bankacılık sektöründe 2015-2019 yılları arasında faaliyet gösteren bankaların verimlilikleri ölçülmüştür. Verimlilik ölçümlemesi için VZA metotlarından girdi odaklı CCR ve girdi odaklı BCC methodları ayrı ayrı uygulanmıştır. Analiz sonucu ayrıca ANOVA ve t-test gibi istatistiksel metodlar kullanılarak test edilmiştir. Etkinlik puanları yorumlanırken bankalar, devlet bankaları, yabancı sermayeli mevduat bankaları, yabancı sermayeli katılım bankaları, özel sermayeli devlet bankaları ve devlet katılım bankaları olarak gruplara ayrılmıştır. VZA analiz sonuçlarına göre banka gruplarının etkinlikleri değerlendirilirken aynı zamanda ilgili banka gruplarına ilişkin potansiyel iyileştirme önerilerinde bulunulmuştur.

## INTRODUCTION

In today's global world, every provider of the goods and services operates under various competitive conditions. One of the essential requirements for the continuation of these activities in this competitive environment is to be efficient. The efficiency concept behind every production unit can be described as obtaining more outputs using fewer inputs. Efficiency of the banking sector is an issue taken into consideration by the regulators, stakeholders, and customers. According to Kumar and Gulati (2008), inefficient banks pose various risks to all actors that engage with banking sector depending on the role that they play as the efficiency of banks is one of the fundamental conditions for a functioning economy. If we are to address this risk from the perspective of regulators, we can state that inefficient banks represent a high possibility of failure. With regards to the customers, efficiency of banks are directly related to the how convenient the prices that are offered to them. Stakeholders would take into account the bank efficiency in terms of the reasonable returns that only efficient banks can provide. Bank managers would approach the issue of bank efficiency as a matter of survival of the fittest as the competition in the market environment would drive out the inefficient banks while the efficient ones can preserve their market shares.

There are several approaches used in the literature to evaluate the efficiency of various production processes. DEA, which has the most common usage among others, is a non-parametric approach that does not require the inputs and outputs to be in particular forms, and it can evaluate multiple inputs with multiple outputs. At the same time, this approach provides the decision makers with improvement opportunities that can be used for their strategic planning as result of the analysis.

If we are to evaluate the banking sector in Turkey based on the 2021 data, we can conclude that banking is a big sector with regards to its economic value together with 55 banks that it involves. The first section covers the previous studies that have

been conducted in this area. The second section has a brief review of the efficiency measurement and explanation of DEA approaches with their terminology, specifications and methods. At the same time, the study's aim, methods, data, and variables are presented in the second section. The results are exhibited in the third section using 2015-2019 data of deposit and participation banks in Turkey. According to results of the analysis, the efficient and inefficient banks are detected, and the suggestions for potential improvements for the inefficient banks is provided in the third section. At this point, one-way ANOVA was used to find out whether any significant difference exists between the efficiency scores of different bank types and the results showed that the difference between the efficiency scores of different bank types are statistically significant. After this step the t-test was used to discover which types of banks resemble with respect to their efficiency score and which ones differentiate.

## LITERATURE REVIEW

Banking sector efficiency analysis is an issue that is widely addressed in the literature from various angles and with different approaches. In this section, we will give a short brief of other studies about the efficiency topic.

Berger and Humphrey (1997) paper evaluated efficiency analysis on financial institutions in 21 countries consisting of 130 studies. The studies split into non-parametric approaches and parametric approaches. Sixty-nine of these studies can be categorized under the non-parametric method, which covers 62 applications of DEA (Data Envelopment Analysis), additional five applications of FDH (Free Disposal Hull), two applications of other types of applications. The other 60 studies can be categorized under the parametric approach, while one among them has more than one approach, which are SFA (Stochastic Frontier Approach), DFA (Distribution-Free Approach), TFA (Thick Frontier Approach).

Sathye (2001) used DEA analysis to investigate X-efficiency in Australian banks. Two main efficiency terms of X-efficiency have been used this paper which are technical and allocative efficiencies. He also calculated the overall (economic) efficiency score product with technical efficiency and allocative efficiency ( $OE: TE*AE$ ). Also, he investigated which factor has an impact on these three types of efficiencies by using Least Square Regression. Factors were defined indifferently for each types of efficiency. His studies also include a comparison of Australian banks according to their overall efficiency level with their European and USA counterparts and the paper concluded that Australian banks' efficiency was below the world's mean efficiency. The study inferred in addition to that domestic banks' efficiency is greater than their foreign peers.

Xiaoqing Maggie and Heffernan (2007) applied cost x-efficiency in the Chinese banking system by using a parametric model known as the 'stochastic cost frontier approach'. Their report aimed to both find and answer to the question of whether types of ownership of the different banks have an impact on bank efficiency, and

also whether there is a correlation between x-efficiency and banking regulations. The findings of the report revealed that commercial banks that are under government ownership are less efficient than joint-stock banks. However, it was found that efficiency in all types of bank are down 40%-60% on the x-efficiency frontier.

Another study concerning the bank efficiency is Pasiouras (2008) paper that uses DEA. He analyzed the Greek commercial banks over the course of 2000-2004. While he applied intermediation approach in his study he also compared the collected results with another approach named as production approach. To do this, the study is divided into 5 different models using various input and output combinations and 2 out of these 5 models included off-balance sheet items as an output. The article reaches to the conclusion that the efficiency scores are not affected when off-balance sheet items are included in the outputs while higher efficiency is acquired with the inclusion of loan loss provisions in the inputs. Moreover the paper concluded that same result with Isik and Hassan (2003) on that banks operating in domestic level has lower technical efficiency compared to international banks.

The literature on Islamic Banking also addresses the concept of efficiency in the widely cited study of Yudistira (2004). The study examines technical, pure technical and scale efficiency of 18 Islamic Banking from Middle-East and Non-Middle East through applying DEA likewise other studies we mentioned about above. According to the study results, Islamic Banking in non-Middle East region was founded to be more efficient than their Middle Eastern counterparts. The Study was finalized with a suggestion for small-to-medium Islamic Banks and it was advised that M&A could be a solution for dis-economies of scale of these banks.

In Turkish Literature there are various studies that focus on the banking efficiency topic using different methods and different time periods. Oral and Yolalan (1990) evaluated branches of leading commercial banks in the Turkish Banking System in

terms of operating efficiency and profitability. The study has shown that banks based on service-efficient are the most profitable ones.

Zaim (1995) studied the effects of financial liberalization policies on the economic efficiency of Turkish commercial banks over the period of 1981-1990 by using non-parametric frontier methodology. The analysis covers 42 commercial banks chosen for the pre-liberalization era data set from 1981 and 56 commercial banks chosen for the post liberalization era data set from 1990 which reflects the increased number of banks. The study found that state banks are more efficient than private ones and this result contradicts with the hypothesis that the efficiency of the state banks tend to be lower than private banks. The second main finding is that financial reforms affects banking industry in a way that technical and allocative efficiency is improved.

Isik and Hassan (2002) investigated five different types of efficiencies which are cost, allocative, technical, pure technical and scale in the Turkish banking industry using non –parametric approach along with parametric approach. Labor, capital and loanable funds are applied as an input while short term loans, long term loans, off-balance sheet items and other earning assets are applied as an output in the analysis. In contrast to Zaim’s (1995) findings on banking efficiency Isik and Hassan (2002) indicated that state banks founded to be less efficient than the private banks in terms of technical, pure technical and scale efficiency over the period 1988-1996. However overall efficiency of the state banks are higher than the private banks. In a later study, Isik and Hassan (2003) also estimated the efficiency Turkish commercial banks through employing first non – stochastic approach together with GLS and Tobit Regression. Study aimed at measuring the effects of types of ownership, market structure, control&governance and other banks traits effects on banking efficiency.

Diverging from the literature that addresses Turkish bank efficiency, Aysan, Karakaya and Uyanik (2011) applied panel stochastic frontier approach (SFA) in his study for the first time. Study covers post crises era from 2002 to 2007 in

Turkish banking sector to analyze cost and profit efficiency in the sector. Study consists of 32 banks covering 16 foreign banks, 13 domestic banks and 3 state banks. Their study investigates the relationship between mainly three variables as size, profitability and efficiency. The results of the study indicate that while there is a significant relation between size and profitability, there is a non-significant relation between efficiency and profitability. There also exists positive relation between efficiency and size.

Batir, Volkman and Gungor (2017) investigated technical, allocative and cost efficiency of participation banking and conventional banking which operates from 2005 to 2013 in Turkey. In this study, the level of efficiency calculated by using DEA method to gain efficiency scores first and then Tobit regression analysis was applied to those efficiency scores to obtain their determinants. This study finds out that participation banks perform much better with respect to several indicators of efficiency scores which are technical, allocative and cost efficiency. According to this study's result, if we are to rank the bank types based on their efficiency levels, foreign, domestic private, and state banks follow each other from the most efficient to the least one.

## **DATA AND METHODOLOGY**

### **1.1. MEASUREMENT OF EFFICIENCY**

The Efficiency of banking is measured in various ways in recent literature. A short summarize can be listed in three main methods which are parametric methods, non-parametric methods, and the traditional method. The traditional method is based on ratio analysis which is very common and applicable to evaluate the performance of the banks through addressing the relations among the financial data. We can trace the first usage of ratio analysis back to the 1912 study of Alexander Wall in which he compiled a large data of financial statements taken from commercial paper brokers and this analysis terminated in Wall's classic reports (as cited in Horrigan, 1968) "Study of Credit Barometrics" in the year 1919. Ratio analysis can answer the questions of how the performances of the banks are changed throughout different time periods and across different banks in the sector. As we mentioned previously, ratio analysis is practical in many cases. However, it is insufficient where multiple inputs and outputs are analyzed. If analysis has more than one input and one output, parametric or non-parametric methods can be applied. Parametric methods has three approaches which are Thick Frontier Approach (TFA), Distribution Free Approach (DFA) and the most common used one is Stochastic Frontier Approach (SFA). The method is formed on econometric techniques that the score of efficiency obtained from residuals or dummy variables, and it embodies the estimation of production or cost function. The econometric approach appears as a good option as it provides room for noise in measuring inefficiency, however one downside of this approach is its imposition of a certain version of functional form for estimation (Issik and Hassan 2003). We will not be able to give further explanation about parametric methods since we do not use this methods in this study. We will use non-parametric methods to examine efficiency following Sathye (2001), Avkiran (2006), Pasiouras (2008). Non-Parametric methods is a linear

programming and commonly used approaches as Data Envelopment Analysis (DEA) in the literature.

## **2.2. DATA ENVELOPMENT ANALYSIS**

Data Envelopment Analysis (DEA), infrequently called frontier analysis, is based on the technique of assessment of the relative efficiency among comparable units. Comparable units are defined as Decision Making Units (DMU) in this mathematical programming technique. DEA is accepted as a practical approach when the purpose is to obtain the efficiency score from multiple inputs and outputs. DEA analysis could be applied to not only production process, but also to benchmarking operational and managerial process of the organizations.

