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**Original Research Article**

# A Two-step Model for Evaluating Efficiency and Rating banks and Explaining the Role of Credit Risk (A Case Study: Commercial Banks Listed in Tehran Stock Exchange)

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In economies where banks play a key role in aggregating savings and allocating credit to various sectors, it is crucial to evaluate the performance of the banking system using appropriate methods. This research paper presents a model for evaluating the efficiency of commercial banks listed in the Tehran Stock Exchange during the period from 2015 to 2020, with a focus on the impact of credit risk. The study employs a two-step descriptive-correlation retrospective method to rank the banks and explain the role of credit risk in their efficiency. Specifically, the efficiency of the banks is determined using inputs and outputs based on DEA (Data Envelopment Analysis) models. The calculation of efficiency using ideal SBM (Slacks-Based Measure) and DEA methods reveals that Mellat, Saderat, and Tejaret banks were the most efficient during the study period. Furthermore, Tobit and logistic regression models are used to investigate the relationship between the main determinants of credit risk and the efficiency of commercial banks. The findings indicate a statistically significant relationship between the two factors. Overall, this paper highlights the importance of evaluating the efficiency of the banking system in bank-oriented economies and provides a useful model for doing so. The research paper highlights the significant impact of credit risk on bank efficiency, emphasizing its role in shaping effective risk management strategies within the banking sector. It suggests that banks should prioritize these factors to enhance their operational efficiency.

**Keywords:** Banking Efficiency, Credit Risk, Performance Evaluation, Data Envelopment Analysis, Tobit Regression, Logistic Regression
**JEL Classification:** C10, C34, C35, G21, G23

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## 1 Introduction

In economies that are centered around banking, the banking system bears a significant responsibility as it is considered one of the most crucial economic components. The provision of financial resources and a suitable investment platform for various economic sectors by banks can create favorable conditions for investment, leading to an increase in employment opportunities and national production. The significance of the banking sector stems from the fact that banks serve as the primary means of savings and credit allocation within an economy (Dell Ariccia et al., 2014). The financial industry serves a vital function as an intermediary, facilitating the transformation of deposited funds into profitable investments (Chang et al., 2019). In developing countries, financial markets function poorly and often do not function fully and efficiently (Arunkumar & Kotreshwar, 2006). In fact, the financial markets of developing countries are located within the banking sector to fill the gap between savers and borrowers; in other words, the banking sector is responsible for all operations and work related to profitability and the safe transfer of financial funds.

The presence of private and public banks with different trademarks and slogans and specialized and general areas in countries has allowed competition among them to lead to efforts to attract customers, higher savings, more investment, and finally higher profitability. Accordingly, banks tend to improve their performance in functional and financial fields so that they can surpass their competitors and be more profitable (Saleh and Abu Afifa, 2021). Activities of banks and financial and credit institutions in various fields, including granting facilities, investing, issuing various types of partnership bonds, issuing various types of certificates of deposit, issuing guarantees, and providing various types of letters of credit, or in other words, involving in monetary and capital markets have exposed them to specific risks of these activities. Banks are exposed to various types of risks; currently, reputable global banks are taking effective measures to deal with risk, and these measures have been implemented in the Iranian banking system through the central bank in recent years (Guderzai Farahani, et al., 2021). Generally, various risks in the banking system are influenced by financial and banking variables such as cost and capital. On the other hand, bad debts lead to bankruptcy and deterioration of the bank's financial and credit position, with the increased credit risk the bank (Mennawi & Nourrein, 2020). Therefore, many variables can affect the risk level of banks and strongly affect their performance. Bad performance of banks and banking crises also play an

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important role in creating financial crises. Therefore, evaluating their performance and particularly their efficiency will play a significant role in preventing financial and ultimately economic crises.

Performance evaluation of organizations such as banks also means the assurance of performance-plan compatibility and comparison of actual performance with the predetermined goals, which can depend on many financial and non-financial variables. If there is a significant difference between the expected goals and the actual performance of banks, bank managers should also take corrective measures. Therefore, organizational goals will not be realized without management and monitoring of performance indicators; without an effective performance control system, the organization will not be successful in fulfilling its missions and will not be able to use its resources properly (Sharifi Aliabadi, 2012). Hence, this study tends to evaluate the performance of the banking system of the Islamic Republic of Iran by developing a model for evaluating the efficiency and ranking of banks and explaining the credit risk of this industry using several public and private banks listed in TSE for the years 2015-2020. For this purpose, this study answers the following questions:

- How can a model be developed for evaluating the efficiency and ranking banks and explaining the role of credit risk?
- How efficient are the banks during the study period and how they are ranked using data envelopment analysis based on SBM and GPDEA variables?
- How efficient banks are ranked using super SBM technique?
- How effective are credit risk parameters on efficiency of commercial banks?

The theoretical framework and literature review are respectively highlighted in section two and three. In section four, the methodology is explained and results are explained in section five of the study.

## 2 Theoretical Framework

### 2.1 Types of Risks and Their Significance in the Banking System:

Banks are exposed to various risks throughout their activities. In fact, the risk is the cost that the bank is willing to pay for its activity, and its perspective is profit or loss (Van Greening and Sonja Brajovic, 2000). In the financial literature, risk refers to a situation where two or more outcomes are possible. In other words, the risk is a state that involves potential deviation from the path that leads to the expected results (Fitzgerald & Vogel, 2000).

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Principle 13 of the Core Principles for Effective Banking Supervision (25 principles of the Bal Banking Supervision Committee) emphasizes that banking supervisors must ensure that banks correctly identify, measure and control the risks of their activities. More precisely, this principle obliges supervisors to evaluate risk management system of banks.

Generally, four types of characteristics are considered for risk: First, risk is a measure that can be quantified. Second, risk is caused by uncertainty about future. Third, risk should be calculated in a specific time horizon, because if the time horizon changes, the risk itself will change significantly. Fourth, risk is often calculated relative to a base value; for example, compared to an absolutely risk-free investment (Gharachorlo and Anjomen Azari, 2018).

The set of risks in the banking industry can be classified into two main groups extra-organization and intra-organizational economic activity risks. Extra-organizational economic activities-related risk refers to the set of risks that result from the participation of banks in economic activities, particularly financing, and crediting to various economic sectors, and includes operational risk, market risk, liquidity risk, capital adequacy risk, legal risk, and credit risk. Intra-organizational risks are affected by the behaviour and performance of the bank itself, including stewardship risk, ownership risk, and human resources risk (Chiu & Chen; 2009).

Generally, in the banking industry, risks are divided into four general categories: financial, operational, commercial, and accident risks, which are shown in Figure 1 (Van Greening & Sonja Brajovic, 2000).

Financial risks are highly interdependent and generally increase risk of the bank. For example, there is credit risk in most payable loans. This risk is also followed by liquidity risk itself. Operational risks are related to generally improper control and management of bank activities, such as poor management or disruption of an internal control system. Commercial risks are risks that are related to the bank environment, such as macroeconomic, policy-making, and legal conditions. These risks are also known as state risks. Accident risks include all exogenous risks such as political risks and banking crisis risks that can disrupt bank operations or weaken its financial status. The figure below shows the risks by relevant subgroups (Fitzgerald & Vogel, 2000).

