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Evaluation of the Impact of Uncertainty and Risk on the Operational Efficiency of the Credit Business of Branches in Different Areas of Tehran in the DEA Dynamic Network

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Abstract

There are many uncertainties in the banking system due to economic and political crises. It makes it complicated to check their efficiency. However, banks control part of these crises. In this research, a Data Envelopment Analysis (DEA) network model faced with real conditions is presented. North's operational process has three stages: Cost and assets, deposit, and issuance of facilities. For these three stages, uncertainty and risk for operational efficiency have been investigated. The model presented to evaluate the efficiency of 5 branches of Tehran Bank in a DEA network has been used, and the impact of uncertainty and risk on operational efficiency has been investigated. The validity and accuracy of the model were investigated, and the results show that inefficiency and lack of investment are the causes of reducing operational efficiency to overcome uncertainty and maintain efficiency in the banking industry. Also, by increasing the efficiency of service and investment, it increases the productivity of branches.

Keywords: Uncertainty and risk, Data envelopment analysis network, Productivity, Bank credit business operations.

1 | Introduction

The bank, as the central core of the financial sector, is among the crucial and fundamental parts of the economy and the primary facilitator of the financial system's growth and dynamism, ultimately contributing to economic growth and development. By holding a significant portion of society's liquidity, banks play a highly sensitive and vital role in the economic system and have substantial effects on regulating economic relationships and interactions within society [1].

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In the realm of economic development, commercial banks, acting as significant financial intermediaries, actively participate in trade finance [2]. Global trade tensions persist due to ongoing geopolitical issues. Countries have also witnessed a rise in trade protectionism in recent years. Both of these factors have increased trade policy uncertainty [3]. Sovereign risk has impacted banks' assets through government debt holdings. Indeed, the allocation of debt among various investors has significant economic and financial implications, as it is crucial for strengthening the nexus between banks and sovereigns, the effectiveness of sovereign debt restructuring, and the overall stability of the financial system. Banks often hold a substantial amount of government debt, which can trigger a series of macroeconomic risks and uncertainties [4]. To achieve social governance goals, governments utilize economic policies (Such as fiscal, monetary, industrial, and administrative) to regulate and control economic performance and the behavioral patterns of market participants. Following the 2008 financial crisis, many governments proposed and implemented a series of intensive policies to stimulate the economy and alleviate the pressure from the economic downturn. While these policies effectively addressed the economic recession, they also objectively triggered immense economic policy uncertainty [5].

The examination and analysis of the banking system indicate that its future environment is fraught with complexity, turbulence, and ambiguity, and this system will face a series of challenges and concerns in the near future. Today, business prosperity occurs in an unstable environment with high uncertainty. Customer behavior, competitive strategies, technological advancements, and economic conditions are moving towards a complex and unpredictable path [6]. Failure to maintain balance and equilibrium within the organization may lead to a fall in stock value, jeopardizing interests, and even bankruptcy [7]. Iranian banks will face larger systemic problems, such as difficulties in liquidity management and the balance between deposits and facilities, high rates of non-performing loans, lack of transparency in banks' financial statements, high cost of funds, unnecessary focus on deposit collection without financial analysis, and destructive competition regarding the increase in bank interest rates. Improving the business model of the banking system is one of the solutions to address the significant problems of banks [8].

Furthermore, in a competitive economy, organizations, especially banks, are constantly striving to establish a superior position and formulate strategies to improve their financial and operational processes. Therefore, identifying and predicting effective and efficient indicators to guide the organization towards long-term goals seems crucial in such circumstances. Given that the uncertainties within the Iranian banking system have consistently been a concern for economic experts and the Iranian people, reforming the banking system's structure, formulating efficient monetary and fiscal regulations and policies, and effectively monitoring the performance of the country's banks can mitigate the intensity with which uncertainties are transmitted to banks. Only under these conditions can banks develop their performance through long-term planning [9]. Banks utilize the spread between deposit rates and loan rates to generate income, but since banks do not operate in a vacuum, their lending behavior is primarily influenced by environmental factors, particularly macroeconomic rules and factors. Banks adjust their lending behavior in response to increased macroeconomic uncertainty. An increase in macroeconomic uncertainty has a negative and significant effect on the loan-to-asset ratio of banks [10].