DEA does not need any assumptions about the functional form and measurement of DMU is connected to all other DMU's with the only constraint that all DMU's below from efficient frontier or in the efficiency frontier. This leads to divergence of DEA from former parametric approach (Seiford and Thrall, 1990). In other words, the best frontier or best practice in the sample gives us to what the efficiency level for the sample is and comparing each of DMUs with the best frontier shows us which DMU's are efficient or inefficient.

We can mention two main advantages that using DEA method may offer to decision makers. Firstly, it may help to understand if a firm operates efficiently based on the calculated efficiency score. Secondly, it can indicate the required values for input and output to increase efficiency therefore it may guide policy makers for the necessary reduction in input levels or necessary increase in output levels. (Huguenin, 2012).

DEA has been used in the field of education, health and military for public institutions and also for banking sector, aviation sector, defence industry, manufacturing sector, restaurants, city, and regional planning to make a comparison and to evaluate their performances.

### 2.2.1. Terminology of DEA

To provide better grasp of the Data Envelopment Analysis to, the terminology of the approach is listed as below:

**Decision Making Unit (DMU):** Charnes, Cooper & Rhodes (1978) used this term in the paper to make a reference to non-profit organizations. However, over the course of time analysis started to focus on organizations other than non-profit organizations such as firms or industry. The term signifies that DMU has a central role in producing its input into outputs.

**Productivity:** Productivity is defined as the ratio between an output and inputs. Another definition by Prokopenko (1987) stated that production process is creation of any services and goods by using labor, capital, technology, land, energy, information in an efficient way. Achievement of higher output level according to its volume or quality by using same amount of input is accepted as higher productivity.

According to this basic definition, productivity can illustrated as below:

$$Productivity = \frac{Output}{Input}$$

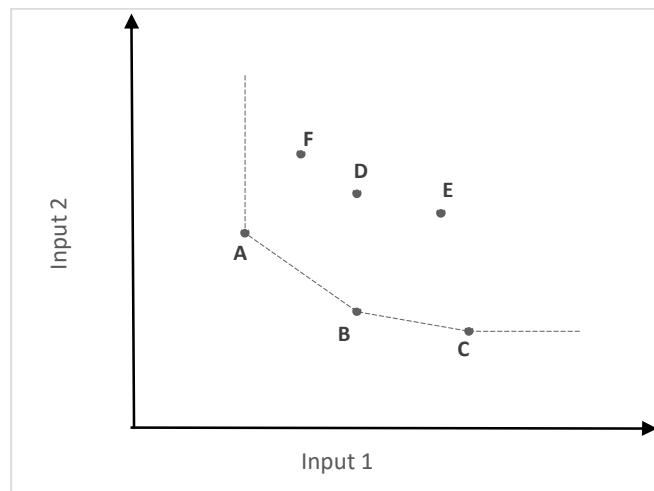
Formulation is easy to apply when there is one input and one output in the case. However, a rise in the number of inputs and outputs in the equation requires accumulating multiple inputs and outputs to ensure that productivity remain the ratio of two scalars (Daraio & Simar, 2007).

**Efficiency:** In the literature, efficiency and productivity are defined in the same in some studies, however these terms are not equal but similar. To put it differently, efficiency is a measurement which measures the level of success that production

unit can convert its inputs to its outputs. Therefore efficiency represents the optimal frontier that combination of input and output can produce.

**Efficiency Frontier:** Efficiency frontier is convex hull that encircles all the data in the sample in Figure 2.1. In the graph (Cooper, Seiford & Tone as cited in (Stokes, 2007)), A B C points constitute the optimal combination of various input 1 and input 2 quantities to produce one output. Any deviation from this line represents an inefficient use of inputs as F D and E points indicate. The reason for these points being inefficient is due to their usage of excessive amount of inputs to produce same level of output with A B and C points. These points need to move to the line of A B and C to reach the optimal combination. This line that is composed of optimal combinations are referred to as "efficient frontier".

**Figure 2.1.** Efficient Frontier



Source: Stokes, Tozer & Hyde, 2007

**Efficiency Score:** In the DEA, after the calculation, every DMU obtains an efficiency score between 0 and 1. If DMU has 1 efficiency score, this expresses that the DMU is efficient and those of DMU's that acquire 1 constitute the frontier. If

DMU score is less than 1, DMU is accepted as relatively inefficient and their efficiency values refers to distance from the efficiency frontier.

### 2.2.2. Types of Efficiency in DEA

**Technical Efficiency:** Technical efficiency is a process based on converting inputs to outputs. This process is qualified as efficient either the given input produces the maximum level of output or a particular output level is produced by the smallest input level. Equation of relative technical efficiency as below:

$$\text{Efficiency} = \frac{\text{Weighted sum of output}}{\text{Weighted sum of input}}$$

In notation forms efficiency of unit is represented as  $i$  :

$$i = \frac{u_1 y_{1i} + u_2 y_{2i} + \dots}{v_1 x_{1i} + v_2 x_{2i} + \dots}$$

In the equation,  $u$  and  $v$  represent the weight that each input and output ;  $x_{1i}$  represent the amount of the input 1 for unit  $i$ , and  $y_{1i}$  represent the amount of output 1 for unit  $i$  (Hassan, Mohamad & Bader, 2009).

**Allocative Efficiency:** Allocative efficiency is defined as choosing the right composition of input for reduction in the cost of production related to cost of inputs. Combination of technical efficiency and allocative efficiency verifies the overall efficiency measurement (Coelli, Rao, O'Donnell & Battese, 2005).

$$OE = TE \times AE$$

**Scale Efficiency:** Scale efficiency represent another element of technical efficiency which can be measured based on operation size. When the optimal scale size is acquired during production process, we can state that scale efficiency is fulfilled. It

is calculated through dividing the technical efficiency by pure technical efficiency (Avkiran, 2006).

$$SE = TE/PTE$$

### 2.2.3. Model Specifications of DEA

DEA should be applied under the following conditions are provided:

- In the analysis, all DMU's should be similar in terms of homogeneity. The study is more feasible when all DMU's have similar environmental structure and it is also crucial that every DMU's in the analysis has to be evaluated with same input and output variables.
- If negative values are used in the analysis, DEA model is unlikely to ensure a meaningful efficiency score. Because of this, variable of inputs and outputs should have positive values. If variables have negative values, the examiner can implement two approaches. Firstly, adding a positive value for each negative input or output value makes values positive for each of them. Sustaining the same level of efficiency frontier requires a similar adjustment for all DMUs in the sample which involves same input or output value. Secondly, another approach would be changing the negative value assigned for the output with a small positive value. Because DEA model provides the values for which DMU's performance is the highest, this ensures that a very small value chosen for the output do not produce a decisive effect for the efficiency rating (Bowlin, 1998).
- In the study, an increase in any input should be followed by an increase in output level and never by a decrease. This condition depends on the mathematical property of isotonicity which was stated by Charnes, Cooper, Golany, Seiford and Stutz (1985).

- A meaningful analysis for DEA requires adequate number of DMU's selection. Each input and output variable in the sample demands at least three number of DMUs. Unless the analysis has at least three DMU's for each input and output, it may result in designating an extra number of efficient DMUs than it should have. Avoiding this kind of error, the examiner can divide DMU's data into quarters which would allow to treat each quarter as a separate DMU (Bowlin, 1998). Additionally, according to Chaparro, Jiménez and Smith's study, stated in 1999 (as cited in Khezrimotlagh, 2015), if there is  $m$  number of DMU and  $n$ , number of input and  $p$  number of output respectively then value of  $m/(n+p)$  should be large enough. While Dyson *et al.* , also advocated in 2001 (as cited in Khezrimotlagh, 2015), that DEA misinterprets the efficiency if  $m$  is not greater than  $(2 \times n \times p)$ .

#### **2.2.4. Methods of DEA**

In 1957 with his milestone study Farrell, developed the idea of measure efficiency. He explained the overall efficiency with two components of it as technical and allocative efficiency. Although his research was the first step towards evaluating efficiency, his models and methods were not applicable for multiple inputs and multiple outputs models. Based on Farrell's study, Charnes, Cooper, and Rhodes launched the first DEA method called CCR, named after the study's authors. The CCR model is a linear programming model, and the model assumed Constant Return to Scale (CRS). It is only acceptable where all DMU's operations are in optimal scale. A later study by Banker, Charnes, and Cooper (1984) developed the BCC model to estimate Variable Returns to Scale.

### 2.2.4.1. CCR Model

As we mentioned before CCR model is based on Constant Return to Scale which means any increase in input level should result in an increase in outputs with the same proportion (Toloo & Nalchigar, 2011).

The mathematical model, is also known CRS, developed by Charnes, Cooper and Rhodes (1978), is illustrated below:

In the evaluation, we assume that  $n$  numbers of DMUs are using  $m$  different inputs which producing  $s$  different outputs where  $DMU_j; j=1, \dots, n$ .

Objective Function:

$$\text{Max } k_0 = \frac{\sum_{r=1}^s u_r y_{r0}}{\sum_{i=1}^m v_i x_{i0}} \quad (2.1)$$

$$\text{St.: } \frac{\sum_{r=1}^s u_r y_{rj}}{\sum_{i=1}^m v_i x_{ij}} \leq 1; \quad j=1, \dots, n \quad (2.2)$$

$$u_r \geq 0; \quad v_i \geq 0; \quad r=1, \dots, s; \quad i=1, \dots, m \quad (2.3)$$

$u_r$  : the weights for output  $r$

$v_i$  : the weights for output  $i$

$x_{ij}$  : the positive value of inputs  $i$  for unit  $j$

$y_{rj}$  : the positive value of outputs  $r$  for unit  $j$

- (2.1)  $k_0$  represented the relative efficiency score of  $DMU_j$ . The ratio aimed to be maximized.
- (2.2) Efficiency ratio can not obtain a value higher than one. If the value is equal to one, decision-making units will be on the efficient frontier (Chen & Ali, 2002).
- (2.3) Suppose that the number of output is represented as  $s$ , then the value of  $r$  obtains between 0 and  $s$ , and the number of input is represented as  $m$ , then the value of  $i$  obtain between 0 and  $m$ . The weighted value of inputs and outputs should not be negative.

DEA models diverge into two types as input-oriented and output-oriented models. The input-oriented model aims to keep outputs constant while inputs are minimized. The output orientation model is also trying to reach a maximum level without changing the given inputs.

- **Input-Oriented CCR**

The following equation represent the input-oriented CCR method in linear programming (Cook, Tone & Zhu, 2004):

Objective: 
$$\text{Max } \sum_{r=1}^s u_r y_{rj_0} \tag{2.4}$$

Subject to.: 
$$\sum_{i=1}^m v_i x_{ij} - \sum_{r=1}^s u_r y_{rj} \geq 0$$

$$\sum_{i=1}^m v_i x_{ij_0} = 1 \quad u_r \geq 0 ; \quad v_i \geq 0$$

$$r=1, \dots, s ; \quad i=1, \dots, m ; \quad j=1, \dots, n$$

The fractional equation is converted to the primal equation by making the denominator value ( $\sum_{i=1}^m v_i x_{ij_0} = 1$ ) equal to 1 (2.4). The objective function shows how much of the inputs of the relevant decision-making units are reduced to achieve a particular output level.