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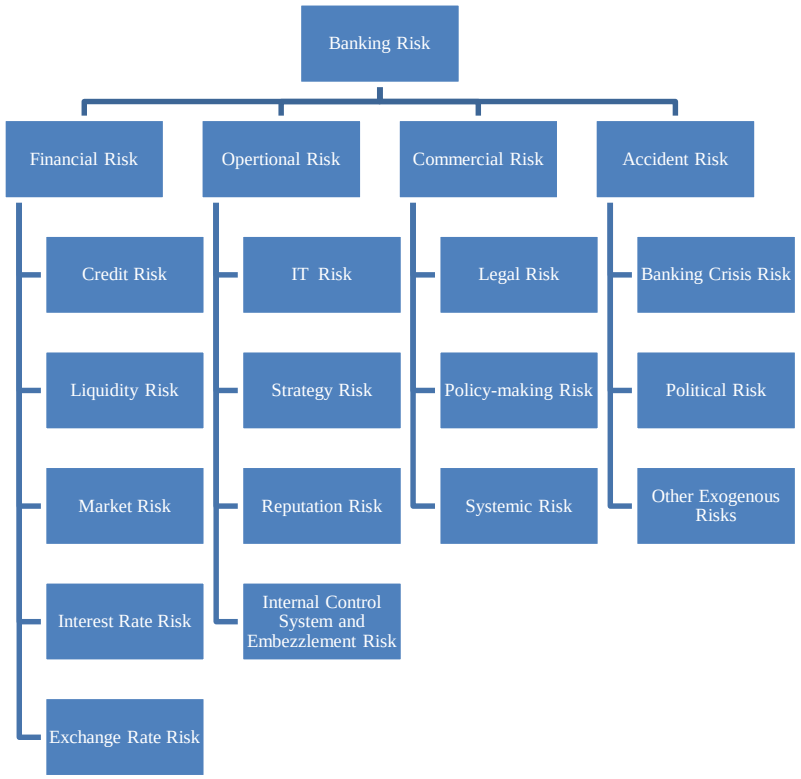


*Figure 1*. Various risk in banking industry
*Source*: Khosh Sima, Shahiki Tash; 2012

## 2.2 Credit Risk and Its Sources

Credit risk is one of the most important measures of financial stability and sustainability of the banking system, and it is created when a bank debtor refuses to repay debt or is unable to fulfill obligations on time. This risk is related to the quality of the banking system assets and the potential bankruptcy of the banks and usually is exhibited in financial statements. Therefore, by definition, the net income of banks and their stock value are always faced with uncertainty, which is influenced by the failure to pay the original and interest of debts to the banking system (Hassan et al., 2019).

Among various banking risks, credit risk is the oldest and biggest risk related to the banking business, so most of the literature on banking risk management is devoted to the field of credit risk (Arunkumar & Kotreshwar,

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2006). The evolution and growth of the Ball Committee's set of regulations have focused on credit risk (Meulbroek, 2002). Recent economic crises caused by systematic risk showed that credit risk management is essential not only for the continued activities of banks but also for the entire economy (Kimura et al., 2015). Hence, according to the belief of many researchers, the most common reason for bank bankruptcies is considered to be credit risk (Zribi & Boujelbène., 2011). The 2008 credit crisis, marked by subprime mortgages, serves as a tangible example of the recent significance of credit risk in the banking system.

The history of credit risk assessment goes back to the era of invention and the creation of money (Beltratti & Stulz, 2012). In the past, people also tended to consider the financial abilities of different groups and people when giving loans to them. Since at that time, the effective variables on financial ability were very limited, lending institutions gave loans to people based on their prior knowledge. However, the borrower's financial ability was always considered one of the effective factors in giving a loan (Imbierowicz & Rauch, 2014).

From a macro perspective, credit risk is considered a consequence of systematic risk. Systematic risk indicates major financial challenges resulting from the inability of financial market participants to fulfill credit obligations (Nijskens & Wagner, 2011). The Basel Committee, in a documented manner, has indicated that in most banks, the largest and most significant source of credit risk is the facilities they provide (Basel Committee on Banking Supervision, 2001). In other words, granting loans and facilities exposes banks to credit risk. This risk increases when banks extend facilities to customers who do not have the financial capacity to repay them. Therefore, credit risk is a consequence of improper interaction with financial system participants. According to another study conducted by the Basel Committee, the most influential factors on the credit risk of banks are internal and external factors such as customer repayment capacity, overall economic conditions, the type of industry and business activities, customer financial management practices, and ultimately the level of customer indebtedness (Financial Stability Board Report, 2022).

## 2.3 Efficiency Measurement and Its Methods

One of the necessary and effective tools for the economic development of a country is an efficient banking system. Banks that have acceptable performance and efficiency control financial activities and the situation governing them can have a great impact on other economic sectors of society.

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By organizing and directing receipts and payments, banks facilitate business and commercial exchanges and cause expansion of markets and economic growth and prosperity (Adesina, 2022).

Efficiency is a management concept that has a long history in empirical studies. Efficiency is a part of productivity and is defined in different ways. Simply put, it includes the ratio of output to input in a system (Wanke & Barros, 2016). Efficiency shows how well an organization has used its resources for production concerning the best performance at a certain point in time.

In general, there are two main methods for evaluating the efficiency of banking units: ratio analysis and frontier analysis. Ratio analysis is one of the oldest methods of determining efficiency at the level of banking units. By calculating the financial ratios such as ROI, ROA, and ratio of capital adequacy, and comparing these ratios with one of the standardized indicators in the banking industry, their efficiency or inefficiency is argued. An example of these studies can be the researches of Petersen and Schoeman (2008), Lin and Zhang (2009); Laing and Dunbar (2015) observed. Despite the successes of this method, unfortunately, there are problems with the methodology of this approach. A basic weakness of this method is that complete information about various aspects of a bank's performance cannot be obtained by choosing a few simple ratios. Another problem is a comparison of multiple indicators between financial institutions, such as banks. Because banks are units that produce multiple outputs by using multiple inputs, ratio analysis has many disadvantages in this field (Al-shammari & Salimi, 1998).

In frontier analysis which is mainly focused on in academic research, a frontier is first created as an efficiency frontier (uniform production function or random production function) for banks through the process of measuring a production, cost, or profit function; the banks that operate on the frontier are known as efficient banks and banks outside it as inefficient banks. Since the work of Farrell (1957), the estimation of frontier functions as efficiency frontier has been seriously highlighted. Farrell (1957) considered the efficiency of economic units to include two components: technical efficiency and allocation efficiency, from the product of which economic efficiency (overall efficiency) is obtained. In the studies related to frontier analysis of efficiency of banking units, there are at least four very important and widely used methods as the econometric parametric method, which includes stochastic frontier analysis (SFA), thick frontier analysis (TFA), and distribution-free analysis (DFA); the linear parametric method is called Data Envelopment Analysis (DEA) (Nasiri, Haghighat,2004).

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Efficiency measurement methods are introduced through an operation based on Farrell's method. Farrell suggested that it is better to compare the performance of an enterprise with performance of the best enterprises in that industry. This method includes concepts of frontier function, which is used as a measure of efficiency in static conditions (a point of time). Measurement of technical efficiency through diagrams can be input-based and out-based, as shown below (Emami Meybodi, 2006).

