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# Evaluation of the Dynamic performance of banking industry using NDEA in the presence of undesirable intertemporal Intermediate products (Case study: Tejarat Bank)

Mohammad Reza Razmkhah[a], Amin Mostafaee[b,*], Saber Saati[b] and Maryam Shoar[a]

[a]*Department of Industrial Management, North Tehran Branch, Islamic Azad University, Tehran, Iran,*
[b]*Department of Mathematics, North Tehran Branch, Islamic Azad University, Tehran, Iran.*

**Abstract.** Performance evaluation has become an unavoidable necessity for the long-term survival of organizations. In particular, efficiency measurement plays a central role in performance evaluation. The banking industry is considered as one of the most important economic sectors, and hence, one of the most important challenges in efficiency evaluation using Data Envelopment Analysis (DEA) is the selection of input-output factors. Since banking industry have complex and multi-stage process, traditional models that follow a simple black box structure cannot be used to evaluate the efficiency of banks. This study develops a slack based method for evaluating the dynamic efficiencies of banks with a network structure. The main aim of this study is to develop a dynamic two-stage DEA model for evaluating the efficiencies of 55 Tejarat bank branches in the presence of undesirable intertemporal intermediates. The results show that the proposed model measures the overall and stage efficiencies more accurately and reveals the source of branch inefficiency. The presented model can be developed straightforwardly to other network structures and applications.

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**Keywords:** Efficiency; Network Data envelopment analysis; Slack based measure; Banking industry.

**Index to information contained in this paper**



## 1. Introduction

Today's world is facing constant changes and complex structures. The banking industry is one of the most complex economic industries in the world. And, it is the main carrier of countries assets and wealth and one of the most important pillars of any country's the economy of each country. Due to the provision of various financial and credit services (minor and major), it plays a central role in economic development and economic improvement of countries. The provision of desirable services by banks not only has a huge and significant impact on the economic growth and prosperity of a country, but also affects the aspects of people's daily lives. For this reason, evaluating the efficiency and

*Corresponding author. Email: a_mostafaee@iau-tnb.ac.ir


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performance of banks has attracted the attention of many academic researchers. There are two main methods for determining the efficiency of banking industry: the ratio analysis method and the production function or efficient frontier method. The ratio analysis method is one of the oldest methods for measuring efficiency at the banking industry level. In the production function or efficient frontier method, which is highly emphasized in academic research, banks first estimate the production functions (cost or profit), establish a frontier as the efficient frontier (isoquant curve and stochastic production function), and hence, the bank branches operating at the efficient frontier are called efficient branches and the branches located under it are called inefficient branches. In general, the methods used for estimating of production function or efficient frontier can be divided into two main categories: parametric and non-parametric methods. In the studies conducted in the last 20 years related to frontier analysis or efficient frontier of bank branches, there are at least four very important and widely used methods: the stochastic frontier method, the mass frontier method, and the distribution-free method, all three of which are parametric methods of econometrics. The last one, which is non-parametric, is a linear programming-based method of Data Envelopment Analysis (DEA). Because the production process of the banking industry involves multiple inputs and outputs, most studies in the field of bank performance evaluation use the DEA technique. In addition, several applied articles have used the DEA technique in the banking and finance industry, and it is considered one of the widely used techniques with the highest growth in practical applications. Bank and banking along with the terms DEA, efficiency, decision-making unit, linear programming, and operations research, are known as the most commonly used keywords in the DEA [22]. DEA is a non-parametric method that has no restrictions regarding the form of the relationship function between inputs and outputs. The property as mentioned earlier is suitable for financial institutions as they do not have a pre-defined production function [9]. Traditional DEA models have been used in many bank evaluation studies. In the traditional models, the decision-making units (DMUs) are considered black boxes and only their inputs and outputs are included in the evaluation. Their internal structure is not taken into account and no assumptions are made about the internal activities of a unit. So, the source of the inefficiency is not determined for the inefficient units. In a unit, inputs usually go through several processes before they become the final outputs. In traditional models that consider the DMU as a whole unit, a unit can be considered efficient regardless of its processes while its components and processes are not efficient [19]. To solve the problem of traditional models, Network DEA (NDEA) models have been developed. Since the performance of banks, like many other organizations, is a multi-stage process, traditional models consider them in the black box form, and the internal processes in the evaluation are not considered. Therefore, they could not comprehensively evaluate the performance of banks. NDEA models have been proposed to evaluate the bank efficiencies. In addition to the weakness of traditional models, another reason for using NDEA models is how to determine the input-output factors for reflecting the objective of bank managers. There are three approaches to determining the inputs and outputs of the bank: Production, mediation, and performance, and the production and intermediation approaches have been used most frequently [1]. From the production perspective, deposits are the output, and in the perspective of intermediation, deposits are the input. None of the viewpoints has a particular advantage over the other, and researchers use one of these viewpoints, which has led to inconsistencies in the estimation of efficiency among studies. Although all previous studies have been devoted to determining the target intermediate value and optimal intertemporal products, no one solved the problem successfully. A bank with larger deposits is considered inefficient in the financial intermediation approach but can be evaluated as efficient in the production approach [9]. If you consider the network structure of the bank, this difficulty can be solved. In the NDEA approach, the deposits are the output of one stage and the input of another stage, and in fact, the deposits play a dual role in efficiency measurement. Several scholars have developed NDEA models for the banking industry. But unlike the traditional models, the NDEA models have no standard form, especially in modeling the intermediate products [12]. Thus, their model depends on the structure of the DMU, the way the intermediate components are connected, and the nature of the inputs and outputs.

The main aim of this study is to develop the DEA models for the Tejarat Bank branches with a network structure in the presence of intermediate products and undesirable intertemporal products. The proposed model assumes normal economic conditions and not economic stagnation and inflation. In economic recession and inflation, the deposit collection and profitability stages have the role of leader and the other stage has the role of follower. In this study, private deposits are included in the model as an intermediate variable. In other words, private deposits have the dual role of the input of the profitability stage and the output of the deposit collection stage. Some non-current liabilities are included in the model as undesirable intertemporal products and the process of doubtful installment as undesirable output.