- **Output-Oriented CCR**

Output-orientation is presented as below (2.5) and for this one, ratio is defined as its inputs to its outputs (Cooper, Seiford & Zhu, 2011):

$$\text{Min } \sum_{r=1}^s v_i x_{ij_0} \quad \text{St.} : \sum_{i=1}^m v_i x_{ij} - \sum_{r=1}^s u_r y_{rj} \geq 0 \quad (2.5)$$

$$\sum_{r=1}^s u_r y_{rj_0} = 1$$

$$u_r \geq 0 ; \quad v_i \geq 0$$

$$r=1, \dots, s ; \quad i=1, \dots, m ; \quad j=1, \dots, n$$

If the decision-making unit is efficient under the input-orientation CCR model, It will be also efficient under the output-oriented CCR model (Behdioğlu & Özcan, 2009).

#### 2.2.4.2. BCC Model

In 1984, another model was launched by Banker, Charnes, and Coopers' studies and named after its author called the BBC model.

Huguenin (2012) indicates that the CRS model is designed for the model units that are operating at an optimal scale, as opposed to the VRS model which is used when the model units are not operating at an optimal scale. Interference of governments and imperfect competition environment are the examples for usage of VRS model.

The BCC model is the same as the CCR model, besides adding constraint ( $\sum \lambda_j = 1$ ). The primal formulation has a measurement of the variable returns on the scale for the axis denoted as  $c_0$  (2.6) . Likewise, the CCR model, the BCC model has input orientation and output orientation. Input orientation model of BCC is trying to minimize the input level, while the output orientation model of BCC aims to maximize its output level. The formulation for BCC model is presented as below (Huguenin, 2012):

- **The Input Oriented BCC Model**

$$\text{Maximize } \sum_{r=1}^s u_r y_{rj_0} + c_0 \quad (2.6)$$

$$\text{Subject to } -c_0 + \sum_{i=1}^m v_i x_{ij} - \sum_{r=1}^s u_r y_{rj} \geq 0$$

$$\sum_{i=1}^m v_i x_{ij_0} = 1$$

$$u_r \geq 0; \quad v_i \geq 0$$

$$r=1, \dots, s; \quad i=1, \dots, m; \quad j=1, \dots, n$$

- **The Output Oriented BCC Model**

$$\text{Minimize } \sum_{r=1}^s v_i x_{ij_0} - c_0 \quad (2.7)$$

$$\text{Subject to } -c_0 + \sum_{i=1}^m v_i x_{ij} - \sum_{r=1}^s u_r y_{rj} \geq 0$$

$$\sum_{r=1}^s u_r y_{rj_0} = 1$$

$$u_r \geq 0; \quad v_i \geq 0; \quad r=1, \dots, s; \quad i=1, \dots, m; \quad j=1, \dots, n$$

Scale and technical efficiency are evaluated under the BCC model, and the model calculates the efficiency frontier according to variable return to scale (VRS). The overall efficiency is the combination of technical and scale efficiency. Firstly,  $c_0$  (2.7) is the point on the efficiency frontier where it represents returns to scale and it can have positive, zero, and negative values. It indicates that the DMU has increasing, constant, or decreasing returns to scale depending on the value that it gets. If DMU at the efficiency frontier according to the overall efficiency value, it means that DMU is technical and scale efficient. If DMU is at the efficiency frontier according to the overall efficiency value, it means that DMU is both technical and

scale efficient. Put it differently, If DMU is inefficient according to its value of overall efficiency, DMU can be technically efficient but scale inefficient or vice versa. At this point BCC model can distinguish the efficiency or inefficiency sources from overall inefficiency (Lo, Chien & Lin, 2001).

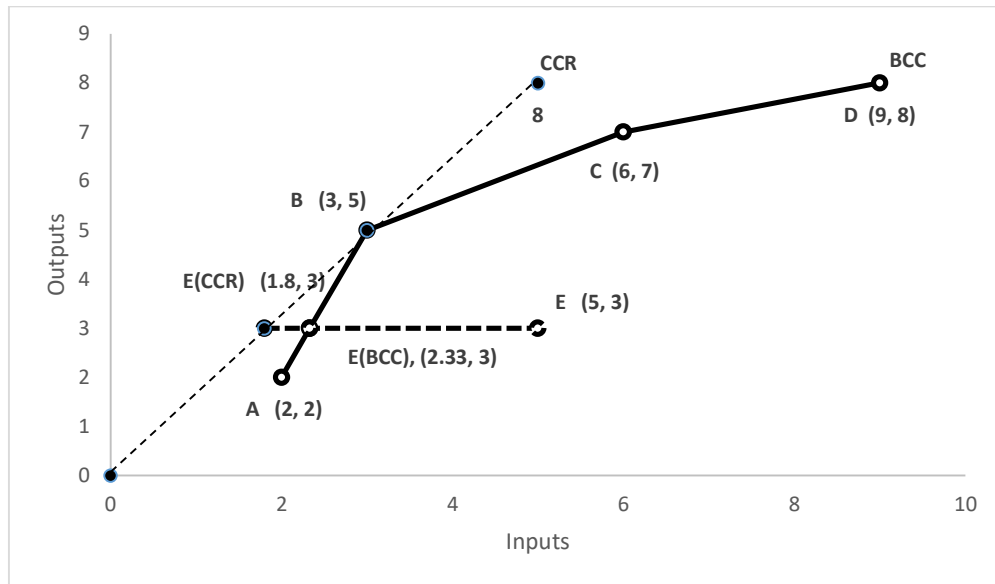
All the equations were given in the primal version in this study. We will not detail further, but one can see other versions of this equation, such as dual linear and dual linear programming with slacks in the literature.

There are two other models called additive model and multiplication model in DEA. In CCR and BCC models, examiner has to decide which orientation types should be applied to the model. However, additive model combines both input orientation and output orientation in one model. It allows us to answer both how much reduction in input level and how much increase in output level should be made in the model at the same time and what differentiate multiplication model from others is that it multiplies the input and outputs values. Therefore, it applies multiplier sign ( $\prod$ ) instead of summation sign ( $\sum$ ) in the equation.

### **2.2.5. DEA Methods in Graph**

Figure 2.2 exhibits a single input / single output model using both CCR and BCC models. Decision-making units of A, C, D are on the efficient frontier according to the BCC model, and DMU B is the best practice in both CCR and BCC model while E is not on the efficiency frontier.

Figure 2.2. DEA in Graph



Source: Bowlin (1998)

The efficiency frontier of BCC indicates that units of A, B, C, D are technically efficient; however, their level of returns to scale is different from each other. For instance, from point A to point B, an increase in output level is greater than the increase in input level, which demonstrates the increasing returns to scale. Unit A and Unit B are both technically efficient, but unit A is not scale efficient as opposed to unit B, because it does not provide the condition that makes unit B scale efficient which is having constant returns to scale. Lines from point B to C and from C to D are examples of the decreasing return to scale as we can see an increase in input level results in a less amount of increase in output level. Therefore, unit C and D is technical efficient, but not scale efficient (Bowlin, 1998).

How the efficiency of BCC model and CCR model differs from each other can be illustrated in the inefficient unit E in Figure 2.2 If the inputs of unit E is reduced to the point of 2.333, unit E can be found efficient in point E (BCC). In this case, unit E receives 0.47 efficiency score, and it indicates that inputs of unit E will need a

reduction equal to 53% . Furthermore, if unit E moves on the CCR efficiency line, it would receive a 0.36 efficiency score. It means that unit E needs to decrease its input level by 64% to be located at E(CCR) in the CCR efficiency frontier. It is the point where unit E would be technical and scale efficient. Therefore, it can be understood that the CCR model's efficiency score is always less than the score of the BCC model; besides the case where the decision-making units are found to be efficient in both CCR and BCC model, for instance, unit B (Bowlin, 1998).

### **2.3. DATA AND VARIABLES**

Cook, Tone and Zhu (2014) noted that the examiner should consider the following questions to proceed with the analysis:

- What is the aim lying behind measuring performance and analyzing it?
- Which decision-making units (DMUs) outputs and inputs are utilized to determine the level of DMUs performance with a fix number of output and input?
- What is the optimal number of DMUs?
- What can be defined as the most suitable model orientation?

In the previous sections, we gave information about the aim of efficiency measurement. The rest of this section will discussing the data selection, input and output selection, and the model selection we used in this study in detail.

#### **2.3.1. The Purpose of the Analysis**

We aimed to analyze and compare the performance of the different types of banks in Turkish Banking System. To make this analysis, we used data from state owned deposit banks, private deposit banks and participation banks from 2015 to 2019.

We used the CCR model via pyDEA, which is a software package developed in Python.

### 2.3.2. Selecting DMUs

As of January 2021, the exact number of the banks that are performing in Turkey is fifty-five. Thirty-five of them are deposit banks, while three of them are state-owned, thirty of them are private, and two of them perform under the Saving Deposit Insurance Fund of Turkey (SDIF). Among these, while fourteen banks are classified as investment banking, six others are participation banks and these participation banks also diverge into two branches as three are state-owned, and other three are foreign. We excluded Turkiye Emlak Katılım Bankası A.Ş. because their operation as participation banks started in 2019. This study analyzes these banks during the period of 2015- 2019. We excluded from our analysis two banks operating under the (SDIF) and also six foreign banks which have branches in Turkey. 14 development and investment banking were also excluded because their business structures differ from deposit banks. Bank of China is also exempt from the analysis here because their operation started on 10 January 2017 in Turkey. The banks which we analyzed as listed below:

**Table 2.1** List of Banks in Analysis

Number	Types	Banks
1	State-owned deposit bank	Halkbank A.Ş.
2		VakıfBank T.A.O.
3		Ziraat Bankası A.Ş.
4	Foreign deposit banks	Alternatif Bank A.Ş.
5		Arap Türk Bankası A.Ş.
6		Burgan Bank A.Ş.
7		Citibank A.Ş.
8		DenizBank A.Ş.

Number	Types	Banks	
9	Foreign deposit banks (continue)	Deutsche Bank A.Ş.	
10		Garanti BBVA A.Ş.	
11		HSBC A.Ş.	
12		ICBC Turkey Bank A.Ş.	
13		ING Bank A.Ş.	
14		MUFG Bank Turkey A.Ş.	
15		Odeabank A.Ş.	
16		QNB Finansbank A.Ş.	
17		Rabobank A.Ş.	
18		T-Bank A.Ş.	
19	Foreign participation banks	Albaraka Türk A.Ş.	
20		Kuveyt türk A.Ş.	
21		Türkiye Finans Katılım Bankası A.Ş.	
22	Privately owned deposit bank	Akbank T.A.Ş.	
23		Anadolubank A.Ş.	
24		Fibabanka A.Ş.	
25		Şekerbank T.A.Ş.	
26		Türk Ekonomi Bankası A.Ş.	
27		Turkish Bank A.Ş.	
28		Türkiye İş Bankası A.Ş.	
29		Yapı Kredi Bankası A.Ş.	
30		State owned participation bank	Vakıf Katılım Bankası A.Ş.
31			Ziraat Katılım A.Ş.