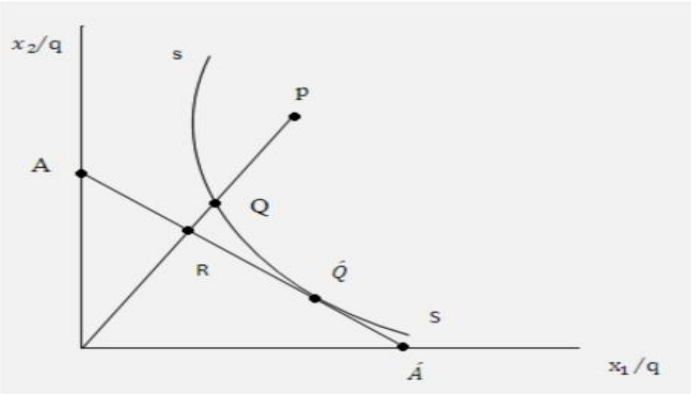


*Figure 2.* Description of input-based efficiency by Farrell's method (Emami Meybodi, 2006)

Assuming enterprises that produce an output Y with two inputs, X1 and X2, in a state of constant returns to scale, the points on the SS curve indicate full efficiency, and the enterprises that are on it will be efficient. If an enterprise uses values of inputs defined by point P to produce one unit of product, the technical inefficiency of that enterprise is represented by QP interval, which is the extent to which all inputs can be reduced in proportion without reducing output. Therefore, technical efficiency, allocative efficiency, and economic efficiency at a point equal to P are equal to the following relations, all of which will range from zero to one (Emami Meybodi, 2006):

1) Technical efficiency TE = OQ/OP
2) Allocative efficiency AE = OR/OQ
3) Economic efficiency (total cost efficiency) TE*AE = OP/OP

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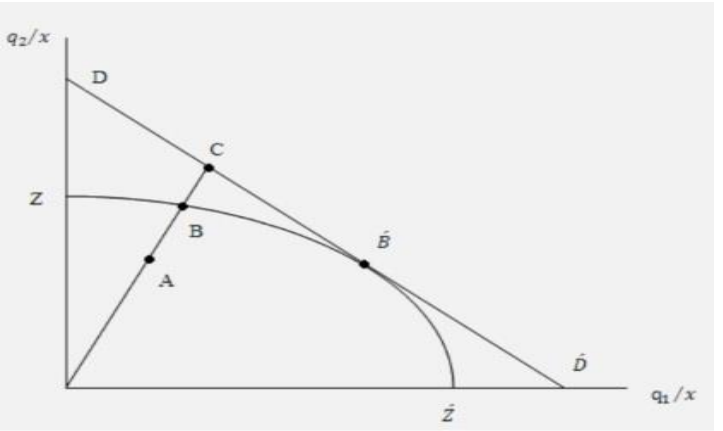


*Figure 3.* Description of output-based efficiency by Farrell's method (Emami Meybodi, 2006)

In this approach, values of efficiency will be calculated as follows:

1) Technical efficiency TE = OA/OP
2) Allocative efficiency AE = OB/OC
3) Economic efficiency (total cost efficiency) TE*AE = OA/OC

### 2.3.1 Evaluation of Efficiency and Data Envelopment Analysis in Banking System

In recent years, many studies have been conducted to measure efficiency in the banking industry with data envelopment analysis, which is a non-parametric approach to estimating frontier function. This method was first introduced by Charnes, Cooper, and Rhodes (CCR) in 1978. These scholars popularized Farrell's proposed method and since then it has been used in many studies. In this method, optimization is done without taking into account a specific form for the functions, using linear programming (LP) and considering a series of inputs and outputs, and efficiency of the investigated units is calculated assuming constant return to scale and variable return to scale. In DEA, there are different forms, such as relative form, incremental form, and envelopment (or inclusive) form, in each of which efficiency of the studied units is determined specially. For this purpose, different methods such as one-step, two-step, or multistep methods are used (Nasiri & Haghighat, 2004).

Regardless of the parametric or non-parametric nature of the existing efficiency studies, the most important components and steps of these studies

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are deciding on the explanation of the terms "inputs" and "outputs" employed in it. In research focusing on productivity within the banking sector, two primary methodologies are identified in specifying, determining, and defining inputs and outputs, one of which is the production approach and the other is asset approach. In the production approach, banks are enterprises that use capital and human labor to produce different types of deposit and loan accounts. In the asset approach, banks are considered intermediaries of financial services rather than producers of loan account services. In this approach, the value of loans and investments are output and human labour and capital are process inputs. Under the asset method, banks are viewed as facilitators of financial services instead of being seen as creators of loan account offerings. Within this framework, the worth of loans and investments is regarded as the output, while human labor and capital represent the inputs in the process (Basso et al., 2018).

In a non-parametric approach such as data envelopment analysis (DEA), it does not need price data for technical efficiency analysis and it can be done using cross-sectional data. On the other hand, non-parametric analysis, such as the distribution-free method (DFA), is also limited to panel data, which may not be available to scholars who have to work with available data. The latter also includes definitions of indicators, because it is somewhat difficult to define inputs and outputs in the banking industry. This is why, as Berg (1991) argues, efficiency values depend to a large extent on selection of inputs and outputs, and therefore, with their change, efficiency values will naturally change.

According to Assaf et al. (2011), in studies related to efficiency with actual data for a certain set of banks in a regional or national economic system, it is necessary to decide on features of methodology among the set of possible features theoretically and at three different levels. In the first level, the scholar should set the goal of choosing one of the two approaches of minimizing input or maximizing output. In the second level, decisions are made about choosing one of the two approaches by treating the enterprise as a decision-making unit (DMU) with one of the production or intermediation approaches to check technical or economic efficiency with one of the two measurement methods with parametric or non-parametric estimation and selection and determination of inputs and outputs. In the third level, return on the scale is also considered, and efficiency values are measured according to the prevailing conditions among the decision-making units, with one of the assumptions of constant return to scale (CRS) or variable return to scale (VRS).

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Naturally, CRS assumption will be true when all enterprises operate to their optimal scale, while enterprises may operate to a smaller or bigger scale than their economic scale for some reasons; thus, it is better to evaluate them assuming a variable return to scale.

Table 1
*Features of methodology, efficiency measurement and analysis model in banking system*

| ***1st level*** | | **2nd level** | **3rd level** |
|---|---|---|---|
| *Depending on bank tendency and ability to make decisions about input and output variables* | Output maximization | Production ↔ technical efficiency ↔ non-parametric | VRS<br>CRS |
| | | Intermediation ↔ economic efficiency ↔ parametric | VRS<br>CRS |
| | Input minimization | Production ↔ technical efficiency ↔ non-parametric | VRS<br>CRS |
| | | Intermediation ↔ economic efficiency ↔ parametric | VRS<br>CRS |
| | | The three features for decision making and selection at this level do not have priority over each other, but as soon as a decision is made about choosing from one of the two possible modes for each one, in fact, the decision making about other features is limited. | Considering enterprise tendency to examine efficiency in short term or long term, one of the two assumptions of variable and constant return is chosen relative to the scale of production. |

*The condition for separating and classifying the above three levels is that making a decision about any of them does not affect the other levels and is not affected by them. **The above levels do not have priority over each other and the enterprise can start making decisions from each of the levels and specify its method.