The remainder of this paper unfolds as follows: Section 2 examines the related methods and reviews previous studies. Section 3 introduces the research method and model. The fourth section is devoted to analyzing the data and the research results concerning the applied case. Finally, Section 5 includes some short conclusions.

## 2. Literature review

The operations of organizations are linked in a chain throughout their lifetimes. Therefore, it is necessary to evaluate the performance of organizations over multiple periods, which provides better information to managers. According to recent studies, Chinese commercial banks experienced a gradual increase in efficiency levels from 2010 to 2015. After that, the efficiency level fluctuated slightly, and at the end of 2018, the efficiency score was 0.746 on a scale of 0 to 1. This indicates that banks with a lower efficiency level will have a favorable impact on profitability as the efficiency level improves and these banks will focus their business on traditional banking activities. Banks that have a higher level of efficiency should find alternative and profitable banking businesses to maintain a higher level of efficiency [11]. The standard DEA models for evaluating multiple periods consider the sum of inputs and outputs and determine an efficiency score for the entire period, hence, the efficiency of each period is not determined individually. If a decision-making unit becomes efficient as a whole system, this does not necessarily imply that it is efficient in each period. The DMU may be inefficient in one period while overall efficient. Therefore, it is better to determine the efficiency of each period separately [20]. If, on the other hand, the sum or average of the inputs and outputs of several periods is considered, unrealistic and unreliable efficiency scores are obtained. However, they ignore the effects of continuous activities between two successive periods (intertemporal products) corresponding to each DMU and they also do not consider the links between different stages of each DMU in a fixed period (intermediate products) [27].

In [13, 15], the dynamic DEA concept has been introduced. Kao's idea of dynamic structure is the same as his idea about sequential series structures. The second proposed improvement direction of [13] for inefficient units to reach the efficiency frontier is not applicable.

Tone and Tsutsui [27] presented a non-radial slack-based model. They divided the intertemporal variables (links) into four categories: desirable (good), undesirable (bad), free, and fixed. They also classified inputs and outputs into fixed and non-fixed categories. Toloo et al.[24], based on the slack-based measure (SBM), evaluated and developed 18 active auto parts manufacturers in the largest Iranian securities. Li et al. [8] analyzed and evaluated the operational management efficiency of 33 Chinese state-owned toll enterprises from 2013 to 2019 using a three-stage SBM model to achieve high-quality and efficient development. The DEA models mainly consider the DMUs in each period as a single stage. Therefore, the vacancy of a model that accurately considers the internal structure of the DMUs and is dynamic, taking into account the influence of time in successive periods, is obvious .Tone and Tsutsui [28] developed the slack-based measure (SBM) model presented for dynamic black-box systems [27] to the situations in which each period has a network structure and intertemporal variables can have a positive or negative effect on the production of the next periods. Tone et al. [28] presented and developed a method based on a nested dynamic network model with an infinite number of DMUs to evaluate the performance of the financial portfolio in several periods. Liu et al. [23] examined and studied the mechanisms of the impact of FinTech on the efficiency of commercial banks in China based on the DEA-Malmquist model to calculate the productivity of the total factors of 74 commercial banks from 2012 to 2019 through the generalized dynamic NDEA model. In the standard models of DEA, inefficient DMUs can be improved by the proper operation of their input-output factors (increasing output or decreasing input) to increase efficiency. Usually, in every production process, there are problems and limitations that the organization or institution in question does not consider for reasons of profitability or time-saving. For example, we can mention the undesirable outputs that occur together with the desired outputs of the organization. We know that these types of outputs should be considered in measuring the efficiency and productivity of any organization with inputs. Therefore, models that decrease the undesirable outputs despite the decrease in inputs and increase in outputs should be provided [5]. In the models presented in the evaluation of the efficiency of data envelopment analysis, the two main models that can be used to check the undesirable outputs are shown, the direct model based on the model of Chang [2] and the indirect model based on the model of [26]. In [31], the overall efficiency of the whole system with the undesirable outputs of the units is evaluated by the SBM model approach based on the performance of commercial banks in China from 2012 to 2016. From the results, it was found that the main sources of inefficiency of the units are related to the process of profitability. On the other hand, improving the production factors for one stage may be ineffective for the whole system's efficiency.

## 3. Research method

According to the evaluation and classification of [30], the research method of this article belongs to the type of analytical research methods, and is known as a subgroup of mathematical-analytical research. These methods do not employ examples and calculations to verify or prove their theory. These models develop relationships between variables mathematically and use numerical examples to describe and explain their method. Research in this subgroup includes research in business or management sciences. This classification aims to develop relationships between defined concepts using mathematical relationships and examine how these models behave under different conditions. The current research is developing-oriented, both in terms of the purpose of the study and the implementation of the model in the applied bank. In terms of data collection and compilation, this research is a descriptive survey as it describes the relationships between the variables.

The research literature on evaluating bank performance using network models mainly considers a two-stage structure for the bank. In the first stage, banks utilize human capital and assets and attract deposits (equipment of resources), and in the second stage, they invest through the attracted deposits, they invest and disburse facilities (lending or resource allocation), which usually generate a profit in this area (profitability stage) ([19], [9], [10], [7], [25]). In addition, banks transfer part of the profit generated in the profitability stage (the bank's output in one period) back to the next period for investment and the granting of facilities (entry into stage 2 of the bank in the next period), which acts as an intertemporal variable. That is, the output of one period serves as the input of the same unit in the next