Because we do not have any data for Vakıf Katılım Bankası A.Ş. including loans, total deposits, and off-balance sheet items in its financial tables for the year of 2015, we excluded this year for Vakıf Katılım Bankası A.Ş. from the analysis as DEA model is sensitive to its outlier values. All the data used in this analysis is collected from Turkish banks' financial statements disclosed by the Bank Association of Turkey (BAT) and Participation Banks Association of Turkey (PBAT). Dwelling on specifications rules that we covered under the title of DEA Specification sufficient number of DMUs are selected for this study.

### **2.3.3. Selection of Model Orientation and Approaches**

Evaluating banking efficiency, the researcher should define inputs and outputs, and it is a controversial subject for researchers. Berger and Humphrey (1997) stated there are two approaches called the intermediation approach and the production approach. As stated in their reports, the production approach considers banks as the institutions that produce loans and deposits with the physical inputs provided as labor and capital. Banks are mainly recognized as a financial institution that is producing services for account holders. On the other hand, under the intermediation approach, banks play a role as intermediaries between savers and investors. According to this approach, the bank produces loans and other assets using deposit funds and labor.

We applied the intermediation approach because Berger and Humphrey (1997) confirmed that intermediation approach is the suitable method if the analysis focuses on a financial institution in its entirety while production approach is more suitable for the analyses that focus on branches of the banks.

The method that will be chosen is determined by whether inputs and outputs can be controlled. If the control over inputs is limited, an output oriented model and if the control over outputs is limited then an input oriented model should be used. It is more appropriate to use additive models if an orientation cannot be established (Özçelik & Kandemir, 2017). We implemented the input orientation approach because in this analysis banks have more power over its inputs than its outputs.

### **2.3.4. Input and Output Selection**

In the literature, there are various perspectives regarding the inputs and outputs to be selected. There has not been any consensus reached so far, and we can observe that the usage of certain variables as deposits differs from one study to another. For example, some studies included the deposit as an input variable while others defined

them as an output. Holod and Lewis (2011) stated that deposit is considered as a service offered by banks to its costumers according to the production approach. If an analysis uses the production approach, it is common to use deposits as an output instead. The intermediation approach assumes that banks are collecting the deposits to make loans and it is the reason for deposits' being considered as an input under the intermediation approach. However, the generally accepted method is choosing fixed assets as the input and earning assets as the output. We gathered different combinations of input/output selection as in Table 2.2.

**Table 2.2.** Input and Output Selection in Literature

<b>Author</b>	<b>Inputs</b>	<b>Outputs</b>
Zaim (1995)	Total number of employees, Total interest expenditures, Depreciation expenditures, Expenditures on materials	Total balance of demand deposits, Total balance of time deposits, Total balance of short-term loans, Total balance of long-term loans
Mester (1996)	Labour, Phsical capital, Borrowed money	Real estate loans, Commercial loans, Individual loans
Brockett, Charnes, Cooper (1997)	Interest Expense, Non-Interest Expense, Provision for Loan Losses, Total Deposits	Interest Income, Total Non-Interest Income, Allowances for Loan Losses, Total Loans
Cingi ve Tarım (2000)	Number of branches, Number of employees, Total interest expenses, Total assets	Net profit, Total interest income, Total deposits
Altunbas, Liu, Molyneux, Seth (2000)	Labour, Funds, Capital	Total loans, Total securities, Off-balance sheet items

<b>Author</b>	<b>Inputs</b>	<b>Outputs</b>
Sathye (2001)	Labour, Capital, Loanable funds	Loans, Demand deposits
Isik, Hassan (2002)	Labour, Capital,  Loanable funds	Short term loans, Long term loans, Risk adjusted off-balance sheet items, Other earning assets
Casu, Molyneux (2003)	Total costs, Total deposits	Total loans, Other earning assets
Mercan, Yolalan (2003)	Personnel expenses/Earning assets,  Total expenses/Total income	Earning Assets/Total Assets, (Shareholders' equity+Net profit)/Total liabilities, Average return on equity (Net profit/Average shareholders' equity)
Yudistira (2004)	Staff cost, Fixed cost, Total deposits	Total loans, Other income, Liquid assets
Maggie, Heffernan (2007)	Cost of Funds, Cost of Fixed assets, Cost of Employees	Total deposits, Total loans, Total investments, Non-interest income
Aysan, Ceyhan (2007)	Capital, Labour,  Loanable funds	Short term credits, Long term credits, Off-balance sheet items, Other earning assets

<b>Author</b>	<b>Inputs</b>	<b>Outputs</b>
Hassan, Mohamad, Bader (2009)	Labour, Fixed assets, Total funds	Total loans, Other earning assets, Off-balance sheet items
Sufian, Noor (2009)	Total deposits, Capital	Total loans, Income, Investments
Aysan, Karakaya, Uyanik (2011)	Labour, Capital, Funds	Short term commercial loans, Long term commercial loans, Off-balance sheet items, Other earning assets
Ismail, Majid, Rahim (2013)	Labour, Capital, Total deposits	Total loans, Other earning assets, Off-balance sheet items
Kamarudin, Nordin, Muhammad, Hamid (2014)	Deposits, Labour	Loans, Income
Ada, Dalkılıç (2014)	Total assets, Total equity	Total deposits, Period net income/loss
Batir, Volkman, Gungor (2017)	Labour, Capital, Funds	Total Loans, Off-balance sheet items
Pasiouras (2008) Model 1	Fixed assets, Customer deposits and short term funding, Number of employees	Loans, Other earning assets
Pasiouras (2008) Model 2	Fixed assets, Customer deposits and short term funding, Number of employees	Loans, Other earning assets, Off-balance items
Pasiouras (2008) Model 3	Fixed assets, Customer deposits and short term funding, Number of employees, Loan loss provisions	Loans, Other earning assets

Inputs and outputs are selected according to the following studies; Altunbas et al. (2000), Sathye (2001), Isik, Hassan (2002), Pasiouras (2008), Hassan et al., (2009), Aysan, Karakaya and Uyanik (2011), Ismail, Majid and Rahim (2013), Batir et al. (2017):

### **Inputs**

- Capital
- Total Deposit
- Labour

Capital is the tangible assets property and equipment which are owned by the banks. Labour is the expenses for employee displayed in the financial tables. Finally, total deposit are sum of deposit, borrowed funds and marketable securities.

### **Outputs**

- Loans
- Other-Earning Asset
- Off-Balance Sheet Items

Loan is the sum of short term and long term loans. Other-earning assets contain money market securities, banks other financial institutions and securities which are held for trading and available for sale and held to maturity. Off-balance Sheet items are sum of off-balance sheet commitments and contingencies (guarantees and sureties, commitments, derivative financial instruments) and custody and pledged items (items held in custody, pledged items and confirmed bills of exchange and sureties).

## RESULTS

Analysis contains data of 30 banks for the year 2015 and 31 banks for the years of 2016, 2017, 2018 and 2019 (154 DMU's in total). Three inputs and three outputs were selected according to the intermediation approach, and the CCR-input orientation along with BCC-input orientation method have been applied via pyDEA. The results of our analysis are exhibited in table 3.1 and table 3.3. The boxes where efficiency score are equal to 1 shows that the units are using capital, deposits, and labor sources efficiently to produce sufficient output levels. DMU's whose efficiency score are not equal to 1 indicate a situation that they are not realizing their potentials however these inefficient units can be rendered efficient through taking the efficient units as the base. Table 3.1 shows the overall technical efficiency scores based on CCR methods, while Table 3.3 indicates the technical efficiency score (as known as pure technical efficiency) based on the VRS model. As we noted, CCR measures the overall technical efficiency score, BCC measures the pure technical efficiency score, therefore through evaluating CCR and BCC in the same data, we can also obtain a scale efficiency score (Table 3.6) as CCR is composed of scale efficiency and pure technical efficiency ( $SE = OE/PTE$ ).

Table 3.1 illustrates the results of overall technical efficiency scores from 2015 to 2019 with regards to their types. According to these results, the number of the efficient banks for the years of 2015 and 2016 are determined as two, while this number increases to three for the years of 2017, 2018, and 2019. MUFG Bank and Rabobank are foreign deposit banks and they were ranked as the only efficient banks in 2015. They preserve their seats for the years of 2017 and 2018 and ranked as the most efficient banks among all other types of banks. The results further indicate that Deutsche bank was also founded to be efficient for three consecutive years from 2016 to 2018, however its score dramatically decreased to 0.890 in 2019. It is also noted that Vakıf Katılım acquires an efficiency score of 1 in 2016 a year after its establishment. In 2019 two state-owned banks, Ziraat and Vakıf were founded be efficient together with Rabobank.

**Table 3.1.** Efficiency Scores According to CCR Methods

<b>Banks</b>	<b>Types</b>	<b>2015</b>	<b>2016</b>	<b>2017</b>	<b>2018</b>	<b>2019</b>
Ziraat Bankası	1	0.857	0.888	0.943	0.989	1
Halk Bankası	1	0.797	0.822	0.886	0.920	0.964
Vakıflar Bankası	1	0.894	0.953	0.973	0.963	1
Alternatifbank	2	0.725	0.819	0.870	0.865	0.913
Arap Türk Bankası	2	0.625	0.758	0.647	0.686	0.584
Burgan Bank	2	0.761	0.865	0.956	0.937	0.876
Citibank	2	0.797	0.787	0.722	0.485	0.517
Denizbank	2	0.669	0.698	0.740	0.799	0.795
Deutsche Bank	2	0.950	1	1	1	0.890
HSBC Bank	2	0.602	0.582	0.592	0.619	0.763
ICBC Turkey Bank	2	0.589	0.615	0.770	0.794	0.786
ING Bank	2	0.747	0.757	0.800	0.760	0.719
MUFG Bank	2	1	0.962	1	1	0.949
Odea Bank	2	0.795	0.849	0.812	0.949	0.906
QNB Finansbank	2	0.791	0.764	0.809	0.796	0.815
Rabobank	2	1	0.982	1	1	1
Garanti Bankası	2	0.819	0.839	0.838	0.838	0.841
Turkland Bank	2	0.807	0.838	0.870	0.462	0.513
Albaraka Türk	3	0.590	0.597	0.617	0.615	0.582
Kuveyt Türk	3	0.662	0.663	0.690	0.699	0.716
Türkiye Finans	3	0.903	0.887	0.888	0.880	0.818
Akbank	4	0.933	0.954	0.971	0.909	0.944
Anadolubank	4	0.595	0.654	0.703	0.684	0.749
Fibabanka	4	0.846	0.868	0.887	0.892	0.841
Şekerbank	4	0.902	0.997	0.954	0.972	0.974
Türk Ekonomi Bankası	4	0.707	0.667	0.700	0.636	0.634
Turkish Bank	4	0.482	0.557	0.606	0.574	0.736
Türkiye İş Bankası	4	0.727	0.736	0.748	0.755	0.765
Yapı ve Kredi Bankası	4	0.817	0.821	0.800	0.989	0.900
Vakıf Katılım Bankası	5	-	1	0.901	0.789	0.868
Ziraat Katılım Bankası	5	0.711	0.749	0.950	0.853	0.934
<b>Average</b>		<b>0.770</b>	<b>0.804</b>	<b>0.827</b>	<b>0.810</b>	<b>0.816</b>
<b>Average Inefficiency</b>		<b>0.230</b>	<b>0.196</b>	<b>0.173</b>	<b>0.190</b>	<b>0.184</b>
Note: Types 1, 2, 3, 4, 5 are state-owned deposit bank, foreign deposit banks, foreign participation banks, privately owned deposit bank, state-owned participation bank respectively.						