In addition to the orientations and depreciation of efficiency measurements, factors affecting the performance of banks have also been discussed and reviewed. In a general aggregation, these factors are divided into two main categories. First, the economic conditions of the society are

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related to changes outside the banking system, and secondly, the internal functioning of banks is affecting the operation. Basically, the overall functioning of the economy of each country is defined by the authors of the economies such as: GDP, flooding, currency rate and employment level. The theoretical basis for explaining the relationship between the economic conditions of the currency and the performance of banks is more likely to turn to uncertain models and market risks. With an emphasis on the role of financial intermediaries in business stability, these models provide a good framework for modeling the determinants of bank efficiency. Among the studies that have measured the effect of external bank variables on internal bank variables, we can refer to the studies of Fisher (1936), (Rinaldi and Sanchi-Arellano, 2006) and Amiri (2018). Based on this framework, the performance of banks behaves cyclically in a way that decreases during recessions and increases during periods of recession. In the growth phase with an increase in national output, households and establishments enjoy a flow of income and sufficient capacity to secure the flow of debt repayment and their commitments, and therefore the volume of foreign claims is limited. Thus, a decrease in banking claims leads to the worsening of the banking industry (Rinaldi and Sanchi-Arellano, 2006). Amiri (2018) has also demonstrated that fluctuations in currency rates and instability negatively affect the performance of banks in Iran. In the second category, there are components such as bank size, ownership, amount of capital, interest and non-interest income, overhead costs, as well as credit risk, which are evaluated using several key financial metrics used in several studies. are used and emphasized. In a study on Malaysian banking, Kamarudin et al. (2019) determined that in terms of cost efficiency, international Islamic banks outperform Malaysian Islamic banks. These researchers attribute the higher efficiency of foreign banks to several factors, including larger size, wider branch network, and greater adoption of technology. Corporate governance is also one of the important components that has been one of the most important topics in the banking system in recent decades and has played a significant role in the performance effectiveness of banks. The purpose of establishing corporate governance in banks is to increase security and financial stability and protect investors (Cublis & Gonzalez, 2014). Bukhari et al. (2015) have shown that the type of ownership is also effective in the level of efficiency. Therefore, in their study, they have concluded that the average technical effectiveness of financial institutions in the Persian Gulf Cooperation Council (GCC) countries has increased during the years under review (2005-2013) and that, regarding technical efficiency, private banks have demonstrated greater efficiency compared to public banks.

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Therefore, this shows that private banks work better in using their resources to produce outputs. Among other variables that have been investigated in several studies related to banking efficiency, is the risk variable. The inverse correlation between efficiency and risk is a fact that has been confirmed in most studies. Especially when increased risk leads to additional costs and management efforts, it reduces the technical performance of banks. Hence, it is anticipated that risk will exert a substantial and adverse effect on the bank's performance. So on this basis, low-risk banks will be technically more efficient than middle risk and high risk banks. This indicates that banks that are at higher risk do not use their resources more efficiently to generate outputs (Alhassan, Ohene-Asare, 2016). Salim et al. (2017) in a study on Iranian banks conclude that credit risk has had a negative impact on the performance of Iranian private and government banks during the years 2011-1998. In this study, the ratio of non-performing loans to total loans (NPL) is used as an indicator of credit risk.

The increase in costs and their lack of optimal control is another factor that, along with reducing the cost efficiency of banks, leads to a decrease in profitability and also imposes overhead and additional costs on banks. The increase in the number of branches, bank personnel and current assets such as buildings and machines can negatively affect the performance effectiveness of banks. Numerous research findings indicate that the rise in operational and ongoing expenses of banks significantly detracts from their profitability without yielding any beneficial impact on the bank's income (Sufian et al., 2016). The amount of facilities granted to banking units is also one of the important components that has always played a significant role either as an input or as an output in the performance effectiveness of banks, which has been used in many domestic and foreign studies to calculate efficiency. Alvani et al. (2012) is one of the researchers who has investigated the technical efficiency of Sepeh Bank branches in Tehran and the factors affecting it during the period from 2008 to 2012 using the random frontier function. The results of this research show that there is a positive relationship between the degree of branches and the average technical efficiency and the amount of facilities granted to the private sector, and with the passage of time, the average technical efficiency has decreased (Motaharinejad, 2007).

## 3 Literature Review

Several studies have been conducted concerning the performance effectiveness of banks using both parametric and non-parametric methods. However, there are very few studies that have examined the relationship

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between efficiency and financial risks; some of the most recent ones are listed in the table below.

Table 2
*Summary of the studies*

| Author | Objective | Method | Results |
|---|---|---|---|
| Peykani et al. (2021) | Evaluation of bank performance in the Tehran Stock Exchange | Non-parametric/using DEA and ideal planning | Efficiency and capability of the proposed approach in the banking industry |
| Khosh Sima and Shahiki Tash (2020) | Investigating the effect of credit, liquidity, and operational risks on the efficiency of the Iranian banking system | Using parametric SFA and non-parametric MEA | There is a significant relationship between efficiency and all three risks in the Iranian banking system |
| Bigdoley et al. (2018) | Experimental test of the effect of business environment risk on the relationship between credit risk and financial performance | Correlation/regression | Credit risk of loans, financial leverage, and the size of banks have a direct and significant effect on the financial performance of the Iranian banking industry. |
| Sayadi et al. (2019) | Studying the role of risk management on the relationship between management ability and increasing investment efficiency | Parametric/regression with fixed effects | Risk management alone does not affect management's ability to increase investment efficiency or reduce investment inefficiency of companies. |
| Dehghan and Gholami (2018) | The relationship between credit risk and financial performance indicators of private banks | Parametric/regression model using a mixed method with random effects | Increased credit risk of banks increases the level of doubtful reserves of banks and consequently increases the costs of banks; hence, as the level of credit risk increases, the return of banks decreases. |
| Ferdowsi and Fotros (2017) | The effect of credit risk and liquidity risk on the performance of banks | Parametric/fixed effects regression and generalized least squares technique | Credit risk and liquidity risk have a negative effect on bank profitability. In addition, diversification has a negative effect, and concentration and cost management have a positive effect on profitability. |

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| | | | |
|---|---|---|---|
| Adesina (2022) | A multi-objective two-stage fuzzy DEA model for evaluating US bank performance | Non-parametric / two-step DEA model | This model provides a common scale for performance comparison, increases the power of discrimination, and simplifies the calculation process. |
| Rahmanullah (2021) | Effects of credit risk on the profitability of commercial banks | Parametric/regression | Improving credit management, increasing the efficiency of asset management or effectiveness of business models can increase the profitability of commercial banks. |
| Al-Sharif and McMillan (2021) | Bank efficiency and stock performance: Evidence from Saudi Arabia | Non-parametric / data envelopment analysis / multiple regression | Banks are technically more efficient and their price efficiency is more volatile. Furthermore, changes in bank efficiency are positively related to stock performance. |
| Catherine (2020) | Credit risk management and financial performance | Parametric/regression | Bank performance has a significant relationship with customer evaluation, credit risk control, and risk diversification. |
| Rafqa and Hassan (2019) | The correlation among credit risk, liquidity, capital adequacy, and profitability within the Indonesian banking sector | Parametric/regression | Banks with high sustainability scores are less risky and have contributed less to the risk of the financial system. |

*Source*: Reviews of literature

## 4 Methodology

The current study was a descriptive-correlational retrospective study and documentary in terms of data collection. It was also applied research in terms of objective. The proposed methodology of this study consisted of 2 steps; in the first step, the efficiency values of the selected banks were obtained using the suggested parameters in two DEA models, and their similarities or differences were checked while ranking them through the two proposed approaches. Finally, the relationship between the obtained efficiency of banks and important credit risk parameters was investigated by performing regression analysis in the second step.