Managers need to control uncertainty in constraints and parameters, as uncertainty plays a fundamental role in network design [11]. In this research, input, intermediate, and output parameters are considered uncertain. To address the existing uncertainties, contingency planning is employed. Finally, the sensitivity analysis of the model is examined and presented using GAMS software.

2 | Research Methodology

The main objectives of the present research are as follows:

I. This study examines the operational efficiency of businesses in different branches over a specific time horizon with various inputs and outputs using dynamic network Data Envelopment Analysis (DEA).

II. The present research investigates the uncertainty and risks present in the branches of Tejarat Bank in different districts of Tehran.

III. Contingency planning is employed to address the existing uncertainties.

IV. The impact on the trade credit operations of these banks is analyzed. Given the dynamic nature of the financial sector, this research considers how these characteristics change over time.

V. To address the uncertainty of the input, intermediate, and output parameters, a contingency fuzzy planning model has been developed.

The present research, based on the findings and analysis, offers strategic and policy recommendations tailored to the unique environment of banking. An increase in leverage leads to a reduction in risk and uncertainty. The model design is divided into three stages: 1) assets, 2) deposits, and 3) loan distribution. The network DEA model plays a significant role in the capital resilience and credit risk assessment stage. Employees, assets, and costs serve as the initial inputs. The output of the first stage is deposits, which act as an intermediate variable and the input for the second stage. The output of the second stage is loan distribution [12].

3 | Designing the Network Data Envelopment Analysis Model

To enhance the accuracy of operational efficiency assessment for credit businesses, the Malmquist index is integrated with a multi-stage network DEA model. The model is coded in GAMS software. By considering the dynamic interrelationships and inherent uncertainties of the banking industry, a comprehensive evaluation of credit operation efficiency across five districts of Tejarat Bank branches is ensured.

3.1 | Data Envelopment Analysis-BCC Model

The network DEA-BCC model demonstrates greater efficiency within the banking operational system. Risk and uncertainty play a significant role in complex banking operations. Considering economic conditions and analyzing the risk and uncertainty of operational efficiency and their combination, the model's flexibility in comprehensively evaluating loss-making branches is identified, contributing to its development and refinement.

In the present study, three types of indicators are evaluated: 1) input, 2) intermediate, and 3) output. The input variables for the first stage include employees, costs, and assets. The output of the second stage includes deposits and the quality of service delivery. The output of the first stage enters the network once as intermediate variables and once as outputs. The output variables for the final stage include loans. Increasing assets and service delivery leads to improved branch productivity.

4 | Mathematical Model of the Problem

4.1 | Multi-Stage Network Model

The general structure of network DEA is either parallel or serial. The network structure of the present research is in series. A series network has an internal sub-process. By developing two sub-processes, the internal structure of a Decision-Making Unit (DMU) can be formed. *Fig. 1* illustrates this concept. *Eqs. (3)-(6)* represent the network DEA model:

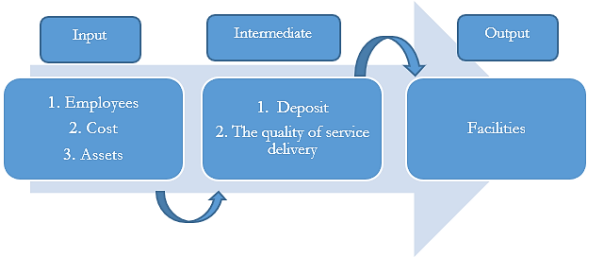

Fig. 1. Data envelopment analysis network of the present research.

Indices

r	Set of first outputs
j	Set of DMUs
i	Set of inputs
s	Set of intermediates

Parameters

γ_i	Weight assigned to each DMU
x_{ij}	First stage input
z_{ik}	First stage output and second input
y_{rj}	r-th output (r=1,...,R), second stage

Decision variables

s_r^+	Auxiliary variable for input variable
s_j^-	Auxiliary variable for input variable
y_i	Output variables
x_i	Input variables
β	Productivity assessment
$\theta_{(s)}$	Intermediate variable
λ_{sr}	Input variable
n_{sj}	Output variable

$$\min\left[\beta-\varepsilon\left(\sum_{j=1}^{m}s_j^-+\sum_{r=1}^{s}s_r^+\right)\right], \tag{1}$$