According to CCR results, the remaining banks in the table 3.1 with an efficiency score less than one, are technically inefficient. The lowest scores are 0.482, 0.582, 0.592, 0.462, 0.513 for the years 2015, 2016, 2017, 2018 and 2019 respectively and the banks which have the lowest efficiency score are Turkish Bank for the year of 2015, HSBC Bank for the years of 2016 and 2017, Turkland Bank for the year of 2018 and 2019. Another conclusion from the Table 3.1 is that, average score efficiency score for the year 2015 is 0.770, and the average inefficiency score is 0.23. It suggests that an average bank would need to use only 77% of its inputs if it produces its outputs on the efficient frontier. In other words, banks manage to create the same output level while reducing their inputs of capital, total deposits, and labor by at least 23% on average. This explanation can be applied to any average score of the year in the sample.

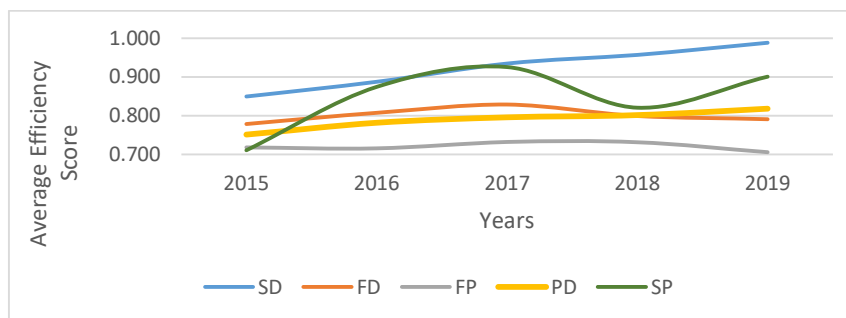
If we listed the inefficient banks group by group, Halk Bank is founded to be inefficient every year in the group of state-owned deposit banks. ICBC Turkey is the most inefficient bank for 2015, then HSBC Bank places as the most inefficient bank in 2016 and 2017. As we noted above, in 2018 and 2019, Turkland Bank is founded to be the most inefficient bank among all the types of banks, and it is also the same for the group of foreign deposit banks. In the group of foreign participation banks, Albaraka Turk has the lowest efficiency score from 2015 to 2019. Turkish Bank is the most inefficient bank for 2015, 2016, 2017, 2018, while TEB is the most inefficient bank in 2019 in the group of privately-owned deposit banks. The last group is the state-owned participation banks, and we can see that Ziraat Katılım has lower efficiency score in 2016 while Vakıf Katılım has lower efficiency score in 2017, 2018, 2019. Due to the lack of efficiency score for Vakıf Katılım in 2015, it was not evaluated for this year.

**Table 3.2.** Average Overall Efficiency Score Based on Types of Banks

Types	Types	Average				
		2015	2016	2017	2018	2019
State-owned deposit banks	1	0.849	0.888	0.934	0.957	0.988
Foreign deposit banks	2	0.778	0.808	0.828	0.799	0.791
Foreign participation banks	3	0.718	0.715	0.732	0.731	0.705
Privately owned deposit banks	4	0.751	0.782	0.796	0.801	0.818
State-owned participation banks	5	0.711	0.874	0.926	0.821	0.901

Further analysis indicates (via table 3.2) the average efficiency score of banks related to their types. First and foremost, the state-owned deposit banks and privately-owned deposit banks' efficiency scores have an increasing trend among the years in the analysis. Although a currency crisis was accrued in August 2018, average efficiency score of state-owned deposit banks and privately-owned deposit banks was increased by 2,5 and 0,6 percentages respectively from 2017 to 2018. The highest average efficiency scores belong to the state-owned deposit banks in 2015, 2016, 2017, 2018, and 2019. It is interpreted that public capital structure has an increasing effect on efficiency in terms of bank capital.

**Figure 3.1.** Average Overall Efficiency Score Based on Types



Note: Types SD, FD, FP, PD, SP are state-owned deposit bank, foreign deposit banks, foreign participation banks, privately owned deposit bank, state-owned participation bank respectively.

Table 3.3 indicates the efficiency score based on BCC methods under the assumption of VRS in the same DMU's from previous methods. Under the VRS assumption, we can answer if the inefficiency is caused by disproportionate scale size or managerial underperforming for instance input utilization. Based on the VRS results, the efficiency scores are higher than the CCR results.

**Table 3.3.** Efficiency Scores According to BCC Methods

Banks	Types	2015	2016	2017	2018	2019
Ziraat Bankası	1	0.912	0.933	0.982	1	1
Halk Bankası	1	0.920	0.928	0.946	0.972	1
Vakıflar Bankası	1	0.951	0.995	1	0.967	1
Alternatifbank	2	0.987	0.981	1	0.928	0.940
Arap Türk Bankası	2	0.797	1	0.794	0.940	1
Burgan Bank	2	0.923	0.989	1	1	1
Citibank	2	1	1	1	0.626	0.611
Denizbank	2	0.946	0.942	0.952	1	1
Deutsche Bank	2	0.966	1	1	1	0.910
HSBC Bank	2	1	1	0.959	0.922	1
ICBC Turkey Bank	2	0.768	0.787	0.910	1	1
ING Bank	2	0.943	0.956	1	0.925	0.968
MUFG Bank	2	1	1	1	1	0.977
Odea Bank	2	0.910	0.981	1	1	0.993
QNB Finansbank	2	1	0.956	0.953	0.914	0.956
Rabobank	2	1	1	1	1	1
Garanti Bankası	2	0.922	0.956	0.951	0.965	1
Turkland Bank	2	0.921	0.997	1	0.641	0.770
Albaraka Türk	3	0.796	0.832	0.841	0.842	0.796
Kuveyt Türk	3	0.787	0.804	0.826	0.819	0.818
Türkiye Finans	3	0.957	0.914	0.900	0.894	0.894
Akbank	4	1	1	1	0.938	1
Anadolubank	4	0.795	0.840	0.875	0.876	0.976
Fibabanka	4	0.911	0.932	0.970	1	0.978
Şekerbank	4	0.952	1	1	1	1
Türk Ekonomi Bankası	4	0.995	0.991	1	0.957	0.945

Turkish Bank	4	0.667	0.683	0.627	0.694	0.744
Türkiye İş Bankası	4	0.920	0.936	0.967	0.923	0.938
Yapı ve Kredi Bankası	4	0.993	1	0.966	1	1
Vakıf Katılım Bankası	5		1	0.924	0.810	0.897
Ziraat Katılım Bankası	5	0.810	0.808	1	1	1
<b>Average</b>		<b>0.915</b>	<b>0.940</b>	<b>0.946</b>	<b>0.921</b>	<b>0.939</b>
<b>Average Inefficiency</b>		<b>0.085</b>	<b>0.060</b>	<b>0.054</b>	<b>0.079</b>	<b>0.061</b>
Note: Types 1, 2, 3, 4, 5 are state-owned deposit bank, foreign deposit banks, foreign participation banks, privately owned deposit bank, state-owned participation bank respectively.						

In 2015, there are six efficient banks, which are Citibank, HSBC Bank, MUFG Bank, QNB Finansbank, Rabobank, Akbank. Among the efficient banks in 2015, Akbank is the only private deposit bank, and the rest are foreign deposit banks.

In 2016 and 2017 number of efficient banks were increased to 10 and 14, respectively. In 2016 the efficient banks were listed as following Arap Turk Bank, Citibank, Deutsche Bank, HSBC Bank, MUFG Bank, Rabobank, Akbank, Şekerbank, Yapı ve Kredi Bankası, Vakıf Katılım Bankası. As we can see, the foreign deposit banks were mostly founded to be efficient in 2016. The private deposit banks and state-owned participation banks are the following efficient banks group in 2016.

In 2017 every type of bank group had at least one efficient bank besides private participation banks. Vakıflar Bank, Alternatifbank, Burgan Bank, Citibank, Deutsche Bank, ING Bank, MUFG Bank, Odea Bank, Rabobank, Turkland Bank, Akbank, Şekerbank, Türk Ekonomi Bank, Ziraat Katılım Bank are the efficient banks.

The number of efficient banks was decreasing to 12 in 2018. The efficient banks were Ziraat Bankası, Burgan Bank, Denizbank, Deutsche Bank, ICBC Turkey Bank, MUFG Bank, Odea Bank, Rabobank, Fibabanka, Şekerbank, Yapı ve Kredi Bankası, Ziraat Katılım Bankası in 2018.

In 2019, all state-owned deposit banks had an efficiency score of 1 and founded to be efficient along with other types of banks which are Arap Türk Bankası, Burgan Bank, Denizbank, HSBC Bank, ICBC Turkey Bank, Rabobank, Garanti Bankası, Akbank, Şekerbank , Yapı ve Kredi Bankası, Ziraat Katılım Bankası.

Among all DMU's in the sample, around 3.2 percentages of state-owned deposit banks, 22,1 percentages of foreign deposit banks, 8,4 percentages of private deposit banks, and 2,6 percentages of participation banks owned by the state have an efficiency score of 1. Group of private participation banks are not founded to be efficient in the sample.