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## 4.1 Population and Sample

The population under examination comprised banks that were listed on the Tehran Stock Exchange, with a sample specifically focusing on commercial banks, which consisted of 17 listed and over-the-counter commercial banks, including: Saderat, Tejarat, Mellat, Aindeh, Gardeshgari, Parsian, Sermaye, Pasargad, Melel, Melli, Sepeh, Tose Taavon, Tose Saderat, Refahe Kargaran, Eghtesade Novin, Saman, Karaferin whose data will be collected for six years (2015 to 2020). In addition, other banks were also selected, which unfortunately were omitted from the study due to the lack of access to some data in some of the years under review.

## 4.2 Data Collection Instruments

The first library method was used to collect information from literature and theoretical foundations, and the required data was collected by taking notes. In addition, the information available in the library of the stock exchange organization and financial documents and reports, information and data of the accounting software "Tadbir Pardaz" and "Rehavard Novin" and information from the website www.Rdis.ir were used. Part of the information was also extracted from financial statements and notes of banks, including balance sheets, profit and loss statements, and financial statements.

## 4.3 Data Analysis

### 4.3.1. Calculating Efficiency and Ranking with DEA Models

*4.3.1.1. Determining efficiency of units using SBM model*

Since the advent of data envelopment analysis, which was first introduced by Charnes et al. (Charnes et al., 1978), many studies have been published on the methods and applications of this approach. To solve problems of radial models, Tone (2001) introduced a non-radial model called "slack-based" model or Slack Based Measure (SBM) model, where there is an objective function that is not sensitive to variable input and output units while providing a scalar as efficiency point.

This model is suitable when inputs and outputs may not change in the same proportion. In general, these models have the following two important features:

1) This model is stable concerning unit change in both inputs and outputs.
2) This model is strictly uniform concerning inputs and outputs.

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That is, any type of increase in output variables increases efficiency and any type of decrease in input variables decreases efficiency (Jahanshahlou, 2009).

To calculate the efficiency of the selected banks, the following model is used, which is known as slack-based measure:

$$Min_{p0} = \frac{1-\frac{1}{m}\sum_{i=1}^{m}\frac{s_i^-}{x_{io}}}{1+\frac{1}{s}\sum_{r=1}^{r}\frac{s_r^+}{y_{ro}}} \quad (1)$$

S.t.

$$\sum_{j=1}^{n}\lambda_j x_{ij} + s_i^- = x_{i0} \quad \text{I =1,…..,m} \quad (2)$$

$$\sum_{j=1}^{n}\lambda_j . x_{rj} - s_r^+ = y_{r0} \quad \text{r =1,….,s} \quad (3)$$

$$\lambda_j . s_r^+ . s_i^- \geq 0 \quad (4)$$

*4.3.1.2. Data envelopment analysis with the ideal planning approach*

To compare results of efficiency obtained from the above model, a new computational base is added and weaknesses of previous similar studies are overcome by using both data envelopment analysis and ideal planning. In these models, improvement patterns can be introduced by using management goals and ideals for each of the decision-making units (both effective and ineffective). This model can be introduced as follows:

$$\text{Min}=\Delta + \varepsilon[\sum_{i=1}^{m} w_{ik}^i . \delta_{ik}^i . \sum_{r=1}^{ms} w_{rk}^0 . \delta_{rk}^0] \quad (5)$$

$$\sum_{j=1}^{n}\lambda_j . x_{ij} - \delta_{ik}^i \leq ag_{ik} + (1-a)x_{ik} \quad \text{i=1,2,….,m} \quad (6)$$

$$\sum_{j=1}^{n}\lambda_j . y_{rj} - \delta_{rk}^0 \geq ah_{rk} + (1-a)y_{rk} \quad \text{r=1,2,….,s} \quad (7)$$

$$\Delta - w_{ik}^i . \delta_{ik}^i \geq 0 \quad \text{i=1,2,….,m} \quad (8)$$

$$\Delta - w_{rk}^0 . \delta_{rk}^0 \geq 0 \quad \text{r=1,2,….,s} \quad (9)$$

$$\lambda_j \geq 0 \quad (10)$$

To convert the above model from constant returns to scale (CRS) to variable returns to scale (VRS), constraint $\sum_{j=1}^{n}\lambda_j \leq 1$ can be added to the model (Momeni, 2007).

*4.3.1.3. Ranking units with super SBM*

SBM model is also able to determine effective decision-making units from ineffective ones. But this model cannot differentiate between efficient units. In other words, one of the weaknesses of that model is that efficient units are not ranked. To solve this problem, Tone (2002) proposed a model called Super

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SBM, which can rank efficient units, as Anderson and Patterson A-P efficiency model. Efficiency values in this method may be larger than one.

$$Min_{p0} = \frac{1+\frac{1}{m}\sum_{i=1}^{m}\frac{w_i^-}{w_{ik}}}{1+\frac{1}{s}\sum_{r=1}^{s}\frac{w_r^+}{y_{rk}}} \quad (11)$$

S.t.

$$\sum_{j=1.j\neq k}^{n}\lambda_j . x_{ij} - w_i^- \leq x_{ik} \qquad i=1,2,\ldots,m \quad (12)$$

$$\sum_{j=1.j\neq k}^{n}\lambda_j . y_{rj} + w_r^+ \geq y_{rk} \qquad r=1,2,\ldots,s \quad (13)$$

$$w_r^+ \leq y_{rk} \quad (14)$$

$$\lambda_j . w_r^+ . w_r^- \geq 0 \quad (j=1,\ldots\ldots,n,j\neq k)(i=1,\ldots,m)(r=1,\ldots,) \quad (15)$$

**4.3.2 Regression Analysis**

To investigate the effect of credit risk parameters on efficiency values obtained by DEA introduced in the previous step, which had numbers between zero and one, two separate regressions are used in the second step, Tobit regression and logistic regression, and the relationship between efficiency and credit risk parameters is fitted.