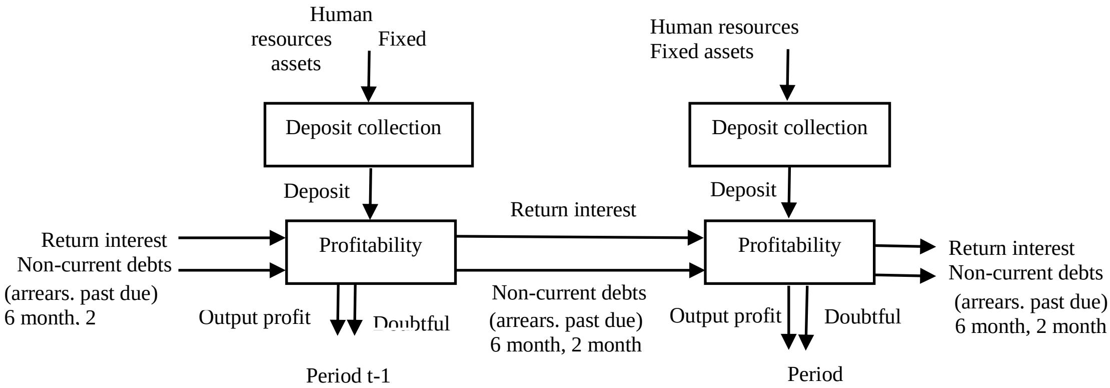


**Figure 1: Network structure of the model.**

period and establishes a relationship between two successive periods [20]. Regarding the variable of non-current debt, it should be noted that almost all studies that have evaluated bank efficiency along with undesirable outputs have used this variable in the model. In this study, non-current debt acts as an intertemporal variable, i.e., the output of one period serves as the input of the same unit in the next period and establishes a relationship between two consecutive periods. At this point, it is important to mention that the non-current liabilities indicate an increase in risk as an undesirable variable in the performance of banks and just the opposite is the profitability part as a desirable variable and these two variables are the basic elements in the performance and efficiency and determine the profit and loss of banks. This structure shows *n* decision-making units (*j*=1,…,*n*) and one unfavorable intertemporal variable (non-current liabilities ) as output for one period and input for the next period as shown in Figur 1.

According to the network presented, it is important to mention this point. In all previous research, non-current debt is considered as undesirable output, while only doubtful debt is an undesirable output, and the rest of non-current debt, including deferred debt, overdue debt, and outstanding debt, are undesirable intertemporal products and should not be considered undesirable outputs.

*Model variables include*

$\lambda_j^{1t}\,; j = 1, \dots. n\,, t = 1, \dots., T. periods\ or\ years$

Stage 1 intensity variable at period *t*

$\lambda_j^{2t}\,; j = 1, \dots. n\,, t = 1, \dots., T. periods\ or\ years$

Stage 2 intensity variable at period t

$S_i^{t-}$ ;= $1\,, 2\,.$ $The\ slack\ variables\ related\ to\ human\ resources\ \&\ fixed\ assets\ at\ period\ t$

$S_b^{t+}$ ; $The\ slack\ variable\ related\ to\ bad\ debts\ in\ the\ period\ t$

$S^{t+}$ ; $The\ slack\ variable\ related\ to\ the\ output\ profit\ in\ the\ period\ t$

$S_z^{t+}$ ; $The\ slack\ related\ to\ output\ deposit\ of\ the\ deposit\ collection\ department\ at\ period\ t$

$S_z^{t-}$ ; $The\ slack\ related\ to\ the\ deposit\ as\ the\ input\ of\ the\ profitability\ section\ in\ the\ period\ t$

$S_p^{(t+1)}$ ; $The\ slack\ related\ to\ profit\ intertemporal\ that\ palys\ the\ role\ of\ output$

$S_q^{t-}$ ; $The\ slack\ related\ to\ the\ deferred\ liabilities\ of\ the\ period\ t+1$

$S_q^{(t+1)}$ ; $The\ slack\ related\ to\ deferred\ liabilities\ output\ of\ period\ t+1$

*The parameters are defined as follows.*

1) $X_{ij}^t$ ; $including\ human\ resources\ \&\ fixed\ assets\ as\ network\ input\ I = 1{,}2$

2) $b_j^t$ ; $including\ doubetful\ receivables\ arrive\ as\ undesirable\ output$

$3) Z_j^t\ ;\ including\ the\ deposit\ section\ as\ resource\ allocation\ (output)\ \&\ the\ allocation\ of\ profit\ or\ loss\ resources\ (input)$

$4)\ P_j^t\ ;\ including\ intertemporal\ variable, return\ interest\ as\ output\ and\ input\ of\ the\ period$

$5) q_j^t\ ;\ including\ intertemporal\ (intermediate) variable, non-current\ debts\ (overdue\ \&\ past\ due$

$6)\ y_j^t\ ; including\ profit\ output\ as\ the\ desirable\ output\ (\ profit\ )\ \&\ the\ undesirable\ output\ (\ loss)$

The research results for each inefficient branch show how to become more efficient in different stages. The model proposed in [19] is one of the most common models for evaluating two-stage structures, which cannot provide a target point for inefficient units while the model proposed in this article does not have this flaw and introduces a reference unit to achieve efficiency. In [14], models for multistage structures with additional input and output also have this flaw. By presenting two articles based on the additive model, Kao measured the efficiency of the internal structure of intermediates in the network under study and concluded that the dependent type (link) models are more suitable than others [16,17]. To continue his research related to the SBM model, Kao presented an article to calculate the maximum efficiency of SBM for public power generation systems, so that the maximum efficiency of SBM can be greater than the radial efficiency; Although the minimum efficiency of normal SBM is always lower than the radial efficiency for inefficient units. The results showed that the average maximum efficiency of SBM is 35% higher than the average minimum efficiency of SBM [18]. Moreover, in Kao's models, all network outputs increase proportionally at each stage. Kang et al. [4] investigated a two-stage compositional network model with the shared input model, the results of it show the maximum profit and the possibility of further improvement of systems and subsystems in the network. They divided the two-stage models into two categories: Decomposition and Composition. In the decomposition approaches, the efficiency of the network is calculated first and then the efficiency of the stages is calculated using it, and in the decomposition approaches, the efficiency of the stages is calculated first and then the efficiency of the network is calculated using the efficiency of the stages [6]. Most models in the research literature for network structures have a decomposition approach [14]. In this article, however, the overall efficiency was calculated based on the efficiency of the identified stages and periods (combination approach). It has been shown that the analysis method's efficiency estimation is subject to errors and deviations [7]. Many articles on bank evaluation using DEA models have not considered the risk of banking transactions [10]. In this article, however, this important issue has been considered by looking at deferred installments under the title of non-current liabilities with a variable role between time and doubtful liabilities with an undesirable output role. Since banking activities are a continuous process over time, bank branches have been evaluated in this article by considering the structure and time simultaneously. NDEA models mainly consider DMUs in each period in a single stage. According to this, the presented model considers both the internal structure of the units and the dynamics and effects of time in successive periods. And, by adding a slack variable to the SBM model and using intertemporal slack variables, the proposed NDEA model considers the positive or negative effect of these variables on the efficiency of the next period and the whole system. The proposed model for this article, which is based on a fractional linear SBM model, is now presented as follows:

$$\text{Min}\quad \frac{\frac{1}{T}\sum_{t=1}^{T}\left[1-\frac{1}{m+K+1}\left(\sum_{i=1}^{m}\frac{S_i^{t-}}{x_{io}}+\frac{s_b^t}{b_0^t}+\sum_{k=1}^{K}\frac{s_z^{t-}}{Z_0^E}\right)\right]}{\frac{1}{T}\sum_{t=1}^{T}\left[1+\frac{1}{S+K+P+Q}\left(\sum_{i=1}^{J}\frac{S_i^{t-}}{r=1}+\sum_{k=1}^{K}\frac{s_z^{t+}}{Z_k^t}+\frac{S_p^t}{P_0^t}+\frac{S_f^t}{q_0}\right)\right]} \tag{1}$$

$$\text{s.t}\quad \sum_{j=1}^{n}\lambda_j^{1t}\; X_{ij}^t+S_i^{t-}=x_{io}^t,\; i=1,2,\, t=1,\ldots,T$$

$$\sum_{j=1}^{n}\lambda_j^{2t}\; b_j^t+S_b^{t+}=b_o^t,\qquad t=1,\ldots,T$$

$$\sum_{j=1}^{n}\lambda_j^{2t}\; y_j^t-S^{t+}=y_o^t\;,\qquad t=1,\ldots,T$$

$$\sum_{j=1}^{n}\lambda_j^{1t}\; Z_j^t-S_z^{t+}=Z_o^t,\qquad t=1,\ldots,T$$

$$\sum_{j=1}^{n}\lambda_j^{2t}\; Z_j^t+S_z^{t-}=z_o^t,\qquad t=1,\ldots,T$$

$$\sum_{j=1}^{n}\lambda_j^{2t}\; P_j^t+S_p^{t+1}=p_o^t,\qquad t=1,\ldots,T$$

$$\sum_{j=1}^{n}\lambda_j^{2(t+1)}\; P_j^t-S_p^{t-}=P_o^t,\qquad t=1,\ldots,T$$

$$\sum_{j=1}^{n}\lambda_j^{2t}\; q_j^t-S_q^{t-}=q_o^t,\qquad t=1,\ldots,T$$

$$\sum_{j=1}^{n}\lambda_j^{2(t+1)}\; q_j^t+S_q^{t+}=q_o^t,\qquad t=1,\ldots,T$$

$$\sum_{j=1}^{n}\lambda_j^{1t}=1\qquad t=1,\ldots,T$$

$$\sum_{j=1}^{n}\lambda_j^{2t}=1\,,\qquad t=1,\ldots,T$$

$$\lambda_j^{1t}\;,\;\lambda_j^{2t}\;,\qquad \text{all variables are non-negative}$$

In model (1), parameter T indicates the number of periods in such a way that 1/T represents the efficiency coefficient from period 1 to 4 based on the performance of the decision variable units in the network or the conceptual model, which expresses the efficiency from period 1 to period 4 and of the network. Since non-current liabilities are undesirable in model (1), their role in the model is input instead of output and output instead of input. In addition, we have divided and distinguished the λs into two parts according to the difference of the reference unit in the calculation of each efficiency stage, each of which refers to the reference unit of stage 1, 2 and network (N). In addition, the index t indicates the time period and the reference unit refers to the period. In the model presented and the conceptual network drawn, the decision-making units act based on their inputs, which constitute human capital and fixed assets, to provide services based on the branch network under consideration. Considering that the purpose of providing services to customers is to maximize benefits and profitability and thereby increase efficiency, the units concerned act in this direction to attract resources through customers, in other words, the customers make a deposit and the selected branches then proceed to allocate resources and grant facilities. At the end of each period, the performance of each unit is calculated separately and based on the return, and the efficiency of each unit is determined, which ultimately leads to the profit or loss of the units. Meanwhile, the return on investments received from customers based on a certain and fixed time frame is very important and is one of the effective components in determining the amount of profit and loss and the efficiency ratio of a unit, which has a negative and destructive effect on the desired unit. With the reduction in efficiency, the role of non-current liabilities as an intermediate variable is very important for the unit, so the increase in non-current liabilities greatly reduces the efficiency and profitability index and overshadows the final efficiency of the unit. Another component and index that is affected directly and in parallel by the increase and decrease of non-current liabilities is the profit of a unit, which is called the intermediate variable (intertemporal variable). With the increase in non-current liabilities, the amount of profitability decreases in the same proportion, and in some cases, this leads to a loss of units that are important during a long period and the interruption of payment of installments and non-return of resources at the end according to the graphical network, a component of the name of doubtful debts is considered as undesirable outputs in the presented conceptual network and model. The rise of this index confronts the units with challenges and crises in such a way that with the transfer of customer debt from non-current liabilities to doubtful debts and as soon as this event is realized, the reserve ratio also systematically rises and finally, at the time of the analysis of the financial statements, its destructive effects on the calculation of profit and loss are visible. This issue and the problem of the red line of the units is such that this index is one of the most important components in determining the position and relationship of the performance and level of efficiency of the units in question. Thus, if a unit is faced with an increase in this index, it is likely to be considered a loss-making unit at the end of the period, which is reflected in the calculation of production profit as final production and finally reflected in the returned profits after deducting the proportionate reserves. It should be recalled that the only way for the sample units is to reduce losses, get out of the crisis, and increase the efficiency of resource and expenditure management. As it turned out, the model presented in this article is a non-linear SBM model whose linearization is done by Charnes-Cooper transformations. In other words, this non-linear model can first be transformed into a linear model and then solved [30].

## 4. Data analysis and research results (applicable case)

The research results can be analyzed from two viewpoints:
The first case is the topic of performance evaluation, that is, the performance of each bank branch has been determined with an efficiency score between 0 and 1, and this evaluation was made by considering the structure, periods, and stages of bank branches and the performance of each stage is also visible. Thus, the source of inefficiency of each unit is identified. In the traditional models that consider the black box structures, the details of the performance of the stages are not specified and only an overall efficiency score for bank branches is provided, which does not accurately measure the overall efficiency and does

not determine the sources of inefficiency for inefficient branches.