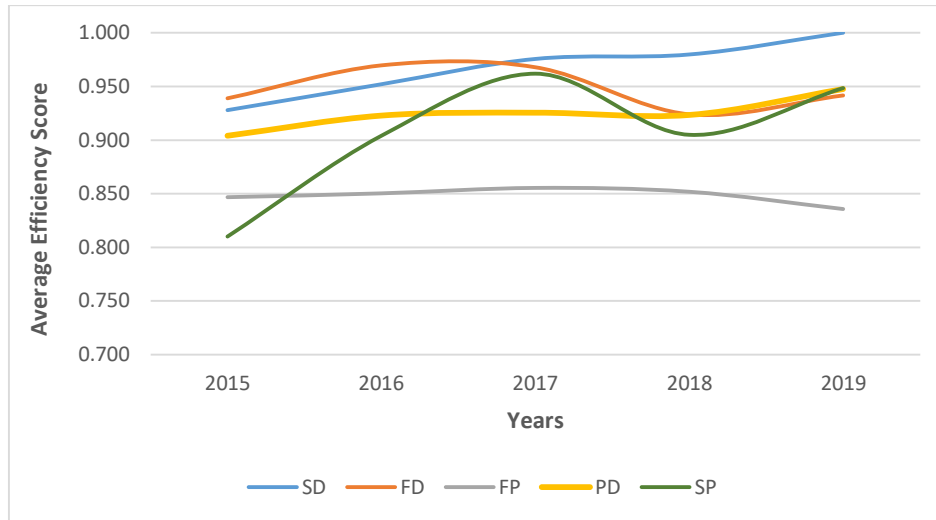
**Table 3.4.** Average Pure Technicall Efficiency Score Based on Types of Banks

Types	Average				
	2015	2016	2017	2018	2019
State-owned deposit banks	0.928	0.952	0.976	0.980	1.000
Foreign deposit banks	0.939	0.970	0.968	0.924	0.942
Foreign participation banks	0.847	0.850	0.855	0.852	0.836
Privately owned deposit banks	0.904	0.923	0.926	0.923	0.948
State-owned participation banks	0.810	0.904	0.962	0.905	0.948

Table 3.4 (and also Figure 3.2.) illustrates the average efficiency score of types of banks according to BCC methods from 2015 to 2019. In 2015, the average score of foreign deposit banks is 0,939, and it is the highest score among other types of banks. The foreign deposit banks also had the highest average score in 2016. Nevertheless, it did not preserve its seats in 2017, 2018, and 2019. The types of state-owned deposit banks had the highest average score in 2017, 2018, and 2019. Especially the last year of the analysis, the state-owned deposit banks had an efficiency score of 1 and the founded to be the most efficient types of banks. The foreign participation banks had lowest average scores of all years. Another note that from 2017 to 2018, every type of bank's average efficiency score was diminishing except the state-owned deposit banks. We can conclude that state-owned banks

seemed not to have been affected by the currency crisis in August 2018, while other types of banks were affected.

**Figure 3.2.** Average Pure Technical Efficiency Score Based on Types of Banks



Note: Types SD, FD, FP, PD, SP are state-owned deposit bank, foreign deposit banks, foreign participation banks, privately owned deposit bank, state-owned participation bank respectively.

**Table 3.5.** Statistics of the Results

	CCR	BCC
<b>Total Numbers of DMU</b>	154	154
<b>Efficient DMU</b>	13	56
<b>Inefficient DMU</b>	141	98
<b>The Lowest Efficiency score</b>	0.462	0.611
<b>The Highest Efficiency Score</b>	1	1
<b>The Average Score of Inefficient DMU's</b>	0.787	0.893
Note: Total Numbers of DMU: Sum of the number of banks evaluated in each years		

Table 3.5 presents the summary statistics about the results of CCR and BCC methods. As we noted before, BCC methods have better results than CCR results.

We assumed that all banks were operating in the same legal and business environment. However, they do not have the same market power, which supports the point of view on that imperfect competition exists. The BCC methods have better results because it does not involve the efficiency of scale and does not assume that every DMU's is operating in optimal scale. According to the summary of results, the efficient DMU number of BCC methods is 4.3 times higher than the efficient DMU number of CCR. It is concluded that if the unit is founded pure technically efficient but not overall efficient, its inefficiency originates from the scale efficiency score. The average inefficiency score of the BCC model is 13 percent greater than the score of average inefficiency according to CCR methods. In addition to this, the lowest score of CCR results is around 24 percent fewer than the lowest score of BCC results.

Decomposing the overall technical efficiency into two parts can answer the question of where the inefficiency comes from. For this purpose, we began with CCR models to find inefficient units, then we continue to apply the BCC model to find efficient units according to pure technical efficiency. If the unit is inefficient via CCR models while it is founded to be efficient via the BCC model, the unit is not scale efficient.

Jemric and Vujcic (2002) stated that in the CCR model, efficient units are analyzed as "globally efficient" instead of "locally efficient" as in BCC model. We can conclude that if the DMU is founded to be efficient according to both CCR and BCC methods, it is locally and globally efficient.

Table 3.6 exhibits the year of 2019 results both overall technical and pure technical efficiency within scale efficiency scores. There is also their RTS (Returns-to-scale) classification according to BCC results. If an increase in the input level does not culminate in an increase at the output level with the same proportion, there are two situations: Increasing returns to Scale (IRS) and Decreasing Returns to Scale (DRS). In summary, IRS means the proportion of the increase in the output level is more than the increase in the input level, and DRS means an increase in output level is less than the increase in the input level. On the other hand, where the banks

operate at an optimum scale, constant returns to scale (CRS) is occurred. In this analysis for 2019, every inefficient DMU is founded to be IRS (Increasing Returns to Scale).

**Table 3.6.** Comparison of Overall, Pure Technical and Scale Efficiency Scores in 2019

<b>Banks</b>	<b>Types</b>	<b>OE</b>	<b>PTE</b>	<b>SE</b>	<b>RTS</b>
Ziraat Bankası	1	1	1	1	CRS
Halk Bankası	1	0.964	1	0.964	CRS
Vakıflar Bankası	1	1	1	1	CRS
Alternatifbank	2	0.913	0.940	0.971	IRS
Arap Türk Bankası	2	0.584	1	0.584	CRS
Burgan Bank	2	0.876	1	0.876	CRS
Citibank	2	0.517	0.611	0.845	IRS
Denizbank	2	0.795	1	0.795	CRS
Deutsche Bank	2	0.890	0.910	0.978	IRS
HSBC Bank	2	0.763	1	0.763	CRS
ICBC Turkey Bank	2	0.786	1	0.786	CRS
ING Bank	2	0.719	0.968	0.742	IRS
MUFG Bank	2	0.949	0.977	0.972	IRS
Odea Bank	2	0.906	0.993	0.912	IRS
QNB Finansbank	2	0.815	0.956	0.852	IRS
Rabobank	2	1	1	1	CRS
Garanti Bankası	2	0.841	1	0.841	CRS
Turkland Bank	2	0.513	0.770	0.666	IRS
Albaraka Türk	3	0.582	0.796	0.731	IRS
Kuveyt Türk	3	0.716	0.818	0.875	IRS
Türkiye Finans	3	0.818	0.894	0.916	IRS
Akbank	4	0.944	1	0.944	CRS
Anadolubank	4	0.749	0.976	0.767	IRS
Fibabanka	4	0.841	0.978	0.861	IRS
Şekerbank	4	0.974	1	0.974	CRS
Türk Ekonomi Bankası	4	0.634	0.945	0.671	IRS
Turkish Bank	4	0.736	0.744	0.989	IRS
Türkiye İş Bankası	4	0.765	0.938	0.815	IRS
Yapı ve Kredi Bankası	4	0.900	1	0.900	CRS
Vakıf Katılım Bankası	5	0.868	0.897	0.968	IRS
Ziraat Katılım Bankası	5	0.934	1	0.934	CRS
<b>Average</b>		<b>0.816</b>	<b>0.939</b>	<b>0.868</b>	

As we see from table 3.6, there are three scale efficient banks in 2019, and those are also overall and pure technical efficient. Results are the evidence for the overall efficiency provided by the pure technical efficiency within scale efficiency. And also, Ziraat, Vakıf and Rabobank are locally and globally efficient in 2019. It is observed that the pure technical efficiency score is higher than both scale efficiency score and overall efficiency score on average for the year 2019. However, scale efficiency scores of Alternatifbank, Citibank, Deutsche Bank, Kuveyt Türk, Türkiye Finans, Turkish Bank, Vakıf Katılım Banks outnumber their pure technical efficiency score. It is interpreted that those banks have a better level of diseconomies scale than their managerial performance.

### Reference Set

DEA analysis designates the peer groups for each inefficient units and potential improvement values measured based on the references sets. Table 3.7 shows one example of the peer grouping with their lambda values according to CCR results, while Table 3.8 is an example of the BCC results.

**Table 3.7.** Example of Reference Set according to CCR Results

DMU	Peer	Lambda
<b>Akbank T.A.Ş.2015</b>	Rabobank A.Ş.2019	14.085492
	Deutsche Bank A.Ş.2016	5.133605
	Rabobank A.Ş.2017	18.342873
	Türkiye Vakıflar Bankası T.A.O.2019	0.161555
	MUFG Bank Turkey A.Ş.2015	18.664517
<b>Türkiye Halk Bankası A.Ş.2018</b>	Türkiye Cumhuriyeti Ziraat Bankası A.Ş.2019	0.341941
	Rabobank A.Ş.2017	8.628467
	Türkiye Vakıflar Bankası T.A.O.2019	0.005702
	Vakıf Katılım Bankası A.Ş.2016	29.30282

Based on table 3.7 using lambda values of each peers we can calculate how much reduction is needed for inefficient DMU to become efficient. For example

efficiency score of Akbank 2015 is 0.933 and its peer group is consist of Rabobank A.Ş.(2019), Deutsche Bank A.Ş. (2016), Rabobank A.Ş. (2017), Türkiye Vakıflar Bankası T.A.O. (2019), MUFG Bank Turkey A.Ş (2015). Lambda values are (approxiametly) 14.085, 5.134 , 18.343, 0.162 18.665 respectively. The required input and output values for Akbank to be efficient in 2015 can be calculated as below:

$$X_{Akbank\ 2015} = (X_1, X_2, X_3) = \{(19311; 8074; 682437) \times 14.9 + (35379; 1929; 2782231) \times 5.14 + (15405; 1373; 553640) \times 18.3 + (2837255; 3018660; 346732193) \times 0.16 + (15657; 5405; 5008683) \times 18.7\} \cong (1486802; 737376; 183551777)$$

$$Y_{Akbank\ 2015} = (Y_1, Y_2, Y_3) = \{(771304; 801933; 1894231) \times 14.9 + (1398853; 1564967; 50809292) \times 5.14 + (1084573; 234368; 2039856) \times 18.3 + (292091050; 78877628; 4195761586) \times 0.16 + (3034371; 1412441; 4833809) \times 18.7\} \cong (141763483; 62734158; 1093001314)$$

Calculation mainly shows that in 2015 Akbank labour cost should decrease from 1.593.719 TL to 1.486.802 TL, capital from 790.401 TL to 737.376 TL and total deposit from 196.751.010 to 183.551.777. On the output side , the amount of loan and other earning assets do not require change but the amount of balance sheet items should be decreased to 1.093.001.314 TL.

If we apply the same approach to Halkbank for 2018 we could reach the results that labour cost is decreased to 2.201.479 TL, capital is decreased to 2.878.976 TL and the total deposit is decreased to 288.787.620 TL .