The Tobit model pertains to regression models where the dependent variable is constrained within specific limits and is observable only within a certain part of its range. The Tobit econometric model is structured as follows:

$$y_i = +\beta' x_i + u_i \qquad i= 1,\ldots,n \quad (16)$$

$$\text{If } y_i > 0 \quad y_j \qquad y_i = y_{i^*} \quad (17)$$

$$\text{If } y_i \leq 0 \qquad y_i = 0 \quad (18)$$

Logistic regression can also be used in cases where the response variable takes only two states (zero and one). In logistic regression, there is no limitation for the normality of independent variables and equal variances of two groups (Shirinbakhsh et al., 2011). In logistic regression, the concept of odds is used for value of dependent variable. In statistical terms, odds means the ratio of probability of an event (Pi) to probability of its absence (Pi -1). The probability value varies from 0 to 1, while odds may be more than one. Logistic regression is estimated based on an exponential function of the following independent variables:

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$$z_1 = \ln\left(\frac{P_i}{1-P_i}\right) = \beta_0 + \sum_{i=1}^{n} \beta_1 X_1 \quad (19)$$

*4.3.2.1 Tests Related to Assumptions of Regression Models*

To perform regression analysis and to ensure the initial conditions of variables such as their normality and absence of collinearity between independent variables, appropriate tests were performed. Although considering previous similar studies, it is not necessary to check normality of the variables in these studies, the regression models will fit better if the data are normal. Therefore, the Kolmogorov-Smirnov (K-S) test was used to check the variables. The results of this test showed that the significance level of all independent variables used in regression models (Tobit, logistic and fractional response) was greater than 10%, and therefore all variables have a normal distribution. To assess the existence of a collinear association among the independent variables, calculation of variance inflation factor, VIF, and tolerance determined that the tolerance factor of all variables was high and almost close to one and VIF for all variables was less than 2. Therefore, the assumption of collinearity between variables is completely rejected.

*4.3.2.2 Correlation Test*

Spearman's correlation test was used to check the difference or correlation between rankings obtained from two Super SBM methods as well as the ideal DEA.

# 5 Results

## 5.1 Estimating Efficiency and Ranking the Selected Banks

Efficiency calculations were performed by 6 important parameters considered as appropriate parameters of inputs and outputs of the banking system of Iran. These variables are shown in the table below. In this table, the following constraints are applied considering the technical limitation in the selection of data used in DEA models:

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(Number of Banks) < = 3 (sum of outputs + sum of inputs)

Table 3
*The selected inputs and outputs based on the factor analysis process and fuzzy Delphi*

| Symbol | Type | Name |
|---|---|---|
| I1 | Input | Number of branches |
| I2 | Input | Deposit size |
| I3 | Input | Total costs |
| O1 | Output | Profit-to-equity ratio |
| O2 | Output | Profit to assets ratio |
| O3 | Output | Loan size |

Considering these variables, output-oriented efficiency estimation results of all studied banks and reference units and finally their ranking by specialized GAMS software were obtained and analyzed separately by the studied years. As shown in Table 4, only 8 banks (about 47% of the listed banks), Tejarat,Saderat, Mellat, Ayandeh, Parsian, Pasargad, Melli, and Eghtesad Novin have achieved 100% efficiency in 2016 using SBM method. The next column, listing efficiency results of data envelopment analysis with ideal planning (GPDEA), indicates that only 5 banks (about 29% of banks), Tejarat,Saderat, Mellat, Parsian, and Pasargad, achieved 100% efficiency. Hence, in the GPSBM method, both the quantity of efficient units and the average efficiency are less than those in the SBM method.

Despite the ability and advantages of both SMB and GPDEA methods, unfortunately, these methods are also incapable of the final ranking of units with 100% efficiency. Therefore, the efficiency values of the units are calculated using Super SBM and finally their final ranking is shown in the next column. As shown in SSBM column, efficiency values of all the fully efficient and inefficient units are observed, which show values greater than one, allowing accurate ranking of the units. According to these values, final ranking of the banks in 2015 shows that Mellat, Parsian, and Saderat banks have the best performance ($1^{st}$ to $3^{rd}$), and Melel, Tose Taavon, and Tose Saderat banks also have the worst performance ($15^{th}$ to $17^{th}$). Similarly, in 2016, Saderat, Mellat and Tejarat banks respectively have the best rank and Melel, Tose Taavon and Refahe Kargeran Banks got the lowest performance rank.

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For inefficient units, units can be shown as models and references so that they can improve their efficiency by setting them as models and adjusting the inputs or increasing the outputs according to the weight composition of these model units. For example, in 2014, the 1st, 2nd, 5th, 7th, and 17th banks were introduced as models for Ghavamin Bank.

Table 4
*Results of efficiency, ranking, and benchmarked banks (2015 and 2016)*

| 2015 | | | | | | 2016 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Bank** | **SBM** | **GPDEA** | ***SSBM*** | **SSBM rank** | **SBM Benchmarked Banks** | **Bank** | **SBM** | **GPDEA** | **SSBM** | **SSBM rank** | **SBM Benchmarked Banks** |
| Tejarat | 1 | 1 | 4.29 | 4 | - | Tejarat | 1 | 1 | 4.316 | 3 | - |
| Mellat | 1 | 1 | 4.682 | 1 | - | Mellat | 1 | 1 | 4.651 | 2 | - |
| Saderat | 1 | 1 | 4.416 | 3 | - | Sadeeat | 1 | 1 | 4.701 | 1 | - |
| Ayandeh | 1 | 0.916 | 4.404 | 7 | - | Ayandeh | 1 | 0.981 | 3.986 | 5 | - |
| Gardeshgari | 0.74 | 0.911 | 1.681 | 14 | 1,2,3,4,6 | Gardeshgari | 0.859 | 0.95 | 2.856 | 11 | 1,2,6,8 |
| Parsian | 1 | 1 | 4.516 | 2 | - | Parsian | 1 | 1 | 4.02 | 4 | - |
| Sarmayeh | 0.912 | 0.801 | 3.012 | 9 | 3,4,8,15 | Sarmayeh | 0.94 | 0.99 | 3.42 | 8 | 2,3,4,6 |
| Pasargard | 1 | 1 | 4.211 | 5 | - | Pasargard | 1 | 1 | 3.853 | 6 | - |
| Mellal | 0.59 | 0.802 | 1.498 | 17 | 1,2,3,6 | Mellal | 0.659 | 760 | 1.402 | 17 | 2,3,6,8 |
| Melli | 1 | 0.925 | 4.101 | 6 | - | Melli | 1 | 0.88 | 3.571 | 7 | - |
| Sepah | 0.826 | 0.89 | 1.589 | 11 | 2, 3, 4, 6 | Sepah | 0.839 | 0.911 | 2.252 | 13 | 3,4,6,8 |
| Tose'e Ta'avon | 0.66 | 0.712 | 1.701 | 16 | 1,2,6,8 | Tose'e Ta'avon | 0.72 | 0.82 | 1.704 | 16 | 1,2,3,8, |
| Tose'e Saderat | 0.692 | 0.83 | 1.878 | 15 | 3,5,11,8 | Tose'e Saderat | 0.799 | 0.61 | 1.952 | 14 | 2,38,9 |
| Refah Kargaran | 0.752 | 0.693 | 2.141 | 13 | 2,4,5,15 | Refah Kargaran | 0.788 | 0.68 | 1.853 | 15 | 9,4,6,8 |
| Eghtesad Novin | 1 | 0.817 | 3.147 | 8 | - | Eghtesad Novin | 1 | 0.814 | 2.99 | 10 | 4,5,7,9 |
| Saman | 0.793 | 0.85 | 1.742 | 12 | 1,2,8,15 | Saman | 0.853 | 0.895 | 2.76 | 12 | 1,2,4,6,8 |
| Karafarin | 0.831 | 0.912 | 1.978 | 10 | 1,3,8,15 | Karafarin | 0.916 | 0.82 | 3.125 | 9 | 1,2,3,6,8 |
| Mean | 0.8 | 0.88 | 2.999 | - | - | Mean | 0.899 | 0.89 | 3.14 | - | - |

*Source*: Research findings

To summarize, efficiency results of the studied years are not included and merely the results are discussed. Table 5 presents average values of efficiency for these 17 banks in both SBM and ideal DEA for 6 years. As shown in the table, in SBM, only the Mellat bank could have 100% efficiency, and the rest operated with different percentages of efficiency. Looking at the adjacent column, in ideal DEA approach, none of the banks can be seen with an average efficiency of 100% in these six years. According to this table, the best 5 banks in terms of efficiency in SBM are Mellat, Tejarat,Saderat, Parsian, Melli, and Karafarin and in DEA, they are Mellet,Saderat, Tejarat, Parsian, Eghtesad Novin, and Melli, respectively.