S.t.

$$\sum_{i=1}^{n}\gamma_i x_i+s_j^-=\beta x_{i0}, \quad \text{for all j}, \tag{2}$$

$$\max\sum_{s=1}^{s}\left(\sum_{r=1}^{R}\lambda_{sr}\,y_{rj}^{(s)}+\sum_{k=1}^{k}\theta_{k=1}z_{ik}^{(s,s+1)}\right), \tag{3}$$

$$\left\{\sum_{j=1}^{J}n_{Ij}x_{ij}^{(I)}+\sum_{s=2}^{s}\left(\sum_{k=1}^{s}\theta_{(s-1)}z_{ik}^{(s-1,s)}+\sum_{j=1}^{J}n_{sj}x_{ij}^{(s)}\right)\right\}=1, \quad \text{for all i}, \tag{4}$$

$$\left(\sum_{r=1}^{R}\lambda_{Ir}\,y_{rj}^{(I)}+\sum_{k=1}^{k}\theta_{Ik}z_{ik}^{(I,2)}\right)\le\sum_{j=1}^{J}\alpha_{Ij}x_{ij}^{(I)}, \tag{5}$$

$$\left(\sum_{r=1}^{R}\lambda_{sr}\,y_{rj}^{(s)}+\sum_{k=1}^{k}\theta_{k=1}z_{ik}^{(s,s+1)}\right)\le\left(\sum_{k=1}^{s}\theta_{(s-1)}z_{ik}^{(s-1,s)}+\sum_{j=1}^{J}n_{sj}x_{ij}^{(s)}\right), \tag{6}$$

$$\sum_{i=1}^{n} \gamma_i y_i - s_r^+ = y_{i0}, \quad \text{for all r,}$$

$$\sum_{i=1}^{n} \gamma = 1,$$

$$\gamma \geq 0, s^+ \geq 0, s^- \geq 0.$$

The structural form and the above model, x_{ij}, represent the i-th $(i = 1, \dots, I)$ input of the first stage. Considering the degree of correlation between the processes, the output of each sub-stage acts as an intermediate variable, denoted by z_{ik}. Specifically, $(k = 1, \dots, K)$ represents the output of the first stage and the input of the second stage. Furthermore, y_{rj} represents the output of the r-th $(r = 1, \dots, R)$ stage of the second phase. The variables n_{sj}, λ_{sr}, and $\theta_{(s)}$ represent the input, output, and intermediate variables, respectively.

By examining the uncertainty in bank lending processes, the series DEA network model exhibits very high effectiveness for the bank. *Fig. 1* presents a method for evaluating and improving the performance of DMUs with n stages. This method ensures correlation by considering the complexity between phases.

5 | Contingency Planning Approach

One of the methods for dealing with uncertainty and risk is fuzzy optimization. Fuzzy planning models are divided into two categories: Flexible fuzzy planning and contingency planning.

Flexible planning is based on fuzzy sets or priorities. Contingency planning, on the other hand, is modeled using target and available data, along with the decision-maker's knowledge [13]. In the present research, contingency planning has been used to address uncertain parameters.

Based on the aforementioned points, the contingency planning model of the research is as follows:

$$\max \sum_{s=1}^{s} \left(\sum_{r=1}^{R} \lambda_{sr} \left(\frac{y_{rj(1)}^{(s)} + y_{rj(2)}^{(s)} + y_{rj(3)}^{(s)} + y_{rj(4)}^{(s)}}{4} \right) + \sum_{k=1}^{k} \theta_{k=1} \left(\frac{z_{ik(1)}^{(s,s+1)} + z_{ik(2)}^{(s,s+1)} + z_{ik(3)}^{(s,s+1)} + z_{ik(4)}^{(s,s+1)}}{4} \right) \right), \tag{7}$$

S.t.