Table 3.8 shows BCC reference group for same banks as above. Akbank had 1 efficiency score in 2015 so there is no peer group for efficient units. Halkbank had 0.972 efficiency score in 2018 via BCC method. Its reference sets are Denizbank (2019), Türkiye Cumhuriyeti Ziraat Bank (2018), Türkiye Cumhuriyeti Ziraat Bankası (2019), Burgan Bank (2017). Applying the same calculation methods we can conclude that Halkbank inputs are decreased to 2.326.190 TL, 3.059.343 TL , 305.147.068 TL respectively.

**Table 3.8.** Example Reference Set according to BCC Results

<b>DMU</b>	<b>Peer</b>	<b>Lambda</b>
<b>Akbank T.A.Ş.2015</b>	Akbank T.A.Ş.2015	1
<b>Türkiye Halk Bankası A.Ş.2018</b>	Yapı ve Kredi Bankası A.Ş.2019	0.169345
	Akbank T.A.Ş.2015	0.142547
	Rabobank A.Ş.2017	0.205711
	Türkiye Vakıflar Bankası T.A.O.2019	0.171348
	Türkiye Cumhuriyeti Ziraat Bankası A.Ş.2019	0.31105

Target values shows the all required improvement for each DMU and it is meaningful to improve the inefficient units. The target values recommends a reduction in inputs and an increase in outputs to replace the DMU in the efficient frontier.

The results of target values based on CCR and BCC methods indicate great inefficiency in the input side on average. Their usage of excessive amount of input is the reason for being inefficient. It is noticeable that the amount of capital founded to be disproportionate in general. We can conclude that the inefficient banks in Turkey need a reduction of their expenditures of property and equipment. Another conclusion can made from CCR results which calculate the target values for outputs, the first improvement should be made in other earning asset in general due to the fact that great inefficiency is arised from other earning assets. On the other hand, if we look at the output side of BCC results we can find the highest differences is occurred in Off Balance Sheet Items.

The Table 3.9 shows the example of the CCR and BCC target values.

**Table 3.9.** Target Values According to BCC and CCR Method

CCR Results					
DMU	Efficiency Score	Category	Original	Target	Difference
Albaraka Türk Katılım Bankası A.Ş.2016	0.59671617	Labour (x1)	416420	248484.5494	-40.33%
		Capital (x2)	517131	51752.14381	-89.99%
		Deposit (x3)	28072113	16751083.81	-40.33%
		Loans (y1)	21843075	21843075.09	0.00%
		Other Earning Assets (y2)	4275545	4275545.018	0.00%
		Off Balance Sheet Items (y3)	65337204	65337204.04	0.00%
QNB Finansbank A.Ş.2019	0.81475745	Labour (x1)	1716360	1398417.075	-18.52%
		Capital (x2)	3376349	876358.0706	-74.04%
		Deposit (x3)	143086020	116580399	-18.52%
		Loans (y1)	118972351	118972349.7	0.00%
		Other Earning Assets (y2)	32760233	32760232.63	0.00%
		Off Balance Sheet Items (y3)	1310114111	1310114096	0.00%
BCC Results					
DMU	Efficiency Score	Category	Original	Target	Difference
Albaraka Türk Katılım Bankası A.Ş.2016	0.83245926	Labour (x1)	416420	309639.1721	-25.64%
		Capital (x2)	517131	314431.0452	-39.20%
		Deposit (x3)	28072113	23368890.55	-16.75%
		Loans (y1)	21843075	21843075.08	0.00%
		Other Earning Assets (y2)	4275545	4275545.028	0.00%
		Off Balance Sheet Items (y3)	65337204	205869548.2	215.09%
QNB Finansbank A.Ş.2019	0.95632949	Labour (x1)	1716360	1641405.698	-4.37%
		Capital (x2)	3376349	2221398.05	-34.21%
		Deposit (x3)	143086020	136837382.1	-4.37%
		Loans (y1)	118972351	118972352.2	0.00%
		Other Earning Assets (y2)	32760233	32760233.37	0.00%
		Off Balance Sheet Items (y3)	1310114111	1310114126	0.00%

### Statistical Analysis

For the statistical analysis, ANOVA was applied on CRS and VRS scores to find out whether there is a difference between the efficiency scores of bank types and T-test was used to answer the question of which bank types are different. To do this, the efficiency scores of the banks are gathered based on the types of banks. Before applying Anova test, we tested if the samples have equal variance via Levene test. Table 3.10 shows the results of CRS Levene Test and table 3.12 shows the results of VRS Levene test.

**Table 3.10.** Results of CRS Levene Test

SUMMARY						
<i>Groups</i>	<i>Count</i>	<i>Sum</i>	<i>Average</i>	<i>Variance</i>		
Type 1	15	0.8	0.05326	0.001		
Type 2	75	8.1	0.10742	0.0076		
Type 3	15	1.5	0.10319	0.0033		
Type 4	40	4.8	0.1189	0.0047		
Type 5	9	0.7	0.07668	0.0027		

ANOVA						
<i>Source of Variation</i>	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>P-value</i>	<i>F crit</i>
Between Groups	0.0549	4	0.01373	2.4564	0.0482	2.4324
Within Groups	0.8329	149	0.00559			
Total	0.8879	153				

Note: Types 1, 2, 3, 4, 5 are state-owned deposit bank, foreign deposit banks, foreign participation banks, privately owned deposit bank, state-owned participation bank respectively.

According to Levene test of CRS efficiency scores, we can conclude that the sample does not provide homogeneity of variance assumption as the P-Value is small than 0.05. From this point, Welch's test appears as the suitable option to make ANOVA analysis with different sample sizes when the condition of homogeneity of variances is not provided.

H0:  $\mu_1 = \mu_2 = \mu_3 = \mu_4 = \mu_5$

H1: At least one is different

The hypothesis as above was applied by Welch's ANOVA Test via Python. Since the p-value of Welch's test (0.00000223) is smaller than 0.05, we reject the null hypothesis. It is concluded that there is significant difference between the efficiency scores of bank types.

**Table 3.11.** Welch’s ANOVA Test Results

<b>Statistic</b>	12.20054
<b>pvalue</b>	0.00000223
<b>nobs_t</b>	154
<b>n_groups</b>	5
<b>means</b>	[0.79 0.72 0.80 0.92 0.86]
<b>nobs</b>	[40. 15. 75. 15. 9.]
<b>vars_</b>	[0.019 0.015 0.019 0.004 0.009]
<b>use_var</b>	Unequal
<b>welch_correction</b>	TRUE

**Table 3.12.** Results of VRS Levene Test

SUMMARY

<i>Groups</i>	<i>Count</i>	<i>Sum</i>	<i>Average</i>	<i>Variance</i>
Type 1	15	0.4	0.02831	0.0002
Type 2	75	4.2	0.05665	0.0043
Type 3	15	0.6	0.04253	0.0007
Type 4	40	3.1	0.07709	0.0049
Type 5	9	0.7	0.07584	0.0014

ANOVA

<i>Source of Variation</i>	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>P-value</i>	<i>F crit</i>
Between Groups	0.0343	4	0.00856	2.3739	0.0548	2.4324
Within Groups	0.5375	149	0.00361			
Total	0.5717	153				

Note: Types 1, 2, 3, 4, 5 are state-owned deposit bank, foreign deposit banks, foreign participation banks, privately owned deposit bank, state-owned participation bank respectively.

On the other hand if we look at the Levene Test of VRS results from table 3.12, we can see that the sample of ANOVA test satisfies the homogeneity of variances assumption (p value: 0.0548). The following step is to apply ANOVA test upon this equal sample of VRS scores. The hypothesis is shown above.

H0:  $\mu_1 = \mu_2 = \mu_3 = \mu_4 = \mu_5$

H1: At least one is different

**Table 3.13.** ANOVA Test Results

SUMMARY							
<i>Groups</i>	<i>Count</i>	<i>Sum</i>	<i>Average</i>	<i>Variance</i>			
Type 1	15	14.50601	0.96707	0.00107			
Type 2	75	71.13012	0.94840	0.00759			
Type 3	15	12.71988	0.84799	0.00263			
Type 4	40	36.98736	0.92468	0.01103			
Type 5	9	8.24835	0.91648	0.00786			

<i>ANOVA</i>							
Source of Variation	SS	df	MS	F	P-value	F crit	
Between Groups	0.1488		4	0.03719068	5.006823862	0.000817	2.432
Within Groups	1.1068		149	0.007428			
Total	1.2555		153				

Note: Types 1, 2, 3, 4, 5 are state-owned deposit bank, foreign deposit banks, foreign participation banks, privately owned deposit bank, state-owned participation bank respectively.

According to table 3.13, we can reject the null hypothesis as the p-value is smaller than 0.05. We can conclude that some types of banks have different means. T-test was applied on CRS and VRS results to determine which bank types have different means.

The t-test is the practical way to compare the means of two groups therefore it was applied to two groups separately in this analysis. We used Excel for the t-test. The

formula of the function differentiate based on whether the sample is equal or unequal. We found before that the sample of CRS results did not match the equal variance assumption. From this point we tested whether the variances of the pairs were equal or not. The answer is accrued by applying Levene Test on each group. The p-value of the types (total 10 group) is shown in the table 3.14.

**Table 3.14.** Levene Test on Each Group

	Type 1	Type 2	Type 3	Type 4	Type 5
Type 1	1	<u>0.021</u>	<u>0.006</u>	<u>0.00086</u>	0.186
Type 2	<u>0.021</u>	1	0.858	0.473	0.306
Type 3	<u>0.006</u>	0.858	1	0.435	0.268
Type 4	<u>0.00086</u>	0.473	0.435	1	0.091
Type 5	0.186	0.306	0.268	0.091	1

Note: Types 1, 2, 3, 4, 5 are state-owned deposit bank, foreign deposit banks, foreign participation banks, privately owned deposit bank, state-owned participation bank respectively

According to Table 3.14, variance of types 1 to types 2, types 1 to types 3, types 1 to types 4 are unequal while the rest of group are equal.

At this point, the t-test is applied via excel and the function is applied in two different ways depending on whether the group has equal variance or unequal variance. Table 3.15 indicates the results of t-test for CRS efficiency scores. Normally, we use the 0.05 p-value for comparison but we need to use Bonferroni Correction for comparison for this time. The aim of applying the Bonferroni Correction is avoiding type 1 errors which is the rejection of a true null hypothesis. The process is explained as such if you have five groups of pairs that you will address separately, should divide the p-value by the total number of the groups. In this case we will choose p-value as 0.05 and then we will divide it to the number of groups which is 10. So the comparison is made according to p-value of 0.005.

**Table 3.15.** The Results of t-test for CRS scores

	Type 1	Type 2	Type 3	Type 4	Type 5
Type 1	1	0.000003	0.000010	0.000011	0.07183831
Type 2	0.000003	1	0.03974858	0.675914212	0.208435307
Type 3	0.000010	0.03975	1	0.095047918	0.007124963
Type 4	0.000011	0.675914212	0.095047918	1	0.147375691
Type 5	0.07183831	0.208435307	0.007124963	0.147375691	1

Note: Types 1, 2, 3, 4, 5 are state-owned deposit bank, foreign deposit banks, foreign participation banks, privately owned deposit bank, state-owned participation bank respectively.