Another discussion related to the research results is to present a model for achieving efficiency of inefficient units. The results of the empirical study for each of the inefficient branches show how to become more efficient in different stages. Based on the presented model, 55 branches were examined and evaluated in 4 consecutive periods between 2016 and 2019. The data required for the real implementation of the research objective were extracted from the general ledgers, financial statements, branch statistics, profit and loss statements, branch classification status, and movable and immovable assets statistics separately for each unit (sample branches) and based on negotiations with those responsible for the relevant matters. In this context, normalized data were used for the analysis (to preserve confidentiality), which has no impact on the efficiency of the results due to the stability of the model. Table 1 shows the results of assessing the efficiency of 55 bank branches using model (1).

Table 1 shows that none of the units achieved unity efficiency in the four periods evaluated. In other words, the efficiency of the decision-making units has been evaluated separately and separately, and according to the results listed in Columns 6 and 13 of Table 1, only 10 units have approached the relative efficiency, and the status of 45 other units indicates their lack of efficiency according to the results obtained. On the other hand, the efficiency of the branches is evaluated based on the period and schedule (4 periods) and the source of this inefficiency is known for each inefficient unit, since all units are inefficient, the performance of 4 units that are efficient in some periods can be seen from Table (2).

Table 2 shows that units 1 and 5 were efficient in only one period and ranked 13th and 11th respectively, unit 33 was efficient in all other periods except period 4 and managed to reach first rank place. Furthermore, unit 35 was inefficient only in period 3 and efficient in the other remaining periods. Thus, despite performing well could not manage to reach the second rank place but ranked third among all units.Of course, it is emphasized at this point that the performance of the units was evaluated separately and the efficiency of the units was rated independently of each other.

Using the conceptual network and model presented and based on the normalized data, we can now analyze the desired units practically. Unit 5 has shown the best performance in terms of one of the input components say Fixed assets during all periods, especially in the fourth period, compared to the other units listed in the table. Of course, we consider the type of property, inflation rate, location, and revaluation of assets Another component, human resources, is another input that has remained constant over the 4 evaluation periods. In the context of doubtful debts of access as undesirable output, DMUs 35 and 33 have had the best efficiency among all units (55 units) so DMU 35 scored zero in all 4 periods and

DMU 33 also except for the second period, and on the other hand, in terms of non-current liabilities, which plays a role as an intermediate variable, unit no. as we have explained in the text of the article, doubtful debts and non-current liabilities, respectively, contribute significantly to the undesirable performance of a unit, so these two units have shown good performance in controlling these two indicators. In terms of the component of resource and expenditure management, i.e. attracting deposits and granting facilitation as an intermediary variable, DMU 1 had the best performance among all units (55 units) in the third period and then DMU 33 won the first rank among all units in the first and second period, and achieved their target in this area. However, in the area of resource allocation, i.e. granting facilities, none of the 4 DMUs under evaluation has performed acceptably considering that when examining the data related to the output profit as an intermediate variable, only DMUs 33 and 5 have relatively acceptable performance in the fourth period. This poor performance in this period shows the lack of management of resources and costs.

Although the units performed well in attracting deposits, they did not perform well in allocating resources. In the policy of granting facilities in terms of interest rate, terms of repayment of installments, term and period, cost of money, and attracting cheap deposits, and in general, they have not achieved acceptable performance in cost-benefit management. In the field of return profit as an intertemporal variable indicating the final performance of the profit and loss of the evaluated units in a period, the performance of he evaluated units, especially DMU 1 in the first period among all sample units (55 units), was desirable after making the necessary adjustments. After reviewing and evaluating the units based on the courses, we now analyze $\lambda_j^{1t}, \lambda_j^{2t}$ the efficiency of stage 1, stage 2, and the network, respectively. To calculate the efficiency of the whole system, the current output is compared with the optimum output when both stages are working efficiently. So we increase the output of the first stage concerning $\lambda_j^{1t}$ to make the first stage efficient. Then, considering the optimal value of the intermediate variable, we calculate how high the total output should be to make the second stage efficient, i.e. by how much the output of the system should be increased by optimizing the operation of stage 1 and stage 2 so that the network also becomes efficient. Now we can show Stages 1 and 2 (λ's) by considering the periods while calculating the efficiency of the units, the performance of other units to make an inefficient unit efficient in different periods, separately by periods as shown in the Tables 3 and 4 show the first and second stage model units of the inefficient decision-making units in the sample.

As can be seen from Table 3, only DMU 35 waz able to achive unit efficiency in all four time periods when evaluating the first stage.Thus; if we examine the performance of this unit, we find that this unit is at the frontire of efficiency in the first stage, with adequate managementof resources and expenses and optimal utilization of inputs, outputs, intermediate variables,intertemporal variables, and consequently efficiency in the network.The noteworthy point is that the DEA technique provides a target-efficient unit composed of virtual stages in each period. Each of its virtual stages at each period is composed of the convex combination of the reference DMUs.The amountsof slacks related to shortfall inputs and excess outputs of the inefficient branches are determined compared to the target virtual unit. The inefficient DMUs should learn from the reference set and follow them to improve thire performance. In the above table, DMU 35 is considered a target unit for improving the efficiency of other units, that is, according to the results obtained in various courses and comparisons. DMU 35 can optimally influence (model) other units to improve their efficiency, e.g., in the evaluation of the first stage of DMU 17 in the second and third periods, DMU 35 is an efficient unit, and DMU 17 should follow DMU 35 as its target to improve its efficiency. In the evaluation of the first stage of DMU 55, a convex combination of DMUs 35 and 5, in the second period completely, and in the third period along with DMU 46 shows how the unit under study can improve its efficiency. Now, consider DMU 33, which was efficient in three periods and showed desirable performance, we find from the figures and values shown in Table 3 that this DMU should achieve efficiency in the fourth period by following and learning from the performance of DMUs 35 and 55. Based on the results shown in Table 4, we can now express the difference in the efficiency of the studied DMUs in the second stage compared to the first stage as follows when examining and evaluating the performance of the units:

- Units 1, 3, 22, 35, 42, 46, and 55 performed weaker in the second stage compared to the first stage. For example, DMU 35 performed well and efficiently in all periods in the first stage, while in the second stage in the third period, it lost half of its efficiency. For this reason, this unit did not perform significantly well in the second stage as a reference unit compared to the efficiency of the other units. The source of this inefficiency comes from the lack of management of resources and expenses, which despite the best performance in doubtful debt and non-current liabilities in all periods, the unit is the weakest among all units (55 units) in terms of profitability in the second and third periods. This is because it performed very well in deposit acquisition and resource management but struggled with weak management in resource allocation and product sales. This imbalance, the lack of allocation of deposits to grant facilities, the accumulation of resources, and the payment of interest on deposits to customers ultimately led to inefficiencies during the period in question.