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Table 5
*Average efficiency and the final ranking of banks for the period 2015-2020*

| SBM | | | GPDEA | | |
|---|---|---|---|---|---|
| **Bank** | **Average efficiency** | **Final ranking** | **Bank** | **Average efficiency** | **Final ranking** |
| Tejarat | 0.981 | 2 | Tejarat | 0.942 | 3 |
| Mellat | 1 | 1 | Mellat | 0.991 | 1 |
| Saderat | 0.972 | 3 | Saderat | 0.963 | 2 |
| Ayandeh | 0.712 | 12 | Ayandeh | 0.678 | 15 |
| Gardeshgari | 0.743 | 10 | Gardeshgari | 0.826 | 7 |
| Parsian | 0.951 | 4 | Parsian | 0.921 | 4 |
| Sarmayeh | 0.782 | 9 | Sarmayeh | 0.692 | 14 |
| Pasargard | 0.803 | 7 | Pasargard | 0.72 | 13 |
| Mellal | 0.432 | 17 | Mellal | 0.539 | 17 |
| Melli | 0.823 | 5 | Melli | 0.904 | 6 |
| Sepah | 0.73 | 11 | Sepah | 0.736 | 12 |
| Tose'e Ta'avon | 0.593 | 16 | Tose'e Ta'avon | 0.601 | 16 |
| Tose'e Saderat | 0.691 | 13 | Tose'e Saderat | 0.812 | 10 |
| Refah Kargaran | 0.623 | 15 | Refah Kargaran | 0.759 | 11 |
| Eghtesad Novin | 0.796 | 8 | Eghtesad Novin | 0.858 | 9 |
| Saman | 0.68 | 14 | Saman | 0.786 | 8 |
| Karafarin | 0.812 | 6 | Karafarin | 0.913 | 5 |

*Source*: Research findings

According to the results of ranking with ideal DEA, it seems that these rankings are somewhat consistent with ranking of Super SBM, and efficiency ranking of the units is not very different from each other. Therefore, Spearman's correlation test was performed. Since the significance level of the test is less than 0.05, hypothesis H0 is rejected and the opposite hypothesis is confirmed, thus, the presence of correlation is confirmed. Therefore, the application of each of these two methods separately can provide the same results in terms of ranking the investigated units, regardless of the objectives.

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Table 6
*Spearman's rank correlation test for the estimated rankings of the banks*

| | | **SBM** | **GPDEA** |
|---|---|---|---|
| SBM | Correlation coefficient | 1.000 | 0.809** |
| | test (one way) | - | 0.009 |
| | N | 17 | 17 |
| GPDEA | Correlation coefficient | 0.809** | 1.000 |
| | test (one way) | 0.009 | - |
| | N | 17 | 17 |

*Source*: Research findings

In order to better observe the performance of the banks according to the rankings obtained from Super SBM, the trend of performance rankings of all banks during the studied years can be shown in Table 7. According to this table, Mellat Bank was ranked first in most years (three years in intermittently). Saderat Bank was also ranked second and operated with 100% efficiency for two intermittently years. The ranking of other banks can be seen separately during the period.

Table 7
*Trend of efficiency rankings of the studied banks with super SBM*

| **Ranking of banks during 2015-2020** | | | | | | |
|---|---|---|---|---|---|---|
| Bank | 2015 | 2016 | *2017* | 2018 | 2019 | 2020 |
| Tejarat | 4 | 3 | 2 | 5 | 5 | 3 |
| Mellat | 1 | 2 | 1 | 2 | 1 | 2 |
| Saderat | 3 | 1 | 4 | 4 | 2 | 1 |
| Ayandeh | 7 | 5 | 10 | 11 | 13 | 10 |
| Gardeshgari | 14 | 11 | 9 | 16 | 11 | 11 |
| Parsian | 2 | 4 | 3 | 1 | 4 | 4 |
| Sarmayeh | 9 | 8 | 14 | 3 | 6 | 5 |
| Pasargard | 5 | 6 | 5 | 6 | 11 | 15 |
| Mellal | 17 | 17 | 16 | 17 | 14 | 17 |
| Melli | 6 | 7 | 13 | 8 | 3 | 7 |
| Sepah | 10 | 13 | 12 | 15 | 9 | 8 |
| Tose'e Ta'avon | 16 | 16 | 17 | 12 | 15 | 16 |
| Tose'e Saderat | 15 | 14 | 6 | 13 | 10 | 14 |
| Refah Kargaran | 13 | 15 | 15 | 14 | 12 | 13 |
| Eghtesad Novin | 8 | 10 | 7 | 7 | 16 | 6 |
| Saman | 12 | 12 | 9 | 10 | 8 | 12 |
| Karafarin | 10 | 9 | 8 | 9 | 7 | 9 |

*Source*: Research findings

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## 5.2 Regression Analysis and Effect of Credit Risk on Efficiency

### 5.2.1 Tobit Model Regression Results

To identify the effect of credit risk parameters on efficiency values, the classical Tobit model was used. The estimated model is as follows.

Table 8
*Results of Tobit regression model*

| Symbol | Variable | Coefficient | Standard error | p-value | Final effect |
|---|---|---|---|---|---|
| C | Fixed coefficient | -19.22 | 43.00 | 0.000 | - |
| X1 | Loan to all bank assets | 0.323 | 6.529 | 0.050 | 2.476 |
| X2 | Capital adequacy | 0.0875 | 0.563 | 0.032 | 4.061 |
| X3 | Bad debt to all loans | -1.736 | -0.16 | 0.049 | -1.231 |
| Z | Dummy variable bank size | 0.0651 | 3.431 | 0.000 | 0.607 |
| Loglikelihood | | 249.89 | | | |
| Avg-Loglhood | | 1.88 | | | |
| LR (prob=0.000) | | 191.78 | | | |
| $R^2$ | | 0.84 | | | |
| J-B | | 2.7 (0.19) | | | |

*Source*: Research findings

According to the results, there is a significant statistical relationship between all independent variables and efficiency of the banks. Therefore, there is a positive relationship between loans to total assets ratio of the bank and level of efficiency at confidence level of 90%. Similarly, there is a positive and significant relationship between capital adequacy ratio and efficiency at 95% confidence level. At the same level of confidence, there is an inverse and negative relationship between bad debts to total loans ratio and level of efficiency. Finally, a direct and positive relationship can be seen between bank size and efficiency at a significance level of 99%; thus, as bank size increases, efficiency also increases. According to the values related to final effect coefficient of these variables, a one percent increase in the ratio of loans to total assets of the bank increases the efficiency of the bank by 2.476 % (and vice versa). Similarly, one unit of increase in capital adequacy ratio will improve and increase the level of banking efficiency by 4.061%. Therefore, it seems that capital adequacy, as an important financial variable, will have a greater effect than other independent variables in increasing the efficiency of the banking system. As the bad debt to total loans parameter is negative, a 1% increase in this parameter will reduce banking efficiency by 1.231% (and vice

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versa). Log likelihood and LR values, which are equal to 239.89 and 191.87, respectively, show the goodness of fit of the model and adequacy of distribution and fit of the regression function. Average Logliklihood (Avg-Loglhood) indicates that the model has the best ability to predict the observed data and therefore the overall performance of the model is also high.