$$\left\{ \sum_{j=1}^{J} n_{Ij} \left(\frac{x_{ij(1)}^{(I)} + x_{ij(2)}^{(I)} + x_{ij(3)}^{(I)} + x_{ij(4)}^{(I)}}{4} \right) + \sum_{s=2}^{s} \left(\sum_{k=1}^{s} \theta_{(s-1)} \left(\frac{z_{ik(1)}^{(s-1,s)} + z_{ik(2)}^{(s-1,s)} + z_{ik(3)}^{(s-1,s)} + z_{ik(4)}^{(s-1,s)}}{4} \right) + \sum_{j=1}^{J} n_{sj} \left(\frac{x_{ij(1)}^{(s)} + x_{ij(2)}^{(s)} + x_{ij(3)}^{(s)} + x_{ij(4)}^{(s)}}{4} \right) \right) \right\} = 1, \quad \text{for all i,} \tag{8}$$

$$\left(\sum_{r=1}^{R}\lambda_{Ir}\left(\frac{y_{rj(1)}^{(I)}+y_{rj(2)}^{(I)}+y_{rj(3)}^{(I)}+y_{rj(4)}^{(I)}}{4}\right)+\sum_{k=1}^{k}\theta_{Ik}z_{ik}^{(I,2)}\right) \leq \sum_{j=1}^{J}\alpha_{Ij}\left(\frac{x_{ij(1)}^{(I)}+x_{ij(2)}^{(I)}+x_{ij(3)}^{(I)}+x_{ij(4)}^{(I)}}{4}\right), \tag{9}$$

$$\begin{aligned}&\left(\sum_{r=1}^{R}\lambda_{sr}\left(\frac{y_{rj(1)}^{(s)}+y_{rj(2)}^{(s)}+y_{rj(3)}^{(s)}+y_{rj(4)}^{(s)}}{4}\right)\right.\\&\quad\left.+\sum_{k=1}^{k}\theta_{k=1}\left(\frac{z_{ik(1)}^{(s,s+1)}+z_{ik(2)}^{(s,s+1)}+z_{ik(3)}^{(s,s+1)}+z_{ik(4)}^{(s,s+1)}}{4}\right)\right)\\&\leq\left(\sum_{k=1}^{s}\theta_{(s-1)}\left(\frac{z_{ik(1)}^{(s-1,s)}+z_{ik(2)}^{(s-1,s)}+z_{ik(3)}^{(s-1,s)}+z_{ik(4)}^{(s-1,s)}}{4}\right)\right.\\&\quad\left.+\sum_{j=1}^{J}n_{sj}\left(\frac{x_{ij(1)}^{(s)}+x_{ij(2)}^{(s)}+x_{ij(3)}^{(s)}+x_{ij(4)}^{(s)}}{4}\right)\right).\end{aligned} \tag{10}$$

6 | Finding

In this section of the research, the model has been coded and solved using the CPLEX solver in the GAMS software. It presents an analysis of the operational effectiveness of five branch regions of Tejarat Bank in Tehran.

Evaluating the operational efficiency of a business is highly important and necessary for the banking industry. The banking industry faces numerous obstacles, one of which is the economic conditions of society. *Table 1* shows the operational impact of credit on the branches. The overall operational average has decreased from 0.533 to 0.089. The numerical results indicate that investment has a significant impact on efficiency. Larger branches are more flexible compared to smaller branches. On the other hand, managers emphasize innovation to reduce and merge unprofitable branches.

Table 1. Operational impact of credit on branches.

Branch Region Name	Capital Amount (Rial)	Average
Central Branch Management (MGMT)	200,000,000	0.533
Northeast (N.E.) Branches MGMT	100,000,000	0.453
Northwest (N.W.) Branches MGMT	80,000,000	0.254
Southeast (S.E.) Branches MGMT	50,000,000	0.154
Southwest (S.W.) Branches MGMT	20,000,000	0.089

The average operational efficiency has a direct relationship with the size of the branches. Increasing the financial resources (Size) of the bank leads to increased efficiency. *Fig. 2* shows a comparison of the efficiency of five branch regions in Tehran (Central Branch, N.E. Branches, N.W. Branches, S.E. Branches, and S.W. Branches) at Tejarat Bank.