**-** DMUs 5 and 17 had acceptable performance in the second stage assessment compared to the first stage. Thus, DMU 17 was effective in the first stage only in the first period, while it had favorable performance in the second stage assessment in periods 2 and 3, and it was ineffective in the first period. This problem is due to the reduction of doubtful debts and the growth of profitability in the second and third periods, its continuation in the fourth period, the increase of resources, and the attracting deposits in the second and third periods leading to a significant increase in the final profitability in the second period and the non-current liabilities section has also managed to maintain the conditions and the lack of growth.

**-** DMUs 11, 16, 24, 32, 33, and 53 have successfully achieved the efficiency of all courses in the second stage according to the performance evaluation. This is due to the optimal management of the units in all the defined components so that the concerned units have achieved adequate and simultaneous efficiency in the intermediate variables, intertemporal variables, proper control of inputs and outputs have managed to obtain the required efficiency in 4 periods for the second stage consecutively.

Thus, after evaluating the stages based on time and during the periods based on the performance of the abovementioned units using an SBM model, it was found that the evaluation of efficiency as made in the objective is monotone in terms of measurement for different inputs and outputs: On the one hand, the input and output of each unit are constantly measured and on the other hand, the objective function decreases uniformly concerning each slack of the input and output.

Table 1. Efficiency value of 55 bank branches.

| DMU | period 1 | period 2 | period 3 | period 4 | Objective function | Rank | DMU | Period 1 | Period 2 | Period 3 | Period 4 | Objective function | Rank |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.0068 | 0.3597 | 0.1906 | 1 | 0.3893 | 13 | 29 | 0.1702 | 0.012 | 0.0011 | 0.0018 | 0.0463 | 40 |
| 2 | 0.0022 | 0.0016 | 0.0125 | 0.0817 | 0.0245 | 45 | 30 | 0 | 0.6231 | 0.0003 | 0 | 0.1558 | 28 |
| 3 | 0.0923 | 0.045 | 0.0467 | 0.3266 | 0.1277 | 30 | 31 | 0.3583 | 0.4534 | 0.8757 | 0.883 | 0.6426 | 5 |
| 4 | 0.0013 | 0.0005 | 0.0178 | 0.2421 | 0.0654 | 37 | 32 | 0.0924 | 0.0732 | 0.701 | 0.0887 | 0.2388 | 27 |
| 5 | 0.1034 | 0.0048 | 0.6819 | 1 | 0.4475 | 11 | 33 | 1 | 1 | 1 | 0.7915 | 0.9479 | 1 |
| 6 | 0.0162 | 0.0168 | 0.7795 | 0.6121 | 0.3562 | 17 | 34 | 0.3501 | 0.1223 | 0.3751 | 0.434 | 0.3204 | 20 |
| 7 | 0.0097 | 0.0021 | 0.8011 | 0.7176 | 0.3826 | 14 | 35 | 1 | 1 | 0 | 1 | 0.75 | 3 |
| 8 | 0 | 0.0936 | 0.6955 | 0.6237 | 0.3532 | 18 | 36 | 0.6962 | 0.7517 | 0.0149 | 0.0014 | 0.3661 | 16 |
| 9 | 0.1965 | 0.1082 | 0.2345 | 0.674 | 0.3033 | 21 | 37 | 0.7059 | 0.7189 | 0.7196 | 0.0456 | 0.5475 | 8 |
| 10 | 0.3372 | 0.7581 | 0.757 | 0.7075 | 0.64 | 6 | 38 | 0.0296 | 0.0051 | 0.0026 | 0.0058 | 0.0108 | 48 |
| 11 | 0.7624 | 0.7212 | 0.806 | 0.7535 | 0.7608 | 2 | 39 | 0.684 | 0.8022 | 0.0049 | 0.0028 | 0.3735 | 15 |
| 12 | 0.1801 | 0.979 | 0.2728 | 0.1571 | 0.3972 | 12 | 40 | 0.3915 | 0.3067 | 0.2333 | 0.2402 | 0.2929 | 22 |
| 13 | 0.0012 | 0.0005 | 0.0028 | 0.0676 | 0.018 | 46 | 41 | 0.0328 | 0.3626 | 0.0036 | 0.013 | 0.103 | 33 |
| 14 | 0.0108 | 0.0093 | 0.0034 | 0.1165 | 0.035 | 43 | 42 | 0.2725 | 1 | 0.0329 | 0.0264 | 0.3329 | 19 |
| 15 | 0.7656 | 0.5714 | 0.5696 | 0.1057 | 0.5031 | 10 | 43 | 0.4289 | 0.0426 | 0.0235 | 0.0269 | 0.1305 | 29 |
| 16 | 0.7981 | 0.6129 | 0.2936 | 0.8184 | 0.6308 | 16 | 44 | 0.0157 | 0.0019 | 0.001 | 0.0083 | 0.0067 | 50 |
| 17 | 0.0042 | 0.4602 | 0.4559 | 0.2508 | 0.2928 | 23 | 45 | 0.1092 | 0.0097 | 0.0039 | 0.0197 | 0.0356 | 42 |
| 18 | 0 | 0.0004 | 0.0034 | 0.0246 | 0.0071 | 49 | 46 | 0.0496 | 0.0035 | 0.0018 | 0.0023 | 0.0143 | 47 |
| 19 | 0.0009 | 0.0338 | 0.0467 | 0.1761 | 0.0644 | 38 | 47 | 0.0086 | 0.001 | 0.001 | 0.0027 | 0.0033 | 52 |
| 20 | 0.0534 | 0.0273 | 0.305 | 0.0549 | 0.1102 | 31 | 48 | 0.1025 | 0.0011 | 0.0021 | 0.0009 | 0.0267 | 44 |
| 21 | 0.6572 | 0.2237 | 0.2568 | 0.0017 | 0.2848 | 25 | 49 | 0.021 | 0 | 0 | 0.0019 | 0.0057 | 51 |
| 22 | 0.0003 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 55 | 50 | 0.6566 | 0.3161 | 0 | 0.1731 | 0.2865 | 24 |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 23 | 0.0029 | 0.0023 | 0.0016 | 0.0058 | 0.0031 | 53 | 51 | 0.0058 | 0.0013 | 0.0002 | 0.3326 | 0.085 | 36 |
| 24 | 0.2402 | 0.1877 | 0.2196 | 0.4276 | 0.2688 | 26 | 52 | 0.1414 | 0.1489 | 0.0115 | 0.0922 | 0.0985 | 34 |
| 25 | 0.001 | 0.0017 | 0.0033 | 0.0059 | 0.003 | 54 | 53 | 0.7736 | 0.5604 | 0.8664 | 0.4679 | 0.6671 | 4 |
| 26 | 0.0067 | 0.0111 | 0.0268 | 0.2106 | 0.0638 | 39 | 54 | 0.0318 | 0.6824 | 0.7646 | 0.5354 | 0.5035 | 9 |
| 27 | 0.0107 | 0.0057 | 0.2499 | 0.0953 | 0.0904 | 35 | 55 | 0.0058 | 0.0007 | 0.0008 | 0.1435 | 0.0377 | 41 |
| 28 | 0.0001 | 0.0001 | 0.003 | 0.4104 | 0.1034 | 32 | | | | | | | |