### 5.2.2 Logistic Model Regression Results

To develop and fit the Logit model, a progressive step-by-step method was used. In this method, first, all the variables are incorporated into the model. Through the incremental stepwise approach, a variable that did not show statistical significance was excluded from the model and the significance of removing this variable was confirmed using Wald test in the table below. Based on F and $Chi^2$ values in Wald test, the elimination of a variable called dummy variable (bank size) is statistically significant, and therefore the final model is defined by 3 variables related to credit risk which is effective on the performance effectiveness of banks.

Table 9
*Results of Logit model estimation*

| Variable | Coefficient | Standard error | Wald value | Final effect | p-value |
|---|---|---|---|---|---|
| Fixed effect | 27.34 | 2.780 | 3.42 | - | 0.012 |
| Loans to total assets | 1.47 | 0.046 | 1.60 | 1.330 | 0.005 |
| Capital adequacy | 0.052 | 0.710 | 2.49 | 2.790 | 0.004 |
| Bad debts to total assets | -0.087 | 0.060 | -1.49 | -0.530 | 0.033 |
| Loglikelihood | | | 88.12 | | |
| LR(Prob)= 0.000 | | | 39 | | |
| Mc Fadden R-squared | | | 0.78 | | |

*Source*: Research findings

In the above table, there is a positive and direct relationship between loans to total assets ratio and capital adequacy ratio at a 95% confidence level. There is an inverse relationship between bad debts to total loans ratio at a 95% confidence level. Thus, the smaller this ratio is, the more efficiency will increase, and if this ratio increases, the efficiency will decrease. Thus, it can be concluded that as the capital adequacy of banks increases, loans will increase, and the performance effectiveness of banks will also increase. On the other hand, as unused assets (in the nominator) as well as bad debts (in the denominator) increase, the performance effectiveness of banks decreases. According to the final effect, the effect of variations in each of the independent

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variables can be interpreted on the dependent variable. As a result, a 1% rise in the loan-to-total-assets ratio is projected to boost efficiency by 1.33% (and conversely). Moreover, 1 unit of increase in capital adequacy ratio, as an important parameter of credit risk, will increase efficiency by 2.79 % (and vice versa). As in Tobit model, there is an inverse relationship between bad debts to total loans ratio and efficiency. Thus, a 1% increase in this ratio will reduce efficiency by 0.53% (and vice versa).

For the goodness of fit of the model, LR, Log Likelihood, and Mc Fadden's R-squared were used at a 95% confidence level, which indicates the very good capabilities of the model in predicting the potential efficiency of the listed banks. Since there is no problem with colinearity and heterogeneity of variance in this model, the results can be defined as follows:

$$Z = \text{Log}(Pi/1\text{-}Pi) = 27/34 + 1/470\ X1 + 0/052\ X2 - 0.087\ X3$$

Since in logit models, the sigmoid function is used to estimate the probability of the dependent variable, the proposed model for predicting the efficiency of the listed banks will be as follows:

$$Effi = 1 / 1 + e^{-(27/34 + 1/470\ X1 + 0/052\ X2 - 0.087\ X3)}$$

## 6 Conclusion

The primary goal of this research is to devise a model for appraising efficiency, ranking banks, and elucidating the influence of credit risk. To achieve this objective, questions were formulated and suitable answers were found for them. DEA models concerning the selected inputs and outputs for the period of 2015-2020 obtained very important results. The results of efficiency estimation in SBM and DEA models showed that three banks, Mellat, Saderat, and Tejarat, were the best in terms of efficiency and Melel and Tose Taavon were the most inefficient banks.

The results of Tobin and logistic regression models show that all three important parameters of credit risk (capital adequacy ratio, ratio of bad debts to total loans, and loans to total bank assets) have a significant effect on the efficiency of banking units. Investigations showed that bank size is the only variable in the Tobit model that has a positive and significant relationship with efficiency. Significance of loans to assets ratio is consistent with Bigdoley et al. (2018), Sayadi et al. (2019), Erza et al. (2017), Fallah Shamsi and Tehran

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(2014). Significance of the bad debts to loans ratio in both regression models is consistent with Dehghan and Gholami (2018), Arabmazar et al. (2018), Zalbagi Darestani (2014), Kordbache and Pordel (2012), and Ozili (2019). The significance of capital adequacy ratio and its positive effect on efficiency was also confirmed in both fitted models, which is consistent with Moradi and Saadatpour (2015), Ferdosi and Fotros (2017), Al-sharif and Macmillan (2021), Rahmanallah (2021), Rifqah and Hasan (2019). Finally, it was shown that bank size is significant only in the Tobit model and has a positive relationship with efficiency. This finding is consistent with Bigdoley et al. (2017).

This study, like similar studies in the field of efficiency measurement in banking sector, has faced two types of limitations. The first group is the limitations related to access to complete data of banks and the next limitation is related to the quality of collected data, which will cause us to be deprived from checking a number of banks. In addition, an important challenge is comparing the performance effectiveness of banks in different conditions. This challenge can be caused by various factors such as differences in the size of banks, differences in products and services provided by banks, or differences in the operational environments of banks, which due to the diversity of these factors, we refrained from examining them. Despite these limitations, studies related to measuring efficiency in banks can provide valuable information about the performance of banks and the factors that affect their efficiency. This information can be used to improve the performance of banks and increase their efficiency.

Therefore, the following implications are presented:

- *Improving credit risk management*: Banks should accurately assess their credit risk using scientific and modern methods and take the necessary measures to reduce it. These measures can include things like improving validation processes and strengthening the supervisory system, using new technologies and increasing employee training.
- *Setting policies and standards*: for this purpose, it can be done by: setting policies and standards that guarantee the correct implementation of risks; Develop and implement strategies to maintain the balance between productivity and risk control.
- *Strengthening investment and capital increase*: for this purpose, by examining and improving the capital structure of banks, as well as increasing the initial capital and empowering the bank against possible risks, it is possible to help improve the efficiency and optimal performance of banks.

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- *Analysis of bank size*: for this purpose, the most optimal scale of activities for banks can be determined by proper evaluations of the size and dimensions of the bank.
- *Development of new products and services*: Banks should develop new products and services according to the needs of customers. This can lead to an increase in the income and profitability of banks.
  Improving operational efficiency: Banks should improve their operational efficiency by using new technologies and efficient management methods. This can lead to the reduction of operating costs and increase in profitability and ultimately increase the performance effectiveness of banks.
- *Increasing capital adequacy ratio*: This measure increases the bank's power to bear risk and can prevent financial losses in the future.
- *Optimum management of outstanding claims*: By facilitating the granting of loans with reasonable conditions and improving the process of granting facilities, it is possible to help reduce outstanding claims and improve bank credit.

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