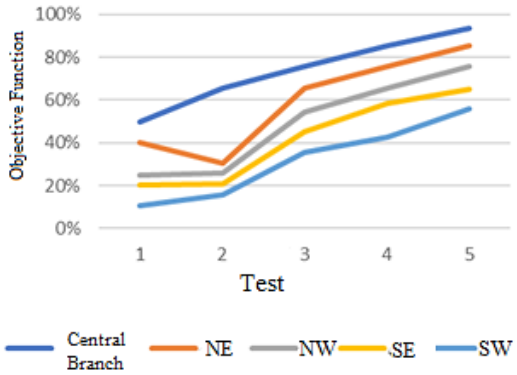

Fig. 2. Efficiency comparison.

Table 2 shows a comparison of the ranking of branches in the five regions of Tehran. Service delivery and assets have a positive relationship with the ranking of branches. With an increase in the efficiency of service delivery and assets, the ranking and productivity of the branches increase.

Table 2. Comparison of branch ranking in the five regions of Tehran.

Branch Name	Service Delivery (%)	Ranking	Productivity
Central	50	5	0.071
N.E.	60	3	0.964
N.W.	70	4	0.502
S.E.	80	2	0.987
S.W.	90	1	0.993

Table 3 shows the decomposition of comprehensive efficiency based on the operational stage. Across the three parameters of employees, cost, and assets, assets have the most significant impact on the objective function. Return on assets has the highest yield, and loan disbursement has the lowest performance.

Table 3. Decomposition of comprehensive efficiency based on the operational stage.

Branch Name	Employees	Cost	Assets (%)	Objective Function
Central	175	200	15	1.000000E+10
N.E.	175	100	30	2.300000E+10
N.W.	175	80	20	2.100000E+10
S.E.	175	50	50	2.500000E+10
S.W.	175	20	60	2.600000E+10

Fig. 3 shows a comparison of three stages. Stage 3 has the lowest yield, meaning that loan disbursement leads to a decrease in profit.

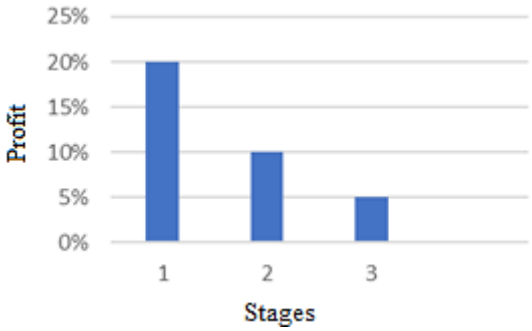

Fig. 3. Comparison of three stages.

Fig. 4 shows the changes in the objective function under different confidence levels. As the confidence levels increase, the objective function also increases. The outputs indicate that dealing with uncertainties leads to better efficiency and performance.

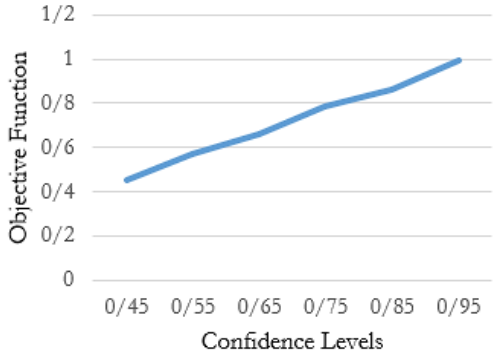

Fig. 4. Changes in the objective function under confidence levels.

7 | Conclusion

Considering the presence of uncertainty in the real world, data are non-deterministic. The present research examines the interaction between risk, operational efficiency, and uncertainty. The results indicate that branches that are not strict in providing facilities to their valuable customers and their subordinate personnel cause the bank's resources in the branch to increase due to cash generators such as personnel salaries, customer deposits, and loan origination fees. These branches with the most services receive the highest ranking. They show flexibility by changing the efficiency value from a decreasing to an increasing trend. Numerical results show that inefficiency and lack of investment are the reasons for the decline in operational efficiency to overcome uncertainty, and maintaining efficiency in the banking industry plays a fundamental role in this regard. The average efficiency value has a direct correlation with the scale of financial institutions, which has had a significant impact on the overall average in high-ranking branches. In contrast, the impact of low-ranking branches was relatively small in comparison, which affects the reduction of risk and uncertainty in the credit business of branches and further improvement of their business performance and operational efficiency.

In future research, system innovation can be strengthened, and robust planning methods can be used to deal with uncertainties.

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