Table 2. Overall efficiency and periods of 4 sample decision-making units.

| DMU | Term 1 | Term 2 | Term 3 | Term 4 | objective function | Rank |
|---|---|---|---|---|---|---|
| 1 | 1 | 0.1906 | 0.3597 | 0.0068 | 0.3893 | 13 |
| 5 | 1 | 0.6819 | 0.0048 | 0.1034 | 0.4475 | 11 |
| 33 | 1 | 1 | 1 | 0.7915 | 0.9479 | 1 |
| 35 | 1 | 1 | 0 | 1 | 0.75 | 3 |

Table 3. Target units for inefficient units in stage 1( $\lambda_j^1$).

| The efficiencies of the DMUs compared to reference units | $t_1$ | $t_2$ | $t_3$ | $t_4$ |
|---|---|---|---|---|
| Reference Unit 1 | 1.000 | * | 1.000 | * |
| 30 | * | * | * | 0.580 |
| 35 | * | 0.987 | * | * |
| 45 | * | * | * | 0.037 |
| 46 | * | 0.013 | * | 0.383 |
| Reference Unit 3 | * | * | * | 1.000 |
| 5 | 0.283 | * | * | * |
| 33 | 0.717 | * | * | * |
| 35 | * | 0.560 | 0.510 | * |
| 46 | * | 0.440 | 0.490 | * |
| Reference Unit 5 | 1.000 | * | * | * |
| 35 | * | 0.317 | 0.482 | 0.797 |
| 46 | * | 0.683 | 0.518 | * |
| 55 | * | * | * | 0.203 |
| Reference Unit 17 | 1.000 | * | * | * |
| 35 | * | 1.000 | 1.000 | 0.528 |
| 55 | * | * | * | 0.472 |
| Reference Unit 22 | * | 1.000 | 1.000 | 1.000 |
| 5 | 0.512 | * | * | * |
| 35 | 0.488 | * | * | * |
| Reference Unit 30 | * | * | 1.000 | 1.000 |
| 5 | 0.409 | * | * | * |
| 33 | 0.501 | * | * | * |
| 35 | 0 | 1.000 | * | * |
| Reference Unit 33 | 1.000 | 1.000 | 1.000 | * |
| 35 | * | * | * | 0.657 |
| 55 | * | * | * | 0.343 |
| 35.35 | 1.000 | 1.000 | 1.000 | 1.000 |
| Reference Unit 42 | * | 1.000 | 1.000 | * |
| 5 | 0.798 | * | * | * |
| 24 | * | * | * | 0.116 |
| 35 | 0.202 | * | * | * |
| 55 | * | * | * | 0.884 |
| Reference Unit 46 | * | * | 1.000 | * |
| 5 | 0.692 | * | * | * |
| 21 | * | * | * | 0.832 |
| 22 | * | 1.000 | * | * |
| 35 | 0.308 | * | * | * |
| 55 | * | * | * | 0.168 |
| Reference Unit 55 | | | | 1.000 |
| 5 | 0.580 | * | * | * |
| 35 | 0.420 | 1.000 | 0.064 | * |
| 46 | * | * | 0.936 | * |

Table 4. Target units for inefficient units in stage 2 ( $\lambda_j^2$).