As we see from table 3.15, the difference between type 1 and type 2, type 1 and type 3 and type 1 and type 4 are statistically significant. Table 3.16 shows the results of t-test on VRS scores with the same method. According to table 3.16, there is a difference between the efficiency scores of type 3 and type 1 and also type 3 and type 2.

**Table 3.16.** The Results of t-test for VRS scores

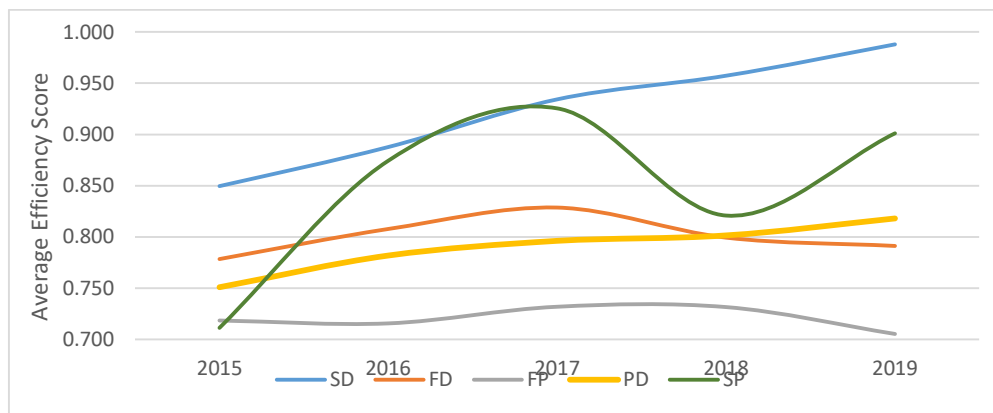
	Type 1	Type 2	Type 3	Type 4	Type 5
Type 1	1	0.417216535	0.00000003	0.132619116	0.056110789
Type 2	0.417216535	1	0.00004339	0.198685853	0.302949297
Type 3	0.00000003	0.00004	1	0.009328888	0.024611808
Type 4	0.132619116	0.198685853	0.009328888	1	0.829136092
Type 5	0.056110789	0.302949297	0.024611808	0.829136092	1

Note: Types 1, 2, 3, 4, 5 are state-owned deposit bank, foreign deposit banks, foreign participation banks, privately owned deposit bank, state-owned participation bank respectively.

We can state that while the difference between the efficiency scores of state banks (type1) and others (foreign deposit, foreign participation, privately owned deposit

banks) are statistically significant according to t-test on CRS scores. The reason for these t-test of CRS results is that there is a huge gap between the state banks' efficiency scores and other groups' efficiency scores except the state participation banks (As we can see from figure 3.3). State participation bank efficiency scores are fluctuating and during some years their efficiency scores even catch the state banks.

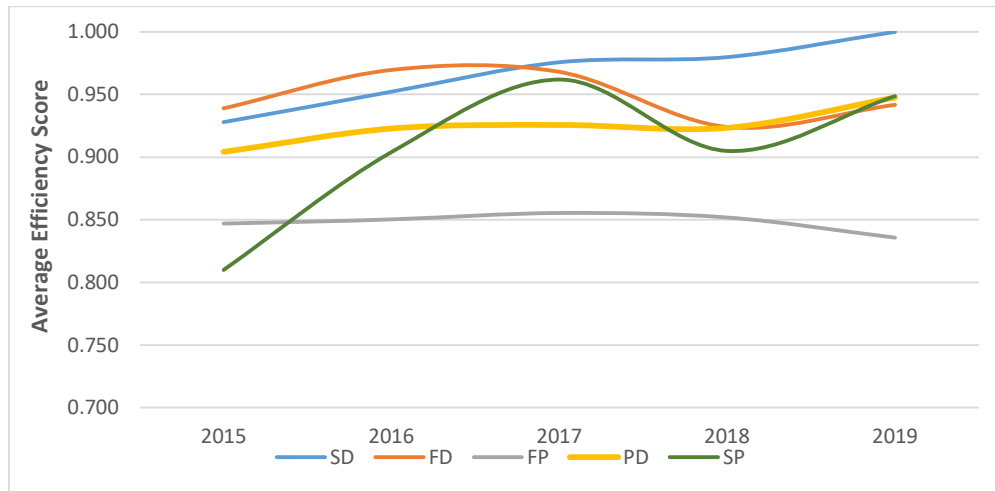
**Figure 3.3.** Average Overall Efficiency Score



Note: Types SD, FD, FP, PD, SP are state-owned deposit bank, foreign deposit banks, foreign participation banks, privately owned deposit bank, state-owned participation bank respectively.

Another conclusion from the t-test for VRS Score is the difference of the efficiency score of private participation banks from the scores of state banks and foreign deposit banks. If we look to the results of VRS scores in overall (Figure 3.4), we will notice that every type of bank has higher efficiency score because the VRS methods has always higher efficiency scores due to the fact that it ignores scale efficiency as we mentioned before. We already founded from DEA analysis that the private participation banks' pure technical efficiency scores are below under the state and foreign deposit scores and the t-test results are also supports this findings.

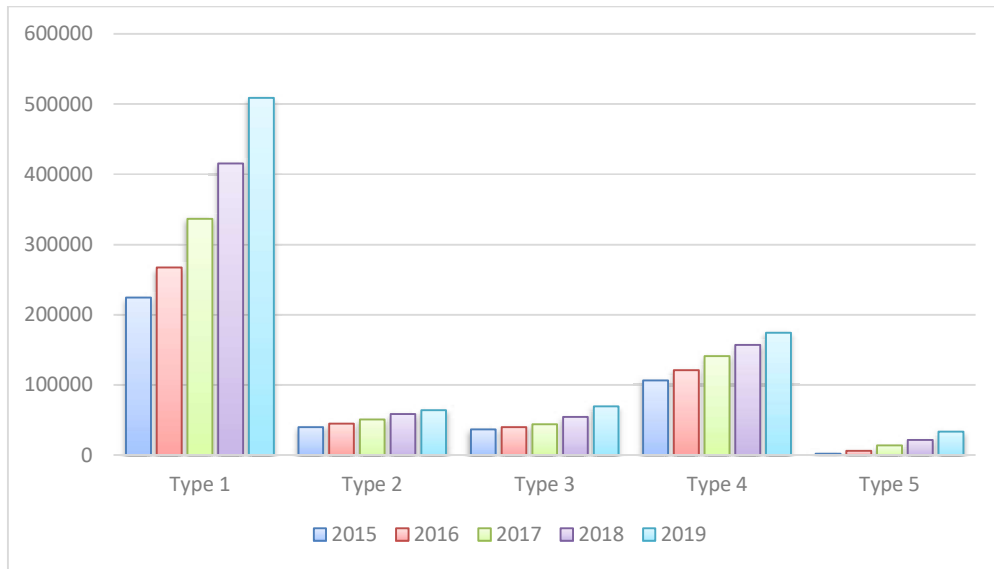
**Figure 3.4.** Average Pure Technical Efficiency Score



Note: Types SD, FD, FP, PD, SP are state-owned deposit bank, foreign deposit banks, foreign participation banks, privately owned deposit bank, state-owned participation bank respectively.

At this point, the analysis is compared to another indicator as total assets of each banks. We collected the amount of total assets of each banks from 2015 to 2019 using the Bank Association of Turkey and Participation Banks Association of Turkey database. And then we used this data to calculate the average total assets for each type in each year as indicated in Figure 3.5. It is concluded from the figures that the state banks' total assets have the highest amount while the participation banks has the lowest among the 5 types. This figure supports that the findings of our DEA analysis that the state banks have higher efficiency score on average and private participating banks have the lowest efficiency scores.

**Figure 3.5. Average Total Assets**



Note: Types 1, 2, 3, 4, 5 are state-owned deposit bank, foreign deposit banks, foreign participation banks, privately owned deposit bank, state-owned participation bank respectively.

## CONCLUSION

The term of effectiveness has a crucial meaning for every production process and also for the banking sector because while the main aim is to increase outputs, the source of inputs is limited. Evaluation of the relative efficiency based on financial history can bring a better future for the entire system. When we look at the literature, the efficiency of the banking system is analyzed with different approaches. DEA is one of them, with a prevalent usage. We also used the DEA approach in this study to evaluate the relative efficiency score. The whole banking system consists of different types of banks in Turkey. We aimed to answer the question of which types of banks are most effective and what improvements should be considered for the inefficient ones. This study dwells upon 31 banks evaluated based on their types. The study has 5 years of financial data of 31 banks with one exception year; therefore, 154 units were evaluated. The data were collected from the Bank Association of Turkey and Participation Banks Association of Turkey. We used the intermediation approach using capital, total deposit, and labor as inputs and loans, other earning assets, and off-balance sheet items as outputs. We applied the input-oriented CCR method, and input-oriented BCC approaches to compare the overall and pure technical efficiency scores. Also, we compare the results of two methods for the year 2015 to find a scale efficiency score. According to our results, In the CCR model, state-owned deposit banks have the highest efficiency score among all types, state owned participating banks follow them, and the foreign participation banks have the lowest efficiency score on average. In BCC models for the first two years, foreign deposit banks have the highest efficiency score on average, but in the years following the first two years, the state-owned banks have the highest average efficiency score. These results may indicate that the public capital structure impacts banking productivity in terms of bank capital. These results are different from Batir, Volkman, and Gungor's (2017) findings as they found the participation banks to be more efficient in Turkey. Our results also differ from another study (Hassan, Mohamad & Bader, 2009) which

investigated the efficiency scores of Islamic banks versus conventional banks in the Middle East area, and the examiners found that there were no significant differences between the overall efficiency scores of conventional banks and overall efficiency scores of Islamic banking. We used ANOVA and t-test methods to control our results statistically. According to ANOVA results, we found out that there is statistically significant difference between different bank types. T-test results exhibit that based on the CCR efficiency score, the difference in the efficiency score of state banks is statistically significant. Based on the VRS score, the difference in the efficiency score of private participation banks is statistically significant. These statistic results are compared to each type of bank's average total assets, and we found that the average total assets of state banks have the highest amount while the participation banks have the lowest among all types of banking groups. We can concluded that the results are compatible with indicators that shows the amount of the average total assets of each bank type.

Our study has a section where suggestions for the potential improvements can be found together with the improvements values, target values with another name, based on the sample's efficient units. According to target values of CCR, the inefficiency is mostly related to excessive using of capital expenditure or lack of other earning asset amount in the balance sheet. At the same time, according to the BCC results, the differences have occurred in the capital on the input side and in the Off-Balance Sheet Items on the output side. We can advise that the manager or decision-makers may consider these findings to reach an efficiency level.

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