| Comparison of the efficiency of units on the basis of model units | $t_1$ | $t_2$ | $t_3$ | $t_4$ |
|---|---|---|---|---|
| Reference Unit 1 | 1.000 | * | * | * |
| 3 | * | * | * | 0.314 |
| 8 | * | 0.272 | * | * |
| 15 | * | 0.237 | 0.538 | 0.152 |
| 16 | * | 0.004 | * | 0.067 |
| 2 | * | 0.028 | * | * |
| 35 | * | * | * | 0.077 |
| 37 | * | 0.459 | 0.462 | 0.389 |
| Reference Unit 3 | * | * | * | * |
| 1 | * | * | 0.217 | * |
| 5 | 0.128 | * | * | * |
| 8 | * | 0.266 | * | * |
| 10 | 0.520 | * | * | * |
| 15 | * | 0.271 | 0.437 | 0.496 |
| 16 | * | * | * | 0.504 |
| 24 | 0.352 | * | * | * |
| 37 | * | 0.463 | 0.346 | * |
| Reference Unit 5 | 1.000 | 1.000 | * | * |
| 8 | * | * | 0.006 | * |
| 15 | * | * | 0.382 | 0.563 |
| 16 | * | * | * | 0.477 |
| 33 | * | * | 0.246 | * |
| 37 | * | * | 0.366 | |
| Reference Unit 11 | 1.000 | 1.000 | 1.000 | 1.000 |
| Reference Unit 16 | 1.000 | 1.000 | 1.000 | 1.000 |
| Reference Unit 17 | * | 1.000 | 1.000 | * |
| 3 | * | * | * | 0.053 |
| 5 | 0.743 | * | * | * |
| 15 | * | * | * | 0.473 |
| 16 | * | * | * | 0.256 |
| 33 | * | * | * | 0.061 |
| 35 | * | * | * | 0.157 |
| 36 | 0.257 | * | * | * |
| Reference Unit 22 | * | * | * | * |
| 5 | 0.074 | 0.007 | * | * |
| 10 | 0.0288 | 0.186 | * | * |
| 15 | * | 0.252 | 0.573 | 0.149 |
| 24 | 0.104 | * | 0.148 | 0.618 |
| 32 | * | * | 0.018 | 0.233 |
| 36 | 0.403 | * | * | * |
| 37 | 0.131 | 0.424 | 0.260 | * |
| 45 | * | 0.131 | * | * |
| Reference Unit 24 | 1.000 | 1.000 | 1.000 | 1.000 |
| Reference Unit 30 | * | 1.000 | * | * |
| 1 | * | * | * | 0.071 |
| 3 | * | * | * | 0.612 |
| 5 | 0.250 | * | * | * |
| 15 | * | * | 0.526 | 0.317 |
| 16 | 0.750 | * | * | * |
| 37 | * | * | 0.474 | * |
| Reference Unit 32 | 1.000 | 1.000 | 1.000 | 1.000 |
| Reference Unit 33 | 1.000 | 1.000 | 1.000 | 1.000 |
| Reference Unit 35 | 1.000 | 1.000 | 0.500 | 1.000 |
| 33 | * | * | 0.100 | * |
| 53 | * | * | 0.400 | * |
| Reference Unit 42 | * | 1.000 | * | * |
| 42.5 | 0.003 | * | * | * |
| 42.15 | * | * | 0.010 | 0.012 |
| 42.21 | * | * | 0.798 | 0.738 |
| 42.24 | 0.799 | * | * | * |
| 42.31 | * | * | 0.081 | * |

| | | | | |
|---|---|---|---|---|
| 42.32 | * | * | * | 0.180 |
| 42.35 | * | * | 0.090 | 0.067 |
| 42.36 | 0.060 | * | * | * |
| 42.37 | * | * | * | 0.003 |
| 42.42 | * | 1.000 | * | * |
| 42.50 | 0.138 | * | * | * |
| 42.53 | * | * | 0.021 | * |
| Reference Unit 46 | * | * | * | * |
| 46.5 | 0.120 | * | * | * |
| 46.6 | * | * | 0.016 | * |
| 46.10 | 0.014 | * | * | * |
| 46.15 | * | 0.039 | 0.055 | 0.049 |
| 46.20 | * | 0.491 | * | * |
| 46.21 | * | * | 0.917 | * |
| 46.24 | 0.525 | 0.405 | * | 0.917 |
| 46.31 | * | * | * | 0.016 |
| 46.36 | 0.189 | * | * | * |
| 46.37 | 0.153 | 0.065 | 0.012 | 0.018 |
| Reference Unit 53 | 1.000 | 1.000 | 1.000 | 1.000 |
| Reference Unit 55 | * | * | * | * |
| 55.5 | 0.092 | * | * | * |
| 55.15 | * | 0.010 | * | * |
| 55.21 | * | 0.196 | 0.525 | 0.197 |
| 55.24 | 0.335 | * | * | * |
| 55.31 | * | 0.003 | 0.393 | 0.331 |
| 55.35 | * | * | * | 0.053 |
| 55.36 | 0.440 | * | * | * |
| 55.37 | 0.133 | 0.014 | * | * |
| 55.51 | * | * | * | 0.419 |
| 55.52 | * | 0.689 | * | * |
| 55.53 | * | 0.088 | * | * |
| 55.54 | * | * | 0.068 | * |

## 5. Conclusion

In this paper, considering the consecutive two-stage structure of the bank branches, a network DEA model was first designed and then developed based on the SBM model by Tone and Tsutsui, [26]. Since the SBM model determines and ranks the DMUs based on their efficiency well, it is a useful model for evaluating the performance of units and bank branches, and its results are reliable.The proposed SBM model has been used for measuring the efficiencies of 55 DMUs in 4 periods from 2016 to 2019. In the proposed model, the deposit has been considered as an intermediate variable to avoid the traditional approaches that use the deposit as an input. Furthermore, imposing the dual role of deferred liabilities as an intertemporal variable and the negative effect of doubtful debts as an undesirable output and as a profitability indicator in the performance and efficiency of bank branches can be considered as one of the features of the model used. The current study confirms that most of the branches analyzed are far from the efficiency level. To be efficient, they should prioritize increasing profitability, managing resources and costs, and seriously reducing long-term liabilities, especially doubtful debts. Considering the rationality of this method compared to other methods that use the traditional measurement approach, this article can be a useful model for managers to make the necessary decisions, make the right organizational policies, and achieve the goals to reduce the risk of bank branches. The results of the effect of these factors in the model can not only be used as a tool for bank managers to make decisions to increase efficiency, but the evaluation of efficiency allows bank managers to rank the branches based on their actual performance and use the results and information related to the evaluated units for their own decisions. The proposed model was presented to measure the performance of bank branches under normal economic conditions and to evolve to situations of economic stagnation and inflation. As can be seen, the shadow prices for the intermediates including the deposit collection and investment stages have different values and directions. The value of intermediates for the deposit collection stage is positive to encourage the deposit collection stage to collect more deposits, while the value of intermediates for the investment stage is negative to encourage this stage to consume fewer deposits. Moreover, the value of intermediates (shadow prices) for the two stages is not only aligned but also quantitatively different. Extending the model presented in this article to situations in which the deposit-taking stage plays the role of leader (inflationary conditions) and the investment stage plays the role of follower, or to situations in which the investment stage plays the role of leader (recessionary conditions) and the deposit-taking stage plays the role of follower can be a good direction for future researches.

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